

## NEURAL SERVOSYSTEMS AND THE STRUCTURE OF PERSONALITY

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This paper is dedicated to Lawrence Kubie in commemoration of his pioneering insights into the importance of the feedback concept in neurology and in the behavioral sciences. An attempt is made to spell out some possible relationships between servosystems in the brain and the structure of personality in the hope that doing so will prove useful to those engaged in psychotherapy.

### HOW THE BRAIN CONTROLS ITS INPUT

Ross Ashby in his now classical *Design for a Brain* (1) models a system which, though stable, adapts to the ever changing circumstances with which it is faced. The first half of his task concerns the description of one set of conditions that evoke stability: "The stability belongs only to the combination; it cannot be related to the parts considered separately... the presence of stability always implies some coordination of action between the parts." His design for this set achieves "ultrastability" through the multilinking of homeostats, an arrangement of servos that keeps certain "essential variables" within bounds while allowing a freer range of values to the remainder.

Unfortunately for this ingenious design, the thing is so constituted that it can't learn—or rather that progressive adaptation is so sluggish that any resemblance to the function of the wet brain is lost. Ashby tackles this problem in the second half of his design by invoking the concept of temporary independence between parts of the system. Such independence is assumed to

occur whenever constancies are achieved between the part and some aspect of its environment—through the process of habituation to the repetitiveness of the stimulus situation. Thus "constancies cut the system to pieces" and adaptation of parts of the system is immeasurably speeded.

My concern here is with a model derived not from engineering considerations, as is Ashby's design, but from neurobehavioral and neurophysiological data obtained in my laboratory. My argument will be that these data lead to a conception so similar to Ashby's as to be encouraging to both efforts. The mammalian brain as well as Ashby's design appears to have at its disposal two opposing methods of organization to assure stability—and each has its virtues and limitations.

The immediate data which lead to the model are electrophysiological. These data were obtained, however, against a background of neurobehavioral evidence which posed the problems to which the physiological experiments were addressed. Briefly, the neurobehavioral data concerned the functions of the then silent regions of the forebrain: the so-called association and the limbic systems. In the primate brain two large divisions of these regions were identified: the posterior "association" cortex and the frontolimbic formations. Experimental evidence accrued to show that the posterior

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cortex dealt with the organism's ability to make differential discriminations—to select among alternatives—and that subunits could be identified, each of which served one or another sensory mode (27). The frontolimbic formations, on the other hand, were shown to be important whenever the organism had to make a sequence of responses in order to adapt to circumstances, *i.e.*, whenever behavior had to be guided by some internal program which determined serial order (15).

The puzzle remained as to how these parts of the forebrain effected their function. The puzzle is not yet solved, but one part of the picture is becoming clear. The concept which had dominated thinking about these regions of the brain for over a half-century was that these areas were the "highest integrating centers," the locus where inputs were amalgamated, "associated" into more complex functions. A considerable literature had accumulated of reports to test this conception—much of it stimulated by the late Karl Lashley. And this evidence overwhelmingly failed to confirm the guiding hypothesis (6, 8, 14, 29, 36, 37, 40). The question thus arose as to an alternative view, and I proposed the possibility that these forebrain systems effected their influence through cortico-fugal, efferent pathways that operate by making transformations on the input through direct control over the functions of the input channels (22, 24, 26). The tests of this possibility led to the following results.

Experiments were performed on fully awake monkeys implanted with small bipolar electrodes and a device which allows chronic repetitive stimulation of one of the electrode sites. The monkeys were presented with pairs of flashes and the interflash interval was varied from 25 to 200 msec. Electrical responses were recorded from the striate cortex and the amplitude of the responses was measured. A comparison of the amplitude of the second to the

the first response of each pair was expressed and plotted as a function. The assumption underlying the interpretation of this function is that when the amplitude of the second of the pair of responses approximates that of the first, the responding cells have fully recovered their excitability. In populations of cells such as those from which these records are made, the percentage of diminution of amplitude of the second response is used as an index of recovery of the total population of cells—thus, the smaller the percentage, the fewer the number of recovered cells in the system.

Chronic stimulation (8 to 10 per sec) of several cerebral sites alters this recovery function (Figure 1). When the inferotemporal cortex of monkeys is stimulated, recovery is delayed. Stimulation from control sites (precentral and parietal) has no such effect. Nor does the stimulation of inferotemporal cortex alter auditory re-

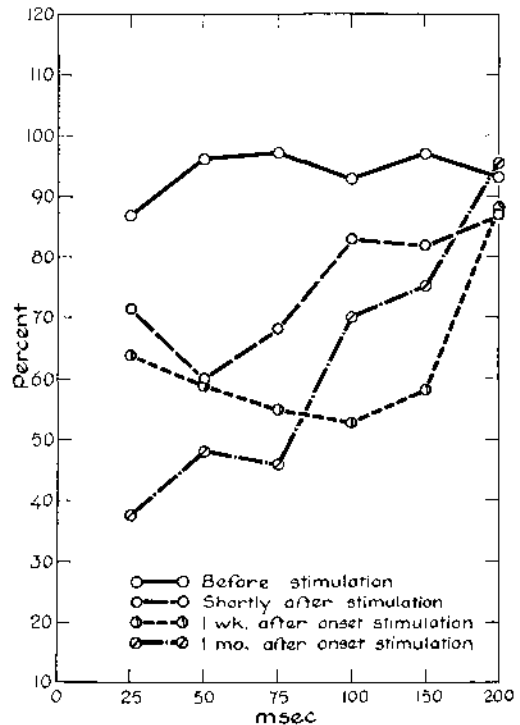


FIG. 1. A plot of the recovery functions obtained in one monkey before and during chronic stimulation of the inferotemporal (IT) cortex.

covery functions. These, however, can be changed by manipulations of the insular-temporal cortex, as was shown in a parallel experiment performed on cats. Here the crucial cortex was removed and recovery functions obtained on responses recorded from the cochlear nucleus (7). Removal of insular temporal cortex shortens recovery in the auditory system.

A great many neurobehavioral experiments have shown the importance of these isocortical temporal lobe areas (and not others) to visual and auditory discrimination. These studies are reviewed elsewhere (23, 27). What concerns us here is that a corticofugal, efferent mechanism is demonstrated and that this mechanism alters the rapidity with which cells in the visual and auditory afferent systems recover their excitability. Further, since stimulation delays and ablation speeds up recovery, the inference is that the normally afferent inhibitory processes which delay recovery are enhanced by the ordinary operation of these temporal lobe isocortical areas.

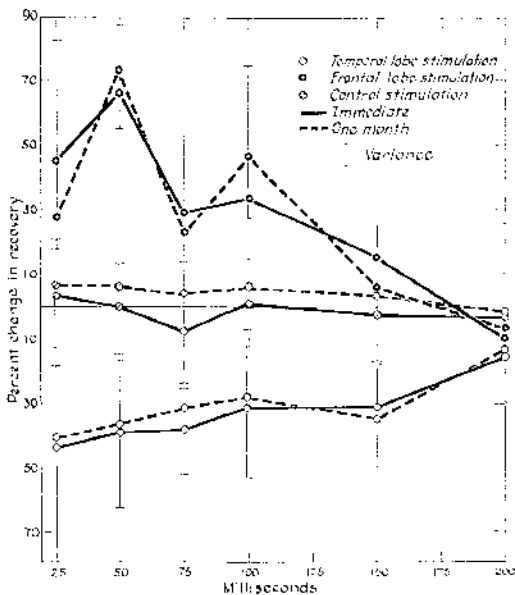


FIG. 2. This figure plots the percentage change in recovery for all subjects in the various experiments. It is thus a summary statement of the findings.

But the opposite effect—namely, inhibition of afferent inhibition—can also be obtained when cerebral tissue is chronically stimulated (Figure 2). In these experiments the cortex of the frontal lobe and the basolateral nucleus of the amygdala were chronically stimulated and recovery of cells in the visual system was shown to be speeded. This result has suggested that the frontal and mediobasal portions of the forebrain—the frontal cortex and limbic regions—function as efferent systems which inhibit afferent inhibitory processes.

This antagonistic effect of these two efferent control systems is perhaps best illustrated by data obtained at the unit level (Figure 3). These unit recordings were made from the striate cortex of Flaxedilized cats to whom flashes of light were presented. Note that the silent period of a cell can be lengthened by concurrent inferotemporal stimulation. Note also that concurrent frontal stimulation can shorten this silent period. Finally, note the unit whose silent period is lengthened by inferotemporal and shortened by frontal stimulation.

These data demonstrate the existence of mechanisms in the brain which can exert afferent, corticofugal control over the input channels. Such effects have been shown by similar experiments to extend as far peripheral as the cochlear nucleus in the auditory system (17) and the optic nerve in the visual system (39). There can, therefore, be little question that the brain controls its input.

#### A STABLE-LABILE DIMENSION

The results of these experiments also give a clue as to at least one dimension over which the control is exercised. The classical interpretation of recovery functions is what their name implies: When the second response to a pair of stimuli is smaller than the initial response of the pair, the assumption is that some cells in the system are still occupied with process-

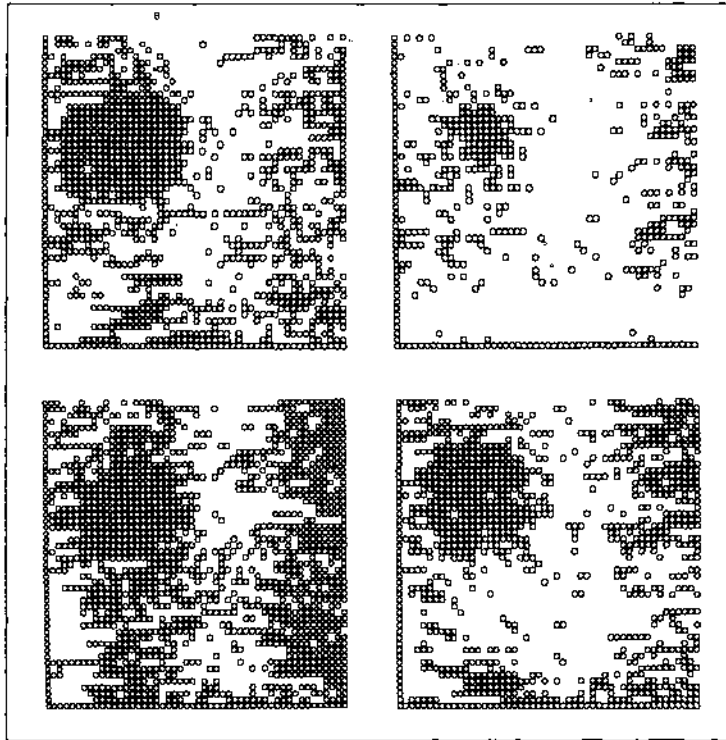


FIG. 3. Receptive field maps from a lateral geniculate unit. *n*, top left, control; *i*, mapped while inferotemporal cortex was being stimulated; *j*, mapped during frontal cortex stimulation; *n*, bottom right, final control. A third control was taken between the *i* and the *j* maps and was not included because it was not significantly different from the first and the last. Note that inferotemporal stimulation decreases the size of the "on" center; frontal cortex stimulation, while not really changing the circular part of the receptive field, brings out another region below it. The level of activity shown is 3 standard deviations above the normal background for this unit.

ing the initial stimulus. This interpretation suggests that any parameter which delays recovery effectively decouples the system with regard to successive inputs while any parameter which enhances recovery effectively links the units of the system to each other. This independence-interdependence dimension is exactly the one which emerges so clearly in Ashby's design. The further suggestion is, therefore, that the mammalian brain, just as its hardware model, has at its disposal two antagonistic reciprocal mechanisms, both of which assure stability to the system in which they act: a mechanism of "external" control, through which constancies are achieved between parts of the system and their en-

vironment; and a mechanism of "internal" control, which relies on achieving a joining between parts. Lacey (13) has good evidence from another source that a stable-labile dimension determines the responsiveness of organisms, and this evidence has been amply confirmed in my laboratory (10, 11).

#### AN EFFECTIVE-AFFECTIVE DIMENSION

According to the experimental results discussed above, another of the possible reactions an organism may have to a situation is to control the input initiated by that situation. Elsewhere I have suggested (25) that "e-motion" is manifest when an organism meets a situation by input con-

tol rather than through instrumental action. In this view, emotion, or what is now so aptly referred to by today's young as "a hangup," is not conceived to be an haphazard affair. Rather, just as action is motivated, that is, controlled, by the operation of a hierarchy of neural servo-mechanisms, programs, or plans (16), so passion is e-moted, that is, decontrolled by relinquishing or "pruning" smaller or larger segments or subroutines of these same programs, and restoring and strengthening earlier or simpler versions. As an example, take the interesting descriptions of the turning of the motive "love" into the emotion "in love" through separation as given by Reik (31).

According to this analysis, then, one dimension along which a person's character may vary is the extent to which interaction with his environment displays action or passion—is effective or affective. Persons as *actors*, effective, normal, and useful in their society, have been chiefly considered by social scientists; explorations of the *passions* have been left to clinical psychologists and psychiatrists. Consequently, emotion, affect, has been suspect: we have come to think of it as somehow unhealthy, abnormal, futile. And yet, the error of this view is obvious. Attributes such as strength of character, creativity, and so on are known even by the layman to depend on the nonbehavioral reactions of a person to his situation. The techniques are at hand; there is no longer any good reason to withhold physiological observations from experiments made to investigate these processes, even by social scientists. The objective study of behavior can now be fruitfully complemented by the objective study of such nonbehavioral, internal, "mental" reactions of experimental subjects.

#### AN ESTHETIC-ETHICAL DIMENSION

For the purposes of this paper I wish to elaborate more fully a third dimension

which can be discerned from this set of neurophysiological and neurobehavioral experiments. This dimension deals with the fact that the brain contains a mechanism by which the amount of redundancy in a system, the amount of synchronous activity, can be governed. In the experiments cited, this regulation was shown to be effective over input, and there is evidence (4, 5) that a similar effect operates on motor systems.

As already noted, the importance to the psychological process of redundancy regulation has as yet been only partially explored. On the input side, redundancy *reduction* is involved when interest and sensory *participation* are called forth; redundancy *enhancement* helps *focus* and *restrict* the organism's sensory interaction with the situation. The two processes are ordinarily balanced, for they converge on the same input mechanism, even on some of the same cells in the mechanism (38). It is likely that the adjustment of this balance differs in different individuals in different situations.

Here, therefore, is an example of another dimension along which individual differences and differences among individuals may be produced from occasion to occasion. Some individuals are more inclined to sensory participation with their environment, and some situations tend to evoke participation more than others. Such evocation is the essence of esthetic endeavor, and for this reason redundancy reduction can be thought of as a mechanism underlying an esthetic mode of reaction. Its opposite, an increase in redundancy, tends to focus and remove the organism from participation and to turn him inward. He is therefore responsive more to his own neural organization than to the organization of his environment. This mode of reaction is characteristically displayed, for instance, when ethical considerations are involved (as when a person asks whether he is being true to himself).

A convergent line of evidence concerning this dimension comes from observations of behavior. Here, also, two processes are identified, and the processes bear a resemblance to those already identified. In a recent study Schachter (34) examined the determinants of eating in obese and non-obese persons and showed that the obese person's eating is more under the control of external than of internal determinants, while the opposite is true of the nonobese person. In other words, most people eat when their physiological state demands; the gourmand responds to opportunity.

Another convergence comes from psychophysiological experiment. Lacey (12) has used heart rate and other measures of autonomic nervous system reactivity to gauge the receptivity of an organism to stimulation. The evidence is that two modes exist—one "open" and one relatively "closed": "Cardiac deceleration accompanied and perhaps even facilitated ease of 'environmental intake' whereas cardiac acceleration accompanied or facilitated 'rejection of the environment.'" Data are presented to show that cognitive problem solving demanding "internal" work produces cardiac acceleration while situations demanding anticipatory vigilance, an "external orientation," are accompanied by cardiac deceleration. Clearly, an "open-closed" dimension is discernible in these results. It remains to be shown that the convergence with the recovery cycle data is real and not spurious: simultaneous recording of heart rate and evoked recovery functions in the two types of situation is an indicated next step.

The delineation of the esthetic-ethical dimension finds parallels in conceptions derived from still other types of observations. Developmental studies led Piaget to formulate the suggestion that two complementary processes guide cognitive growth. One process he labels *accommodation*; the other, *assimilation*. "In their

initial directions, assimilation and accommodation are obviously opposed to one another, since assimilation is conservative and tends to subordinate the environment to the organism as it is, whereas accommodation is the source of changes and bends the organism to the successive constraints of the environment" (21, p. 352). Thus, "the nursing's psychic activity is at first only simple assimilation of the external environment to the functioning of the organs. Through the medium of assimilatory schemata, at first fixed, then mobile, the child proceeds from this elementary assimilation to putting means and ends into relationships such that the assimilation of things to personal activity and the accommodation of schemata to the external environment find an increasingly stable balance. The undifferentiated and chaotic assimilation and accommodation which characterize the first months of life are superseded by assimilation and accommodation simultaneously dissociated and complementary (21, p. 350)." Accommodation thus resembles the effect which a neurologically based redundancy reduction mechanism would be expected to exert; assimilation could well be effected by redundancy enhancement.

This convergence of conceptions does not in itself mean that accommodation is necessarily accomplished through redundancy reduction and that assimilation occurs through an increase in the synchronous operation of the organism's input mechanism. However, as hypotheses these possibilities can be fruitfully explored since the parts of the brain responsible for shifts in redundancy are known, as are the effects of removal of these parts on problem solving in adult primates. Thus, removal of the appropriate structure in young animals should have effects predictable from Piaget's formulation.

Other convergences come to mind. Factor analytic methods of studying subjects with brain lesions have been undertaken

by Halstead (9), Reitan (32), and Teuber's group (35). Of particular relevance here is the fact that most factor analytic studies have yielded some sort of introversion-extroversion dimension. Petric some years ago (20) presented in detail carefully controlled evidence that frontal leukotomy leads to changes "on test measurements associated with the dimension of extraversion-introversion." The finding that these changes occur in the direction of greater extraversion is convergent with the model based on the recovery cycle here presented: removal of the influence of frontal lobe tissue leads to redundancy reduction in the input channels and hence "greater sensitivity to the complexities of the input." More recently (19) Petric has extended her work by devising a set of behavioral tests with which she has delineated additional ways of characterizing persons: a stimulus augmentor-stimulus reducer dimension and an autonomy-externally controlled dimension. She is at present engaged in a series of studies, using neurosurgical patients, aimed at relating her behavioral observations to their neural substrates. Should this current work be combined with some simple neurophysiological observations, for example, elucidating recovery functions as in the experiments described here, another convergence among models could readily be accomplished. On the whole, electrophysiological data taken in conjunction with factor analytic analysis should prove extremely fruitful. Pioneering studies of this sort have been undertaken. Pawlik and Cattell (18) have analyzed the organism's readiness to be aroused and Barratt (2, 3) has investigated the above mentioned stable-labile dimension of readiness to react established by the work of Lacey and Lacey (13).

Considerably more remote would be studies which relate the neurologically derived models with those based on social-

cultural observation. Nonetheless, I believe such studies are possible. For example, Riesman (33) has, from social-historical observation, delineated what he calls "inner-directed" and "other-directed" individuals. It could be that developmental exigencies mold some individuals along primarily redundancy-reducing, accommodative modes of communicative intercourse. And it could be that other circumstances yield primarily redundancy-enhancing, assimilative modes of communicative discourse. In this way a person (or even a whole population) would become primarily esthetic or primarily ethical in interpersonal interactions, depending on the formative culture.

Many questions can be raised within the framework of these observations: for instance, is inner- and other-direction synonymous with introversion and extroversion? Are there indeed more gourmands in other-directed societies, as the Schachter experiments might suggest, or is the relationship between inner- and other-direction specific to a reaction mode? Can the balance between esthetic and ethical sensitivity be altered by later experience or is there a limited "critical" period during development which "sets" the organism on one or another course? Does society and its culture determine not only the balance between the esthetic and ethical mode but also the emotional consequences of each reaction? In another paper, Melges and I (28) tentatively proposed a classification of affects based in part on the difference between an ethical mode of reaction, which we called preparatory (or better, pre-reparatory) and an esthetic mode which we called participatory. The suggestion was made that the affect associated with the ethical, preparatory type of reaction is, as a rule, pessimistic, whereas esthetic participation begets optimism. This suggestion was based on current clinical experience and attributed to the

fact that the social outcome of participation was, on the basis of experience, appraised by an organism as potentially successful in establishing or reestablishing control, whereas preparatory maneuvers could, on the basis of experience, be expected to pose difficulties. However, this view is surely culture-bound: participatory reactions are rewarded in a society populated by persons holding the Freudian point of view, but the preparatory mode is the more effective in a society subscribing to the Protestant ethic (30). In fact, those of an older generation often find the cocktail party the epitome of a demand for an almost exclusively participatory mode of intercourse—and hence a most trying experience accompanied by anxiety produced by the enhanced internal uncertainty and reduced redundancy necessary to be simultaneously open to a large number of information sources. For this earlier generation, the ethical mode of living true to one's principles proved a gratifying experience and thus led, in them, to optimistic affects.

#### SUMMARY

In summary, then, three dimensions of "person" have been delineated from one set of neurobehavioral and neurophysiological results. I have here explored, for one of these dimensions, some possible convergences with other conceptions derived from other data and have suggested experiments and applications that come to mind as a result of the exploration. I have dwelt on convergences. An alternative would have been to spell out a more inclusive set of dimensions; I have eschewed this alternative—partly because I feel it would be premature to espouse it. But there is another reason for my choice. So much of scientific endeavor today is concerned with checking the reliability of conceptions by logical and experimental analytic procedure. Too often the validity

of the conceptions remains either unquestioned or is dismissed by ridicule—as when a model is maligned as "reductive" or its converse, "soft." I urge that the validity of many conceptual systems can be tested by attention to convergences among them and by testing these convergences by performing experiments and observations in situations or contexts that combine elements from those which led to the original formulations. Without such synthesis through cross-disciplinary effort, science is likely to culminate in a tower of Babel where the many, by referring to the same event structured in different realms of discourse, fail totally to communicate.

Specific to our present concern is the fact that societies are made up of persons whose *brains* shape the interactive matrix. There should therefore be no barrier in using data from social observation, personality analysis, and neurological experiment to come to a common understanding. In the spirit of this kind of cross-disciplinary endeavor, starting with a set of experimental results delineating neural servo-mechanisms accomplished in my laboratories, I have described several areas where the investigations have led to an apparent convergence of concepts about the organization of personality, a convergence which persuades follow through: one such area would explore a stabile-labile dimension, a second an effective-affective dimension, and another an esthetic-ethical dimension, along which persons may vary.

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