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Summary

The results of the first stage of a research effort to develop a "sophisticated" computer model of human cognitive behavior are described. Most human decision making is an experience-based, relatively straightforward, largely automatic response to internal goals and drives, utilizing cues and opportunities perceived from the current environment. The development of the architecture and computer program (MoCog1) associated with such "recognition-primed" decision making is discussed. The resultant computer program was successfully utilized as a vehicle to simulate earlier findings that relate how an individual's implicit theories orient the individual toward particular goals, with resultant cognitions, affects, and behavior in response to their environment.

Introduction

The approaching era of manned space stations and space exploration carries with it the promise of advanced automation featuring intelligent computer programs and machines. Polson (1987) and Connors (1989) indicate that if such systems are to achieve a truly symbiotic relation with humans, they will require sophisticated modeling of their human partners. As a step toward achieving the long-term goal of developing a sophisticated computer model of human decision making, the initial aim of research efforts at NASA has been to develop a computer model of human cognition and decision making that focuses on the influence of affects. The ability to simulate actual psychological observations with the resultant system is one measure of the success of the effort.

We define "motivated cognition" as the process that emphasizes the role of affects in human cognition and decision making. These affects appear to be a major contributor to the distinctly different way in which human decision making is done relative to the more rational approaches generally considered in artificial intelligence. To date there has been a dearth of computer programs emphasizing the role of affects, though Colby (1973), Thagard and Kunda (1987), Woods et al. (1987), O'Rorke et al. (1989), and Sanders (1989) have all made contributions in this direction. DAYDREAMER (Mueller 1990) is the most sophisticated such program thus far developed, and Pfeifer (1988) recently reviewed artificial intelligence computer models of emotion.

There does not appear to be a universally accepted definition of "affects," so I will follow the lead of Buck (1988) and define affects as the motivational system underlying emotion. In this framework, emotions are interpreted as the readout process (self-awareness and outward expression) carrying information about motivation.

The material presented herein is an expanded version of an earlier work by the author (Gevarter 1991).

Relevance to NASA

The relevance of this research to NASA can be partially gleaned from the following quotes from Polson (1987):

> NASA has articulated a very ambitious design philosophy for expert systems to be used on the Space Station calling for the development of cooperative human-computer problem-solving systems. . . . Some of the issues are:
>
> - vigilance of the human operator
> - safe transition from the automatic to manual modes of operation
> - successful completion of a task after the automatic system has failed
> - allocations of functions between man and machine
> - and the development of truly symbiotic human-computer problem solving systems.
>
> . . . powerful problem solvers can be developed if systems exploit the complimentary strengths of human and machine permitting one to compensate for the weaknesses of the other. . . . A cooperative system must incorporate an extremely sophisticated model of its human partner which in turn requires a detailed understanding of how humans carry out the specific task performed by the system as well as the general characteristics of the human processing system and its failure modes. . . . In summary, the design and development of cooperative, human-computer problem solving is the most difficult of the technological goals related to cognitive science associated with the Space Station.

The need for such sophisticated human modeling can be expected to become even more important as long-range space missions are considered (cf. Kanas 1990).

Approach

In this report we limit our model to the type of relatively automatic single-pass decision making outlined in Gevarter (1991). This automatic, basically nonanalytic, decision making in response to environmental factors is very common in humans, particularly when they are under stress. Klein (1989) has termed this "recognition-primed decisions." Though, it is not necessary to emphasize it for this type of response, the ultimate decision maker in humans (cf. Gevarter 1975) is the structure provided by the combination of innate motivations and those programmed into the human subconscious during the human growth and maturation process. Associated with these motivations are emotional charges that tend to direct our thoughts and behaviors. Mueller's (1990) computer program, DAYDREAMER, is a good initial approach to an artificial intelligence program that simulates the resultant response. The focus of his program is emotionally based control of the human "train of thought." This type of process—which controls how the mind recalls associated information and moves its focus of attention about as it attends to the current situation—will be the subject of a follow-on report and its accompanying simulation (MoCog2). MoCog2 is being designed to handle much more complex thought and decision processes than the single-pass recognition-primed decision making described in the current report.

Pursuant to the long-term goal of developing a sophisticated model of human beings, the aim of our initial research has been to develop a computer model of human decision making that focuses on the influence of affects. Thus, for the first phase described in this report, the rational portion of the decision making has been kept simple.

Our plan has been to first develop in diagrammatic form the human decision-making approach from the perspective of information processing in the human brain (cf. Baron 1987; Paritsis 1987), and to couple that with a synthesis of the current psychological theories in motivated cognition (cf. Landy and Becker 1985; Abelson 1988; Buck 1988; and Dweck and Leggett 1988). The resultant composite can serve as an initial framework for developing computer programs demonstrating diverse theories and experiments in motivated cognition. In the process, the central framework will be iteratively refined and a more general computer program evolved.

It is important to note that at this stage of our knowledge, much of what is discussed in this paper should be treated as hypothetical rather than as fact. However, if based on these hypotheses our resultant computer models show adequate predictability and explanatory capability when applied to existing studies and future experiments, then our purposes will have been served.

Deriving a Model from Brain Research

In our approach we have found the three-level perspective of brain processing drawn from MacLean (1975) to be useful. In its evolution, the human brain has expanded along the lines of three basic patterns (a triune brain) which can be viewed as reptilian, paleomammalian (old mammal brain), and neomammalian (new mammal brain). The reptilian brain is associated with instinctive programming, the paleomammalian brain (which includes the limbic system) is associated with emotional programming derived from experience and socialization, and the neomammalian brain is cognitive, being associated with holistic perception, abstract thought, and language.

Affects are the motivational systems most commonly associated with emotions. From emotions, arise subjective experience and expressive behavior (and autonomic physiological response). Humans appear to be born with (or with the potential for) basic affect characteristics. Basic affects are associated with the lower levels of brain development, particularly with that of the limbic system.

Figure 1 is a simplified flow diagram of what might be considered basic inborn human responses to internal bodily states. Figure 2 illustrates our view of some of the affects encountered as one moves from the lower levels to the higher levels of the brain, though several of these affects are not available until later in the maturation process.

Based on the preceding, and on Baron's (1987) treatise, we have augmented the elementary flow diagram of figure 1 for motivated cognition to include the higher levels of the brain, as indicated in figure 3. The affect patterns referred to in the diagram can be considered to be vectors of affects indicating their degree of activation.

An individual responds to the world based not only on the current event but also on the individual's internal physiological and mental states. Thus, both of the lower two paths shown in figure 3 provide inputs to the brain's decision-making mechanism. But before elaborating on these paths and the resultant decision making, let us briefly review some of the fundamental aspects of brain functioning on which our approach is based (cf. Baron 1987; Gevarter 1982).

Baron (1987) and others suggest that the brain stores all experiences to which the individual pays conscious attention. In addition, Restak (1988, p. 264) concludes that "first, information can be incorporated into the mind without access to conscious awareness. Secondly, conscious intention cannot modify certain aspects of cognition." Restak also observes (p. 243) that "such memories are 'stored,' but in most instances they cannot consciously be voluntarily recollected."

In the brain, stored along with each experience are the affects that were present at the initiation of the experience and those that resulted from the experience. The affect patterns thus associated with the pre-conditions and post-conditions of the experience are accessible during future interactions. Thus, when an event is perceived it is automatically compared with the store of past events and, depending on similarity conditions (Baron 1987, p. 57), the associated affect patterns are activated. Thus the brain automatically renders a judgment on the degree to which this event is "for me or against me."

With this view, we can now follow the lower path in figure 3. Attributes of an event are observed by the sensory system, and the resulting sensory signals are compared with stored visual, auditory, and other sense experiences. These then elicit past situations and associated affect patterns that had similar patterns of sensory signals. This results in the current situation being perceived in terms of similar past situations and their associated affect patterns. The resulting inputs to the stored events yield a perceived event. The perceived event and its associated affect pattern may then activate associated ideas, concepts, and their stored affect patterns. These serve as a prediction of the consequence of the current event and its resultant affect pattern.

Following the middle path of figure 3, receptors sense the body's internal physiological state and the individual's current mental state, thereby activating the associated affect centers. This activation is combined with the activation induced by the affect patterns from the perceptions associated with the bottom path. The combined result is a current emotional state, or affect pattern (indicated in the top path of the figure).

We view a "need" as the difference between this current (or predicted) affect state and the optimal affect state [defined in a manner similar to that used by Baron (1987, pp. 468–470)]. "Goals" can be viewed as the things that if achieved will satisfy needs. "Procedures" are actions or strategies to achieve goals.

The current affect state and the expected affect states resulting from the current event act as inputs to the brain's control mechanism, which generates needs and goals to move the anticipated resultant affect state to a more desirable condition. These needs and the current context elicit applicable stored procedures. [This is in keeping with Sharkey and Bower's (1987) findings indicating that goals and plans are stored in memory as associative structures.] The predicted results and affiliated affect patterns (associated with the various applicable procedures) are then fed to the decision-making mechanism. This mechanism then seeks to select procedures that would produce the most desirable overall satisfaction of the generated needs, considering the weights or priorities given each affect and their current degree of activation.

Many elements of our approach are consistent with Buck's (1988) conceptual model of motivation and resultant emotional responses. In Buck's model, the process begins with an internal or external stimulus. This stimulus is evaluatively filtered by the biological motivational "primes" and relevant learning experienced by the individual. According to Buck (pp. 26–27), "The latter may be classically conditioned associations as well as direct or vicarious social learning experiences about the stimulus situation and the individual's social role in that particular situation. . . . Thus, the impact of a particular stimulus for a given person is determined by (1) the state of arousal of the neural system in question, and (2) the individual's relevant learning experiences associated with that stimulus."

Simplifications Used in Developing MoCog1

To develop MoCog1, the simulation of recognition-primed human decision making (our initial computer program), several simplifications were made.

1. Because data on the day-to-day variations in the internal affect state indicated by the middle path of figure 3 are often not available, this path has not been simulated. Instead it has been approximated by assigning initial values to the individual's relatively stable base (normal) affects such as self-image, happiness, and self-esteem.

2. Affect levels are taken to range linearly from –9 to 9 (from very negative to very positive) or from –9 to 0 or 0 to 9, as appropriate.

3. As a first approximation, the value of the total affect state has simply been taken as the sum of the individual affect states.

4. Affects have not been prioritized.

5. Because of the lack of actual data, the vectors of incremental affect values that procedures can be expected to produce are chosen subjectively.

6. In addition to the task preconditions, only the salient needs (those above a critical level) are considered necessary to access applicable procedures.

With these simplifications, figure 3 reduces to figure 4 for simulating an individual's response to a task.

Characterizing the Individuals

A significant computer program mirroring human behavior must be able to simulate real psychological experiments and observations. However, if an individual's response is based not only on the stimuli, but also on the individual's inherent nature and life experiences, then programming an individual's response (in general) means that these, or some attribute set or schema that meaningfully summarizes them, have to be entered into the program. One approach has been to try to characterize people by personality types with attributes such as introvert and extrovert. Dweck and Leggett (1988) have instead tried to build a system based on the individual's world view. We have used their work as a first test of our framework.

Dweck and Leggett (1988) suggest that one's behavior is very much influenced by how one views the world (a result of the world's responses to one's past behavior). In particular, they focus on two views: (1) things in the world being malleable and therefore subject to control and change, and (2) things being relatively fixed and therefore relatively uncontrollable. If we categorize something important to us as being uncontrollable, then our relationship to it is to monitor, measure, or judge its attributes. Whereas, if we view something important to us as controllable, then our response tends to be to act on or develop it—to understand and improve it. Table 1 indicates the cognitions, behaviors, and affects associated with these two views.

Dweck and Leggett observe that behavior is situation-dependent and is aimed at maximizing the composite positive affect (or minimizing the negative affect) resulting from trying to balance the multiple goals in response to the demands of the situation. This is consistent with figure 3 where the approach is to optimize a complex affect pattern.

Dweck and Leggett imply that their theory is applicable to many domains, such as intelligence, social, moral, physical skills, and even physical attractiveness. Their theory is supported by observations of upper-level grade-school children called upon to do intellectual tasks. Stemming from the child's view of the world as either being fixed or malleable, the child either has a performance orientation or goal (i.e., to be judged) or a learning orientation or goal. Table 2 indicates this relationship. Based on Dweck and Leggett's report, table 3 is our depiction of the relationships between (1) the students' general goal, their intelligence, and the task difficulty, and (2) the resultant observed students' behaviors (strategies), and reports by the students of their affects and cognitions. [Dweck and Leggett's findings of observed behavior tend to be in line with the coping strategies reported by Folkman et al. (1986), for adult subjects.]

The parameters associated with Dweck and Leggett's characterization of students and tests in a testing situation are (1) general goal (performance, learning); (2) intelligence (high, low); and (3) test difficulty (high, low, very high, that is, beyond the capabilities of any student).

Because Dweck and Leggett's report was an English language description, it was necessary to make many assumptions to transform their nonnumerical data into a computer program. As an initial characterization of the student, the student's normal (base-level) affect attributes of self-image, happiness, and self-esteem were subjectively assigned on a scale of –9 to 9 to vary from a 7 to 3 for self-image, 7 to 3 for happiness, and 6 to 2 for self-esteem, the high rating in each range being that assigned to high-intelligence, learning-oriented individuals.

Self-image is defined as "the self as the individual pictures or imagines it to be. The self image may differ widely from the true self" (Chaplin 1975, p. 478). "Self-esteem is a positive attitude towards oneself and one's behavior. Quite often it is a lasting personal disposition, but the self evaluation may shift depending on one's environment" (Wolman 1989, p. 309).

The Computer Program

MoCog1, the computer program I devised to simulate Dweck and Leggett's student responses to intellectual tasks, consists primarily of heuristic PROLOG rules used to calculate responses from input data at each input-output module shown in the flow diagram in figure 4. (More consistent with the nature of the brain and as a more universal generalization, the modules can be programmed as neural nets or connectionist networks [cf. McGregor 1987].)

Task Difficulty

Task difficulty was calculated as the students' perceptual responses to attributes of the tests based on the students' past experiences. Thus task difficulty of the various tests was calculated as a function of the subject, number of pages, and test duration.

Task low-level affect consequences– The primary low-level task affects of anxiety, pleasure, and boredom associated with perceived task difficulty were subjectively chosen as a function of task difficulty, student intelligence, and the student goal of performance or learning.

Mid-level anticipated success or failure response– The predicted mid-level cognitive response for the performance-oriented students was chosen as success for students whose ability (intelligence) was equal to or greater than that required by the test, and as failure for students whose capabilities were inadequate for the test. All the learning-oriented students anticipated success.

Mid-level affect response– The mid-level affect response (of pride, shame, and self-image increment) to the anticipated event outcome was computed as a function of the low-level affects, the student's general goal of learning or performance, the student's intelligence, and the student's perceived difficulty.

Predicted outcome– The predicted outcome for all the students with a general goal of learning was taken as "learned." The performance-oriented students' predicted outcome was "judged positively" for those who anticipated success, and "judged negatively" for those who anticipated failure.

Predicted outcome affects– The high-level affect response—of happiness and self-esteem increments—associated with the students' view of the anticipated outcome was subjectively chosen as (1) high-level affect increments of +1 each if the anticipated outcome was learned or judged positively; or (2) happiness reduced by 3, and self-esteem by 1, if the outcome was judged negatively.

Needs– The overall affect pattern was simply the vector constructed by appending the base and low- and mid-level affects to the high-level affects. The need list was constructed by subtracting the resultant affect vector from the ideal affect vector. Relevant needs were then taken to be all elements of the need list that exceeded a value of 3 (which appeared to be a good dividing point based on the simulation results).

Procedures– Procedures are the learned techniques accessible to the students to contend with their current situation (considering their needs and the context). The procedure chosen for execution is the procedure that maximizes the resultant affect total.

Results Obtained Using MoCog1 with Dweck and Leggett's Data

Figure 5 is a printout of a trace of an interaction between a computer user and the MoCog1 program as applied to the data of Dweck and Leggett (1988). Following step by step through this interaction will help illuminate our simulation.

Based on the Dweck and Leggett data and the present model, Jan (considered in fig. 5) is a construct of the high-intelligence, learning-oriented type of individual. Figure 6 is a projection onto figure 4 of the computer simulation of Jan's response to a difficult test. Based on the test's attributes of subject, length, etc., Jan perceives the example mathematics test as being of high difficulty. Associated with this difficulty, Jan's previous experiences cause Jan to experience some anxiety, but also the pleasure of impending challenge. At the next level, experience with this degree of difficulty causes Jan to anticipate a successful outcome, resulting in an associated mid-level affect pattern of pride and bolstered self-image. Based on feelings (and automatic perceptions) associated with the event, Jan views the test as a likely successful learning experience, and experiences a feeling of increased happiness and self-esteem. The relatively diminutive level of needs resulting from Jan's composite affect pattern facilitates access to Jan's rational capabilities (procedures). Thus, high persistence and self-mastery are open to Jan, and the automatic choice of maximum need satisfaction results in Jan exhibiting self-mastery. The resultant affect total shown in the simulation flow diagram (fig. 6), is the result of assuming that the affect effects of a procedure can be simply vectorially added to the existing overall affect structure and then totaled by linearly adding up the resultant components.

Rob (fig. 7) is a construct of the low-intelligence, performance-oriented individual. Based on a history test's attributes, Rob perceives it as being difficult. As shown in figures 7 and 8, Rob's experience with difficult tests results in a low-level affect response of anxiety, negative pleasure, and boredom with another frustrating task. Sensing the task difficulty results in a mid-level response of expected failure with associated shame and decreased self-image. Based on the feelings and insights resulting from the event, Rob's view of the outcome is that Rob will again be judged negatively with resultant loss of happiness and self-esteem. Rob's high level of needs opens up a whole range of defensive response strategies that can be used to reduce the stress. Self-aggrandizement, with its associated rebuilding of self-image and self-esteem, appears to be the most optimal. This is consistent with Dweck and Leggett's data that show some two thirds of the performance-oriented students engaged in self-aggrandizement or diversionary behavior. [Note: Rob's response to a test of very high difficulty (not shown) results in such an emotional upset that, in our simulation, Rob has access to only one procedure—ineffective strategies.]

Table 4 lists the author's subjective assumptions of the effects on need reduction of the procedures utilized in the computer runs for these two examples. Comparable procedure effects have been employed for the other computer runs, which cover the full range of categories covered by Dweck and Leggett's results. It should be noted that the influence on affects of applying various procedures can be expected to be somewhat student-specific, which, coupled with the students' idiosyncratic backgrounds and the day-to-day variations in students' affect levels, would help to account for the various procedural choices observed in Dweck and Leggett's study for the same situations.

Discussion

To obtain a computer simulation of human responses to situations, it is evident that it is necessary to

1. Characterize the individual using such attributes as intelligence, personality, views, and belief systems. Methods other than Dweck and Leggett's approach include Jung's Personality Typology with associated responsive strategies, and the Woods et al. (1987) typology of problem solvers.

2. Develop transformations, based on the individual's characterization, that take the sensory input and develop perceptions of situations, events, and concepts, and their associated affect patterns.

3. Provide procedures or strategies (and their affect consequences) that the individual is likely to be able to access via needs (associated with the composite affect state) and the context.

For simulating Dweck and Leggett's theory, we were guided by their observations in choosing such things as applicable procedures, and used our simulations to highlight how affects select from among the reachable procedures. Obviously more work is needed to succinctly characterize individuals and their available procedures as a function of generic contexts.

In the process of constructing this simulation, the central finding was that with relatively straightforward assumptions, it is possible to represent and manipulate affect structures and resultant behavior to provide a reasonable simulation of affective behavior associated with recognition-primed human decision making. To develop a computer program, given the lack of numerical data, a great many assumptions had to be made. These subjective assumptions were chosen to be as consistent as possible with likely real data, had they been available. The basic agreement of this computer simulation with Dweck and Leggett's findings (see observed behaviors indicated by asterisks in table 3), obtained by the simple subjective assignment of attributes (with virtually no tuning) to the various individual types, is an indication that our normal views of individual characteristics may be in good agreement with reality for studies of this type. It also suggests that relatively simple computer programs may provide adequate simulations of many studies. An interactive version of our simulation, providing examples that cover the full range of categories in Dweck and Leggett's findings, has been packaged on a DOS diskette and is available for study.

The numerous assumptions that we made to construct our computer simulation provide a good indication of some of the research required. First, it is necessary to get a better representation of the affect structure (perhaps pursuing the taxonomy suggested by Ortony et al. 1988). This should include which affects play a major role in cognition and behavior, their relative priority, and how they should be combined in obtaining an overall indication of need level. Further, though in our simulation the chosen range (from –9 to 9, negative to positive) of each affect was considered to be linear with limit cutoffs, it is more likely that these ranges are nonlinear, perhaps approximating a sigmoid shape similar to that employed by Colby (1973). Thus in generating the overall total need level, or the effects of procedures, appropriate nonlinear weighting functions need to be found.

In the MoCog1 simulation of Dweck and Leggett's findings, the effect of day-to-day individual variations in internal psychological and mental states (represented by the middle path in fig. 3), has been omitted. Again, it is likely that these affects are not simply additive with those from the lower path, but that they interact in a nonlinear fashion. This may be particularly true when such factors as general arousal level are considered. In addition, initial affects may not only influence procedural choice, but may color initial perceptions as well (an effect not currently included in fig. 3).

Conclusions

In this report we have reviewed our development of a conceptual architecture for recognition-primed human decision making and our efforts at programming earlier findings as an example based on it. The work to date has demonstrated that there is no fundamental gap in translating these findings into a consistent computer program. Our work also illustrates that it is possible to develop computer programs incorporating affects that show promise of being consistent both with our current knowledge of information processing in the brain and actual psychological findings. Further, the nature of such simulations not only provides new ways of thinking about human mental and behavioral aspects, but strongly points the way to needed research.

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Table 1. Effect of perceptions of controllability

Category	Response	Affect	Cognition	Behavior
Uncontrollable	Judgmental	Evaluative	Rigid, over-simplified thinking	Low initiation of and persistence toward change
Controllable	Developmental	Empathetic	Process analysis, Sensitivity to situational factors	Mastery-oriented goal pursuit

Table 2. Relationship of students' goals to world view

World view	General goal	Goal orientation
Fixed entity	Performance (cognitive judgment)	Maximize positive judgments and pride in ability, while minimizing negative judgments, anxiety, and shame
Malleable	Learning (competence enhancement)	Maximize growth of ability and pride and pleasure of mastery

Table 3. Relationship of students' behaviors in tests to the students' general goals

General goal	Perceived own attribute level	Task difficulty	Resultant affects	Goal	Students' cognitions	Observed behaviors
Performance (cognitive judgment)	High intelligence [Fran]	High	Pride	Seek positive judgment Maintain and increase self-esteem	Success expected	Mastery oriented* High persistence
		Low	Boredom	Seek positive judgment if available	Success expected	Persistence Task avoidance*
		Very high	Anxiety Boredom Shame Depression Reduced self-esteem	Avoid negative judgment	Failure expected Attribute failure to personal inadequacy Loss of belief in efficacy of effort Divided attention Dislike of task	Defensive withdrawal of effort Self-aggrandizement* Ineffective strategies Low persistence Task avoidance Devalue task and evidence boredom
	Low intelligence [Rob]	Very high	Anxiety Boredom Shame Depression Reduced self-esteem	Avoid negative judgment	Failure expected Attribute failure to personal inadequacy Loss of belief in efficacy of effort Divided attention Dislike of task	Defensive withdrawal of effort Self-aggrandizement* Ineffective strategies Low persistence Task avoidance Devalue task and evidence boredom
		High	Anxiety Boredom Shame Depression Reduced self-esteem	Avoid negative judgment	Failure expected Attribute failure to personal inadequacy Loss of belief in efficacy of effort Divided attention Dislike of task	Defensive withdrawal of effort Self-aggrandizement* Ineffective strategies Low persistence Task avoidance Devalue task and evidence boredom
		Low	Pride	Seek positive judgment	Success expected	Mastery oriented* High persistence
Learning (competence enhancement)	High intelligence [Jan]	High	Pleasure Pride	Seek learning experience	Success expected See task as a challenge to be mastered through effort	Self-mastery (effective problem-solving strategies)* High persistence
		Low	Boredom	Seek better use of time	Seen as an unproductive use of time	Task avoidance* Effort leading to success
		Very high	Pleasure Pride	Seek very satisfying learning experience	Opportunity for more satisfying self-mastery Current failure but future success Continuing belief in efficacy of effort	Revised or upgraded strategy Solution-oriented self-instruction, self-monitoring, and self-mastery*
	Low intelligence [Pat]	Very high	Pleasure Pride	Seek very satisfying learning experience	Opportunity for more satisfying self-mastery Current failure but future success Continuing belief in efficacy of effort	Revised or upgraded strategy Solution-oriented self-instruction, self-monitoring, and self-mastery*
		High	Pleasure Pride	Seek very satisfying learning experience	Opportunity for more satisfying self-mastery Current failure but future success Continuing belief in efficacy of effort	Revised or upgraded strategy Solution-oriented self-instruction, self-monitoring, and self-mastery*
		Low	Pleasure Pride	Seek learning experience	Success expected See task as a challenge to be mastered through effort	Self-mastery* High persistence

*Behavior selected by our simulation.

Table 4. Effect of choice of procedure on affect pattern increment

Situation	Procedure	Anxiety	Pleasure	Boredom	Pride	Shame	Self-Image	Happiness	Self-Esteem
Learning-oriented, high-intelligence individual faced with high-difficulty test (Jan)	Self-mastery	+2	+3	+3	+2	0	+1	+1	+1
	High persistence	+1	+2	0	+2	0	+1	+1	+1
Performance-oriented, low-intelligence individual faced with high-difficulty test (Rob)	Ineffective strategies	−1	−1	0	−1	−2	−1	−1	−1
	Defensive withdrawal	+1	+1	+1	−1	+1	−1	0	+1
	Task avoidance	+2	+1	+1	−1	+1	0	+1	0
	Self-aggrandizement	+2	+1	0	+1	+2	+1	0	+1
	Task devaluement	+1	+1	−1	+1	+1	0	+1	0

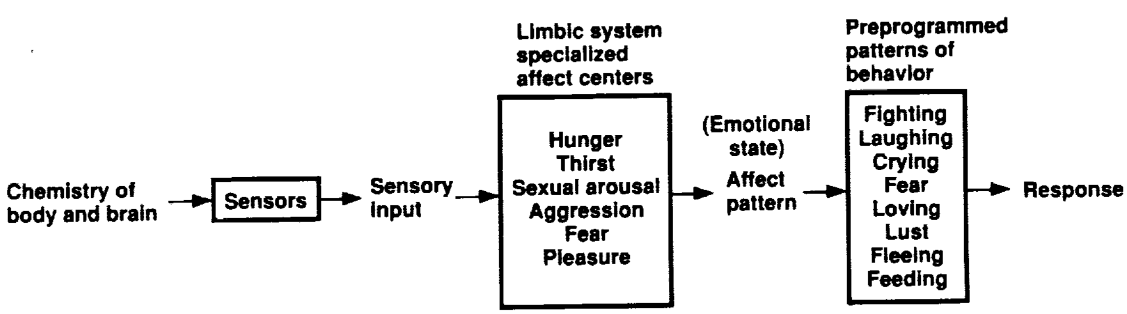

Figure 1. Elementary preprogrammed responses.

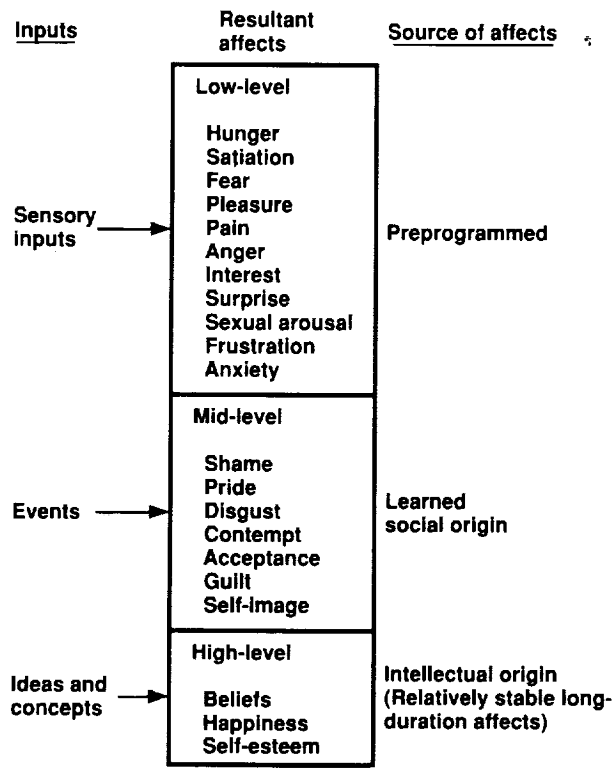

Figure 2. Tentative affect-level structure.

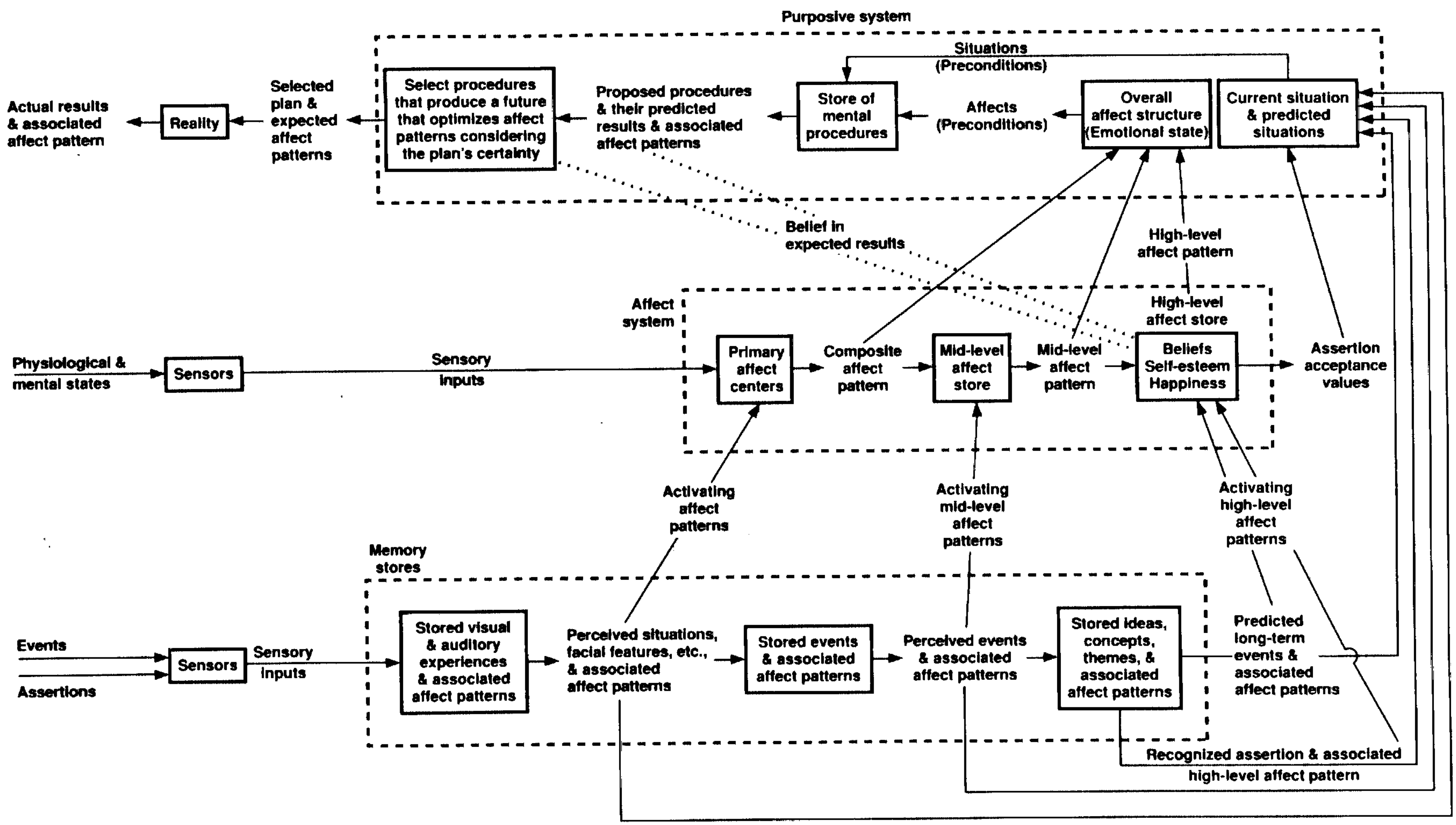

Figure 3. Flow diagram for recognition-primed human decision making.

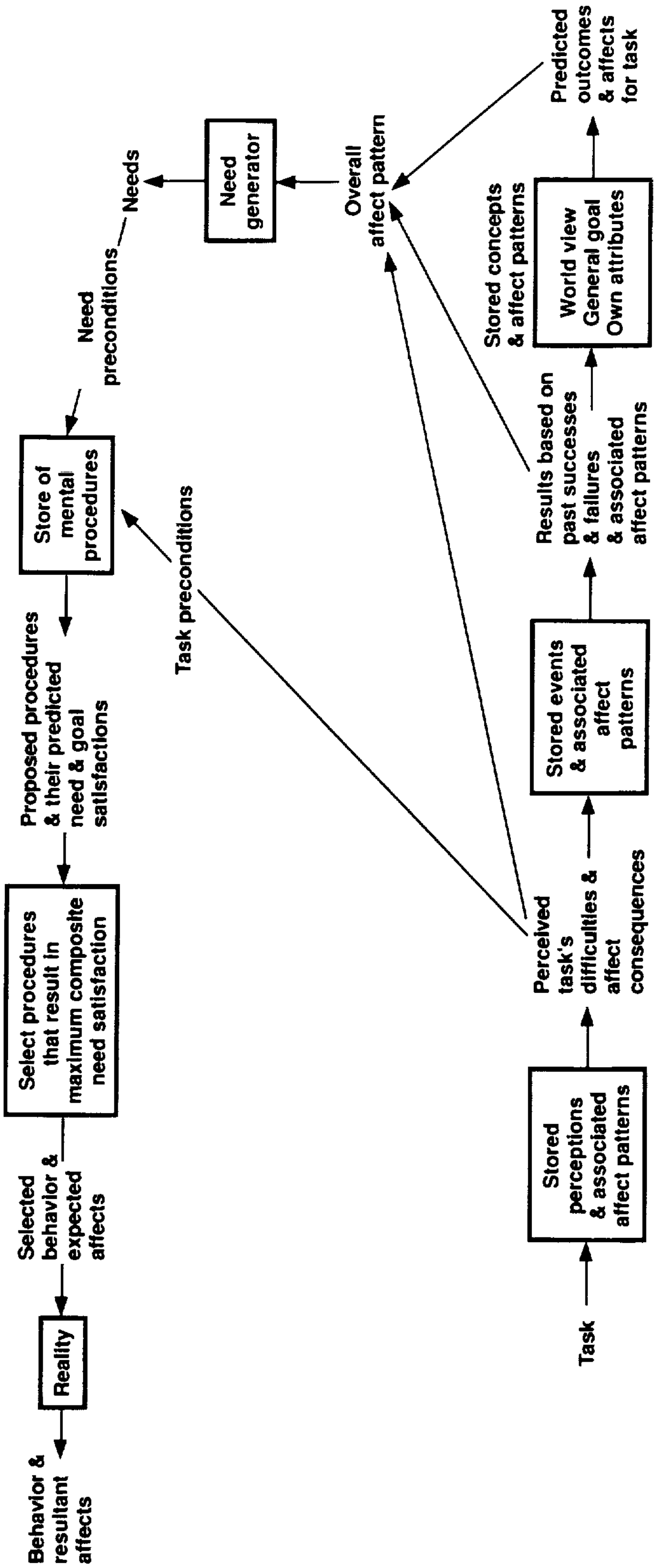

Figure 4. Simplified flow diagram of an individual's response to a task.

```
dldb
Which student are you interested in?
                (fran., rob., jan., pat.)

  Be sure to include the period,
  and do a carriage return after your selection.

jan.

jan, of high intelligence,
 has a  general goal of learning
 a normal mid level affect of self image = 7
 and a normal high level affect pattern of
 happiness = 7 and self esteem = 6,  on a scale of -9 to 9.

Which test are you considering?
                (test1., test2., test3., test4., test5.)
test1.

Based on its attributes, the difficulty of this
math test is perceived by jan to be high

CONTINUE? (yes., no.)
yes.


Perceiving this test produces in jan
a low level affect response of:
 anxiety = -2,  on a scale of -9 to 0
 pleasure = 5,  on a scale of -9 to 9
 boredom  = 0,  on a scale of -9 to 0

CONTINUE? (yes., no.)
yes.


Sensing the task difficulty results in jan
having a feeling of expected success
and an associated mid level affect response of
 pride = 5,  on a scale of 0 to 9
 shame = 0,  on a scale of -9 to 0
 self image  = 8,  on a scale of -9 to 9

CONTINUE? (yes., no.)
yes.


Based on feelings associated with the event,
jans view of the expected outcome is "learned" leading to an

Overall affect pattern = [-2,5,0,5,0,8,8,7]

                         = [Anxiety, Pleasure, Boredom,
                            Pride, Shame, Self_Image_New,
                            Happiness_New, Self_Esteem_New]

and an associated  Need_List = [2,4,0,4,0,1,1,2]
which is the difference between the ideal state and
jans current overall affect pattern

CONTINUE? (yes., no.),
yes.

Based on the preconditions of the task and the relevant
 needs, the following procedures are available to jan

         --- computing ---

procedure1 = high_persistance,   Resultant affect total = 39
procedure2 = self_mastery,   Resultant affect total = 44

          Selected procedure is self_mastery

 If you want to try the program again, type "dldb."


B:\>
```

Figure 5. Trace of a user interaction with a computer simulation of a learning-oriented, high-intelligence student's response to a high-difficulty test.

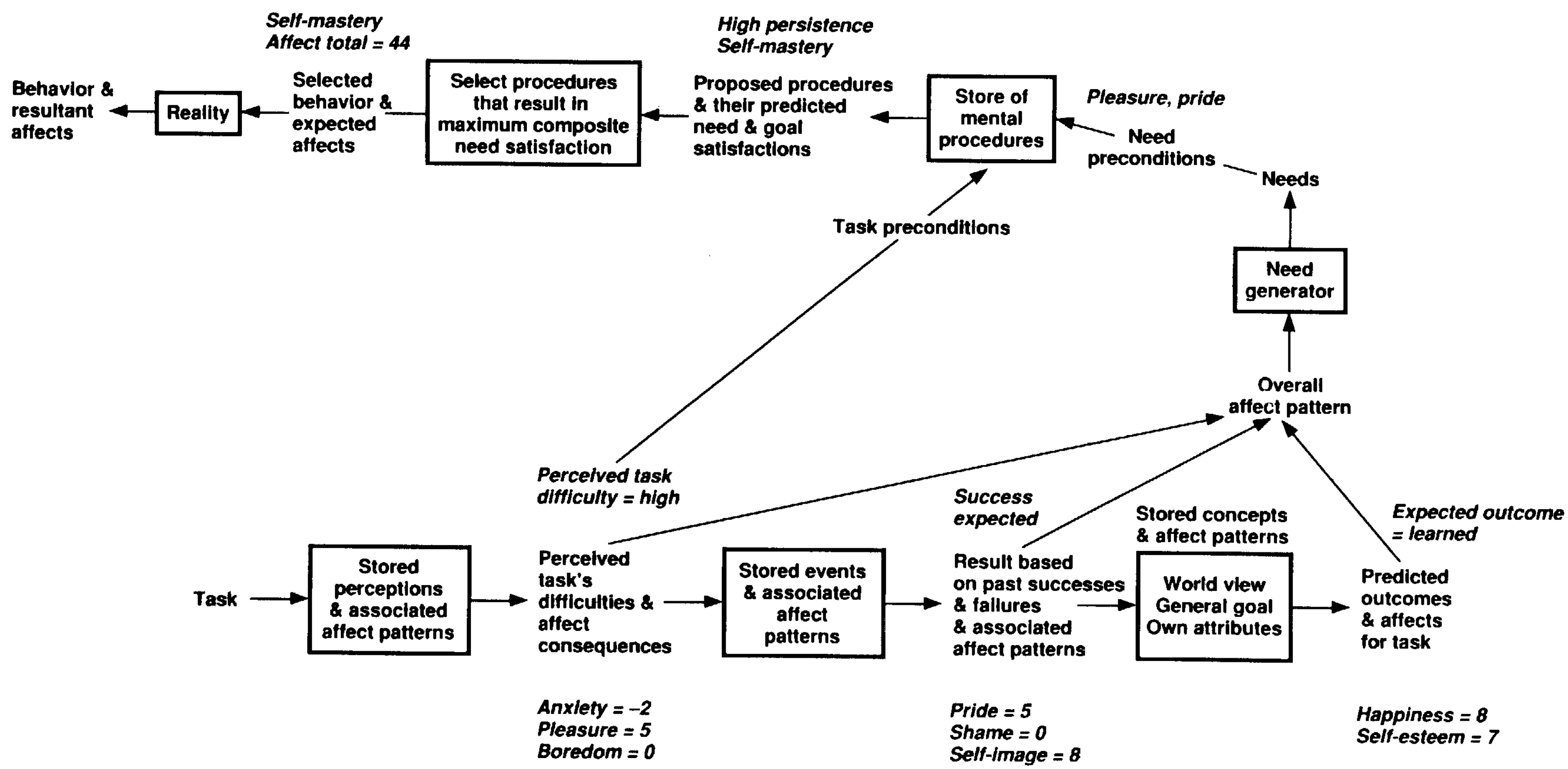

Figure 6. Projection onto figure 4 of a simulation of a learning-oriented, high-intelligence student's response to a high-difficulty test.

```
Which student are you interested in?
                (fran., rob., jan., pat.)

  Be sure to include the period,
  and do a carriage return after your selection.

rob.

rob, of low intelligence,
 has a  general goal of performance
 a normal mid level affect of self image = 3
 and a normal high level affect pattern of
 happiness = 3 and self esteem = 2,  on a scale of -9 to 9.

Which test are you considering?
                (test1., test2., test3., test4., test5.)
test2.

Based on its attributes, the difficulty of this
history test is perceived by rob to be high

CONTINUE? (yes., no.)
yes.


Perceiving this test produces in rob
a low level affect response of:
 anxiety = -4,  on a scale of -9 to 0
 pleasure = -2,  on a scale of -9 to 9
 boredom  = -3,  on a scale of -9 to 0

CONTINUE? (yes., no.)
yes.


Sensing the task difficulty results in rob
having a feeling of expected failure
and an associated mid level affect response of
 pride = 0,  on a scale of 0 to 9
 shame = -4,  on a scale of -9 to 0
 self image  = 2,  on a scale of -9 to 9

CONTINUE? (yes., no.)
yes.


Based on feelings associated with the event,
robs view of the expected outcome is "judged_negatively" leading to an

Overall affect pattern = [-4,-2,-3,0,-4,2,0,1]

                       = [Anxiety, Pleasure, Boredom,
                          Pride, Shame, Self_Image_New,
                          Happiness_New, Self_Esteem_New]

and an associated  Need_List = [4,11,3,9,4,7,9,8]
which is the difference between the ideal state and
robs current overall affect pattern

CONTINUE? (yes., no.)
yes.

Based on the preconditions of the task and the relevant
 needs, the following procedures are available to rob

         --- computing ---

procedure1 = ineffective_strategies,   Resultant affect total = -18
procedure2 = defensive_withdrawal,   Resultant affect total = -9
procedure3 = task_avoidance,   Resultant affect total = -5
procedure4 = self_aggrandizement,   Resultant affect total = -2
procedure5 = devalue_task,   Resultant affect total = -6

          Selected procedure is self_aggrandizement

 If you want to try the program again, type "dldb."


C:\D&L>
```

Figure 7. Trace of a user interaction with a computer simulation of a performance-oriented, low-intelligence student's response to a high-difficulty test.

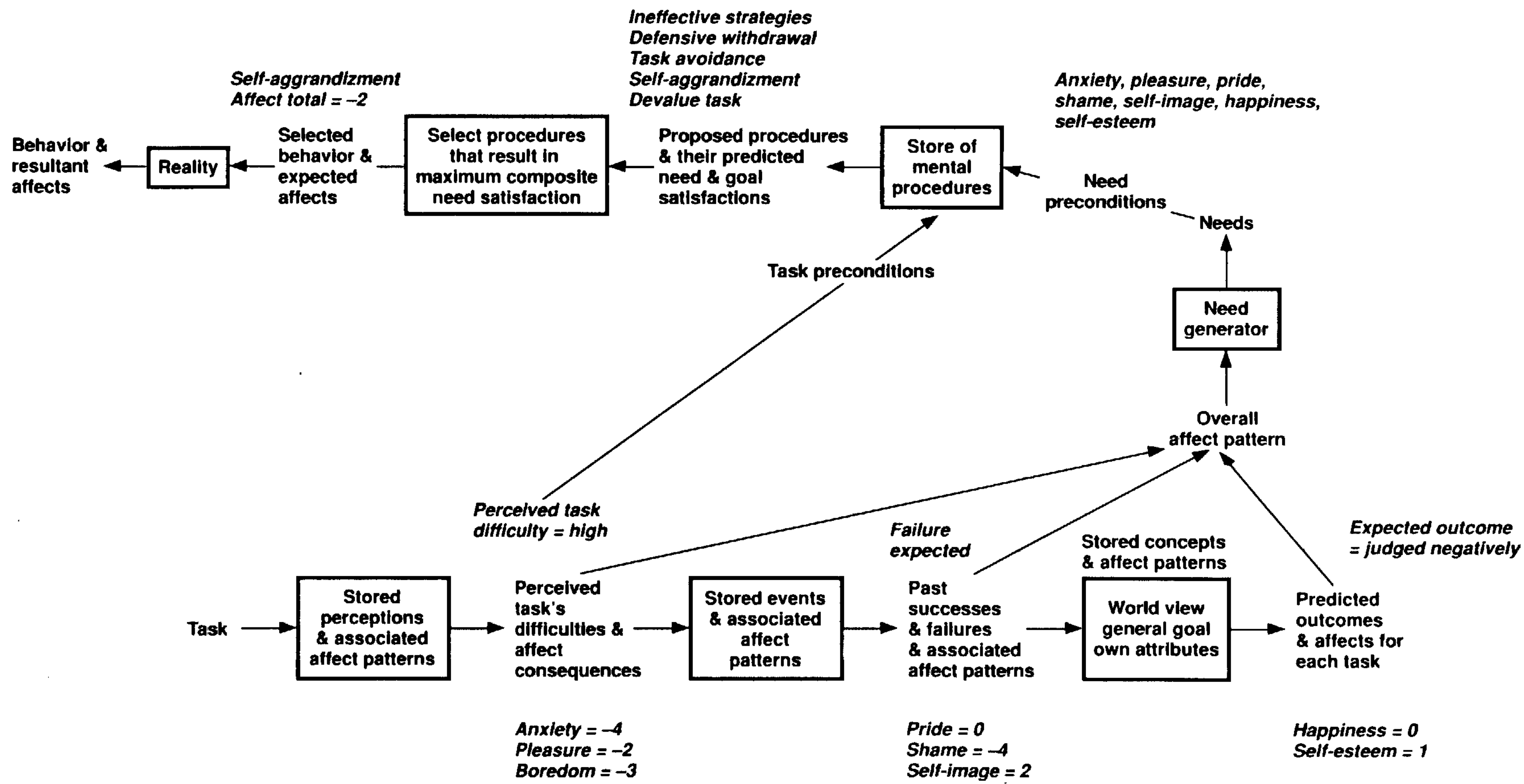

Figure 8. Projection onto figure 4 of a simulation of a performance-oriented, low-intelligence student's response to a high-difficulty test.

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13. ABSTRACT *(Maximum 200 words)*

The results of the first stage of a research effort to develop a "sophisticated" computer model of human cognitive behavior are described. Most human decision making is an experience-based, relatively straightforward, largely automatic response to internal goals and drives, utilizing cues and opportunities perceived from the current environment. The development of the architecture and computer program (MoCog1) associated with such "recognition-primed" decision making is discussed. The resultant computer program was successfully utilized as a vehicle to simulate earlier findings that relate how an individual's implicit theories orient the individual toward particular goals, with resultant cognitions, affects, and behavior in response to their environment.

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