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Chapter 3

Feelings as Monitors

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"Emotion always focuses on the object, while feeling reveals my momentary state of mind" (Magda B. Arnold, 1969, Vol. 1, p. 21).

FEELINGS AND EMOTIONS

For the past decades I too have been struggling to clarify my thinking with regard to the neuropsychological problems encompassed by the term emotion. This struggle has not been an exercise in abstraction; rather, a series of experimental researches have been undertaken and their results systematized. These studies have focussed on the frontal and limbic formations of the forebrain. The bibliography which records these efforts is appended to this manuscript.

I am here today not to review once more the fruits of these efforts, but to voice my continuing dissatisfaction with them. One of the difficulties of re-*search* as opposed to re-search is the proper definition of the problem so that experimental analysis can be engaged. As yet the physiologically oriented community in psychology has failed to come to terms with this issue.

Let me give an example. Many of the students concerned with brain function in emotion are engaged with hypothalamic and limbic mechanisms. Implicit in their approach is the relationship between these structures and the autonomic nervous system. This implicit relationship has been voiced in the term "visceral brain," a term coined to make explicit the "gut" aspects of emotion. Papez (Bull, 1951) was initially responsible for calling attention to the limbic formations as a neural mechanism of emotion. He based his case to a considerable extent on the influences which the limbic systems can exert on hypothalamic structures; "the main central organ which evokes the visceral responses associated with emotional expression . . . ."

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However, taken out of context, this quotation does Papez a disservice. The statement is included in a series of others which are given equal weight. Here is a more complete and faithful reproduction:

" . . . In fact, the autonomic nervous system is involved at these lower levels in support of predisposition, attitude and motor adjustments appropriate to the needs of the organism. More elaborate controls are found in the bulbar reticular formation, especially for the regulation of respiration, vegetative and related functions.

"In the tectal and tegmental regions of the midbrain there are special mechanisms such as the tectospinal tracts and tectopontocerebellar paths for the control of the eyes and head, for shaping the attitudes of sex and defense, and for the exercise of inhibitor controls over locomotion, oral and autonomic activities. The tegmentum of the midbrain is notable for such structures as the red nucleus, rubrospinal tract, rubroreticuloolivary path and the nucleus profundus mesencephali with its numerous connections to the reticular formation, to the subthalamic nuclei and other parts. Of special significance for attitude and inhibition is the substantia nigra with its afferent connections from the cerebral cortex and pretectal nucleus, and its efferent connections to the basal ganglia.

"The ventral thalamus is situated between the tegmentum of the midbrain and the basal ganglia. Two of its major parts are concerned respectively with attitude and visceral activity. (a) In the subthalamus (under the dorsal thalamus) there are primitive subcortical connections from the optic and vestibular systems to the zona incerta. The fasciculus geniculatus interalis comes from the pars ventralis of the lateral geniculate body, a visual relay; and the fasciculus tegmentoincertalis comes from the vestibular region. Both probably exert an important subcortical influence on posture and attitude through the connections of the zona incerta with the basal ganglia. (b) The hypothalamus is an ancient region for the regulation of hypophyseal and autonomic activities. Its action is evoked by the medial bundle of the forebrain and visceral afferent impulses as well as impulses from the basal ganglia. Its efferent fibers pass down to the tegmentum of the midbrain, and in the central gray matter. The hypothalamus is regarded as the main central organ which evokes the visceral responses associated with emotional expression and the accompanying attitude."

The passage is taken from a chapter written by Papez for Nina Bull's *The Attitude Theory of Emotion* (1951, pp. 89-92) where he points to the "many parallel features" between his mechanism and attitude theory. Yet, despite this very specific published account, Papez has been repeatedly claimed as a proponent of the visceral theory of emotion, nor, suprisingly, did he deny this affiliation at any time. This is typical of the confustion displayed in this field of inquiry. Though investigators do not acknowledge it, it would seem to make a difference whether one thinks that the visceral-autonomic accompaniments of

emotional expression are just that or whether gut responses and the messages signalled from them to the brain are *the* characteristics which define emotion.

My own views began with a visceral orientation but experimental results quickly disabused me of such a limited view. Gradually a more comprehensive position was developed—a position not too different from that of Nina Bull and the other great woman theorist on emotion, Magda Arnold, who states simply that "an emotion indicates my attitude . . . ." I am not at all surprised that in this field of inquiry two women should see clearly what has continued to befuddle males.

In my language, emotions are Plans (Miller *et al.*, 1960), neural programs which are engaged when the organism is disequilibrated. Equilibrium is ordinarily maintained through a more or less harmonious "motivated" execution of Plans: they are modified and grow by the consequences produced by their execution. When such execution is hampered, for whatever reason, a "hangup" results: mechanisms of internal adaptation and control such as the regulation of input channels (including those concerned with signals from viscera and those making up the "body image") are brought into play. These mechanisms of emotion are of two sorts. One tends to open, the other to close, the organism to further input. In either case, however, the orderly progression of the growth of the Plan being executed is brought to a halt. If the "hangup" goes on for any length of time because it continues to be infeasible to execute the Plan in its present form, then earlier, more rudimentary organizations become engaged in an attempt to "get the organism moving again." The hampered Plan is then gradually and selectively pruned back to a version which in the experience of the organism has proved feasible of execution. When execution continues to be blocked, considerable "regression" may occur.

In this sense emotion need not be expressed in behavior. When it is, emotional expression is more primitive and encompasses more basic responses than an organism's reasoned actions, i.e., those steered in detail by their consequences. But this is *not* to say that all emotion is "built in" to the organism, that emotion is what is genetically determined in behavior. Quite the contrary: the Plans engaged in emotion, just as motivational Plans, are shaped by the experience of the organism. In fact the "Plans in Action" and "Plans in the Passions" are the same: it is the *consequences of attempted or contemplated execution* which differ. In the language of attitude theory, my attitude toward a person or object remains for a time basically the same whether I can do something about it or not. As noted by attitude theorists, attitude has two aspects: attitude which is preparatory to action and attitude which involves self-regulation with respect to someone or thing.

Having attained some clarity in my thinking on these points, I found that others immediately arose to plague me. Some of these concerned a set of problems usually included under the rubric "emotion," which have to do with

wide-ranging predispositions to behave in one or another fashion. The clinic especially is concerned with physiological determinants of such predispositions or moods — as for example, depression. And depression hardly fits what I conceive of as a Plan (though the more ambiguous term, attitude, would not necessarily encounter this difficulty).

Closely related to this set of problems is another which arises when one tries to detail what is meant by equilibration and disequilibration. Just how is the execution of Plans coordinated into an harmonious activity? And just how and what becomes disequilibrated when the execution of Plans is hampered? Elsewhere (Pribram, 1967a) I have detailed the evidence which suggests that disequilibrium, arousal, is a function of the amount of uncertainty (in the information-theorists's sense). This leaves unanswered the question of the mechanism of appraisal of the amount of uncertainty.

The answers to these questions became possible once it occurred to me that here the concern was primarily with organismic states — in my language with *Images* rather than with *Plans*. And so my focus of inquiry shifted from emotions to feelings. This shift allowed a fresh approach to be made, one which clarified for me a number of hitherto obscure facets. This paper serves as an introduction to this approach.

FEELINGS AND SENSATIONS

From the energy configurations which excite some of our receptors we are able to reconstruct an objective world. Sight and hearing especially give us images which we interpret as being distant from the receptors excited. Touch, taste and smell do not ordinarily allow this attribution of distance; localization is to the receptor surface. Yet even here the judgment is made that one touches, tastes or smells something other than one's own receptor reactions.

But there is another world, a subjective world of feelings. We feel hungry or sleepy or sexy. We feel happy or sad, contemplative or assertive. What distinguishes the objective from this subjective world?

The answer to this question becomes especially tacky when one considers neurological mechanisms. The naive realist can easily state that, indeed, sensations refer to things "out there" but that feelings refer to "internal states." But clinical experience with phantoms produced by limb amputation make it unlikely that our experience of receptor stimulation occurs where we are apt to localize it. Images of objects are formed *in the brain* — why then do we locate objects where we do?

Békésy (1967) has performed some critical experiments to answer this question. Using touch, which ordinarily is not interpreted as distant, he has created conditions under which such an interpretation is made. When one limb is stimulated, the source of excitation is localized to that extremity. When,

however, symmetrical places on both limbs are stimulated, the subjects of his experiments begin to experience the sensation in a location *between* the limbs. The effect is similar to that produced when two loud-speakers replace a single source: the stereo effect localizes the sound source between the speakers.

These are, of course, only some of the conditions which determine objectivity; constancy in the face of movement on the part of the organism, intermodality validation, and recurrence, are others. The point here is, however, that the objective world must be constructed from this evidence because when it is lacking, the verdict is apt to be that the experience is subjective — i.e., felt.

APPETITES AND AFFECTS

Next, let me turn to the specific issues raised earlier. Do the results of recent neurobehavioral experiments clarify earlier obscurities? I believe they do. For instance, the relationship between emotion and motivation takes on new meaning when feelings become a legitimate focus of interest.

The early experiments on the neural control of motivation and emotion produced a major paradox: when lesions were made in the region of the ventromedial nucleus of the hypothalamus, rats would eat considerably more than did their controls and they became obese. But this was not all. Although rats so lesioned would eat a great deal when food was readily available, they were found to work less for food when some obstacle interfered. In addition, it was found that the more palatable the food, the more the lesioned subject would eat. Similar effects are obtained when drinking is studied. This gave rise to the notion that the *lesioned* animals were more "finicky," i.e., had less appetite than the controls. Further, recent experimental results obtained by Krasne (1962) and by Grossman (1966) show that electrical *stimulation* of the ventromedial nucleus *stops* both food and water intake in the deprived rats. Moreover, the animals learned an instrumental response to terminate such stimulation, suggesting that aversive, affective effects may have been produced. Grossman therefore suggests that the neurobehavioral results occur due to alterations in *affect* rather than *appetite* when the ventromedial nucleus is manipulated, that the lesioned animals show an *exaggerated sensitivity to all sorts of stimulation.*

Just the opposite sort of results are obtained when another area in the hypothalamic region is manipulated. Cessation of eating and drinking occurs when a far-lateral region of the hypothalamus is damaged. Here also more widespread effects are obtained, however. The results of a recent study by Bunnell and Thompson (in press) show that such lesions severely impair escape behavior - that the lesioned subjects are insensitive to shock.

Grossman notes that one discrepancy remains, however. How can stimulation of a *stop* mechanism *increase* affect? This remaining discrepancy is resolved if both "go" and "stop" mechanism are conceived to generate feelings — "go"

mechanisms, the feelings of appetite and interest related to motivation, and "stop" mechanisms, the affects related to emotion.

APPRAISAL, AROUSAL, AND SALIENCE

The results of recent neurobehavioral research, when approached from the standpoint of an inquiry into feelings, have given equally clear answers to the second of my questions: the nature of the appraisal mechanism.

Some years ago we showed that the effects of temporal lobectomy on changes in temperament resulted from the removal of the limbic system structures contained within the temporal lobe: the amygdala and hippocampus (Pribram and Bagshaw, 1953; Pribram, 1954). Further analysis showed that these limbic formations were involved in a variety of behaviors labeled as "the Four F's" -- an extension of Cannon's "Fight and Flight" label for sympathetic neural function (Pribram, 1960). Our Four F's included, in addition to Cannon's, feeding and sexual behavior. The close anatomical linkage between the limbic and hypothalamic structures made this result a reasonable one. The problem arose when I became dissatisfied with just a descriptive correlation between brain anatomy and behavior and tried to understand the mechanism of operation of this relationship. What I wanted to know was whether the amygdala regulated only functions ordinarily ascribed to the hypothalamic mechanism or were *other psychological process affected?*

The experiments performed therefore went far afield from the proverbial Four F's. In collaboration with Schwartzbaum (1960), with Bagshaw (1965), and with Hearst (1964a, 1964b), transfer of training experiments were undertaken. In one procedure, transposition behavior was studied; in the other, the reaction to stimulus equivalences. Stimulus generalization was analyzed as a control measure. The tasks were chosen because they seemed to us reasonably remote from hypothalamic influence.

Amygdalectomy affected performance in both transposition experiments but not in those testing stimulus generalization. My conclusion was therefore that the amygdala at least, influences processes other than those ordinarily ascribed to the hypothalamus.

A clue to what these processes might be came from an observation made while testing the monkeys on the transposition task. The amygdalectomized subjects neither transposed nor did they choose the absolute cue. Instead they treated the test trials as a completely novel situation, performing initially at chance (see Douglas, 1966).

Pursuing this observation Bagshaw and her collaborators working in my laboratory showed that amygdalectomy indeed altered monkeys' reactions to novelty (Bagshaw *et al.*, 1965; Kimble *et al.*, 1965; Bagshaw and Benzies, 1968;

Bagshaw and Coppock, 1968: Bagshaw and Pribram, 1968). Behavioral and some components of EEG habituation to novelty were markedly prolonged. On the other hand, the viscero-autonomic "arousal" indicators (GSR, changes in heart and respiratory rates) or orienting to novelty were wiped out by the lesions (without impairing the response mechanisms per se). These results led me to suggest that orienting to novelty proceeds through two hypothetical stages. The first, characterized by behavioral orienting reactions, "samples," scans the novelty. The second, characterized by viscero-autonomic "arousal" reactions, leads to "registration" of the novelty in experience and memory and so to its habituation (Pribram, 1969).

I have elsewhere (Pribram, 1967b) spelled out in detail a plausible neural mechanism to account for these results. The mechanism involves inhibitory interactions in the afferent channels of the nervous system; Bagshaw and Spinelli have shown that these afferent interactions can be influenced by electrical stimulations of the amygdala.
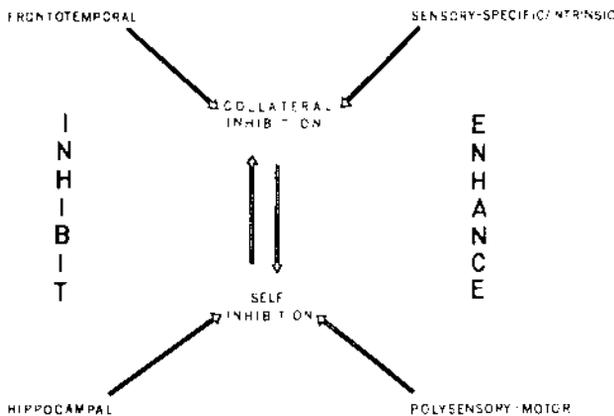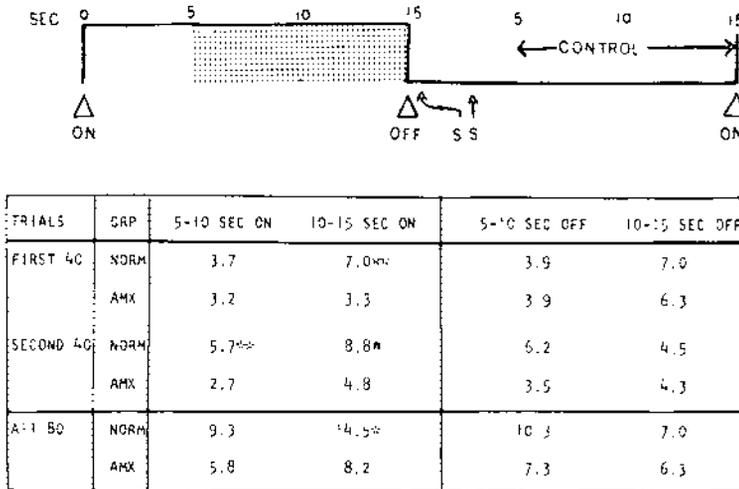

FIGURE 1. A model of corticofugal control over input processing. Collateral inhibition is considered the basic process for the orienting reactions; self-inhibition is the basic process for habituation. Two corticofugal systems enhance and two inhibit this basic mechanism of afferent neural inhibition.

A good deal about the process of "registration" has been learned by Bagshaw and her group. In a classical conditioning situation, normal monkeys show a gradual incrementing of concurrent, and a lengthening of the period during which anticipatory, galvanic skin responses occur as trials are given. In amygdalectomized subjects no such incrementing or anticipating is observed. Thus "registration" apparently involves a selective enhancement of the intensity

and the temporal extension of a process set into operation by the repetition of events. It is as if some sort of "internal rehearsal" were taking place in the normal organism without which registration does not occur (Bagshaw and Coppock, 1968).

TRIALS	GRP	5-10 SEC ON	10-15 SEC ON	5-10 SEC OFF	10-15 SEC OFF
FIRST 40	NORM	3.7	7.0**	3.9	7.0
	AMX	3.2	3.3	3.9	6.3
SECOND 40	NORM	5.7**	8.8*	6.2	4.5
	AMX	2.7	4.8	3.5	4.3
ALL 80	NORM	9.3	14.5*	10.3	7.0
	AMX	5.8	8.2	7.3	6.3

$* = p < .08$

$** = p < .05$

MEAN NO. GSRS IN PERIODS PRECEDING SHOCK

(ANTICIPATORY RESPONSES)

FIGURE 2.   Mean number of GSR occurring in 10-sec period of light on just preceding light offset (CS) in the first 40 and in the second 40 trials for each group,

Note that I have been talking about experiencing. These data help explain an observation I made many years ago (Miller et al., 1960, Chapter 14). A patient on whom a bilateral amygdalectomy had been performed a year earlier had gained much weight. She seemed to present a golden opportunity to find out directly what she experienced to make her eat so much. Her answer was always that she did not feel inordinately hungry, that in fact she could not describe her experience. Chances are that each experience was to her a novelty and therefore not identifiable as hunger.

The converse observation that déjà-vu phenomena, the "as if" experiences of familiarity, result when epileptiform excitations involve the amygdala is in this light also more understandable.

In problem-solving situations the "registration" function becomes manifest in the efficacy with which cues, reinforcers, and deterrents guide behavior. Douglas and I (1966) have detailed elsewhere the basis for invoking such a reinforce-register process. In short, amygdalectomized organisms appear to be
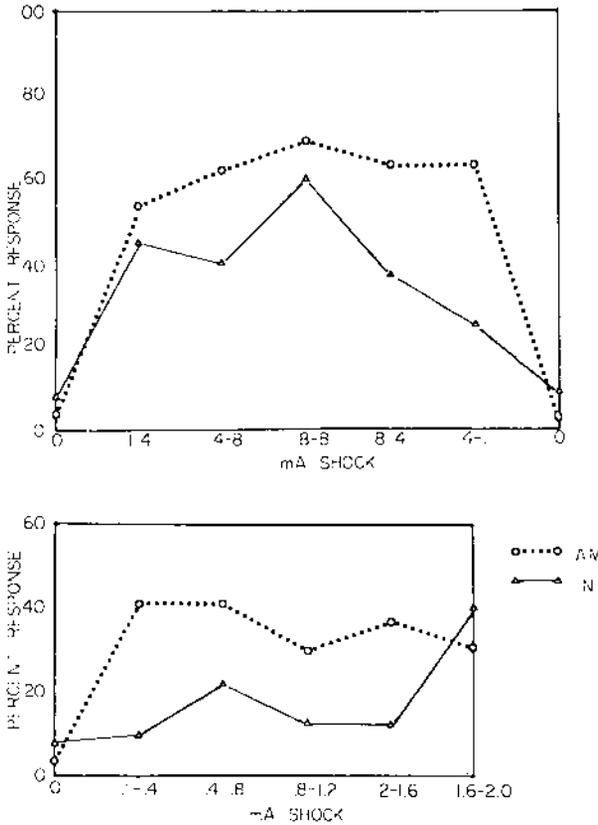

FIGURE 3. Above: Curves of percentage GSR generated by three runs of stimuli of ascending and descending intensity (in mamp) by the amygdalectomized (AM) and control (N) groups. Below: A finer breakdown of stimulus values from .1 to 1.0 mamp, pooled ascending and descending values.

insensitive to what is relevant, salient, correct - to what is the right response to make in a problem. Sensitivity can be achieved only when simpler go and stop mechanisms are modulated. There is ample evidence that in fact the amygdala performs such modulations.

In experiments designed to test psychophysical thresholds, Bagshaw and J.

Pribram (1968) have shown that the amygdalectomized monkey reacts in an all-or-none fashion to foot shock — threshold is if anything lower, but the reaction of the subject is the same for the lowest as for the highest intensities given, Roger Russell *et al.* (1968) has shown by similar psychological techniques that a quantitative relationship can be drawn between the amount of carbachol injected into the amygdala and the amount of water drunk by an already drinking animal, although such injections will neither initiate nor stop drinking.

If this is indeed the psychological process in which the amygdala is involved, what of the hippocampus? There is today much evidence that response-inhibition is primarily affected and that the neural process involved in the production of response-inhibition is akin to what Pavlov called internal inhibition (Gerbrandt, 1965; Kimble, 1969). But as Douglas (1967) has pointed out,
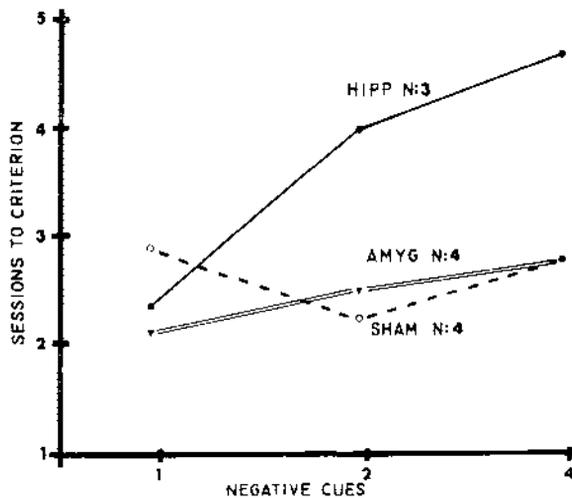

FIGURE 4.   Graph of the results of changing the number of negative cues in a set of discrimination problems. Note the effect on the hippocampectomized monkeys.

the response-inhibition hypothesis does not account for all of the data. There are situations — e.g., passive avoidance (Kimble and Kimble, 1965), discriminations in which both cues are reinforced (Webster and Voneida, 1964), distraction effects (Douglas and Pribram, in press) — in which hippocampectomized monkeys are shown to make as few or fewer responses than their controls. To account for these instances Douglas and I (1966) have ventured the thesis that hippocampectomized organisms cannot gauge what has become nonsalient, irrelevant. Ordinarily repetition of nonsalient occurrences leads to their being ignored. Behavioral habituation takes place and in a problem-solving situation

responses are no longer made to the nonsalient, i.e., the wrong, the nonreinforced cues. Hippocampectomized monkeys continue to make such wrong responses (Douglas *et al.*, 1969) and, in a learning situation in which the number of nonsalient cues was manipulated, their rate of acquisition was proportional to the number of nonsalient cues while that of normal subjects was independent of this manipulation.

I have come to the conclusion therefore that the amygdala and hippocampus provide for a sequence of processes to occur which allow us to appraise the amount of uncertainty. The mechanism which accomplishes this organizes hierarchically the salient within the context of the nonsalient, the reinforced within the context of the nonreinforced, the right within the context of the wrong. The neural mechanism by which these processes are achieved is most likely a modulation of afferent, hypothalamic, and probably, mesencephalic inhibitory interations — though evidence for the nature of hypothalamic and mesencephalic inhibitory organization has still to be investigated.

FEELINGS AS MONITORS

A final word about the specification of feelings and the third of my specific questions: the neural organization of predispositions or moods. There is a difference in the organization of the neuronal aggregates involved in feelings and those involved in sensory perception. Feelings arise from the operation of multiply interconnected core brain structures characterized by short fine-fibered, many-branched neurons. The pattern of organization of neural potentials can be expected to depart considerably from that which occurs in flat sheets of horizontally connected cells cutting across parallel lines of nerve transmission. Little is known as yet of the resultants of excitatory and inhibitory interactions which take place in such networks. From the anatomical picture one might conjecture that these interactions blend into a device which governs the reciprocity between excitation and inhibition (operating somewhat like a gyroscope to keep the system tuned), but this conjecture needs testing at the unit recording level. Because of the multisynaptic nature of the neuronal aggregates involved, they are in themselves especially sensitive to chemical substances circulating in the surrounding blood stream and thus are ideally constituted to serve as receptor sites. This special combination of control and sensitivity could be expected to make of these brain structures superb instruments for continuously monitoring their own state, a requirement basic to any conception of mood.

In conclusion, let me review the sets of problems which remained unanswered when my focus of inquiry was emotion. Does the shift in focus to feelings, and the evidence which makes it useful to consider feelings as monitors, give greater understanding of these problems?

Wide-ranging predispositions to behave, moods, were difficult to conceive as a

set of Plans or programs. There is just nothing sufficiently precise about a depression, for example, to make of it a firm guide to behavior. It would be nonsense to indicate that one *plans* to be depressed. On the other hand, it is fair to say one *is* depressed or *feels* depressed. Treating Feelings as Monitors whose neuroanatomical, neurophysiological and neurobehavioral makeup has been developed here, makes eminent sense to me. Once this much is acknowledged, other feelings are admitted as legitimate entities for study. Feelings of hunger, thirst and sexiness; feelings of salience, of right and wrong, can and should be studied — and have already yielded a good deal to neurobehavioral analysis.

Thus Feelings as Monitors are well equipped to handle the problem of equilibration and disequilibration resulting from the successes and failures of motivated action. One does not plan to be involved or upset; one becomes, is and *feels* involved or upset and generally aroused when Plans succeed or fail to coordinate or when a Plan is adaptively implemented or falls short of execution. In each instance the salience of the outcome of the action, the reinforcement, is appraised and the process of appraisal monitored — i.e., felt. Feelings as Monitors, so conceived, readily encompass the problems raised by interest and commitment. One does not plan these psychological investments — one *feels* them; one either is or isn't interested or committed.

Feelings as Monitors are therefore Images rather than Plans. As such they form the matrix within which Plans are formed; the "go" Plans making up the motivations of the organism and the "no-go" Plans of which emotions are constituted. Concentrating on the experimental analysis of Feelings as Monitors, of "momentary states-of-mind" (Arnold, 1960), has thus proved rewarding, not only in its own right but in clarifying problems which a focus on emotions per se failed to resolve.

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