Title

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A computer simulation approach to the study of emotional behavior[1]

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Although the importance of emotion in human behavior has long been recognized, only recently has there been serious interest in the problem among cognitive scientists (Abelson, 1981; Bower & Cohen, 1982; Dyer, 1982; Lehnert, 1981; Norman, 1980; Mandler, 1975; Pfeifer & Nicholas, 1982; Simon, 1967; Sloman & Croucher, 1981). The present work is an effort to demonstrate that problems of emotion can be approached in an information processing framework. A first step in this direction has been taken by developing a computer simulation model capable of exhibiting certain kinds of *emotional behavior*. *The model, dubbed FEELER* (Framework for Evaluation of Events and Linkage into Emotional Responses), is used to illustrate three basic areas that a theory of emotion must deal with, namely (a) how emotions are generated, (b) what is meant by an occurrent emotion, and (c) how emotions influence our behavior. It is suggested that models or frameworks like the one to be presented will help to make the theory of emotions more accessible to cognitive psychologists, and that it provides new ways of thinking about emotional processes.

Underlying assumptions and related work

Even though the Schachter & Singer (1962) experiments have been criticized on a number of grounds (see e.g. Izard, 1977, for a summary of the criticisms), their hypothesis that emotional processes employ two separate but interacting systems, seems to be accepted by many theorists in the field (see e.g. Lyons, 1980). Stated briefly, the systems are a physiological one, the *autonomic arousal system*, and a *cognitive-evaluative* one. An *occurrent* emotion consists of two parts, a pattern of physiological arousal, *and* a cognitive-evaluative component which, in the individual's belief system, causally links this pattern to an event. A physiological pattern alone does not constitute an occurrent emotion.

The design of FEELER has been influenced by the related work of Abelson (1981), Bower & Cohen (1982), Dyer (1982), Lehnert (1981), and by Mandler's hypothesis that the psychological events that influence arousal are the ones which *interrupt* well-organized behaviors (Mandler, 1975). It is assumed that arousal is an important factor in determining the intensity of an emotion (Clark, 1982; Fiske, 1981; Mandler, 1975).

There have been a number of efforts to include emotions into computer simulation models (Colby, 1981, for example) but in most of them emotion has not been the primary focus.

General description of the model

Basic architecture: FEELER has a production system architecture which is similar to John R. Anderson's ACT model (Anderson, Kline, & Beasley, 1979), but some features have been added. As shown in Figure 1 there is a long term memory (LTM, consisting of two parts, namely a network for declarative knowledge (declarative memory) and a memory for procedural knowledge (production memory)), a cognitive working memory and a physiological working memory. Two working memories are introduced separately to account for the relative independence of the physiological and the cognitive system and their distinct characteristics (e.g. different decay rates). Whenever the term "working memory," or simply "WM" is used without further qualification, it refers to *cognitive* working memory. Similarly when just LTM is used it designates declarative memory.

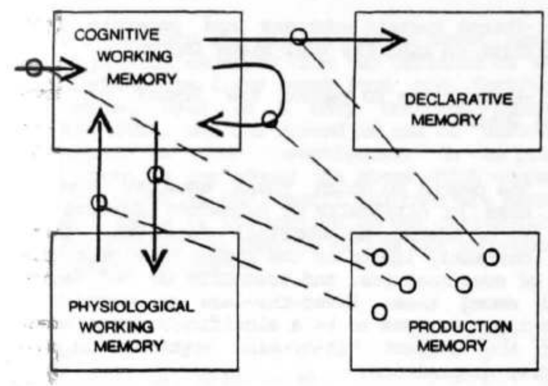

Figure 1: Basic architecture of the model

The arrows in Figure 1 depict the rules which are activated from production memory, as indicated by the circles. The tails designate which working memory they match against, the heads which memory they act upon. The action can consist of adding something to the memory, or in the case of LTM, it can be a process of spreading activation. If an element in LTM exceeds a certain activation threshold, it is automatically added to WM, where it is subject to a decay mechanism. For a discussion of spreading activation see e.g. Ratcliff & McKoon (1981). The arrow pointing into physiological working memory designates the generation of an arousal pattern.

Representation of emotional information: Since emotional experiences can be memorized and the corresponding emotions reexperienced the respective memory structures have to be defined in LTM. Emotional information which is connected to episodic memory structures includes links to the events that are responsible for the occurrent emotion, magnitudes for emotions, and a so-called *arousal image* (Clark, 1982; Mandler, 1975).

Examples of emotional behavior

Emotions generated after interrupt: Consider an example in which the model is executing a plan to take a plane trip.[2] The interrupt occurs on the way to the airport when the taxi develops a flat tire. Arousal is increased by using surprise and importance of the interrupt as multiplicative factors: if either one is small, the increase will be small, if both are large the increase will be large (see Pfeifer, 1982, for details on surprise, importance, and arousal).

Emotions are generated in this situation by emotion generation rules such as R1. R1 is adapted from Weiner's (1982) taxonomy.

R1: IF current state is negative for self and
current state was caused by $person_1$ and
$person_1$ was in control and
the emotional target is $person_1$
THEN generate anger at $person_1$

Since productions only fire if all of their conditions are present in WM, there must be a set of auxiliary productions providing the

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[2] A model of the current environment is constantly maintained in WM.

conditions, such as R2:

R2: IF an interrupt has occurred and
emotion is to be determined
THEN determine target for emotion

Rules like R2 have to do their work for every condition before R1 can apply. The phrase "generate anger at $person_1$" means that an emotion node is created in WM which is linked to the current event structure, to the interrupting event, and to the target of the emotion. When LTM is updated, which is typically the case shortly after an interrupt has occurred, the intensity of the emotion, which is determined from the level of arousal, is attached to the emotion node, and an arousal image, consisting in the current version of a simple level indicator, is added to the current event structure.

Emotions generated after plan completion: If no interrupt had occurred on the way to the airport but instead the model had "arrived" at the airport, rule R3 might have applied:

R3: IF a subplan has been completed
THEN generate satisfaction about subplan completion

Emotions generated from emotions by rules: If anger has been generated, the emotional state of anger as such can lead to the generation of anger again by means of a rule similar to R4:

R4: IF angry and
$person_1$ is entered through perceptual system
THEN generate anger at $person_1$

R4 tries to capture the fact that if a person is angry he or she may generate anger at people who have nothing to do with the original anger-producing situation.

Emotions generated through memory activation: So far the emotion generation processes have been based on rules. Another way in which emotions can be generated is through activation processes in LTM. If elements are entered and encoded into WM through perceptual processes, activation is automatically spread through LTM, i.e. through the perceptual process itself, parts of LTM are activated and added to WM. If emotional information is attached to these elements the earlier emotions may be reexperienced: they can become an occurrent emotion. Moreover, since events in LTM are interconnected via emotion nodes, events with similar emotional qualities can be activated from the current emotional state.

Goal generation influenced by emotions: Emotions may cause certain behaviors which would not otherwise occur. Rule R5, for example, sets up the goal to harm the person (e.g. to insult, hit, yell at) who is held responsible for the individual's current negative state, which lead to the emotion of anger.

R5: IF angry and
emotional target is $person_1$
THEN generate the goal to harm $person_1$

R6: IF angry and
emotional target is $person_1$
THEN generate the goal to reassess the anger reaction

Rule R5 corresponds to a more aggressive reaction, R6 to a cautious one. R7 is a strategy to get rid of the emotion of anger by setting up a goal which diverts attention from the anger-producing situation and thus gives the anger time to decay.

R7: IF angry
THEN generate the goal to count to ten

It should be noted that the goals thus generated do not necessarily have to be pursued. This decision is up to a high-level conflict resolution mechanism.

Interpretations biased by emotions: If the action side of Rule R6 were not to set up a goal but simply to make an assumption about the world, for example "THEN assert that $person_1$ has goal to harm self," we may talk about an inference biased by an emotional state.

Summary and discussion

Table 1 is a systematic account of the possible kinds of rules involved in emotional behavior in FEELER as illustrated by the examples in the last section. The classification is based only on whether the rules directly influence emotions (i.e. they include emotions in their action side) or whether they are influenced by emotions (i.e. they include emotions in their condition side).

Cell (1) contains general inference rules which are typically used as auxiliary rules in the emotion generation process, but they are not particular to a specific emotion. Rules in cell (2) are not influenced by the current emotional state but they result in an

		ACTION SIDE	
		COGNITIVE	EMOTIONAL
CON-DI-TION SIDE	COGNITIVE	R2 (1)	R1, R3 (2)
	EMOTIONAL	R7 (3)	(4)
	COGNITIVE & EMOTIONAL	R5, R6 (5)	R4 (6)

Table 1: Summary of rules

occurrent emotion. Rules in cell (3) represent behavior which is purely motivated by an emotional state. In cell (4) are the rules defining direct interactions between emotions. So far interactions between emotions have only been modeled indirectly via the decay mechanism. Cells (5) and (6) contain rules representing interpretations or action tendencies influenced by an emotion. The rules in cell (6) lead to an emotional state which would not have been caused by the cognitive components alone.

In summary, a number of ways in which emotions can be generated and influence behavior have been modeled and analyzed. The focus in this report was on behavior based on production rules, but it was also seen that network processes participate through spreading activation mechanisms. A comprehensive concept of an occurrent emotion must include both rule-based and network-based processes, as well as their relationship to the physiological patterns of activation.

The current implementation of FEELER shows a variety of interesting kinds of emotional behaviors which have been described above. However, the representational and inference structure needs to be enriched for all aspects of the model and they have to be incorporated in a more coherent system. In addition, some issues have been only marginally addressed or not at all (e.g. learning processes, emotional expression, and high-level conflict resolution mechanisms). Despite its very real limitations FEELER provides a framework for the study of emotion in a cognitive science methodology capable of capturing a wide range of phenomena. Applications to research on mood and to the theory of defense mechanisms are briefly pointed out elsewhere (Pfeifer, 1982).

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