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COMMENTS ON *A LOGICAL CALCULUS OF THE IDEAS IMMANENT IN NERVOUS ACTIVITY*[*]

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A question posed by F.S.C. Northrop, and McCulloch's answer[**], as well as Michael Arbib's comments and references in an introduction to *A Logical Calculus of the Ideas Immanent in Nervous Activity* may help the reader with this most important but difficult paper.

Northrop: Why did you have Pitts working with you on this?

McCulloch: Because I had difficulty at the mathematical level not knowing enough of the behavior of closed loops from a purely theoretical standpoint. That looks very simple as one looks back at it, but I assure you it was anything but. It required a familiarity with modular mathematics which I did not have. Pitts then cleaned up all that was fuzzy in my way of thinking. The paper was extra hard to write because we were all up against Carnapians, and the early Carnapian symbolism is so clumsy that when I read the paper today, I have to scratch my head to figure out what the proof was. It was an inappropriate terminology. So to speak, we were trying to do long division with Roman numerals.

A Logical Calculus of the Ideas Immanent in Nervous Activity by Warren S. McCulloch and Walter Pitts is the classic paper on neurophysiological automata theory and still merits reading

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* Information Storage and Neural Control. Edited by William S. Fields and Walter Abbott. Charles C. Thomas, publishers, Springfield, Illinois, 1963.

** Cross-Cultural Understanding, p. 344. Edited by F.S.C. Northrop and Helen H. Livingstone. Harper and Row.

today, almost forty years after its publication. Section I, which gives the neurophysiological basis for the model, is still valid in all its essentials and remains the most readable discussion of this basis. Section II, on the theory of nets without circles, and the discussion of Section IV are equally excellent.

However, Section III, the theory of nets with circles, was only intended as a sketchy account. It was presented in Carnap's notation, which was not apt for the task at hand, and is incomplete, hard to read, and contains many errors. Hence, for this part of the theory we may turn to more recent publications. The theory of nets with circles was first fully worked out by Kleene, and has since been given an elegant representation by Copi, Elgot, and Wright. The assertions of McCulloch and Pitts concerning the connections between the neural nets and Turing machines have been fully worked out by Arbib.

REFERENCES:

1. Kleene, S.C.: *Representation of Events in Nerve Nets and Finite Automata.* In Automata Studies, ed. by C.E. Shannon and J. McCarthy, Princeton, Princeton University Press, 1956, p. 3.
2. Copi, I.M., Elgot, C.C., and Wright, J.B.: *Realization of Events by Logical Nets.* J. Assn. Computing Mchy., 5:181-196, 1958.
3. Turing, A.M.: *On Computable Numbers with an Application to the Entscheidungs Problem.* Proc. London Math. Soc. (2) 42:230-265, 1936; with a correction, ibid, 43:544-546, 1947.
4. Arbib, M.: *Turing Machines, Finite Automata and Neural Nets.* J. Ann. Computing Mchy.8:467-475, 1961.