ANALYTIC PSYCHOLOGY: SOURCE CONCEPTS FOR ARTIFICIAL INTELLIGENCE

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Communicated by E. Y. Rodin

(*Received August 1980*)

Abstract—As intelligence technology advances from problem specific to adaptive designs it is conceivable that design concepts will be found in analytic psychology. This psychology features a mechanistic and structured model of human adaptivity from which such concepts may derive. This paper develops this position and illustrates it with three examples: the von Neumann machine, digital simulation of dreams, and digital simulation of the mechanism of the creative process. The simulating algorithms of the last two examples are implemented in Fortran.

PART A

Introduction

A great deal of cybernetic research is based upon a quasiliteral replication of biological structure and function; prosthetic limbs, synthetic knee joints, artificial kidney and heart experiments are examples of this. Clearly, a well defined knowledge of both structure and function is prerequisite to such pursuits. If man is partitioned as an adaptive organism into biological and psychological domains then it becomes clear that biophysical structure/function information is available for the biological, while only modelled (representational) structure/function information is available for the psychological.

Freud came to terms with this limitation in the late nineteenth century. His first approach in investigating neurotic and psychotic disorders was to search for specific causes such as toxins, infections, congenital predisposition, and the like. He even attempted to account for these dysfunctions with a general model of neuronal function in 1895 (entitled Project for a Scientific Psychology; with this work Freud renounced the purely organic approach to the psychoneuroses). The outcome of his research was to abandon a literal biological or chemical approach in favor of what evolved into an informational one: Freud slowly realized that while biochemistry defines the human potential for life and adaptivity it is the relationship of the infant human to the surroundings that determines how efficient and well-organized the results of biochemical maturation are. This in turn led to a structure/function theory of human adaptive (and hence also maladaptive) behavior whose primitive terms were not literally biological but metabiological. If the state of scientific knowledge could not afford biochemical identification of life and adaptive processes, direct observation could still afford a structured model for the results of such processes, these results being adaptivity.

There are sound historical reasons for analytic psychology lending itself readily to mathematical description. As a product of late nineteenth century science, Freud regarded that science as complete which resolved its object into well-defined—preferably quantifiable—forces and mechanisms. In an epoch of thermodynamic elaboration, he studied at the Helmholtz School of Physics and Physiology. It is therefore appropriate that analytic psychology is characterized at the macroscopic level by references to work, energy, force, and mechanism. However, the work/energy concepts of thermodynamics are readily related through entropy to information theory (the thermodynamic-information analogy through entropy was not developed until the 1940's by C. E. Shannon at Bell Telephone Laboratories; note that Freud died in 1939). Hence, it appears natural that analytic psychology should lend itself to mathematical (informational) models.

Analytic psychology can be characterized as a mechanistic effort to account for human adaptivity and its failures. This includes the concept of ontogenesis, i.e., the development from birth onward of these adaptive capacities. It is a model of an informational type which at any point in time measures the personality's health (and hence efficiency) by its degree of organization. The following thought experiment will perhaps clarify the perspective of analytic psychology: suppose a device, say x, exhibited adaptive capacities and that a systems engineer was given the task of deducing the algorithms (or informational models) that x employed to achieve its decisions and actions; assuming that the engineer deduced the algorithms with sufficient accuracy the result would be analogous to the analytic model of adaptive personality. If now a mature and healthy human substitutes for x and an analytic psychologist for the engineer the analogy becomes rather reasonable.

If therefore this model is faithful—as far as it has been developed—to the information content of adaptive behavior and if this model is mathematically identifiable then the following question presents itself: can a mathematical description of this model (a mathematical representation of the information content of the analytic adaptive model) be used to suggest designs in artificial intelligence? The question appears reasonable when considering that intelligence is only a part of any adaptive paradigm; indeed what characterizes human adaptivity—and no human invention to date—is elasticity of adaptive capacity. Man unlike any human invention to date is not problem specific in design.

The perspective of this paper is that it may be reasonable to anticipate structured conceptual approaches to artificial intelligence evolving from models of the type referred to above. The point of departure is that while a science like bionics builds on literal recapitulation of parts, the present approach suggests building on recapitulation of informational structure and function. This means more than replicating information content because it includes replicating information structure: in a word, it builds on information plus organization.

The next section of this paper will attempt to present this concept more sharply. Rather than presenting a systematized version of analytic psychology—which space precludes—the format for this paper is to define the notion of source concepts for artificial intelligence (AI) in analytic psychology and to then illustrate this. Three examples follow and together with each is hopefully adequate analytic material to make the derivation of the AI concept from analytic material clear. The examples are the von Neumann concept of the computer, digital simulation of dreams, and digital simulation of the mechanism of the creative process (with an illustration). It is actually necessary to present the second example because, as intuition suggests, the third one subsumes it. The simulating algorithms of examples two and three are then implemented in Fortran.

Human adaptivity as the primitive model

Historically analytic psychology investigated the development (ontogenesis) of human sexuality and aggression as the ultimate sources of neurotic and psychotic disorders. The outcome has been a model of healthy (ideal) human adaptivity derived from studies of unhealthy, often extreme, adaptations. The key to this perspective is an appropriate definition of sexuality: sexuality denotes the human drive to survive in the individual or collective (species) sense. The mental apparatus—termed the ego in Freud's model—which enables securing specific adaptive measures is enlisted by sexual strivings in this sense.

The ideal model of human adaptivity refers, of course, to the mature adult state. The historical studies of infantile sexuality were motivated by quests for the earliest sources of suboptimal maturation to the adult state. In a strict sense the study of infantile sexuality is a study of system initialization and transient to steady state where system refers to adaptive personality. If AI is to be served by psychoanalytic paradigms then they will probably derive from the ideal (adult) model. This, of course, raises an interesting question: is it possible to design and implement a system which fully recapitulates (emulates) a psychic subsystem which is itself achieved through a maturing process? Would the recapitulate also have to mature to completion? The answer is no, in general, as example one below illustrates.

Henceforth, let us restrict the concept of adaptivity to the psychological (informational) domain; this allows nonreference to those somatic capacities enlisted in carrying out the adaptive decisions (such as limbs, senses, etc.) and narrows the focus to how we originate our adaptive decisions. In other words, our attention is henceforth restricted to structure/function concepts on information and organization as seen in the analytic model. A qualitative paradigm for seeking AI concepts in analytic psychology suggests itself if the original problem in AI is suitably posed. Let P denote the original problem definition and S a solution (note that the mapping from problems to solutions is, in general, a one-to-many mapping and could even be a many-to-many mapping). In accordance with systems terminology let H denote the transfer function which associates ("carries P into S") P with S: $H(P) = S$. Before outlining the paradigm some examples will perhaps clarify the meaning of H:

(1) P = find the roots of a quadratic,
S = the roots to a reasonable approximation,
H = the quadratic formula;

(2) P = to order a list,
S = the ordered list,
H = an appropriate algorithm such as bubble sort;

(3) P = translate French into English,
S = a suitable rendering,
H = find someone (perhaps oneself) fluent in both languages;

(4) P = form a prespecified sequence of arithmetic and logical operations on a set of data,
S = output of the results in appropriate media and format,
H = described below under the von Neumann machine.

The first two examples have unique solutions, the third and fourth do not. These examples suggest that H may be a formula, an algorithm, or a procedure; in general H is a transformation on information. The intent here is to suggest how H can be conceptualized from analytic models when P and S are specified, it being assumed that P and S are appropriate from the outset. Examples 1 and 2 illustrate inappropriateness because the procedure (H) is problem specific and hence purely cognitive. Analytic psychology would be of no avail here. It is in the pursuit of devices and methods whose problem solving domain is more general (adaptivity) that this model may be of help. The human cognitive power is, in a sense, a primitive of the model; it is its relatedness to pre- and noncognitive processes within the personality that gives it relevance and utility in this model. To be sure, AI will profit greatly by exploring cognition but it will not broach adaptivity and generalization of function through cognition alone.

A hypothetical situation may clarify this: suppose it were possible to fully replicate human cognition. Would all problems then be solvable? No, for the simple reason that not all problems are cognitive and further the full solution to any problem almost always has cognitive plus noncognitive dimensions. A person who is learning impaired for emotional reasons illustrates this rather well (the emotional problem is not removable by a cognitive process alone). The problem of designing a device to optically scan written text successfully also illustrates this: the variety of representations of the letter *a*, for example, is not deducable from cognition alone because individual variations derive from affectual states (for present purposes, affect may be defined as a generalization of emotion with emphasis on total biological response). The distinction made here is between intelligence (cognition) and adaptivity; the latter both includes and generalizes the former. This is not to intimate that H may be suggested by examining the relation of intelligence to adaptivity but rather that it (H) may be suggested by relating P and S to appropriate analogues in the adaptive model where cognition is a primitive.

The paradigm can be stated as follows:

(1) In the original problem define P and S;

(2) Generalize P, if necessary, to its corresponding class of adaptive demands; generalize S accordingly; call these P^* and S^*;

(3) Determine by reference to the adaptive model the form of H^* for which $H^*(P^*) = S^*$;

(4) Specialize H^* to H such that $H(P) = S$.

The idea of solving a problem by scrutinizing how we ourselves spontaneously (unconsciously) solve it is not original; systems experts and applied scientists have long been doing it in constructing algorithms. The point of departure is that most replication has been of cognitive processes alone and hence the results have tended to be problem specific. Generalizing the problem to adaptive analogues and reapplying the process of examining how we ourselves achieve a solution is to tend toward adaptivity and therefore to elasticity of solution (H^*).

H^* will be presented explicitly in the three examples cited. The approach is conceptual with limited use of symbolic representation which is unavoidable in the second and especially in the third example.

Example 1: The von Neumann machine

Referring back to example 4, the P that the digital computer (von Neumann machine) resolves may be stated "to perform a prespecified sequence of arithmetic and logical operations on a set of data" and S may be stated "to output the results in appropriate media and format." For the moment we can say $H(P) = S$, where H is a von Neumann machine. The goal here is to show how H is abstractable from the analytic model when P and S are suitably generalized. Figure 1 summarizes the organization of the von Neumann machine.

In this model a program queues on an input channel and requests machine resources for execution; when these are available the program is translated, loaded, and executed. This last phase sees the program control system (machine) resources while executing from main memory and under the constraints of the control unit. Upon completion results are directed to an output channel. The program is internally stored, may be self-modifying and may perform arithmetic or logical decisions which either compute functions of the data or store the data or both transform and store the data. This paragraph is a summary of H conceived at the design level. No reference to Boolean logic for circuit synthesis nor to circuit elements for circuit realization has been made. The level of presentation is the design level. It is interesting to note here that the von Neumann design has survived the vicissitudes of materials technology: generation 1 (vacuum tubes); generation 2 (transistors); generation 3 (integrated circuits); etc.

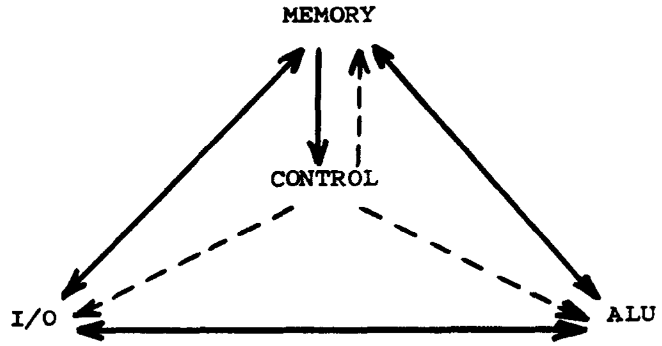

Fig. 1. The organization of the digital computer with control and computational (ALU) units segregated. Dashed lines indicate flow of control information. Solid lines indicate flow of data.

Analytic psychology has a conceptually simple model for adaptive functioning from which the von Neumann design is abstractable. The primitive terms are id, ego, and superego. The id is defined as the seat of human instincts, both sexual and aggressive. The ego is defined as an organizational structure which mediates the aims of id instincts subject to the constraints of external reality and of internal reality (superego). The superego is defined as an ego overseer derived from introjection of parental (familial) values; it is equitable with the "do–don't" values of the parents. Historically the superego has the (external) parents as its precursor; normal development sees ego regulation increasingly defined by internalized parental values. The resulting internalized psychic agency is the superego. The ego then in the mature state has three boundaries or interfaces: the id, the superego, and external reality; the first two are internal. Furthermore, the ego develops ontogenetically from the id out toward reality where id promptings can be satisfied.

With these primitive terms an adaptive model is now presentable. An adaptive measure originates as an id impulse—which may arise spontaneously as hunger or in response to a percept such as the sight of food—seeking to secure its object by enlisting the powers of the ego. The ego acts to master external reality in accordance with (i) the nature of the id impulse, (ii) the constraints of external reality, and (iii) the constraints of the superego. Let P^* = secure satisfaction of an id impulse, S^* = mastery of reality in favor of the id impulse, then H^* is ego reaction to P^* subject to the feedback regulated constraints of external reality and superego. The remainder of this example outlines the specialization of H^* to H.

In this framework we can say that the stored program is in relation to input, to ALU, to control, and to output as ego procedure is to id, to ego capacity, to both superego and external reality, and to reality modifying action. Explicitly, the analogies are id/input, ego procedure/stored program, ego capacity/ALU, superego + external reality/control, and reality modifying action/output. Figure 2 compares the event sequences associated with H and H^*. Note that if control is conceptualized as hardware + software (operating system) then the following analogues obtain superego/hardware control, external reality/software control (= operating system) because the operating system is external to the program.

It is perhaps worth mentioning that memory is a patent recapitulation of human memory, and that the execution state achieved by serially decoding instructions is the analogue of conscious cognition which is also characterized by serial processing (of sensory and recalled data) and thus by flux. There are more ways in which the von Neumann design is a specialized recapitulation of the analytic model for adaptive response (see [1]) however what is outlined here is the essence of the analogy that pairs $H(P) = S$ with

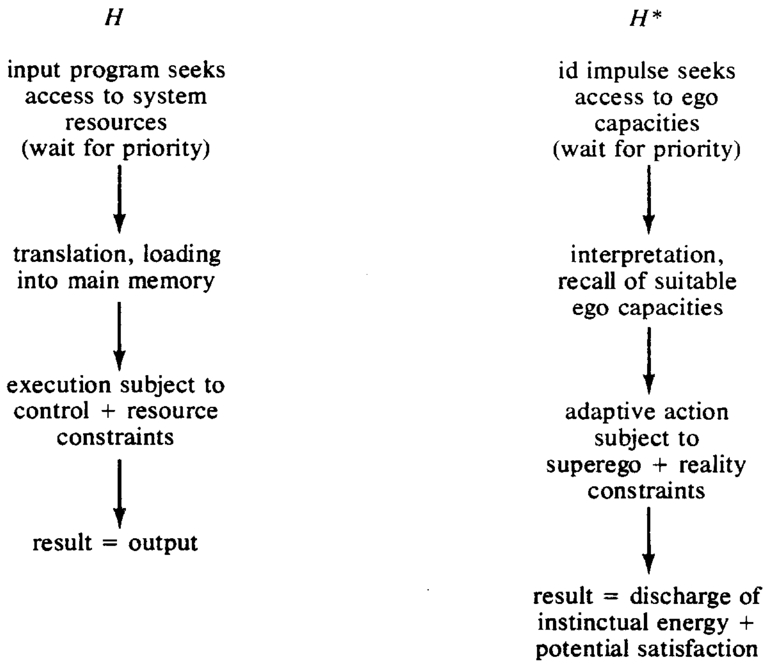

Fig. 2. H and H^* for the von Neumann machine.

$H^*(P^*) = S^*$. Finally, the self-modifying code is the analogue of feedback regulated adaptive response (the ego is so regulated by the three boundaries of id, superego, and external reality but especially by external reality which is dynamic in contrast to the relatively stable contents of the id and superego).

PART B

Introduction

The first part of this paper suggested that the informational structure of analytic psychology may lend itself to formulating solutions to problems in artificial intelligence. If the source problem and solution are P and S then it was suggested that (1) P and S could be generalized to appropriate classes of adaptive demands P^* and adaptive solutions S^*, (2) reference to the analytic model may provide a transfer function H^* such that $H^*(P) = S^*$, and (3) the transfer function H for which $H(P) = S$ could be determined by specialization of H^*.

This was illustrated with the von Neumann machine. The second part of this paper will further illustrate the above approach with simulations of dream formation and of the mechanism of creativity. A transfer function H for each of these problems is constructed by reference to the analytic model. A later section of this part presents a single simulator, implemented in Fortran, for both of these problems. This is appropriate because of the natural relation that prevails between dreaming and creativity. The simulator though rudimentary is designed to accommodate the improvements suggested in the examples below.

Example 2: Simulating dream formation

It is worthwhile to examine dream formation because the dream mechanism which in and of itself has considerable adaptive significance and value is closely related to creativity which is the root of all progress in man's adaptation. Let P = construct an algorithm to simulate the dream process, S = presentation of the result. As previously, we want that H for which $H(P) = S$. Let then P^* = dream synthesis, S^* = dream experience, then $H^*(P^*) = S^*$ if H^* is the mechanism of the dream process.

Only a part of the theory of dream formation is necessary for this. Dreams originate as psychic efforts to achieve satisfaction of wishful tendencies either disallowed in waking life or unachievable for real reasons in the waking state. Let the driving wish be W. Now W has both cognitive (literal) valence and affectual valence: it is the achievement of the affectual valence of W that drives the dream process. Let $A = \{a\}$ be the set of significant affects associated with W. The dream work essentially proceeds by taking elements of A, say a, and associating them with cognitive values, say W^*, other than W which also carry the affectual valence a. That is $W \neq W^*$ but W and W^* share a though not necessarily at the same level of intensity. The objective of the dream mechanism is to synthesize a scenario—which is actually a hallucination because it is a fiction experienced as a fact—which satisfies W yet escapes anxiety because of superego or reality constraints. This is essentially achieved by relocating the significant affects A that W demands onto other cognitive values W^* and to then link the resulting W^*'s into a cohesive whole, a process referred to as secondary revision. The relocation of affect mechanisms are generally regarded as distortion, displacement, and condensation which mean what they suggest excepting condensation which refers to one symbol W^* carrying two or more affects relocated from W. For present purposes all the mechanisms prior to secondary revision can be subsumed under the mechanism of relocation of affect.

This is enough to itemize the event sequence of dream information:

(1) W is defined with cognitive and affectual valence, i.e., W is defined as the sum of its cognitive and affectual attributes (a cognitive attribute is defined here as a descriptive phase).

(2) Each significant affect a of W is relocated to a W^* where $W \neq W^*$ but W^* has affect a among its associated affects.

(3) If the cognitive valence of W^* is too near W then W^* is rejected (superego). Another W^* is chosen not so near W.

(4) The visual percepts associated with the W^*'s are linked serially or simultaneously according to which link maximizes cognitive difference from W.

Steps 1–4 are a simplified but accurate enough accounting of H^*. Constructing H is now a revision of these steps within the constraints of the current capacities for digital simulation:

(1) Define W as $W = \{w_j\}$, where each w_j is a cognitive attribute of W and define $\{a_k\}$ as the affectual attributes of W.

(2) For each a_k define $W_k = \{w_{k_1}\}$, where each w_{k_1} is a cognitive attribute that has affect a_k associated with it. Note that it may be the case that $w_{k_1} \notin W$.

(3) Let $W_0 = \cup W_k$ and define d: $W_0 \times W \rightarrow$ R, i.e., $d(w_1,w_2)$ is a real number that measures, in an assigned sense ultimately based on human response, how near cognitive attribute w_1 (one of the w_{k_1}'s) is to some $w_2 \in W$.

(4) For each a_k choose that w_{k_1} which maximizes

$$\min_{k_1 \neq j} d(w_{k_1},w_j)$$

as j exhausts W. Note that w_{k_1} must satisfy the condition

$$\min_{k_1 \neq j} d(w_{k_1},w_j) > M,$$

where M measures distance from W cognitively and hence is a function of superego pressure and/or reality. If there are two or more such w_{k_1}'s choose the first. If some w_{k_1} maximizes d for more than one a_k this is acceptable and corresponds to condensation. Choose an object, say W_k^*, that has attribute w_{k_1}. If there is more than one such object choose the one that carries the least number of w_j's; if this causes a tie choose the first such (minimizing) object.

The resulting set of W_k^*'s are the literal elements of the dream and the output. If their natural serial order is nonsensical then that is appropriate to dream simulation. Note that maximizing d corresponds to avoiding superego pressure as well as avoiding iteration in step 4 of the definition of H. In a more general model the maximum criterion of step 4 would be replaced by a threshold criterion dependent on each a_k. The mapping from affect (of W) to cognate (of a W^*) is the relocation mechanism. The second set of four steps given is a specialization of H^* to H and is a solution of the problem of simulating dreams.

Example 3: Simulating the mechanism of the creative process

Creative work is a close cousin of dreaming and were it not for constraints on the creative process derived from fidelity to reality the two processes would be identical. In fact if the reality constraint were removed from conscious creativity the result would be a hallucination, a fact that accords well with the traditional tendency to link creativity and madness. In the present context let P = find an algorithmic approximation to human adaptive response, and let S = a simulatable algorithm. By generalization let P^* = response (intrapsychic, creative) to an adaptive demand, and S^* = resulting (manifest) adaptive action. As previously the goal is to find in the analytic model an H^* for which $H^*(P^*) = S^*$ and to then determine H with $H(P) = S$ by specialization. Note the tautology: adaptive response = creativity.

Creative response as dreaming begins with a wishful tendency (W): the wish to resolve (successfully) an adaptive demand. This relates creativity to dreaming in no small way. The class of processes that operate (unconsciously) in dream formation are referred to as the primary process. They are characterized by prelogic where, for example, two distinct cognates, say x and y, with $x \neq y$, are regarded as equivalent if they carry a common affect (unconsciously). This means that there is a common affectual response to x and y and in this sense $x = y$ in response although literal identity fails. Primary process activity is characterized by declaration of full identity (equality) based on partial identity. In fact even x and not x are regarded as (unconsciously) equivalent because they share the common affects of not being each other (cf. Freud's essay Negation, 1925, last paragraph where he states ". . . in analysis we never discover a no in the unconscious."). Clearly the relaxed associative mechanisms of the primary process are essential for creativity.

However, the creative process has an interface with reality that the dream process does not: both processes are set in motion by a real wishful tendency but the resultant for dreams need not be realizable in external reality whereas for creativity it must be. The class of processes whose objective is to assess reality is termed the secondary process. The use of ordinary logic is an example of this. The primitive levels of primary process functioning are unconscious and, appropriately, the most sophisticated levels of secondary process functioning are conscious. In general the primary process is nearer the unconscious and the secondary nearer the conscious. Normal maturation sees the secondary process evolve from the primary in a synergistic way. However it can happen—as seen in paranoids—that the secondary process develops with pathological relatedness to the primary. (In such cases the cognitive powers are intact as long as their object is impersonal and when their object is personal these powers regress to the level of primary process function.)

The essential mechanism of creativity is secondary process (reality oriented) evaluation of primary process results. More specifically the dreamlike constructs of the primary process are evaluated for external realizability by the secondary process. Utilizing prior notation, an event sequence for the creative process is identifiable:

(1) An adaptive demand gives rise to a wish for resolution W where W is defined by its cognitive attributes and by its affectual attributes.

(2) Significant affects of W are relocated to a W^* where $W \neq W^*$ but W and W^* have common affects (primary process).

(3) The cognitive attributes of the W^*'s nearest W are tested for realizability. The secondary process (unconsciously) decides this by determining if the cognitive attributes of the W^*'s are found in sufficient degree among the memories of known objects.

(4) If the secondary process review fails then (3) is repeated for W^*'s further away cognitively from W. Otherwise, the cognitive attributes of the W^*'s rise to consciousness for secondary process evaluation: they are given (if necessary) syntactic relatedness and a reality experiment is conceptualized to resolve those elements of the creative response not yet decidable by prior real experience. Typically this involves configuring known objects (W^*'s from prior real experience) in a yet untested way to decide empirically if such a configuration will work (the affects of W as a wish are operative here very clearly). If the test fails either W is redefined in a feedback fashion and/or other W^*'s (some further away from W) are tested. This continues until the test succeeds or available W^*'s are exhausted and the demand is then regarded as irresolvable *pro tem*. Solution then awaits acquisition through experienc of more W^*'s.

Steps 1–4 are a suitable H^* for the given P^* and S^*.

Note that this process begins with W^*'s that are cognitively close to W. This is actually true of dreaming too, however the distance is increased only as superego constraints demand. In creativity, reality constraints (!) increase the distance toward apparently less related objects. In both processes the affects of W are preserved through relocation to objects W^* which have had affects historically in common with W.

With a little revision H^* can be specialized to H:

(1) W is defined with cognitive attributes $\{w_j\}$ and affectual attributes $\{a_k\}$; write $W = \{w_j\}$.

(2) For each a_k define $W_k = \{w_{k_1}\}$ where each w_{k_1} is a cognate that has affect a_k associated with it. As with dreams note that it may happen that $w_{k_1} \notin W$.

(3) Let $W_0 = \cup W_k$ and define d: $W_0 \times W \rightarrow R$, i.e., $d(w_1, w_2)$ is a real number that measures the distance of cognate w_1 (among the w_{k_1}'s) from w_2 (among the w_k's of W).

(4) For each a_k and each w_j choose the w_{k_1} that minimizes $d(w_{k_1}, w_j)$. If there are two or more, then admit all such minimizing elements one at a time.

(5) The resulting set of w_{k_1}'s are compared to the attributes w_n of known objects for concurrence ($w_{k_1} = w_m$ for some m). If there is at least one known object (note that W is not regarded as a known object) for which a fraction, say p, of the w_{k_1}'s are cognitive attributes then the w_{k_1}'s are presented as an attribute list of a potential solution. Go to (6). If not (4) is repeated by relaxing the minimization serially first for w_1 then w_2, etc. (Relaxation of the minimization means to accept the first runner-up for minimum, followed by the second, etc.) If this fails then pairs of w_j's are relaxed followed by triples should this fail, etc. If all relaxed minimizations fail redefine $p = p - \delta p$, where δp is a prespecified parameter.

Repeat (4) till success or $p < 0$. If $p < 0$ then there is no solution derivable from current memory of object cognitive and affectual attributes.

(6) The attribute list is listed together with known objects carrying these attributes (to within $100p\%$) and verbs used to define W. A statement, not in general unique, is found by linking the known objects through these verbs. This statement (achieved by human evaluation of the output) is a candidate for a reality test. If it fails modify W as appropriate and/or iterate step 5. If no modification of W and/or iteration succeeds then this corresponds to $p < 0$ in step 5.

Steps 1–6 represent H. Step 4 allows generalization to accommodate constraints from reality or superego. For reality set $d(w_{k_1}, w_j) = \infty$ for suitable cognate pairs and for superego constraint do likewise if w_{k_1} associates too much with affect a_k. Note that the intuitive linguistic capacity that links nouns through verbs (referred to in step 6) is formulatable though not outlined here.

The example to follow was chosen to illustrate the mechanics of steps 1–6. It has been greatly simplified to assure rapid convergence thus allowing a listing of the recursions. Hopefully, the simplifications do not comprise reality so much as to make it a poor example.

Consider a child in a playpen. Outside the pen beyond its reach is an object it wishes to fetch. In the pen are a ball, a bottle, and a stick. For simplicity let the set of known objects (to the child) be ball, bottle, stick, hand, and arm (the algorithm would quickly reject most other objects). For this problem W = to reach and grasp the object. W has cognitive attributes w_1 = length, w_2 = grasp, w_3 = shape, and affectual attributes a_1 = mastery, a_2 = curiosity, and a_3 = satisfaction. Here, each a_k ($k = 1,2,3$) is associated with all the attributes w_j ($j = 1,2,3$) which correspond here to the w_{k_1}'s. Table 1 itemizes how the w_j's are associated with objects known to the child. Note that only W has all attributes w_1, w_2, and w_3. Table 2 summarizes the relative proximities of the w_j's. These distances are ordinal, meaning, for example, that length is more related to shape than to grasp or that grasp is more related to shape than length; shape is equally related to length and grasp.

Table 1. Cognitive attributes of known objects (w_j's)

	Length	Grasp	Shape
Ball	N	N	Y
Bottle	N	N	Y
Stick	Y	N	Y
Hand	N	Y	Y
Arm	Y	N	N
W	Y	Y	Y

Table 2. Distances between cognitive attributes

	Length	Grasp	Shape
Length	0	2	1
Grasp	2	0	1
Shape	1	1	0

Begin the algorithm with $p = 0.85$, $\delta p = 0.1$, and bear in mind that arm, hand, and stick are obviously the objects in the solution. Items A–D below together with the paragraph after D summarize the iterations.

(A) $\min d(w_{k_1}, w_1) = 0$ which corresponds to length,
$\min d(w_{k_1}, w_2) = 0$ which corresponds to grasp,
$\min d(w_{k_1}, w_3) = 0$ corresponding to shape; only W has $100p\%$ of these attributes and W is not a known object.

(B) Relax the minimization one at a time;
(w_1 relaxed) obtain w_3, w_2, w_3, or w_2, w_2, w_3 = grasp, shape; only hand as $100p\%$ of these attributes.
(w_2 relaxed) obtain w_1, w_3, w_3, or w_1, w_1, w_3 = length, shape; this yields stick.
(w_3 relaxed) obtain w_1, w_2, w_1 or w_1, w_2, w_2 = length, grasp; this corresponds to no known object.

(C) Relax the minimization two at a time;
(w_1, w_2 relaxed) obtain w_3, w_3, w_3 = shape; this yields ball, bottle, stick, hand; also obtain w_3, w_2, w_3 = grasp, shape; this yields hand; also obtain w_2, w_1, w_3 and w_2, w_3, w_3 which are listed above.
(w_1, w_3 relaxed) obtain w_3, w_2, w_1 as above; also w_3, w_2, w_2 as above; also w_2, w_2, w_1 as above; and w_2, w_2, w_2 which yields hand.
(w_2, w_3 relaxed) obtain w_1, w_3, w_1 as above; also w_1, w_3, w_2 as above; also w_1, w_1, w_1 which yields arm, stick; also w_1, w_1, w_2 as above.

(D) Relax the minimization three at a time to obtain the following triples all of which repeat above triples:
w_2, w_1, w_1; w_2, w_1, w_2; w_2, w_3, w_1; w_2, w_3, w_2;
w_3, w_1, w_1; w_3, w_1, w_2; w_3, w_3, w_1; w_3, w_3, w_2.

If p changes, none of the above changes till $p = 0.65$. However, it is not until $p = 0.45$ and w_3 is relaxed in the minimization that we obtain as attributes w_1, w_2, and w_1 or length and grasp. The known objects having $100p\%$ of these attributes are stick, hand, and arm. The verbs of W are reach and grasp which may be used to link the known objects as arm reach (stick), hand grasp (stick), (stick) reach object and grasp.

This paper does not address mechanizing the linking of the w_{k_1}'s through the verbs of W and so a human judgment of the outputs would be necessary. The purpose of the example is to illustrate in a simple way the convergence to an obvious solution.

If the example were real then after adaptation the object stick would have associated with it the cognitive attribute grasp as well as all affects which are associated with grasp. This fact could be easily generalized and used to augment the present algorithm to an evolutionary (ontogenetic) simulation.

A Fortran implementation of examples 2 and 3

The algorithms (H) presented above lend themselves readily to programming. Figure 3 is a flowchart for a Fortran implementation of these algorithms; Fig. 4 is a listing of the program itself. This implementation is faithful to the algorithms given except for step 5 of the algorithm for simulating the creative mechanism. Relaxed minima are here restricted to being one or two at a time and for each of these only relaxations up to the first runner-up for the minimum distance are allowed.

The implementation given is limited to ten affects, ten cognates, and twenty objects, each affect and each object having up to ten cognates as associates (affect) or attributes (object). These small numbers serve the purpose of illustration and do not define natural limits. Similarly, the numerical data were chosen for appropriateness and clarity of presentation (systematic and exhaustive studies of data of this kind are still pending although first efforts date back to about 1910 with the association experiments of C. J. Jung and E. Bleuler; indeed it is data of this very kind which is among the goals of psychoanalysis).

The notation in the listing features the variables DREAM, M, NA, NC, NOB, P, DP

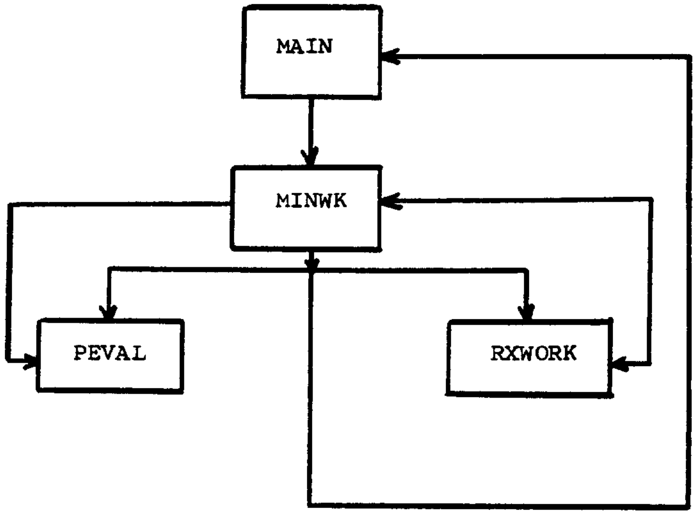

Fig. 3a. The relationship of MAIN to subroutines MINWK, PEVAL, and RXWORK.

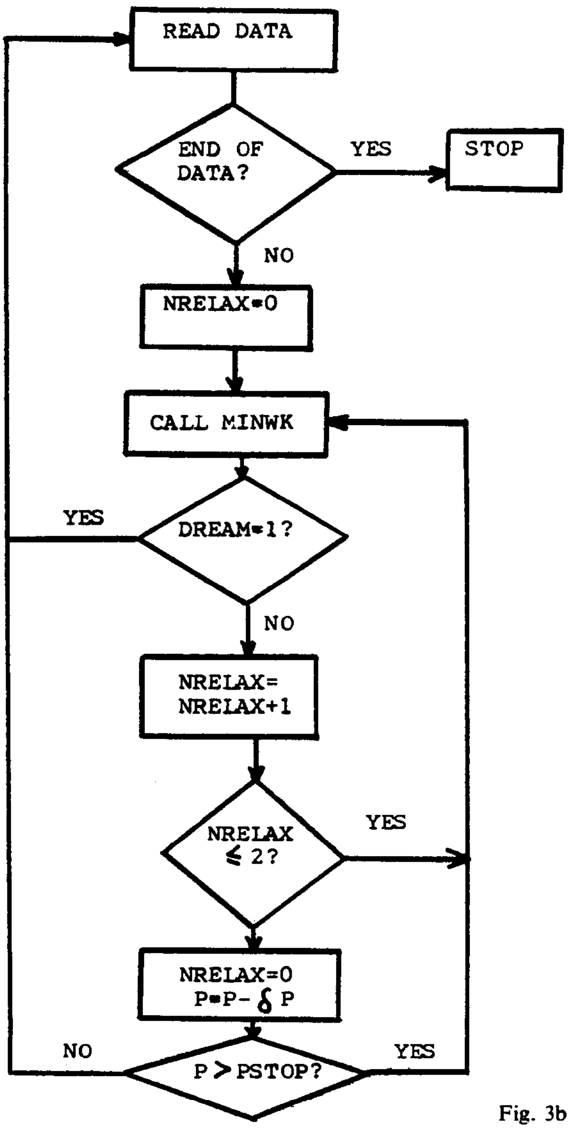

Fig. 3b. The structure of MAIN.

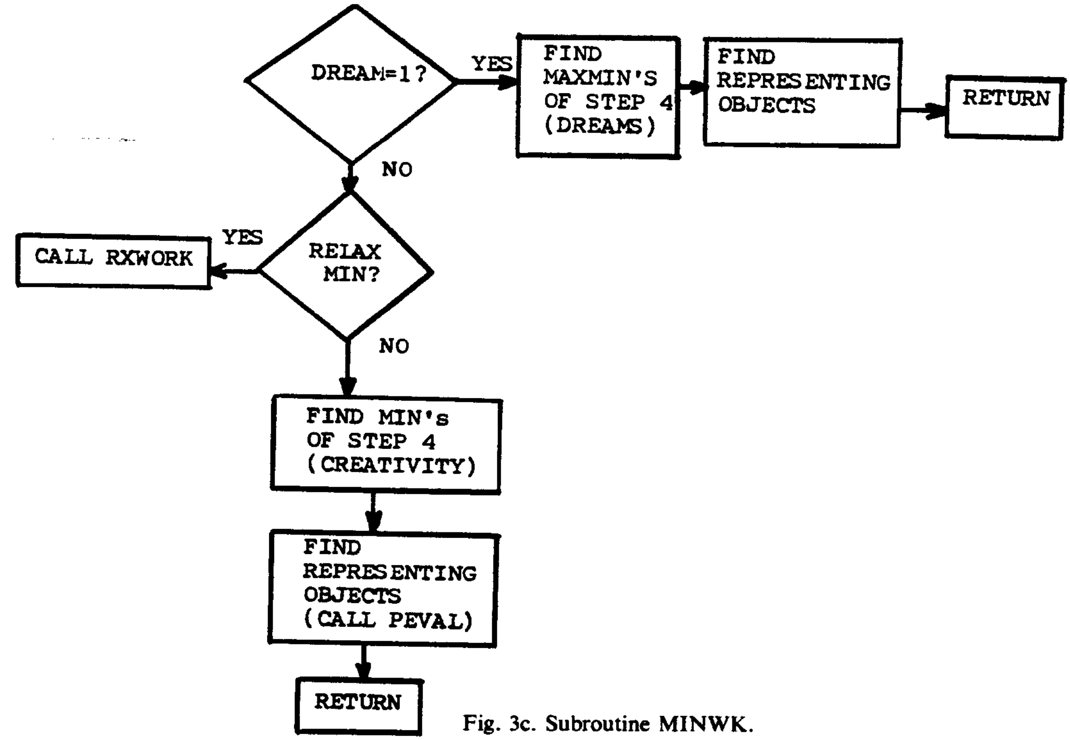

Fig. 3c. Subroutine MINWK.

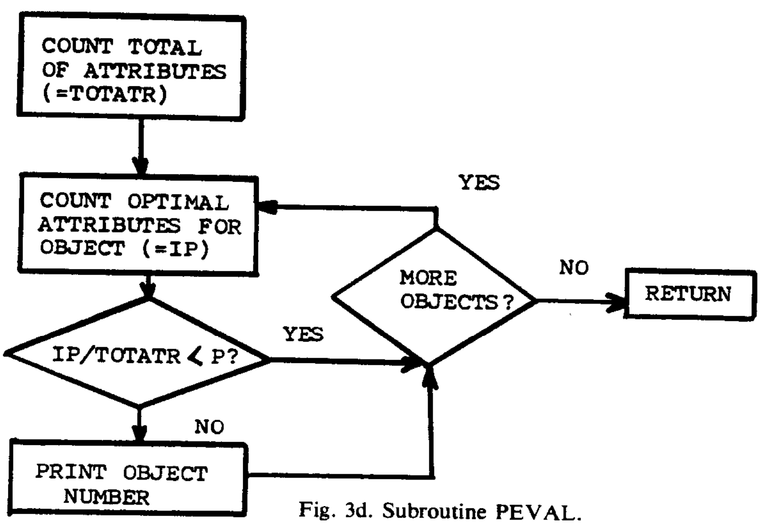

Fig. 3d. Subroutine PEVAL.

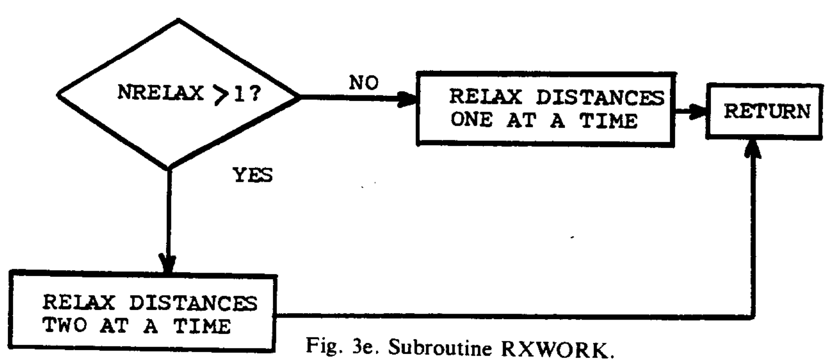

Fig. 3e. Subroutine RXWORK.

and PSTOP which represent, respectively, a simulate dreams flag (if DREAM = 1 then simulate dreaming else simulate creativity), the magnitude criterion of step 4 in dream simulation, the number of affects (of W, the wish), the number of cognates (known to the subject, not necessarily of W), the number of known objects, the fraction criterion of step 5 in creativity, the decrement of p (step 5), and the final value of p for the run. The term cognate indicator refers to a binary variable indicating presence or absence of a cognate with respect to an affect or object.

The data for the dream below is given in Fig. 5 which is the output of the simulation. The dream itself was related to Freud by an adult patient [2]:

". . . She dreamed it when she was four years old, and it was this: 'A fox or a lynx is walking about the roof; then something falls down, or she falls down, and after that, her mother is carried out of the house—dead'; whereat the dreamer weeps bitterly. I have no sooner informed her that this dream must signify a childish wish to see her mother dead, and that it is because of this dream that she thinks her relatives must shudder at her, then she furnishes material in explanation of the

```
      EXTERNAL PEVAL
      INTEGER OBJ(20,10)
      INTEGER DREAM
      INTEGER*2 C(5,80)
      REAL M
      COMMON DW(10,10),OBJ,IA(10,10),NA,NC,NOB,P,DP
      COMMON DREAM,M
C     NA=#AFFECTS OF W: NC=#COGNATES KNOWN TO SUBJECT.
    5 WRITE(6,1600)
      READ(1,1000,END=99)((C(I,J),J=1,80),I=1,5)
      WRITE(6,2000)((C(I,J),J=1,80),I=1,5)
      READ(1,1100)DREAM,M
      READ(1,1200)NA,NC,NOB,P,DP,PSTOP
      WRITE(6,1500)
      DO 100 K=1,NA
      READ(1,1300)(IA(K,L),L=1,NC)
  100 WRITE(6,2100)K,(IA(K,L),L=1,NC)
      WRITE(6,1500)
      DO 110 K=1,NC
      READ(1,1400)(DW(K,L),L=1,NC)
  110 WRITE(6,2200)K,(DW(K,L),L=1,NC)
      WRITE(6,1500)
C     THE FIRST OBJECT IS THE WISH.
      NOB=NOB+1
      DO 130 K=1,NOB
      READ(1,1300)(OBJ(K,L),L=1,NC)
      K1=K-1
      IF(K1.NE.0)WRITE(6,2300)K1,(OBJ(K,L),L=1,NC)
      IF(K1.EQ.0)WRITE(6,2400)(OBJ(1,L),L=1,NC)
  130 CONTINUE
      WRITE(6,1500)
      NRELAX=0
   50 CALL MINWK(NRELAX,PEVAL)
      IF(DREAM.EQ.1)GOTO5
      NRELAX=NRELAX+1
      IF(NRELAX.LE.2)GOTO50
      WRITE(6,1500)
      NRELAX=0
      P=P-DP
      IF(P.GT.PSTOP)GOTO50
      GOTO5
   99 WRITE(6,999)
      STOP
  999 FORMAT(//1X,'JOB RAN TO COMPLETION.')
 1000 FORMAT((80A1))
 1100 FORMAT(I5,F5.2)
 1200 FORMAT(3I5,3F5.3)
 1300 FORMAT(20I1)
 1400 FORMAT(10F5.2)
 1500 FORMAT(//)
 1600 FORMAT(1H1)
 2000 FORMAT((1X,80A1))
 2100 FORMAT(1X,'AFFECT ',I2,' COGNATE INDICATORS: ',20I2)
 2200 FORMAT(1X,'COGNATE ',I2,' DISTANCES: ',10F5.2)
 2300 FORMAT(1X,'OBJECT ',I2,' COGNATE INDICATORS: ',20I2)
 2400 FORMAT(1X,'COGNATE INDICATORS FOR W: ',20I2)
      END
```

Fig. 4. The Fortran source code for an implementation of the algorithms for dream formation and the mechanism of creativity.

```
      SUBROUTINE MINWK(NRELAX,PEVAL)
      INTEGER OBJ(20,10)
      INTEGER DREAM
      REAL M
      COMMON DW(10,10),OBJ,IA(10,10),NA,NC,NOB,P,DP
      COMMON DREAM,M
      DIMENSION IAMIN(10)
      DIMENSION IDREAM(10,10)
      DATA IDREAM/100*0/
      IFOUND=0
      LAX=0
    5 DO 50 I=1,NC
   50 IAMIN(I)=0
      IF(DREAM.EQ.1)GOTO5000
      IF(NRELAX.EQ.0)GOTO25
      CALL RXWORK(NRELAX,LAX)
      IF(LAX.EQ.-1)RETURN
   25 DO 100 I=1,NA
      DO 200 J=1,NC
      DMIN=99.
      IF(OBJ(1,J).EQ.0)GOTO200
      DO 210 K=1,NC
      IF(IA(I,K).EQ.0)GOTO210
      IF(DMIN.LE.DW(K,J))GOTO210
      MIN=K
      DMIN=DW(K,J)
  210 CONTINUE
      IAMIN(MIN)=MIN
  200 CONTINUE
      IF(DMIN.GT.98.)MIN=-1
  100 CONTINUE
      WRITE(6,1000)NRELAX,P,(IAMIN(L),L=1,NC)
 1000 FORMAT(/,' AT RELAXATION: ',I2,' WITH P = ',F5.2,' MINIMIZING ATTR
     1IBUTES ARE: ',10I3)
      CALL PEVAL(IAMIN,IFOUND)
      IF(IFOUND.EQ.0)WRITE(6,1100)P
 1100 FORMAT(1X,'$$$$$NO OBJECTS FOUND AT P =',F5.2)
      IF(NRELAX.EQ.0)RETURN
      GOTO5
C*****ENTRY POINT FOR DREAMS.
 5000 DO 5100 K=1,NA
      OLDMIN=0.
      DO 5200 L=1,NC
      DMIN=98.
      IF(IA(K,L).EQ.0)GOTO5200
      DO 5300 J=1,NC
      IF(J.EQ.L)GOTO5300
      IF(OBJ(1,J).EQ.0)GOTO5300
      IF(DW(J,L).LT.M)GOTO5300
      IF(DW(J,L).GE.DMIN)GOTO5300
      DMIN=DW(J,L)
      MIMLOC=J
 5300 CONTINUE
      IF(DMIN.LE.OLDMIN)GOTO5200
      MAXMIN=L
      OLDMIN=DMIN
 5200 CONTINUE
      IAMIN(K)=MAXMIN
      WRITE(6,7100)K,MAXMIN
 7100 FORMAT(1X,'AFFECT # ',I2,' IS REPRESENTED BY COGNATE # ',I2)
 5100 CONTINUE
      DO 6000 K=1,NA
      IF(IAMIN(K).EQ.0)GOTO6000
      KK=IAMIN(K)
      DO 6000 J=2,NOB
      IF(OBJ(J,KK).EQ.0)GOTO6000
      IDREAM(K,J)=1
 6000 CONTINUE
      DO 6500 K=1,NA
      ISAME=NC
      DO 6600 J=2,NOB
      MATCH=0
      IF(IDREAM(K,J).EQ.0)GOTO6600
      DO 6700 L=1,NC
      IF(OBJ(1,L).EQ.0)GOTO6700
      IF(OBJ(J,L).EQ.1)MATCH=MATCH+1
 6700 CONTINUE
      IF(MATCH.GT.ISAME)GOTO6600
      ISAME=MATCH
C     OBJECT 1 IS THE WISH.
      MINLOC=J-1
 6600 CONTINUE
      WRITE(6,7000)MINLOC,K
 7000 FORMAT(//,1X,'OBJECT # ',I2,' IS A DREAM ELEMENT FOR AFFECT ',I2)
 6500 CONTINUE
      RETURN
      END
```

Fig. 4. *continued.*

```
      SUBROUTINE RXWORK(NRELAX,LAX)
      INTEGER OBJ(20,10)
      REAL M
      INTEGER DREAM
      COMMON DW(10,10),OBJ,IA(10,10),NA,NC,NOB,P,DP
      COMMON DREAM,M
      LAX=LAX+1
      IF(NRELAX.GT.1)GOTO200
      IF(LAX.GT.NC)GOTO100
      DW(LAX,LAX)=99.
      IF(LAX.GT.1)DW(LAX-1,LAX-1)=0.
      RETURN
  100 DW(NC,NC)=0.
      LAX=-1
      RETURN
C     FIND NC OBJECTS TWO AT A TIME.
  200 IF(LAX.GT.(NC*(NC-1))/2)GOTO99
      IF(LAX.GT.1)GOTO225
      L1=1
      L2=2
      DW(1,1)=99.
      DW(2,2)=99.
      RETURN
  225 IF(L2.LE.NC-1)GOTO250
      DW(L1,L1)=0.
      DW(NC,NC)=0.
      L1=L1+1
      L2=L1+1
      DW(L1,L1)=99.
      DW(L2,L2)=99.
      RETURN
  250 DW(L2,L2)=0.
      L2=L2+1
      DW(L2,L2)=99.
      RETURN
   99 LAX=-1
      DW(NC-1,NC-1)=0.
      DW(NC,NC)=0.
      RETURN
      END

      SUBROUTINE PEVAL(MINS,IFOUND)
      INTEGER OBJ(20,10)
      INTEGER DREAM
      REAL M
      COMMON DW(10,10),OBJ,IA(10,10),NA,NC,NOB,P,DP
      COMMON DREAM,M
      DIMENSION MINS(10)
C     COUNT THE NUMBER OF DISTINCT OPTIMAL ATTRIBUTES.
      TOTATR=0.
      DO 50 I=1,NC
      IF(MINS(I).NE.0)TOTATR=TOTATR+1
   50 CONTINUE
C     FIND OBJECT CANDIDATES FOR SOLUTION.
      DO 100 K=2,NOB
      IP=0
      DO 200 L=1,NC
      MINL=MINS(L)
      IF(MINL.EQ.0)GOTO200
      IF(OBJ(K,MINL).NE.1)GOTO200
      IP=IP+1
  200 CONTINUE
      SCORE=FLOAT(IP)/TOTATR
      IF(SCORE.LT.P)GOTO100
      IFOUND=IFOUND+1
      K1=K-1
      WRITE(6,1000)K1
 1000 FORMAT(1X,'OBJECT # ',I2,' HAS 100P% OF ATTRIBUTES')
  100 CONTINUE
      RETURN
      END
```

Fig. 4. *continued.*

dream. 'Lynx-eye' is an opprobrious epithet which a street boy once bestowed on her when she was a very small child; and when she was three years old a brick or tile fell on her mother's head, so that she bled profusely."

The output of the simulation is the set of nouns used to represent the affects of the dream wish W. These nouns are brick, lynx, and house. The wish W is quoted in the text above. Since this simulator does not feature verb synthesis these nouns must be connected independently of the simulation but as indicated in the dream and in Freud's narrative.

```
COGNATES 1,2,3,4 ARE PARENT,VICTOR,WEAPON,HUMAN.
AFFECTS 1,2,3,4 ARE RAGE, JEALOUSY, CONTROL, AND LOVE.
PARAMETERS: DREAM=1, M=.5.
PARAMETERS: NA=4,NC=4,NOB=5,P=0.,DP=0.,PSTOP=0.
(1,2,3,4,5)=(SELF,MOTHER,HOUSE,LYNX,BRICK).


AFFECT  1 COGNATE INCICATORS:  0 1 1 0
AFFECT  2 COGNATE INDICATORS:  1 0 1 0
AFFECT  3 COGNATE INDICATORS:  0 1 0 1
AFFECT  4 COGNATE INDICATORS:  1 0 0 0


COGNATE  1 DISTANCES:  0.0  2.00 3.00 1.00
COGNATE  2 DISTANCES:  2.00 0.0  4.00 3.00
COGNATE  3 DISTANCES:  3.00 4.00 0.0  5.00
COGNATE  4 DISTANCES:  1.00 3.00 5.00 0.0


COGNATE INDICATORS FOR W:  1 1 1 1
OBJECT  1 COGNATE INDICATORS:  0 1 1 1
OBJECT  2 COGNATE INCICATORS:  1 1 0 1
OBJECT  3 COGNATE INDICATORS:  1 0 0 0
OBJECT  4 COGNATE INCICATORS:  0 1 1 0
OBJECT  5 COGNATE INDICATORS:  0 0 1 0


AFFECT #   1 IS REPRESENTED BY COGNATE #  3
AFFECT #   2 IS REPRESENTED BY COGNATE #  3
AFFECT #   3 IS REPRESENTED BY COGNATE #  2
AFFECT #   4 IS REPRESENTED BY COGNATE #  1

OBJECT #   5 IS A CREAM ELEMENT FOR AFFECT  1

OBJECT #   5 IS A DREAM ELEMENT FOR AFFECT  2

OBJECT #   4 IS A CREAM ELEMENT FOR AFFECT  3

OBJECT #   3 IS A DREAM ELEMENT FOR AFFECT  4
```

Fig. 5. Simulation of Freud's "lynx-eye" dream.

The data for the illustration of simulating creativity was given in Tables 1 and 2. Figure 6 is the beginning section of output for this problem and it again itemizes the data. The object water with cognitive attribute wetness has been added to demonstrate how the algorithm rejects irrelevant objects (water is never cited as an element of the solution). The output is lengthy and therefore only the first page with this data as well as the page where the elements of the solution appear are given in that figure. These elements are cited at relaxation 1 with $p = 0.45$ as object numbers 3, 4, and 5 which correspond to stick, hand, and arm.

A final illustration will exhibit the difference in structure between dream and creativity simulation. Here the same wish—to be detailed below—is used to drive the simulation both of dreams and of creativity. Figure 7 presents the data and that page of output for creativity where the (appropriate) elements of a solution are presented (these being object numbers 1, 2, 3, and 6 which occur at relaxation 0 with $p = 0.4$). Here again the output is lengthy and therefore only the relevant pages are given. Note that Fig. 7a summarizes dream simulation and Fig. 7b creativity simulation.

This illustration is a hypothetical reconstruction of the invention of the chain. Consider at an historical time prior to the chain's invention a property owner frustrated by the inability of a rope to block passage along a path onto his property. This rope prior to its ruin joined the tips of two posts planted at the edges of the path. The wish W of a person in this hypothetical circumstance might be stated: W = to join the posts with another kind of rope strong enough to be an effective obstacle.

```
COGNATES 1,2,3,4 ARE LENGTH, GRASP, SHAPE, AND WETNESS.
AFFECTS 1,2,3 ARE MASTERY, CURIOSITY, AND SATISFACTION.
PARAMETERS: DREAM=0,M=0.0.
PARAMETERS: NA=3,NC=4,NOB=6,P=.85,DP=.1,PSTCP=.25.
(1,2,3,4,5,6)=(BALL,BOTTLE,STICK,HAND,ARM,WATER).


AFFECT  1 COGNATE INDICATORS:  1 1 1 0
AFFECT  2 COGNATE INDICATORS:  1 1 1 0
AFFECT  3 COGNATE INDICATORS:  1 1 1 0


COGNATE  1 DISTANCES:  0.0  2.00 1.00 3.00
COGNATE  2 DISTANCES:  2.00 0.0  1.00 3.00
COGNATE  3 DISTANCES:  1.00 1.00 0.0  3.00
COGNATE  4 DISTANCES:  3.00 3.00 3.00 0.0


COGNATE INDICATORS FOR W:  1 1 1 0
OBJECT  1 COGNATE INDICATORS:  0 0 1 0
OBJECT  2 COGNATE INDICATORS:  0 0 1 0
OBJECT  3 COGNATE INDICATORS:  1 0 1 0
OBJECT  4 COGNATE INDICATORS:  0 1 1 0
OBJECT  5 COGNATE INDICATORS:  1 0 0 0
OBJECT  6 COGNATE INDICATORS:  0 0 0 1


AT RELAXATION:  0 WITH P =  0.85 MINIMIZING ATTRIBUTES ARE:   1  2  3  0
$$$$$NO OBJECTS FOUND AT P = 0.85

AT RELAXATION:  1 WITH P =  0.85 MINIMIZING ATTRIBUTES ARE:   0  2  3  0
OBJECT #  4 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  1 WITH P =  0.85 MINIMIZING ATTRIBUTES ARE:   1  0  3  0
OBJECT #  3 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  1 WITH P =  0.85 MINIMIZING ATTRIBUTES ARE:   1  2  0  0

AT RELAXATION:  1 WITH P =  0.85 MINIMIZING ATTRIBUTES ARE:   1  2  3  0

AT RELAXATION:  2 WITH P =  0.85 MINIMIZING ATTRIBUTES ARE:   0  0  3  0
OBJECT #  1 HAS 100P% OF ATTRIBUTES
OBJECT #  2 HAS 100P% OF ATTRIBUTES
OBJECT #  3 HAS 100P% OF ATTRIBUTES
OBJECT #  4 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.85 MINIMIZING ATTRIBUTES ARE:   1  2  3  0

AT RELAXATION:  2 WITH P =  0.85 MINIMIZING ATTRIBUTES ARE:   0  2  3  0
OBJECT #  4 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.85 MINIMIZING ATTRIBUTES ARE:   1  0  3  0
OBJECT #  3 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.85 MINIMIZING ATTRIBUTES ARE:   1  0  3  0

AT RELAXATION:  0 WITH P =  0.45 MINIMIZING ATTRIBUTES ARE:   1  2  3  0
OBJECT #  3 HAS 100P% OF ATTRIBUTES
OBJECT #  4 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  1 WITH P =  0.45 MINIMIZING ATTRIBUTES ARE:   0  2  3  0
OBJECT #  1 HAS 100P% OF ATTRIBUTES
OBJECT #  2 HAS 100P% OF ATTRIBUTES
OBJECT #  3 HAS 100P% OF ATTRIBUTES
OBJECT #  4 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  1 WITH P =  0.45 MINIMIZING ATTRIBUTES ARE:   1  0  3  0
OBJECT #  1 HAS 100P% OF ATTRIBUTES
OBJECT #  2 HAS 100P% OF ATTRIBUTES
OBJECT #  3 HAS 100P% OF ATTRIBUTES
OBJECT #  4 HAS 100P% OF ATTRIBUTES
OBJECT #  5 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  1 WITH P =  0.45 MINIMIZING ATTRIBUTES ARE:   1  2  0  0
OBJECT #  3 HAS 100P% OF ATTRIBUTES
OBJECT #  4 HAS 100P% OF ATTRIBUTES
OBJECT #  5 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  1 WITH P =  0.45 MINIMIZING ATTRIBUTES ARE:   1  2  3  0
OBJECT #  3 HAS 100P% OF ATTRIBUTES
OBJECT #  4 HAS 100P% OF ATTRIBUTES
```

Fig. 6. Simulation of the illustration of Example 3 (child in a playpen). (Note: relaxation number refers to how many variables are being relaxed—here limited to 0, 1, or 2.)

```
AT RELAXATION:  2 WITH P =  0.45 MINIMIZING ATTRIBUTES ARE:   0  0  3  0
OBJECT #   1 HAS 100P% OF ATTRIBUTES
OBJECT #   2 HAS 100P% OF ATTRIBUTES
OBJECT #   3 HAS 100P% OF ATTRIBUTES
OBJECT #   4 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.45 MINIMIZING ATTRIBUTES ARE:   1  2  3  0
OBJECT #   3 HAS 100P% OF ATTRIBUTES
OBJECT #   4 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.45 MINIMIZING ATTRIBUTES ARE:   0  2  3  0
OBJECT #   1 HAS 100P% OF ATTRIBUTES
OBJECT #   2 HAS 100P% OF ATTRIBUTES
OBJECT #   3 HAS 100P% OF ATTRIBUTES
OBJECT #   4 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.45 MINIMIZING ATTRIBUTES ARE:   1  0  3  0
OBJECT #   1 HAS 100P% OF ATTRIBUTES
OBJECT #   2 HAS 100P% OF ATTRIBUTES
OBJECT #   3 HAS 100P% OF ATTRIBUTES
OBJECT #   4 HAS 100P% OF ATTRIBUTES
OBJECT #   5 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.45 MINIMIZING ATTRIBUTES ARE:   1  0  3  0
OBJECT #   1 HAS 100P% OF ATTRIBUTES
OBJECT #   2 HAS 100P% OF ATTRIBUTES
OBJECT #   3 HAS 100P% OF ATTRIBUTES
OBJECT #   4 HAS 100P% OF ATTRIBUTES
OBJECT #   5 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.45 MINIMIZING ATTRIBUTES ARE:   1  2  0  0
OBJECT #   3 HAS 100P% OF ATTRIBUTES
OBJECT #   4 HAS 100P% OF ATTRIBUTES
OBJECT #   5 HAS 100P% OF ATTRIBUTES
```

Fig. 6. *continued.*

```
COGNATES 1 TO 7 ARE LENGTH,TIPPED,STRONG,WOODEN,FLEXIBLE,LIMITED,JOINED.
AFFECTS 1,2,3 ARE CONTROL, ANGER, AND DISAPPOINTMENT.
PARAMETERS: DREAM=1,M=.5.
PARAMETERS: NA=3,NC=7,NOB=7,P=.9,DP=.1,PSTOP=.2.
(1,2,3,4,5,6,7)=(POST,ROPE,SPINE,PEN,OBSTACLE,RING,PARCHMENT).


AFFECT  1 COGNATE INDICATORS:  1 0 1 0 0 0 0
AFFECT  2 COGNATE INDICATORS:  0 0 1 0 0 0 0
AFFECT  3 COGNATE INDICATORS:  0 0 0 0 0 1 1


COGNATE  1 DISTANCES:  0.0   4.00 2.00 2.00 3.00 5.00 2.00
COGNATE  2 DISTANCES:  4.00 0.0   4.00 3.00 4.00 6.00 4.00
COGNATE  3 DISTANCES:  2.00 4.00 0.0   1.00 3.00 6.00 1.00
COGNATE  4 DISTANCES:  2.00 3.00 1.00 0.0   1.00 4.00 1.00
COGNATE  5 DISTANCES:  3.00 4.00 3.00 1.00 0.0   5.00 3.00
COGNATE  6 DISTANCES:  5.00 6.00 6.00 4.00 5.00 0.0   4.00
COGNATE  7 DISTANCES:  2.00 4.00 1.00 1.00 3.00 4.00 0.0


COGNATE INDICATORS FOR W:  1 0 1 0 1 1 1
OBJECT  1 COGNATE INDICATORS:  1 1 1 0 0 0 0
OBJECT  2 COGNATE INDICATORS:  1 0 0 1 1 1 0
OBJECT  3 COGNATE INDICATORS:  1 0 1 0 1 0 1
OBJECT  4 COGNATE INDICATORS:  1 1 0 0 0 0 0
OBJECT  5 COGNATE INDICATORS:  0 0 1 0 0 0 0
OBJECT  6 COGNATE INDICATORS:  0 0 1 0 0 1 0
OBJECT  7 COGNATE INDICATORS:  0 0 0 1 0 1 0


AFFECT #   1 IS REPRESENTED BY COGNATE #  1
AFFECT #   2 IS REPRESENTED BY COGNATE #  3
AFFECT #   3 IS REPRESENTED BY COGNATE #  6


OBJECT #   4 IS A DREAM ELEMENT FOR AFFECT  1


OBJECT #   5 IS A DREAM ELEMENT FOR AFFECT  2


OBJECT #   7 IS A DREAM ELEMENT FOR AFFECT  3
```

Fig. 7a. Simulating a dream associated with the wish that leads to the invention of the chain.

```
COGNATES 1 TO 7 ARE LENGTH,TIPPED,STRONG,WOODEN,FLEXIBLE,LIMITED,JOINED.
AFFECTS 1,2,3 ARE CONTROL, ANGER, AND DISAPPOINTMENT.
PARAMETERS: DREAM=0, M=0.0.
PARAMETERS: NA=3,NC=7,NOB=7,P=.9,DP=.1,PSTOP=.2.
(1,2,3,4,5,6,7)=(POST,POPE,SPINE,PEN,OBSTACLE,RING,PARCHMENT).


AFFECT  1 COGNATE INDICATORS:  1 0 1 0 0 0 0
AFFECT  2 COGNATE INDICATORS:  0 0 1 0 0 0 0
AFFECT  3 COGNATE INDICATORS:  0 0 0 0 0 1 1


COGNATE  1 DISTANCES:  0.0  4.00 2.00 2.00 3.00 5.00 2.00
COGNATE  2 DISTANCES:  4.00 0.0  4.00 3.00 4.00 6.00 4.00
COGNATE  3 DISTANCES:  2.00 4.00 0.0  1.00 3.00 6.00 1.00
COGNATE  4 DISTANCES:  2.00 3.00 1.00 0.0  1.00 4.00 1.00
COGNATE  5 DISTANCES:  3.00 4.00 3.00 1.00 0.0  5.00 3.00
COGNATE  6 DISTANCES:  5.00 6.00 6.00 4.00 5.00 0.0  4.00
COGNATE  7 DISTANCES:  2.00 4.00 1.00 1.00 3.00 4.00 0.0


COGNATE INDICATORS FOR W:  1 0 1 0 1 1 1
OBJECT  1 COGNATE INDICATORS:  1 1 1 0 0 0 0
OBJECT  2 COGNATE INDICATORS:  1 0 0 1 1 1 0
OBJECT  3 COGNATE INDICATORS:  1 0 1 0 1 0 1
OBJECT  4 COGNATE INDICATORS:  1 1 0 0 0 0 0
OBJECT  5 COGNATE INDICATORS:  0 0 1 0 0 0 0
OBJECT  6 COGNATE INDICATORS:  0 0 1 0 0 1 0
OBJECT  7 COGNATE INDICATORS:  0 0 0 1 0 1 0


AT RELAXATION:  0 WITH P =  0.90 MINIMIZING ATTRIBUTES ARE:   1   0   3   0   0   6   7
$$$$$NO OBJECTS FOUND AT P = 0.90

AT RELAXATION:  1 WITH P =  0.90 MINIMIZING ATTRIBUTES ARE:   1   0   3   0   0   6   7
$$$$$NO OBJECTS FOUND AT P = 0.90

AT RELAXATION:  1 WITH P =  0.90 MINIMIZING ATTRIBUTES ARE:   1   0   3   0   0   6   7
$$$$$NO OBJECTS FOUND AT P = 0.90

AT RELAXATION:  1 WITH P =  0.90 MINIMIZING ATTRIBUTES ARE:   1   0   3   0   0   6   7
$$$$$NO OBJECTS FOUND AT P = 0.90

AT RELAXATION:  1 WITH P =  0.90 MINIMIZING ATTRIBUTES ARE:   1   0   3   0   0   6   7
$$$$$NO OBJECTS FOUND AT P = 0.90

AT RELAXATION:  1 WITH P =  0.90 MINIMIZING ATTRIBUTES ARE:   1   0   3   0   0   6   7
$$$$$NO OBJECTS FOUND AT P = 0.90

AT RELAXATION:  1 WITH P =  0.90 MINIMIZING ATTRIBUTES ARE:   1   0   3   0   0   0   7
OBJECT #  3 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  1 WITH P =  0.90 MINIMIZING ATTRIBUTES ARE:   1   0   3   0   0   6   7

AT RELAXATION:  2 WITH P =  0.90 MINIMIZING ATTRIBUTES ARE:   1   0   3   0   0   6   7

AT RELAXATION:  2 WITH P =  0.50 MINIMIZING ATTRIBUTES ARE:   1   0   3   0   0   6   7
OBJECT #  3 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.50 MINIMIZING ATTRIBUTES ARE:   1   0   3   0   0   0   7
OBJECT #  1 HAS 100P% OF ATTRIBUTES
OBJECT #  3 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.50 MINIMIZING ATTRIBUTES ARE:   1   0   3   0   0   6   7
OBJECT #  3 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.50 MINIMIZING ATTRIBUTES ARE:   1   0   3   0   0   6   7
OBJECT #  3 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.50 MINIMIZING ATTRIBUTES ARE:   1   0   3   0   0   6   7
OBJECT #  3 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.50 MINIMIZING ATTRIBUTES ARE:   1   0   3   0   0   0   7
OBJECT #  1 HAS 100P% OF ATTRIBUTES
OBJECT #  3 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.50 MINIMIZING ATTRIBUTES ARE:   1   0   3   0   0   6   7
OBJECT #  3 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.50 MINIMIZING ATTRIBUTES ARE:   1   0   3   0   0   6   7
OBJECT #  3 HAS 100P% OF ATTRIBUTES
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Fig. 7b. Simulating the hypothetical creation of the concept of the chain.

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AT RELAXATION:  2 WITH P =  0.50 MINIMIZING ATTRIBUTES ARE:   1  0  3  0  0  0  7
OBJECT #   1 HAS 100P% OF ATTRIBUTES
OBJECT #   3 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.50 MINIMIZING ATTRIBUTES ARE:   1  0  3  0  0  6  7
OBJECT #   3 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.50 MINIMIZING ATTRIBUTES ARE:   1  0  3  0  0  0  7
OBJECT #   1 HAS 100P% OF ATTRIBUTES
OBJECT #   3 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.50 MINIMIZING ATTRIBUTES ARE:   1  0  3  0  0  6  7
OBJECT #   3 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  2 WITH P =  0.50 MINIMIZING ATTRIBUTES ARE:   1  0  3  0  0  6  7
OBJECT #   3 HAS 100P% OF ATTRIBUTES


AT RELAXATION:  0 WITH P =  0.40 MINIMIZING ATTRIBUTES ARE:   1  0  3  0  0  6  7
OBJECT #   1 HAS 100P% OF ATTRIBUTES
OBJECT #   2 HAS 100P% OF ATTRIBUTES
OBJECT #   3 HAS 100P% OF ATTRIBUTES
OBJECT #   6 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  1 WITH P =  0.40 MINIMIZING ATTRIBUTES ARE:   1  0  3  0  0  6  7
OBJECT #   1 HAS 100P% OF ATTRIBUTES
OBJECT #   2 HAS 100P% OF ATTRIBUTES
OBJECT #   3 HAS 100P% OF ATTRIBUTES
OBJECT #   6 HAS 100P% OF ATTRIBUTES

AT RELAXATION:  1 WITH P =  0.40 MINIMIZING ATTRIBUTES ARE:   1  0  3  0  0  6  7
OBJECT #   1 HAS 100P% OF ATTRIBUTES
OBJECT #   2 HAS 100P% OF ATTRIBUTES
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Fig. 7b. *continued.*

The simulated dream elements that result from this wish are pen, obstacle, and parchment. The pen is accountable for as a distortion of tipped posts; the parchment being derived from wood shares attributes with the rope; obstacle is self-defining and may be amorphous. A dream that could reasonably account for the required wish fulfillment might be: a pen wrote on a parchment a (legal) obstacle to passage. Or, more graphically: one in authority (the self) wrote a decree barring passage.

However, the output for creativity simulation is different. The output is at most object numbers 1 or 3 (post or spine) until relaxation 0 with $p = 0.4$ where object numbers 1, 2, 3, and 6 are given. These object numbers correspond to post, rope, spine, and ring. These may be linked through the verbs of the wish (which are to join and to be) as follows:

join rings; join posts (with result);

or more elaborately:

a spine is joined rings; a spine is rope(like); joined rings are rope(like); join the posts with joined rings.

It is clear in the above examples that these simulations would be greatly enhanced by a verb synthesizing algorithm. Hopefully, the modest simulations outlined here capture enough of the adaptive mechanisms of dreaming and creativity to suggest the relevance of the analytic personality model to the goals of artificial intelligence.

Summary

It may be worthwhile when investigating design approaches to adaptive devices to consider the models of analytic psychology as candidates for a prototype. While not a completely developed science it has a variety of structured models for human adaptive functioning which may be emulatable perhaps via the approach suggested here.

The technology of intelligent devices seems to be maturing from problem specific designs to devices which feature a more general problem solving capability. Such elasticity of function is precisely human. And so while cognitive models have marvelously served the resolution of specific problems in systems science it is conceivable that analytic models can serve the resolution of elastically defined problems. This approach is informational in the sense previously suggested and not literal as in bionics where physico-chemical attributes are replicated. It is worthwhile to bear in mind that in this model all human behavior serves the purpose of securing adaptation. Therefore, although the results of the creative process may be askew in the pathological, nevertheless the concept of creativity subsumes all human response. It follows that no human contrivance can be without the attributes of the mechanism of this process. This is, in the author's opinion, a strong argument in favor of utilizing mechanistic psychological models—such as the analytic one—as inevitable prototypes for design of adaptive devices. Indeed if the human mind did conceive an adaptive device that worked with principles other than those man uses it would still be a result of the creative process and still the attributes of such a device would derive from those of the mechanism of adaptive response: there is no real departure from our own structure in our inventiveness even when we conceive objects that we are not.

REFERENCES

1. A. Badalamenti, Computer Design and Freud's Analytic Model: A Comparison, in *Proceedings of the 1979 North American Meeting of the Society for General Systems Research*, SGSR, Louisville, Kentucky.
2. S. Freud, *The Interpretation of Dreams*, Brill translation, pp. 157-158, Modern Library (1950).