of year. Alate "fundatrigeniae" were collected from several peach trees and alate "alienicolae" were collected from many sprouting mangold roots. Furthermore, a difference in the same sense was reported by Rönnebeck[11], who concluded that *M. persicae* from peach trees ("fundatrigeniae") flew farther in the field than did alate "alienicolae" from stocks overwintering on savoy cabbage seed crops.

It therefore seems likely that many alate "fundatrigeniae" entering the potato crop in early summer remain flight-worthy long enough to spread even a persistent virus like leaf roll if they feed for sufficient time on infected plants during the first few days after their migratory flight. Moreover, their flight capacity is greater in the cool temperatures prevailing at this time of the year, for in experiments carried out in this laboratory, alate "fundatrigeniae" kept at 15° C retained the ability to fly for more than twice as long as alate "fundatrigeniae" kept at 25° C.

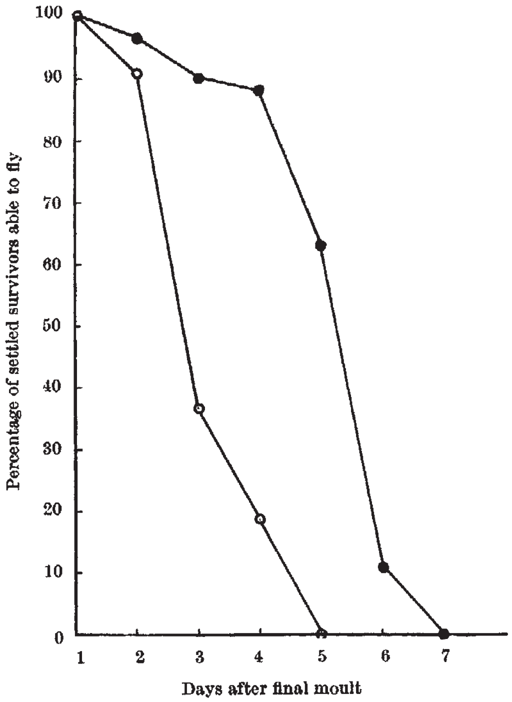


Fig. 1. Flight-worthiness of alatae after an initial flight of 5 h. ●, Fundatrigeniae, n = 110; ○, virginoparae, n = 22.

This work was started under the supervision of the late Dr C. R. Ribbands, for whose encouragement I am grateful. I thank Dr J. S. Kennedy for advice and discussion, Professor Sir Joseph Hutchinson for providing facilities, and the Agricultural Research Council for a grant.

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Received October 31; revised December 14, 1967.

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## GENERAL

# Holographic Model of Temporal Recall

Professor Longuet-Higgins[1] has called attention to the remarkable property of human memory of recognizing and recalling long sequences of which at first only a small fraction is consciously remembered, and he has devised a most interesting, physically realizable mathematical model which achieves just this. He has rightly called this a temporal analogue of holography. I wish to show that there is at least one other mathematical model, which I consider to be a closer analogue of holography, because it operates with triple products of the temporal function to be recognized or recalled.

Let the signal $A(\tau)$ start at $\tau = 0$. At the time $t_1$ we record the convolution integral

$$\varphi(t_1) = \int_0^{t_1} A(\tau)A(t_1-\tau)\mathrm{d}\tau \quad 0 < t_1 < T$$

where $T$ is the total duration of the signal. In order to recognize or to recall the signal we take $\varphi(t_1)$ from the store and form a convolution integral with a signal $A'$ which need be only a fraction of the longer sequence $A$. The recalled function is

$$R(t) = \int_t^T A'(t_1-t)\varphi(t_1)\mathrm{d}t_1 = \int_t^T A'(t_1-t)\mathrm{d}t_1 \int_0^{t_1} A(\tau)A(t_1-\tau)\mathrm{d}\tau$$

Reversing the order of integration in the trapezoidal region $t < t_1 < T$, $0 < \tau < t_1$, we obtain

$$R(t) = \int_0^t A(\tau)\mathrm{d}\tau \int_t^T A'(t_1-t)A(t_1-\tau)\mathrm{d}t_1 + \int_t^T A(\tau)\mathrm{d}\tau \int_\tau^T A'(t_1-t)A(t_1-\tau)\mathrm{d}t_1$$

If now the function $A$ is one which correlates sharply with itself, that is, if it is as often positive as negative and not regular-periodic, the two factors of $A(\tau)$ under the integral signs will be of the nature of delta-factors, $\delta(\tau - t)$, which become noticeably different from zero only for $\tau = t$, so that

$$R(t) \propto A(t)$$

with more or less "noise" if $A'$ is only a fraction of $A$.

This is therefore a possible mechanism for recall. It is also a mechanism for association. It is easy to see that, if we replace $A(\tau)$ by some other function $B(\tau)$ and record its convolution with $A(\tau)$, we shall be able to recall $B$ by means of $A$ or a part $A'$ of it.

The process can also be digitalized. The functions $A$, $B$ can be discrete sequences of $+1$ and $-1$, or of "yesses or noes", defined only for certain points of time, and the integrals are then replaced by sums over the lattice points in the trapezoidal area. This makes the model realizable with "McCulloch–Pitts neurons". The best procedure would be probably to record first $A(\tau)$ in a first store, and then transfer it to a second store, where it is multiplied with itself, back-to-front, one multiplicand starting at $\tau = 0$ and the other, backwards, at $\tau = t_1$. The signal $A$ could then be recalled, by a similar operation in a third, "associative" organ, by a fraction $A'$ of itself, or by any other sequence which has a part (such as a word, or several words) in common with it.

I do not wish to suggest, of course, that this model corresponds any more closely to the reality of the nervous system than Longuet-Higgins's system of resonators.

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Received January 19, 1968.

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