*C. C. Anderson*

# THE LATEST METAPHOR IN PSYCHOLOGY

For a long time psychology has languished as a faintly disreputable science. This is neither because psychologists are inefficient nor because they practise professional duplicity, rigging their results in favour of some hypothesis which cannot as a result be substantiated by neutral research. There are two valid reasons for the doldrums in which the psychologist finds himself. The first is that psychological laws which are invariant and stable over many occasions are usually both trivial and firmly anchored to the unique and specific conditions of the experimental situation from which they originated. When these laws are generalised into something like a system purporting to be applicable to behaviour as a whole, they are disappointingly inadequate, inaccurate in description, and blunt in predictive power. In effect, the analytical techniques of the psychologist are of the blunderbuss variety. Secondly—and this is just as important—psychologists appear to change and discard their metaphors with discouraging speed. This is not merely a verbal complaint, although it is true that recurrent neologisms and "semantic rejuvenation" are unhappily characteristic of psychological terminology. It refers rather to transformations in the way in which the study of behaviour is expressed in concepts.

These two points—the inability of psychological laws to hold up under a variety of conditions, and the changing fashions in metaphor in psychology—are, of course, related. Man must describe "the mind" or behaviour in metaphor, dead, alive, or faded. Richards'[1] well-known account of this is worth quoting again:

> Thinking is radically metaphoric. Linking by analogy is its constituent law or principle, its causal nexus, since meaning only arises through the causal contexts by which a sign stands for (takes the place of) an instance of a sort. To think of anything is to think of it as a sort (as a such and such) and that 'as' brings in (openly or in disguise) the analogy, the parallel, the metaphorical grapple or ground or grasp or draw by which alone the mind takes hold. It takes no hold if there is nothing for it to haul from, for its thinking is the haul, the attraction of likes.

Of late in psychology, technological parallels have been favoured and behaviour has been variously studied as a sort of physiological, biochemical, or engineering product, to be most adequately described and analysed

by the mathematical methods of the physical sciences. The psychologist is prompted, therefore, to discover by evidence and proof the laws governing human nature. According to the canons of the exacter sciences, these laws are hypotheses from which testable predictions may be derived, and the most valid laws are those that hold for a wide variety of conditions and new circumstances. Laws of this type are embarrassingly scarce in psychology.

There are two reasons for this state of affairs. Firstly, as the present writer has indicated elsewhere[2], there is considerable evidence of function fluctuation, an unpredictable functional variability characteristic of cognitive and non-cognitive life. This is "the human factor" or "the human element," which Maugham[3] has described succinctly in his story of that title. He states categorically that "self-contradictory is what most of us are. We are a haphazard bundle of inconsistent qualities." This view is, of course, extreme. Much of our external behaviour, especially that of a cognitive type, is predictable within limits, even though these limits may occasionally be seriously wide.

A second and much more important reason is that whenever the psychologist uses metaphorical models for the explanation and description of "states of mind," these models are not sufficiently flexible (as well as systematic) to approximate to the individual case, which may be the product of a (possibly subtle) interaction between several laws. The psychologist's net is too coarse in texture.

Nothing daunted (and this to his credit) he returns to the attack each decade with a new metaphor, and it would be rank ingratitude not to look for something especially adequate in the new crop.

First of all, by what criteria are we to judge the product? Negative criteria are easy to hand because the metaphor has been discussed since before Aristotle. First, a psychological metaphor should try to be unambiguous. Metaphorical language in ordinary life and in literature is potentially ambiguous and disconcertingly mobile in meaning. When something is described as another thing, it can be taken as referring to quite a variety of (possibly disparate) qualities of that other thing, and multiple meanings begin to split off. Freud[4] has illustrated the extreme case of the "antithetical sense of primal words," in which some words, by metaphorical shifts, come to mean the opposite of what they were originally designed to mean. Examples include *desultory* (originally "skipping," "jumping"), *egregious* (formerly "outstanding"), *fast* (formerly "static"—both meanings are still active) and *cleave* ("split" and "adhere to"). In the same way a word may become synonymous with its negation—*passive* (impassive), *ravel* (unravel), and *valuable* (invaluable).

Of course, language is not quite so ambiguous in psychology. The mobility of psychological terminology lies somewhere between the relatively static meanings in the physical sciences, and the attractive but sometimes rather irritating "esemplastic" property by which the words in everyday language and poetry come to have many meanings. Of course, it is true that the psychologist's terms can be ambiguous. For example, Masserman[5] has pointed out that the word "emotion" has been used in at least thirteen different ways. This is true of any general category in psychology—"memory," "attention" and "perception." However, this imprecision of usage does not refer to overt behaviour: acts of remembrance or attention are quite precise and capable of being measured. The imprecision comes from the attempt to explain overt acts by referring to their relationship with other functional events in conscious life: in other words, by talking about "inner events"—whether acts of attention are specific or general, their relationship with "mental set" and other mental functions, their personality correlates. This reference to inner events is done within the framework of a general metaphorical model or models which somehow breed multiple meanings. This may be because each model gives only a broad coverage which becomes imprecise as these events ramify. Part of the reason must be that the metaphorical "vehicle" has been in the past only functionally illustrative of the metaphorical "tenor" instead of being functionally identical with it. In any case, much of this imprecision in psychological terminology is metaphorical in origin.

The second negative criterion is the tendency to metaphorical confusion of the contexts of "tenor" and "vehicle." The British tradition of empirical philosophy has always actively disliked the use of metaphors in philosophic or any other type of discourse aimed at the discovery of the "facts" or the "truth." The early empiricists took the view that the hard facts of the external world were given to consciousness in a finished state (without being transformed on the way by any activity on the part of the organism) and that the main function of language, as a means to meaningful and correct thinking, was to picture or "mirror" these facts accurately[6]. Both Locke[7] and Berkeley[8] thought that *any* language tended to distort this picture and prevent the truth from being communicated, and metaphor, with its tendency to confound contexts (especially, if these words can be read nowadays without too much wincing, the contexts of "mind" and "matter") was a special anathema. Sprat[9], writing *The History of the Royal Society of London*, has a long passage against "this trick of metaphors," and Hobbes[10], in the *Leviathan* gives as the sixth cause of fallacious reasoning "the use of metaphors . . . instead of words proper," classing metaphors with "senseless and ambiguous words."

Bentham[11] had perhaps the most thoroughgoing attitude towards the eradication of metaphor. He regarded the use of metaphors as a stratagem devised by rulers so that they could more easily repress their subjects, and he tried to remedy matters in an empirical fashion by distinguishing between "real perceptible entities" which "are made known to human beings by the immediate testimony of their senses" and to which "existence" is ascribed, and fictions (the precursors of Vaihinger's[12] "analogical fictions") which are "non entities" with no existence. By the analogical process Bentham terms "paraphrasis"(when propositions have for their subject fictions instead of a genuine or real entity), a metaphorical existence may be ascribed to the fictions, and a reading of these metaphorical propositions tends to produce a concrete image which lends substance to what is otherwise a mere metaphor or allegory. These concrete images often have emotional associations which may suitably be used to subvert rational and unbiassed decision, and in this way the lawyer and the priest deceive the populace. Bentham proposed to expose the hidden metaphors by "phraseoplerosis," or the replacing of fictions with more literal words referring to entities.

This confusion of contexts in metaphor can be easily illustrated from psychology. James' famous "stream of consciousness" induces an idea of the continuity of awareness which present research finds inaccurate. His analogy between habit and the way paper, when creased on a given line, will always fold more readily on that line, tends to leave the impression that there will be a correlative "folded" or "well-trodden" pathway in the brain along which impulses will pass more easily. Thorndike's classical work on animal learning reinforced this metaphorical approach to brain functioning. The most revealing confusion of this metaphorical type is Freud's array of concrete "vehicles" to describe his psychological constructs—seething cauldrons, drains, dams, pumps, and pipes and tubes with fluid in them which flows, gets dammed up, tends to regress, and so on. Two contemporary psychologists, MacCorquodale and Meehl[14], are forced to comment, Bentham-like, that " . . . there are no known properties of nervous tissue to which the hydraulic properties of libido could correspond. Hence this part of a theory about 'inner events' is likely to remain metaphorical." They suggest that the psychologist should avoid postulating these inner events by concentrating instead on describing the overt behaviour of the subject and the empirical variables of the experimental situation.

This is an important distinction. We must ask whether it is possible to describe human behaviour adequately and meaningfully without these postulations. There is no settled opinion about this, but most

psychologists would tend to agree with Tolman[14] that the construction of hypothetical brain-models is necessary even if it is only of a pseudo-neurological kind. More will be made of this later.

Here, then, are two negative criteria to which an adequate psychological metaphor should conform: firstly, it should not be ambiguous; secondly, it should not confuse contexts. And a distinction should be drawn between metaphors describing external behaviour and those describing inner events on the score of their relative adequacy in completely accounting for human behaviour.

What are the positive criteria of an adequate metaphor in psychology? It should be a "physical analogy" in Turner's[15] sense: this occurs when corresponding states in two different sciences or contexts are found to be capable of description and analysis by the same mathematical method. A clear case of this in the nineteenth-century was Lord Kelvin's analogy between electrostatics and heat conduction which made the mathematical methods of Fourier available to electrostatics. A second quality of the physical analogy is implied in the first: that the states being compared must be functioning in a corresponding way. A third, though not a necessary, quality of the physical analogy is that it should direct in the new field to which it is being applied new theoretical and experimental enquiries and hypotheses.

We may ask whether the new metaphor passes muster on these criteria.

The brain is a calculating machine. J. M. Stroud[16] puts this idea very well:

> Man is the most generally available general-purpose computing device. A certain naval officer is reputed to have remarked that no lighter, more reliable, more easily maintained or more versatile one by unskilled labour was available so inexpensively or in such large quantities.

McCulloch[17] has a well-known paper on the brain as a computing machine, in which the theme is that "the brain is a logical machine," and Wiener[18] has said that the brain is "a glorified digital machine."

At once we may say that this metaphor satisfies the first and third positive criteria in that the appropriate mathematical methods have been applied (though not without some criticism, by Cherry[19] among others) in psychology, and new theories and findings have been adduced as a result. This is made plain recently in Quastler. Furthermore, the second criterion appears also to be satisfied. The neuron or nerve cell is taken to work exactly like a thermionic valve or electro-magnetic relay. Von Neumann[20] says that they are " . . . two instances of the same generic

entity, which it is customary to call a 'switching organ' or 'relay organs'." And McCulloch[21] is quite certain of their functional equivalence: "Moreover, nerve cells are cheap . . . engineers cannot hope to compete with nature. . . . Computing machine designers would be glad to exchange their best relays for nerve cells."

An exact physical comparison between the neuron and the valve reveals their similarities in functioning. Many of the principal actions of the nervous system are of a digital kind. McCulloch lists five, of which two are of some interest. Firstly, a digital machine represents numbers as aggregates of digits which may be counted as electrical pulses. In the binary system of notation, there are only two numbers, 1 and 0, which correspond to the pulse and no-pulse (input and no-input) responses of the valve. This binary device parallels exactly the all-or-none working of the nervous impulse. In both cases, if the stimulus is strong enough, there is a response; if not, there is no response, and in both cases the response is unambiguous (of the yes-no type) and does not vary in strength. Secondly, although the stimulus may be weak, these switching organs can in turn activate other stronger impulses because the energy of the response has a source of power independent of that supplied by the original stimulus, which merely directs the flow of energy from this source. The source of energy in the neuron comes from the chemical processes of the cell metabolism; in the valve it is the cathode-plate differential and the heating filament.

To make the physical analogy more complete there are structural similarities between the neuron and the valve. The cell membrane is a control arrangement functioning analogously to the space between the cathode and the grid which controls the electron flow. And the electrical transmission of the impulse in valve and neuron is comparable. The nerve fibre is surrounded by a protein membrane which is electrically charged, positively on the outside and negatively on the inside. When the fibre is stimulated the membrane becomes permeable at the point of stimulation. Successive regions of the fibre are depolarised and an electro-chemical disturbance is transmitted along the fibre.

Certain mechanisms in the body function more closely to the analogue type of computer. This machine is based on the principle that numbers are represented by physical quantities, *e.g.*, distance or the intensity of an electric current. Mathematical operations can be performed by getting natural or physical processes to manipulate the physical quantities in the appropriate and desired way. The name "analogue" is given to these machines to show that there is a complete analogy between physical quantities on the one hand and numbers on the other. The multiplication

of two numbers on a slide rule by placing the two corresponding distances end on end and adding is an example of simple analogue computing. It demonstrates that analogue machines show continuous operations in contrast to the discrete operations of the digital computers. Von Neumann argues that certain bodily mechanisms function in this way. This is generally true of events in the organism which are mediated by endocrine secretions, the chemical composition of the blood or "humoral" media. In particular the mechanism which keeps the blood pressure constant is of this mixed type.

To round off the entire physical analogy, two points might be added. Firstly, "logical machines" built to solve logical problems consist entirely of on-off switching devices and are essentially simple digital computers. However, it might be imprudent to press too far with the analogy that a man is mainly (or even most of the time) a logical machine. Secondly, the "giant brains" and other artificial mechanisms or automatisms constructed from valves exhibit behaviour that is startingly human. They can be conditioned to react to substitute stimuli; receive, select, store and send information; react adaptively to changes in their environment; reason deductively from premises and including in the reasoning the results of previous deductions and data about their accuracy; and engage in behaviour of a seemingly teleological type aligned to a definite goal. Finally, certain kinds of malfunctioning in man and machines can be paralleled. Computing machines with complicated circuits occasionally develop functional faults in which the operation circles endlessly in a closed reverberating loop. This can be compared with Kubie's view that the basis of neurosis is an interactive obsession which sets up a chain reaction in neurone mechanisms. Further, the machine and the neurotic can be cured in remarkably similar ways. The machine can be cured by cutting off the current, by shaking, or by putting it into a "shock" charge. Comparable remedies for the neurotic include sleep or prolonged narcosis, pre-frontal leucotomy, and E.C.T.

In view of so many parallels, the danger clearly lies in a tendency to anthropomorphise the machine and mechanise the man.

This physical analogy is unique in psychology because it appears to satisfy every criterion. Is man, then, largely an information-handling device, a digital machine, glorified by being equipped with a few added decorative tricks of no importance and in which a self-respecting machine would not indulge? If not, where is the flaw in the metaphor?

Mays[22], giving a stock reply, argues that the transformation of formulae according to logical rule is not thinking, except in a very limited sense. It would mean describing behaviour in terms of the very limited

symbolism of mathematics and logic, ignoring everyday and poetic symbolism and the working of the unconscious mind. However, this is scarcely a satisfactory position. A machine can learn, and emotions and aesthetic experiences and the raw data of unconscious life are very largely learned. There seems to be nothing in principle to prevent a machine registering these experiences in terms of its own symbolism.

Neither is von Neumann's[23] argument wholly convincing:

> It is unlikely that we could construct automata of a much higher complexity than the ones we now have, without possessing a very advanced and subtle theory of automata and information. A *fortiori*, this is inconceivable for automata of such enormous complexity as is possessed by the human central nervous system.

This leaves the door ajar: an "advanced theory" might appear, and, in any case, von Neumann's argument does not preclude the possibility that man is basically and for all practical purposes a digital machine with (this time valuable) addenda such as, possibly, an "infinite memory drum."

The best approach is to re-examine the analogy to realize that its success reveals its limitations and that its limitations in turn point to at least the partial inadequacy of the computer metaphor. The analogy is successful (and limited) because it described external behaviour mainly. Its components are the known stimulus and the observed response. This is all that the analogy covers. It says nothing about the "inner events" which go on between stimulus and response. This gap between an electrical impulse in a single solitary nerve cell (a rather artificial model) and behaviour is characteristic of behaviouristic theory. The everyday psychologist feels a need to fill this space with inner events, some sort of model which may help him to understand the external response. The communication model of information theory illustrates the difference in approach:

Source —> Transmitter —> Channel —> Receiver —> Destination
< encoding > < decoding >

The everyday psychologist is interested in the nature of the encoding and decoding process, the information theorist in the amount of information transmitted and the effect on that amount of the noise generally encountered in the transmission of the message.

To be more specific, we know about the way in which nervous impulses are transmitted (that the frequency of impulses in a given fibre depends on the intensity of the stimulation, and so on), but we do not know about the encoding and decoding processes—why, for example, although nervous messages are physically much alike, they are interpreted

in such a discriminating way by the brain and cord activity of the central nervous system, so that messages associated with sensations are differentiated from messages associated with motor functions. Sluckin[24] makes this point neatly: "Even though the brain may be considered to consist of switching organs, there is no reason at all to suppose that it encodes and interrelates items of information along the lines of the digital logical-problem-solving machine." In fact there is evidence[25] to suggest that in the human being magnitude of sensory stimulation is registered by a system of counting, a frequency modulation system, and not by any binary device.

The importance of this point may be decried—after all, the similarity in behaviour is the important thing. However, there are at least three reasons why this point should not be ignored. First, the similarity does not go beyond a certain point, and the computer-mechanists are always at their weakest when dealing with the inner events of conscious life. It is here that the parallel between minds and machines is at its most fragile. Jefferson[26], for example, doubts that a machine could both write a concerto and know, be aware, that it had done it. Turing[27] can offer no arguments against this: instead he wants to assert that its acceptance would lead to an untenable philosophic position:

> According to the most extreme form of this view the only way by which one could be sure that a machine thinks is to *be* the machine and to feel oneself thinking . . . Likewise according to this view the only way to know that a *man* thinks is to be that particular man. It is in fact the solipsist point of view.

Why adopt the extreme view? A much better and usual way of knowing that a man thinks is to infer from our own experiences. As has been noted, we have no proof that the machine encodes and decodes as we do. Consequently we do not infer that it has any conscious life. The onus of proof of that is on the computer-mechanists.

One aspect of conscious life about which the computer-mechanists are especially unconvincing is willing, particularly the sort of willing in which a man decides deliberately to move from a "steady state" of equilibrium and undergo an experience which may be instructive but not obviously pleasant, or where a man makes a decision against his own private interest but possibly in the interests of some ideal such as truth or justice. In both these instances there is a conscious intervention in any "programming" which may be predetermined or which we may hypothesise to be built into the organism on the basis of, let us say, negative feedback to equilibrium. McCulloch[28], for example, adopts what amounts to a deterministic position by assuming that "will" means the ability to detect discrepancies between actual behavioural output (which is determined by

servomechanisms and negative feedback) and desired or "calculated" output:

> What happens in our head does not imply what is to happen in our arms and legs. We send down volleys of signals, but these play on the complicated servomechanisms which keep us . . . adjusted to the world about us. These have their own input from the world, so what happens is in large part determined by them. We intend, they act. Because what we intend and what we do are not always the same, we are forced to distinguish between what we will and what we shall do. Hence, the notion of 'will.' Any computing machine which detects a discrepancy between what is calculated and its actual output may be said to have a will of its own.

It might safely be argued that there is a great deal more to will than this. Even if we take the view that will is predetermined, then presumably it might be inserted in an automaton, but not until the mechanism linking the nervous impulse and behaviour has been analysed, and so far no one has approximated this state.

Secondly, it is important to stress the necessity of taking into account the mysterious nature of human encoding and decoding because postulation of these inner events is unavoidable even by the computer-mechanists themselves. They make assumptions (Hake[29] has a section on the correlates of the type of subjective probability termed "sequential predictive behaviour"), and these assumptions certainly involve metaphors. For example, Tanner[30] says quite openly:

> In any predictive system it is necessary to have a 'rule of inference.' In applying information theory to behavioural problems, the 'rule of inference' exists in the form of the optimisation assumption. This assumption states that an observer makes a decision to optimise his pay-off.

This postulation of inner events seems to add meaning to behaviour. However, officially, it is frowned upon. What goes on between stimulus and response is unimportant, and another metaphor has been designed to draw the curtains down on the whole business. This is the "black box," defined by Quastler[31] in the following way:

> The experimental study of human information processing involves observation of a physical fact, the stimulus; another physical fact, the response; and inferences concerning the system mediating between the two. As far as information theory is concerned, the mediating system is a 'black box.' That means the problem is not how it works, but what it achieves. . . . In its simplest and most general version, the 'black box' has not internal structure.

Von Neumann[32] adds one interesting and significant specification in his definition of "black boxes": "They are viewed as automatisms, the inner structure of which need not be disclosed, but which are assumed to react to certain unambiguously defined stimuli, by certain unambiguously defined responses."

I should be prepared to maintain that most responses will be ambiguous (not meaningful enough or with too many meanings) if we do not know about or hypothesise about the inner structure of the "black box," if we do not know about the stimuli and the interpretation to be placed on them. This is the root which explains and gives meaning to the action. To resolve an ambiguity is to find the interpretation being placed on stimuli, and to understand this interpretation means the construction of a model, of a necessarily metaphorical kind, about the functioning of the "black box." Proof of the assertion lies in the fact that most psychologists have made these postulations partly to get rid of this behavioural ambiguity and also partly to bring generality to their findings because inner events are, in effect, a shorthand method of synthesising observed results and providing new hypotheses to be tested later.

Unfortunately, although such postulations get rid for the time being of behavioural ambiguity, they also introduce a latent ambiguity and imprecision of meaning into the terminology about inner events. Our behaviour may possibly be mechanically determined and operative, but the terminology in which it is encased has not an equivalent precision. Von Neumann[33] notes the work of McCulloch and Pitts and argues that "It proves that anything that can be exhaustively and unambiguously described . . . is *ipso facto* realizable by a suitable finite neural network." This may well be the case. Von Neumann goes on to argue that the formulation of any general concept unambiguously is impossible because the number of words required would be unreasonably excessive. However, a plethora of words to aid local and specific discrimination is not the real barrier to unambiguous formulation. Ambiguity is an inherent characteristic of psychological terminology, and this is the third reason why it is difficult to support completely the computer analogy. As Richards[34] has said, "It is an old dream that in time psychology might be able to tell us so much about our minds that we would at least become able to discover with some certainty what we mean by our words and how we mean it."

This is a rather pessimistic picture. We avoid behavioural ambiguity and trivial findings specific to particular situations and people by postulating "inner events." The metaphors enshrouding these events are impressionistic pictures and, at a distance of years, they fade and become ambiguous. And so we create a new batch.

This is fortunately not quite the *impasse* it seems. Discarded systems there are aplenty in psychology, but a satisfactory number of relationships concerning overt events have been established. Predictive generalisations of external behaviour (subject to the blunting effect of "function fluctuation") are still possible provided that we are willing to assume some handy

"inner event" isolated fiction such as "functions" like intelligence and memory. However, as soon as we try to build up a system, try to take into account, that is, the interactions of these functions, then the metaphorical models, together with their attendant weaknesses, must appear as we seek for laws covering the individual case.

Of course it may be that, in the future, this gap between impulse and decision will be analysed by a technical symbolism that will uncover and pin down finally an adequate physical analogy. This could not be exclusively mathematical because our behaviour does not approximate such a model. If it is verbal it may be too imprecise. The whole matter does not bear much speculation at the moment. Until this solution arrives, psychology will remain an inexact, second-best, though interesting, science. Yet in the words of the hack poet, it may be that "The second best is better after all."

## NOTES

1. I. A. Richards, *Interpretation in Teaching* (1937), pp. 48-49.
2. C. C. Anderson, *Function Fluctuation* (1958), British Journal of Psychology Monograph.
3. S. Maugham, *Cosmopolitans* (1936), p. 95.
4. S. Freud, *Collected Papers* (1934), Vol. IV, pp. 184-191.
5. J. H. Masserman, "A Biodynamic Psychoanalytic Approach to the Problems of Feeling and Emotion," in M. L. Reymert, ed., *Feelings and Emotions*, p. 40.
6. *Cf.* E. Daitz, "The Picture Theory of Meaning," in Flew, ed., *Essays on Conceptual Analysis* (1956).
7. J. Locke, *An Essay Concerning Human Understanding*, Book III, Chapter 9, Section 21.
8. G. Berkeley, *The Principles of Human Knowledge*, Introduction, paragraph 21.
9. T. Sprat, in J. E. Spingarn, ed., *Critical Essays of the Seventeenth-Century* (1908), Vol. 2, p. 117.
10. T. Hobbes, *Leviathan*, ed., Molesworth, Vol. 3, p. 34.
11. J. Bentham, in C. K. Ogden, *Bentham's Theory of Fictions*.
12. H. Vaihinger, *The Philosophy of 'As If'*, trans. C. K. Ogden (1924).
13. K. MacCorquodale and P. E. Meehl, "On a Distinction between Intervening Variables and Hypothetical Constructs," *Psychological Review*, LV (1948), pp. 95-107.
14. E. C. Tolman, Discussion from "Interrelationships between Perception and Personality: a Symposium," *Journal of Personality*, XVIII (1949-1950), pp. 48-50.
15. J. Turner, "Maxwell on the Method of Physical Analogy," *British Journal for the Philosophy of Science*, VI (1956), pp. 226-238.
16. J. M. Stroud, "The Fine Structure of Psychological Time," in Quastler, ed., *Information Theory in Psychology*, p. 174.
17. W. S. McCulloch, "The Brain as a Computing Machine," *El. Eng.*, 68 (1949), pp. 492-497.
18. N. Wiener, *The Human Use of Human Beings* (1950), p. 76.

19. E. C. Cherry, "On the Validity of Applying Communication Theory to Experimental Psychology," *British Journal of Psychology*, 48 (1957), pp. 176-188.
20. J. von Neumann, "The General and Logical Theory of Automata," in L. A. Jeffress, ed., *Cerebral Mechanisms in Behaviour* (1951), The Hixon Symposium.
21. W. S. McCulloch, *op. cit.*, p. 493.
22. W. Mays, "The Hypothesis of Cybernetics," *British Journal for the Philosophy of Science*, II (1951), pp. 249-250.
23. J. von Neumann, *op. cit.*, p. 18.
24. W. Sluckin, *Mind and Machines* (1953), p. 141.
25. J. von Neumann, *op. cit.*, p. 20.
26. G. Jefferson, "The Mind of Mechanical Man," *British Medical Journal*, Vol I. (1949), pp. 1105-1110.
27. A. M. Turing, "Computing Machinery and Intelligence," *Mind*, 59 (1950), pp. 433-460.
28. W. S. McCulloch, *op. cit.*, p. 493.
29. H. W. Hake, in Quastler, *op. cit.*, pp. 257-277.
30. W. P. Tanner, "On the Design of Psychological Experiments," in Quastler, p. 412.
31. Quastler, p. 143.
32. J. von Neumann, *op. cit.*, p. 2.
33. *Ibid*, pp. 22-23.
34. I. A. Richards, *The Philosophy of Rhetoric* (1936), p. 136.