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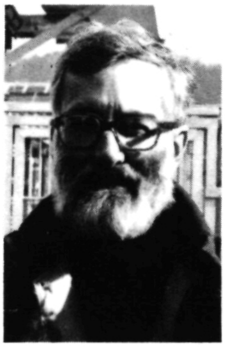

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Dr. Freeman received his M.D. degree from Yale University (1954), clinical training at Johns Hopkins University, and postdoctoral training in neuroscience at the University of California at Los Angeles. He is a professor of physiology in the Department of Molecular and Cellular Biology at the University of California at Berkeley. Dr. Freeman has published, extensively, articles on linear and nonlinear neurodynamics of sensory systems, including a monograph (Mass Action in the Nervous System, Academic, 1975).

IMPLEMENTATION OF PATTERN-RECOGNITION ALGORITHMS DERIVED FROM OLFACTORY INFORMATION PROCESSING

Abstract

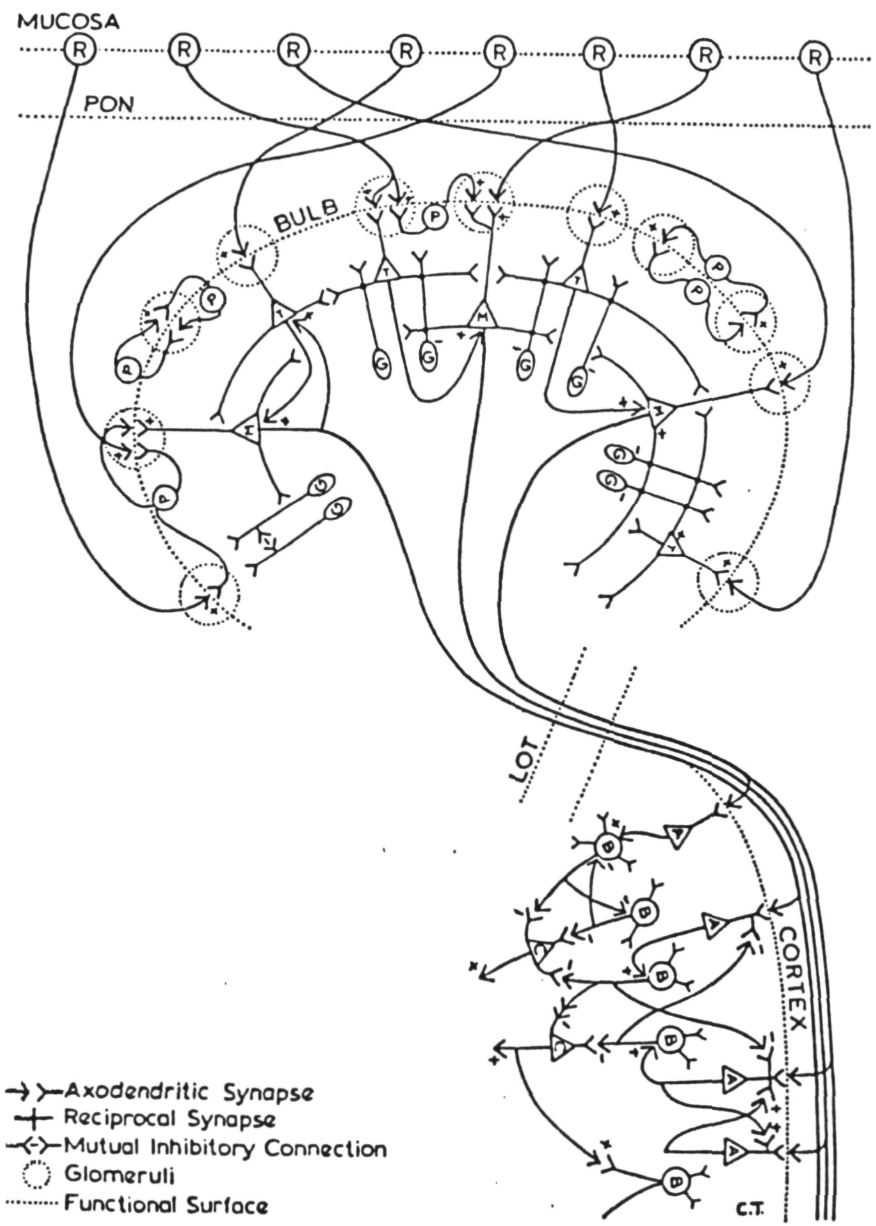
Sensory and perceptual information exists as space-time patterns of neural activity in cortex in two modes. Neural analysis of sensory input, as in feature extraction, is done with action potentials of single neurons in point processes. Neural synthesis of input with past experience and expectancy of future action is done with dendritic integration in local mean fields. Both kinds of activity are found to coexist in olfactory and visual cortex, each preceding and then following the other. The transformation of information from the pulse mode to the dendritic mode involves a state transition of the cortical network that can be modeled by a Hopf bifurcation in both software and hardware embodiments. These models show robust powers for amplification and correct classification of noisy and incomplete patterns corresponding to sensory inputs to biological nervous systems in attentive and motivated animals. The evidence is reviewed and the requirements are summarized for machine simulations of these operations.

C-3

IMPLEMENTATION OF PATTERN RECOGNITION ALGORITHMS DERIVED FROM OLFACTORY INFORMATION PROCESSING

SUMMARY

1. Modes of information in cerebral cortex -
   - point process: action potential frequency
   - local mean field: dendritic potential amplitude
2. Spatial amplitude modulation of carrier waves -
   - olfactory bulb of rabbit
   - primary visual cortex of monkey
3. Implementation with high-dimensional nonlinear ODEs
   - linear integration
   - asymmetric sigmoid nonlinearity
   - modifiable associational connections
4. Comparison of software and hardware embodiments
   - amplification and classification
   - chaos and the tolerance of disorder



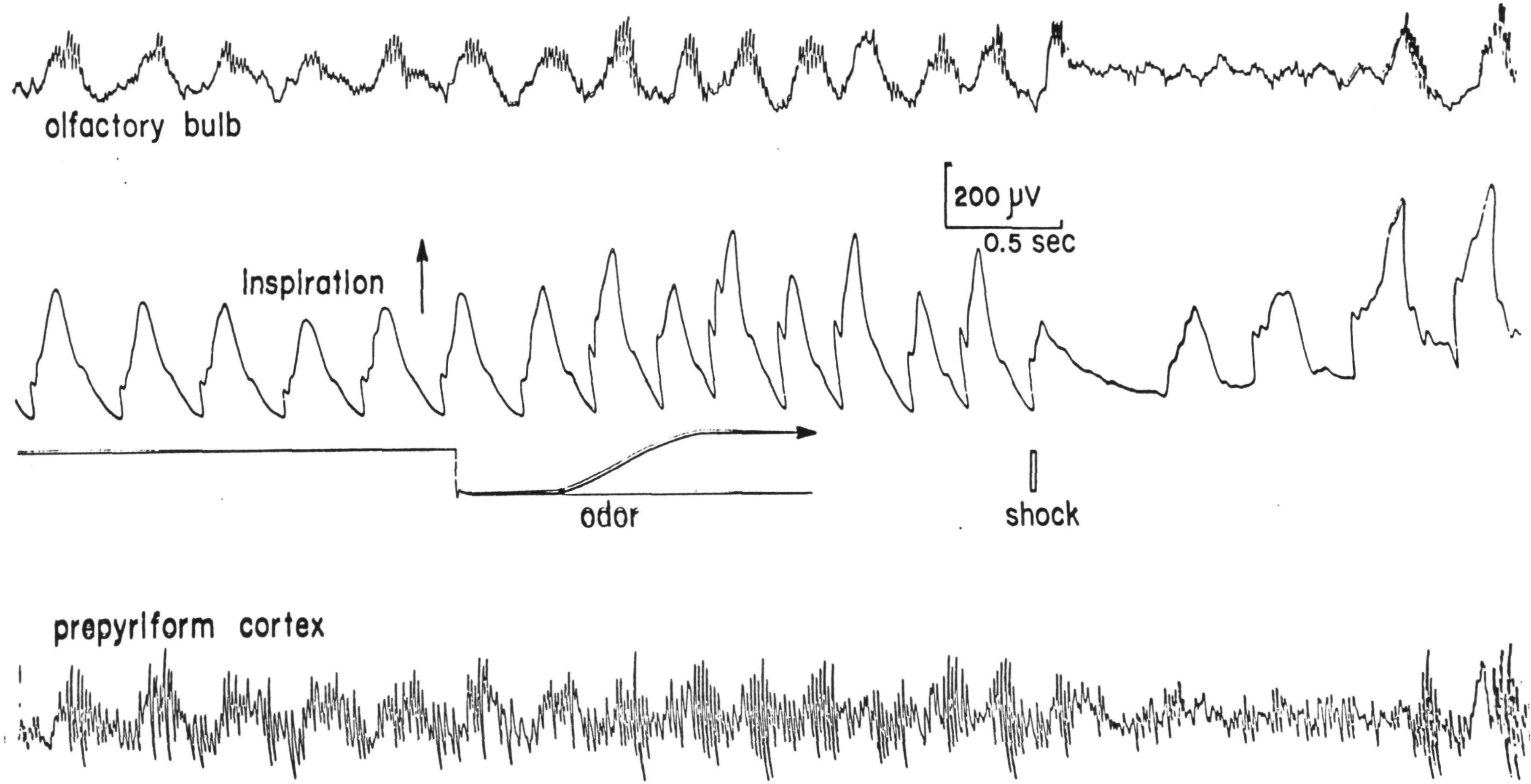
The main cell types in the olfactory bulb are the mitral and granule cells.

Mitral cells form a set of densely interconnected mutually excitatory cells. They also excite the granule cells. Mitral cell axons carry the output signal to the rest of the brain

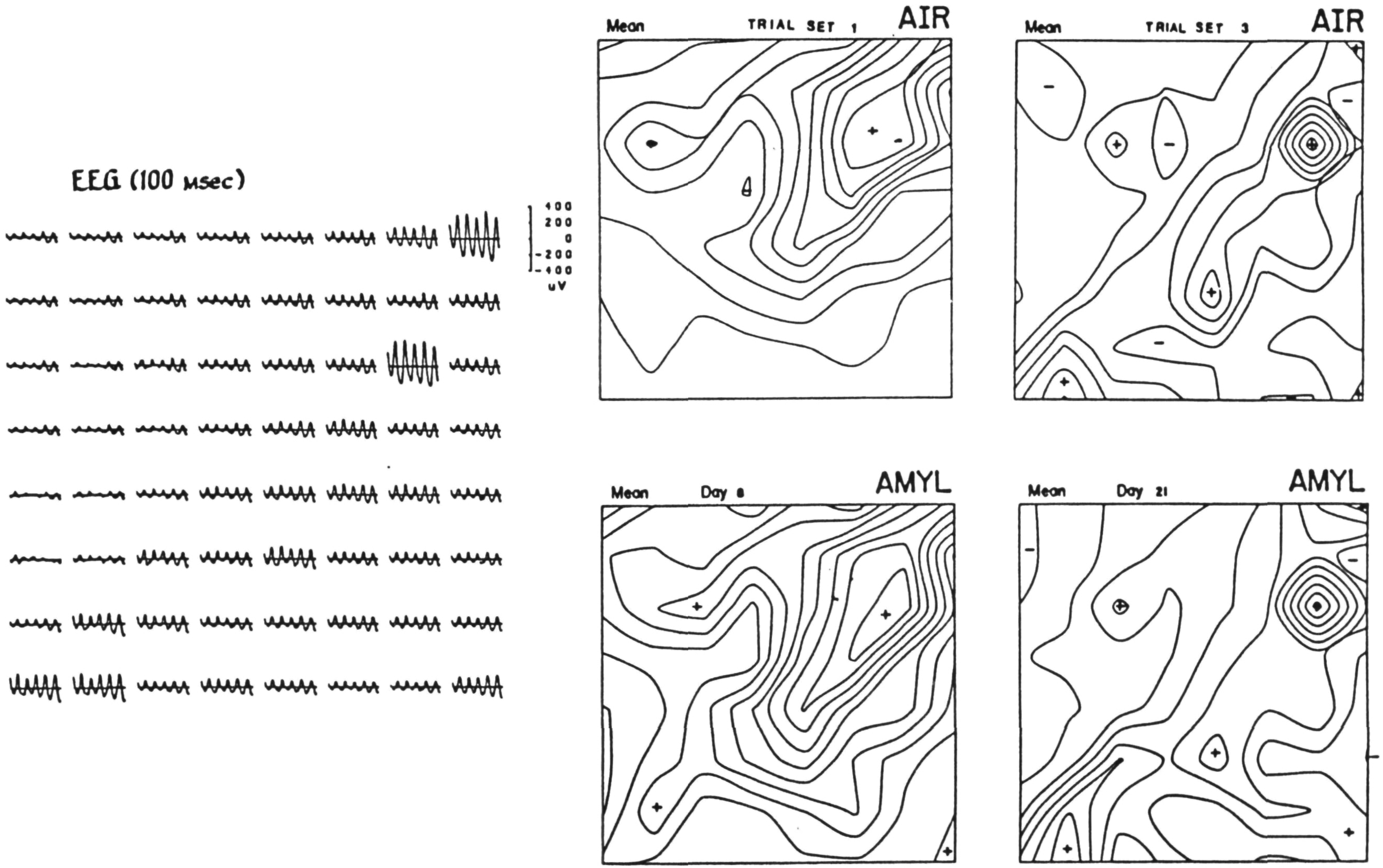
Granule cells form a set of densely interconnected mutually inhibitory neurons They also inhibit the mitral cells.

These two cell types are connected in a negative feedback loop. They form a neural oscillator. The olfactory bulb consists of approx. 2000 such coupled oscillators.

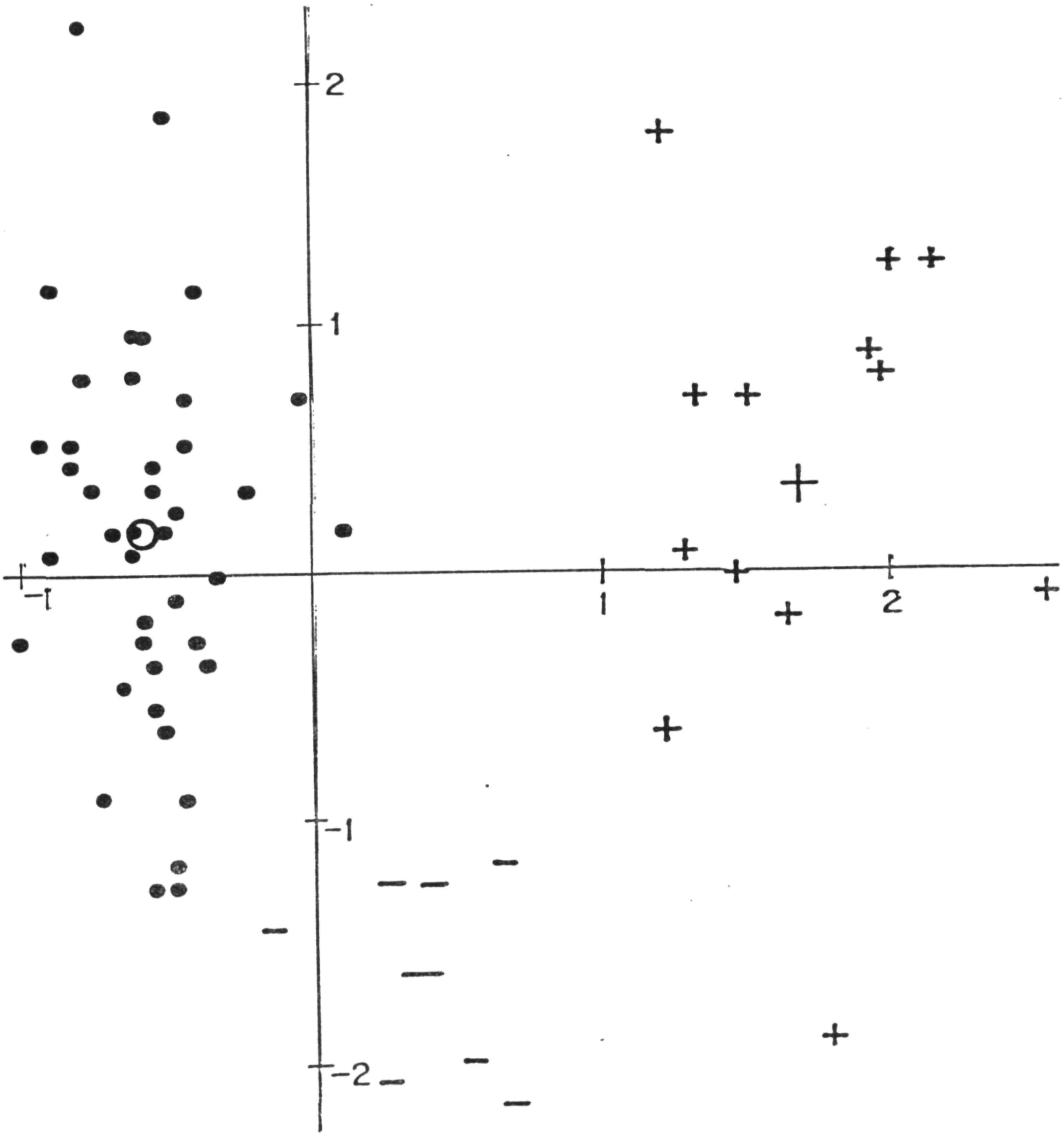
Excitatory couplings provide modifiable synapses in learning and perception. In hibitory couplings provide stability and spatial contrast.



THE BULB GENERATES A BRIEF OSCILLATORY EEG BURST WITH EACH INSPIRATION, WHETHER OR NOT A CONDITIONED STIMULUS ODOR IS PRESENTED. THIS RECORDING IS FROM ONE TRIAL IN A WAKING RABBIT. THE SAME PATTERN OF EEG IS FOUND OVER THE WHOLE MAIN BULB.

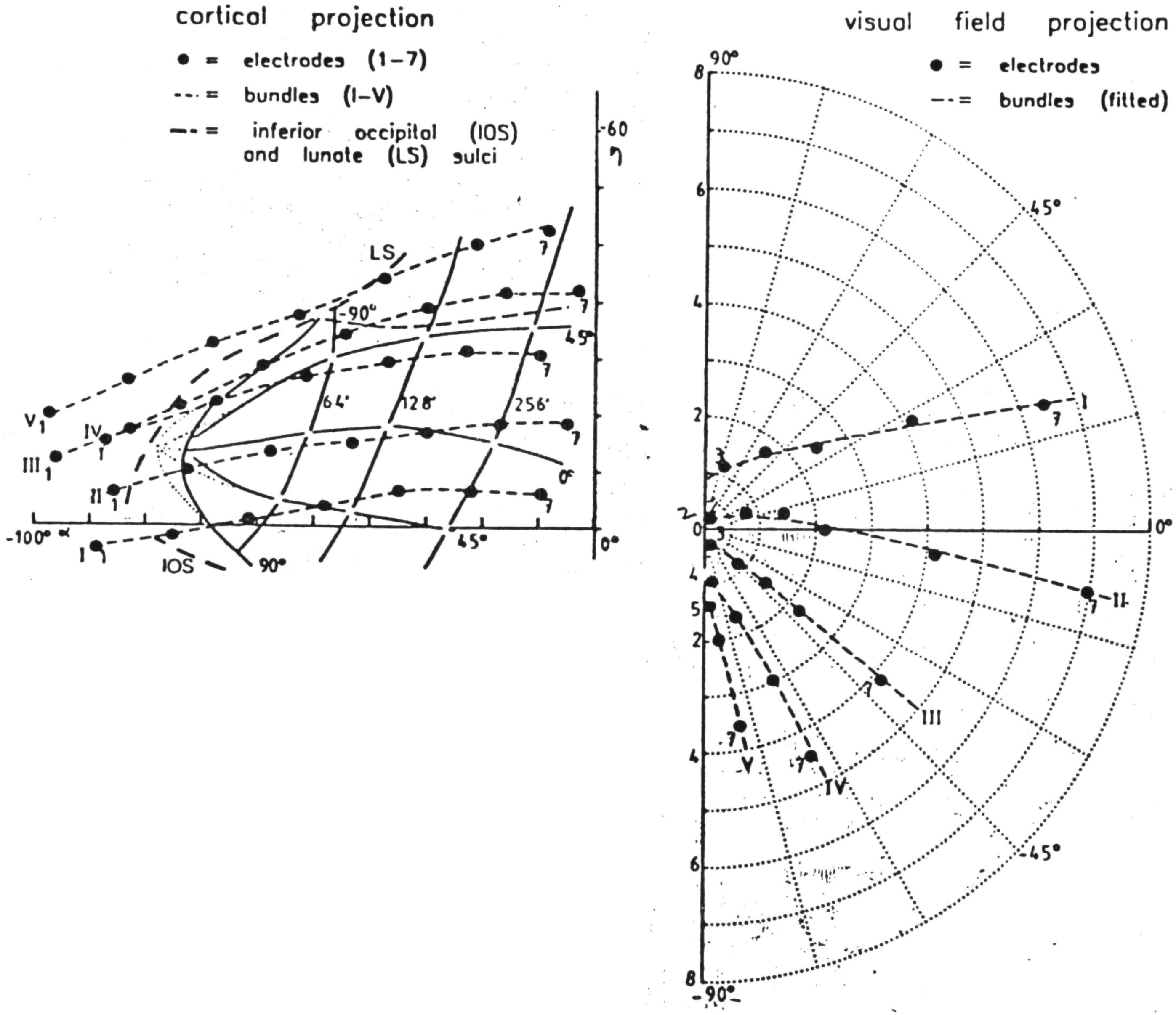


THE SPATIAL PATTERN OF ROOT MEAN SQUARE (RMS) AMPLITUDE FROM 64 EPIDURAL ELECTRODES (4 X 4 MM) CHANGES UNDER CONDITIONING AND RESTABILIZES AFTER EACH NEW TRAINING ODOR.



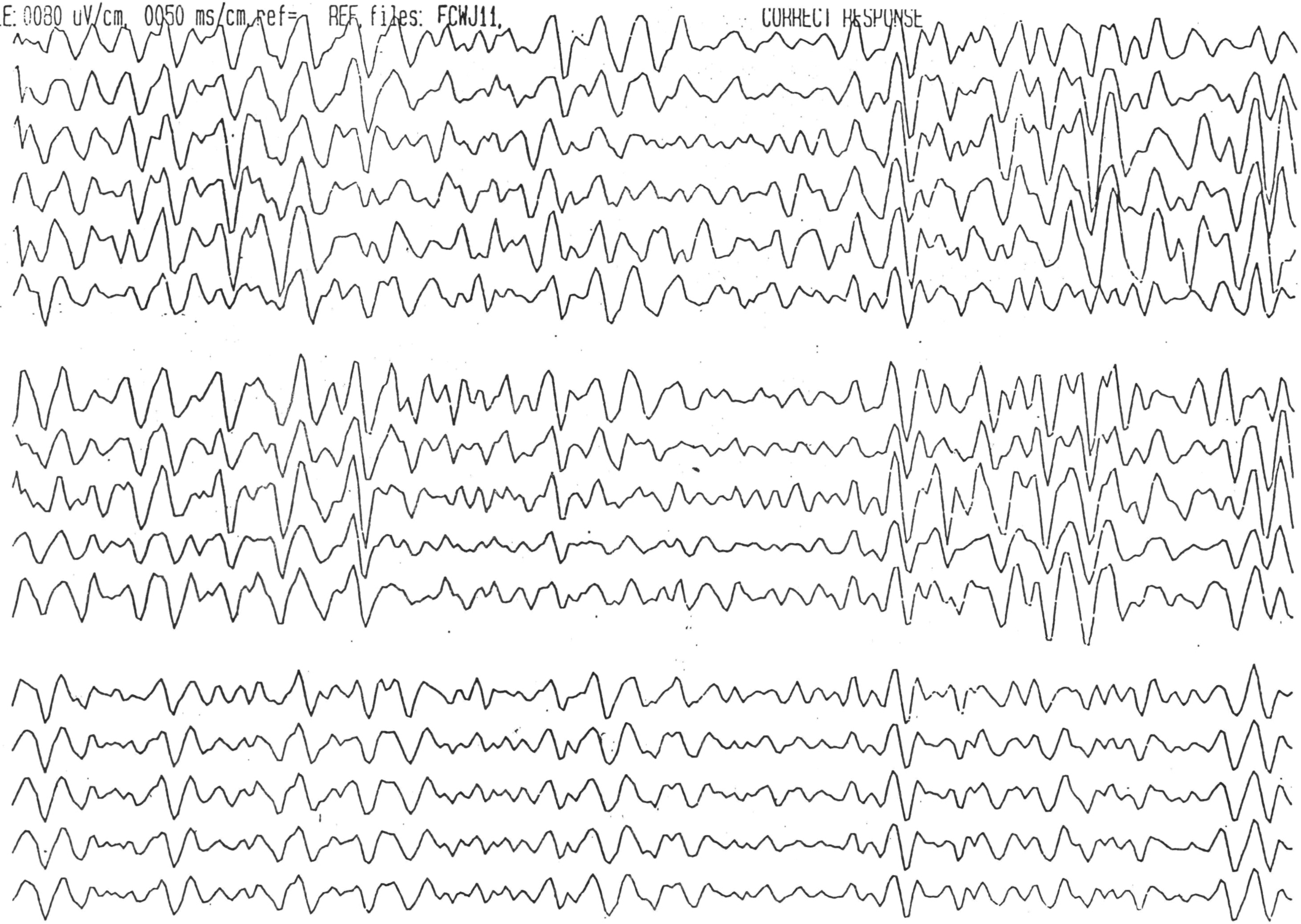
DISCRIMINANT ANALYSIS OF THE FACTOR SCORES SHOWS THAT 75% OF BURSTS ARE CORRECTLY CLASSIFIED WITH 2 DISCRIMINANT FUNCTIONS. A PLOT IS SHOWN OF THE DISCRIMINANT SPACE FOR ONE RABBIT.

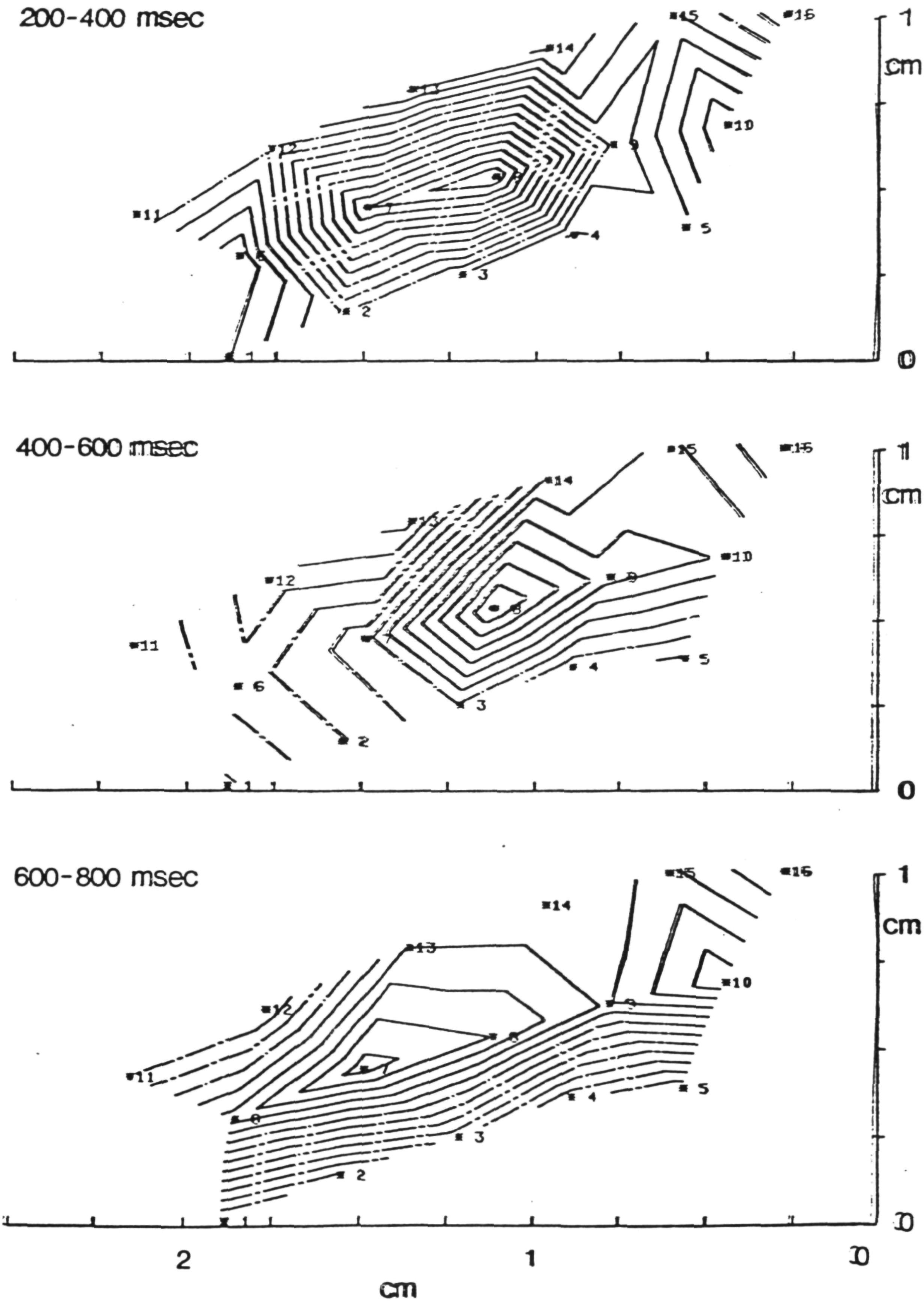
C

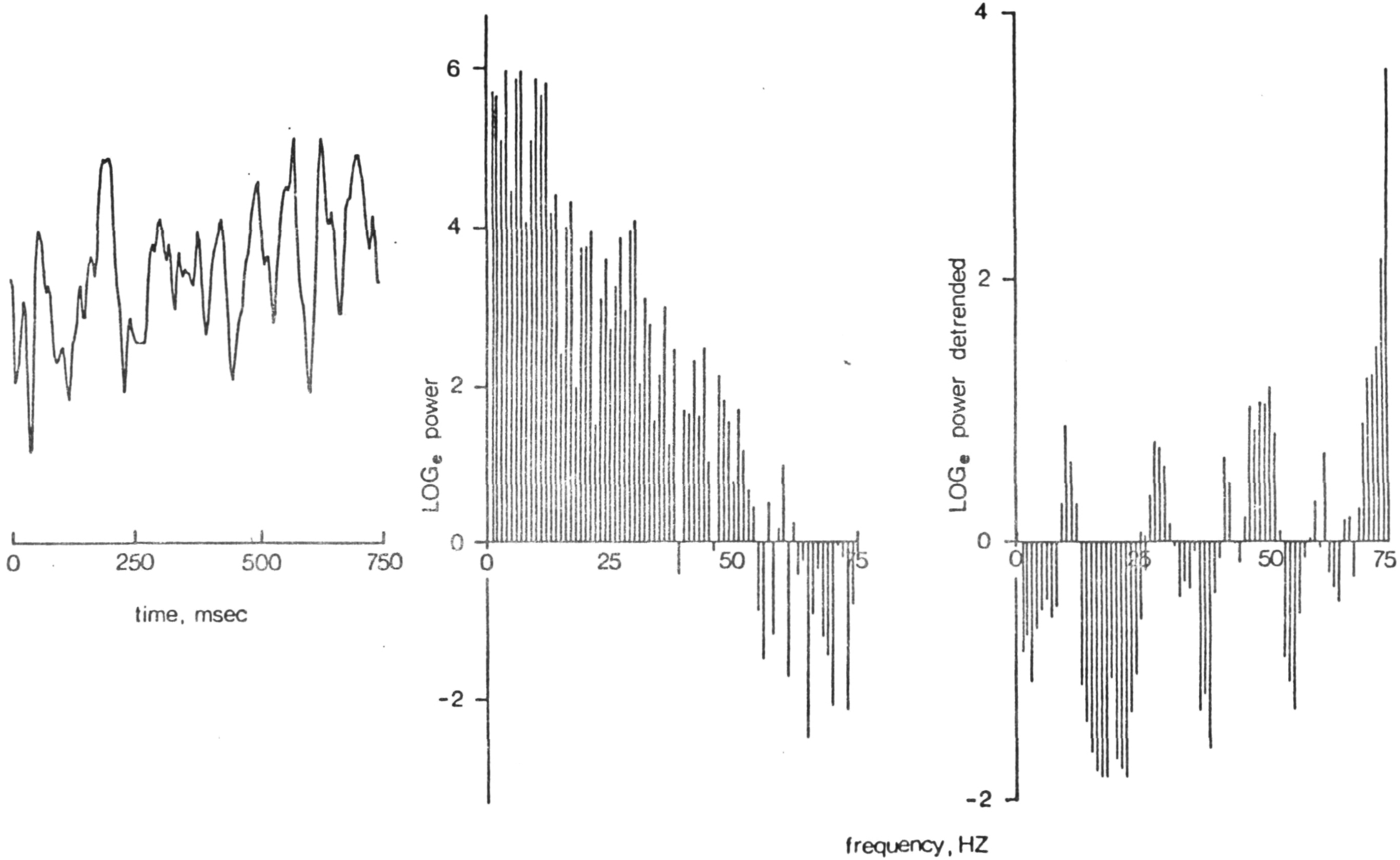


cortical projection
● = electrodes (1–7)
--·= bundles (I–V)
—·= inferior occipital (IOS) and lunate (LS) sulci
LS
IOS
-90°
45°
0°
90°
64°
128°
256°
-100°
-60
visual field projection
● = electrodes
-·= bundles (fitted)
90°
45°
0°
-45°
-90°
I
II
III
IV
V

SCALE: 0080 uV/cm, 0050 ms/cm ref= REF files: FCWJ11, CORRECT RESPONSE




200-400 msec
400-600 msec
600-800 msec
1
cm
0
2
1
0
cm



0
250
500
750
time, msec
LOGₑ power
6
4
2
0
-2
0
25
50
75
LOGₑ power detrended
4
2
0
-2
0
25
50
75
frequency, HZ

BASIC ELEMENTS:

1. Linear integrator- 2nd order.
2. Static sigmoid nonlinearity.
3. Hebb connection & assembly.
4. Parallel input & output.

KEY PROPERTIES:

1. Chaotic basal state.
2. Input-dependent gain.
3. Bifurcation on input.
4. Spatial pattern coding.

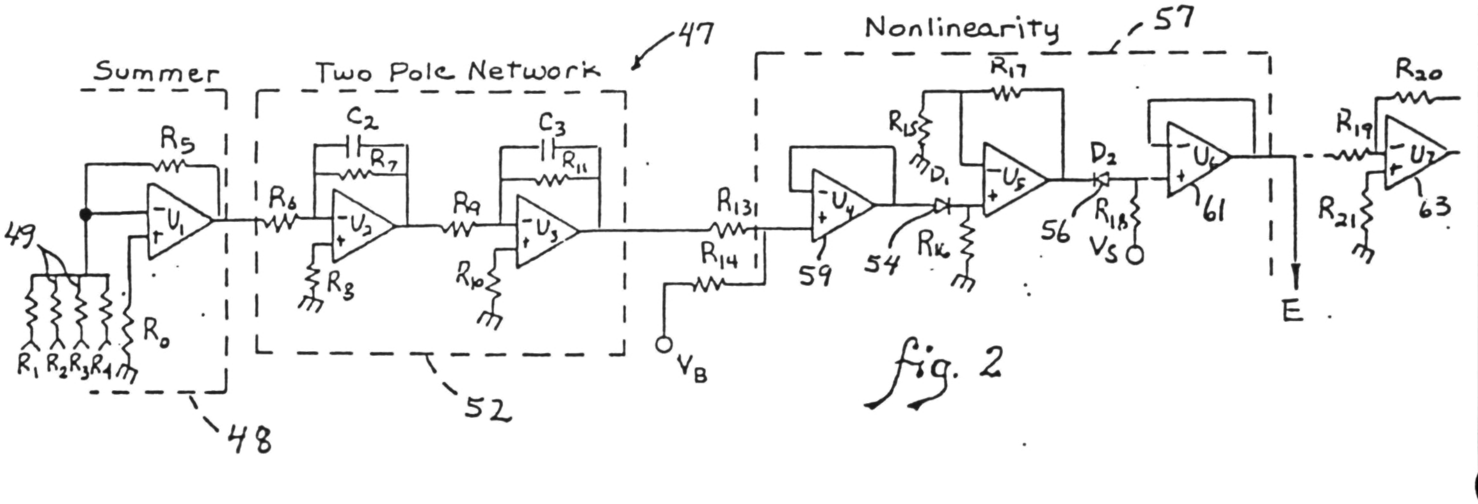
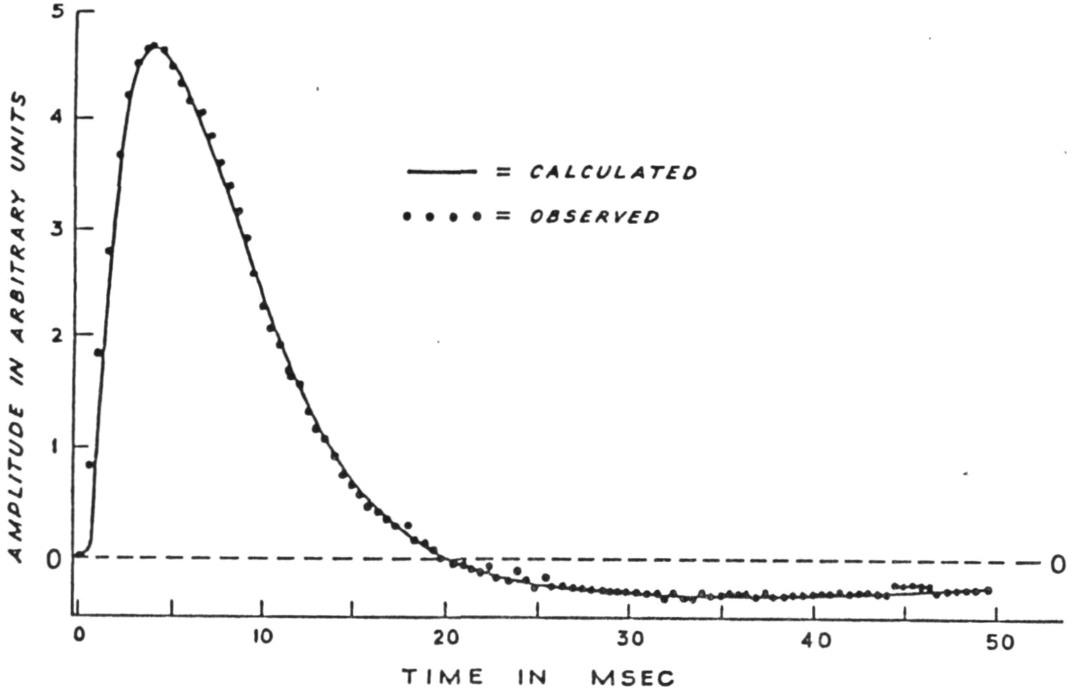
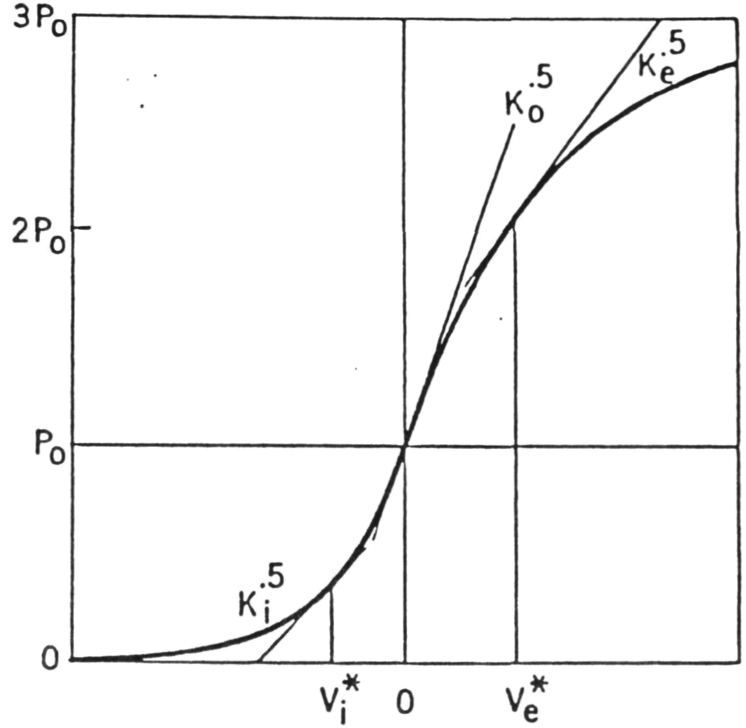


fig. 2





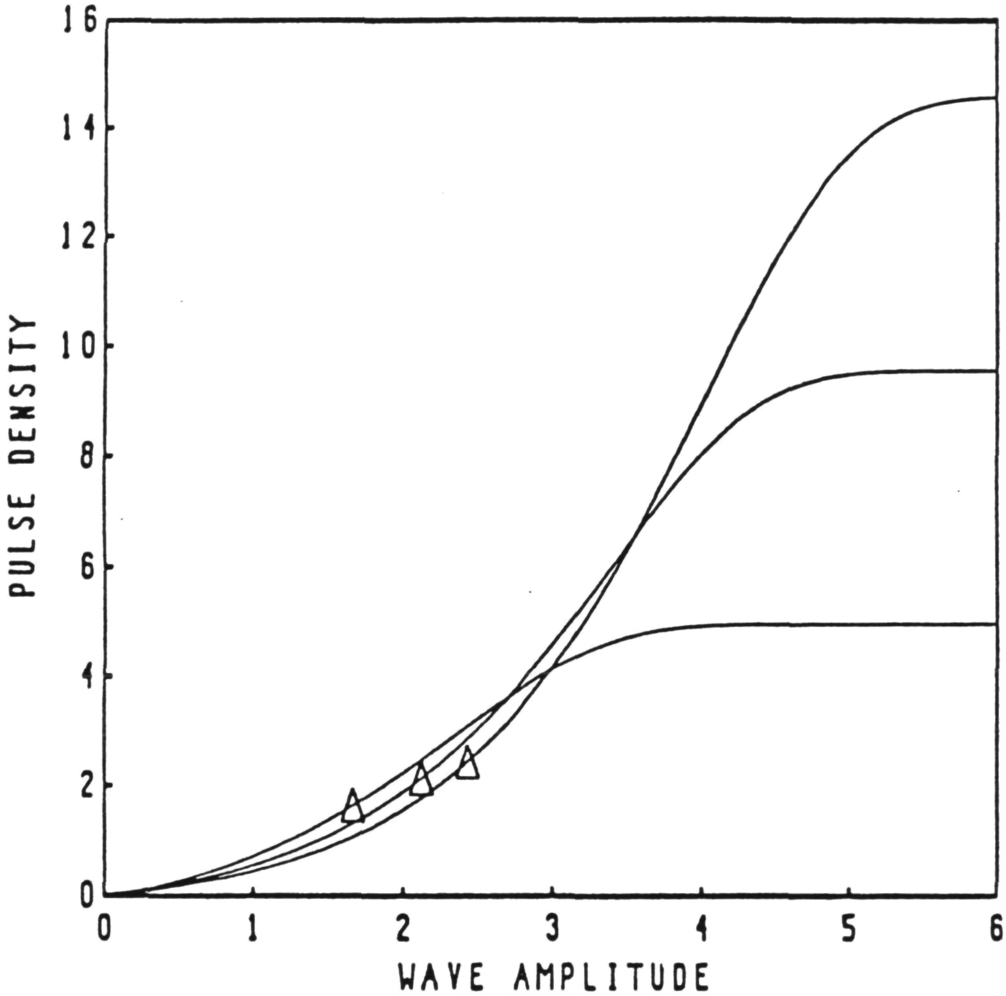
$$F(v_n) \triangleq \frac{1}{ab}\frac{d^2}{dt^2}\left[v_n(t)\right] + \frac{a+b}{ab}\frac{d}{dt}\left[v_n(t)\right] + v_n(t)$$

$$F(v_{e1,j}) = \zeta_e^j k_{ee}^{jj} p_{e2,j} - \zeta_e^j k_{ie}(p_{e1,j} + p_{i2,j}) + \sum_{k \neq j}^{N} \zeta_e^j k_{ee}^{jk} p_{e1,k} + I_j$$

$$F(v_{e2,j}) = \zeta_e^j k_{ee}^{jj} p_{e1,j} - \zeta_i k_{ie} p_{i1,j}$$

$$F(v_{i2,j}) = \zeta_e^j k_{ei} p_{e1,j} - \zeta_i k_{ii} p_{i1,j}$$

$$F(v_{i1,j}) = \zeta_e^j k_{ei}(p_{e1,j} + p_{e2,j}) - \zeta_i k_{ii} p_{i2,j} - \zeta_i k_{ii} \sum_{k \neq j}^{N} p_{i1,k}$$

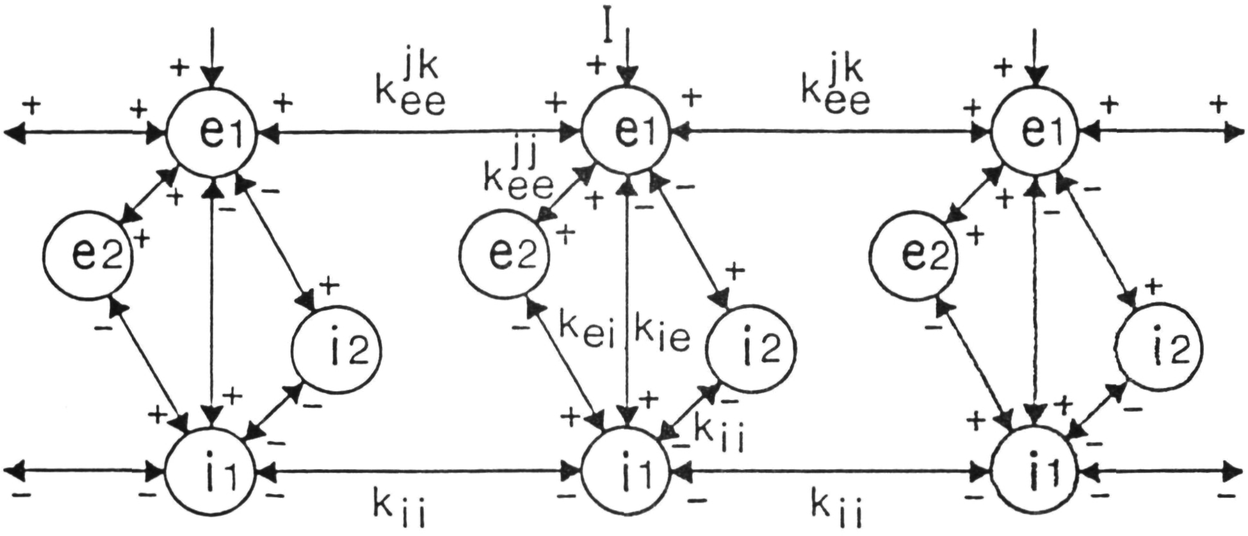


$$Q = Q_m \left\{ 1 - \exp\left[-(e^{v} - 1)/Q_m \right] \right\}, \; v > -\mu_o$$

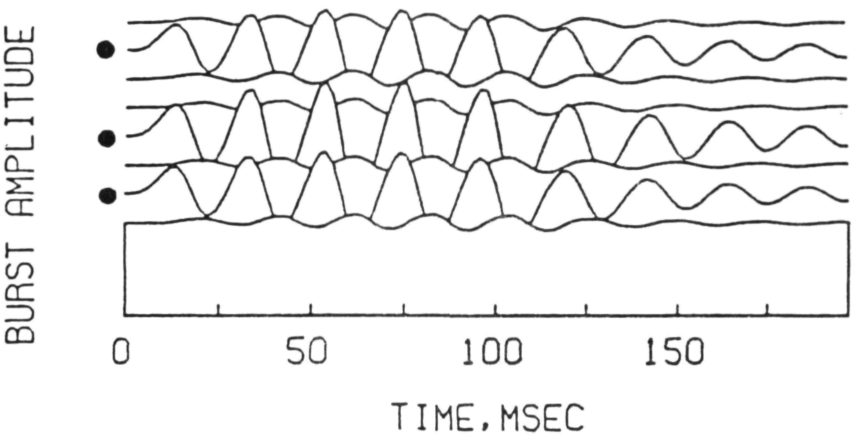
$$Q = -1, \; v \leqslant \mu_o$$

$$\mu_o = -\ln\left[1 - Q_m \ln(1 + 1/Q_m) \right]$$

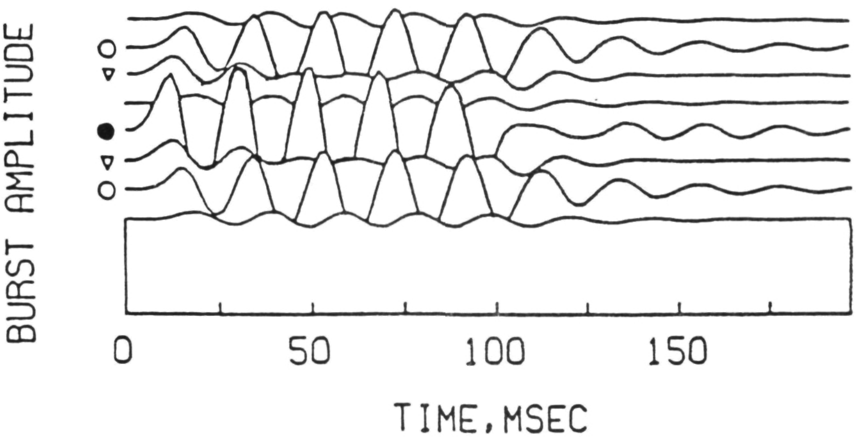
$$p = \mu_o (Q + 1)$$



I
k_{ee}^{jk}
k_{ee}^{jk}
k_{ee}^{jj}
e1
e1
e1
e2
e2
e2
i2
i2
i2
i1
i1
i1
k_{ei}
k_{ie}
k_{ii}
k_{ii}
k_{ii}



BURST AMPLITUDE
0
50
100
150
TIME, MSEC

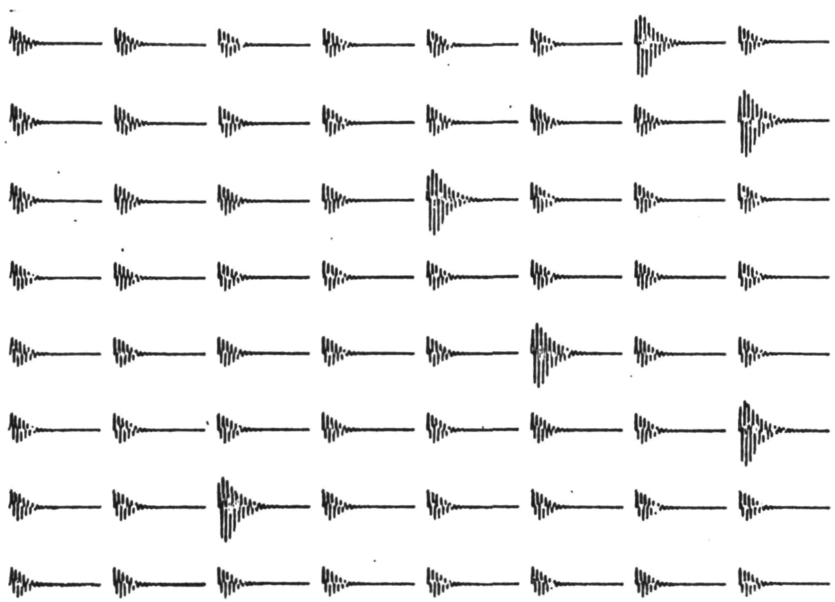


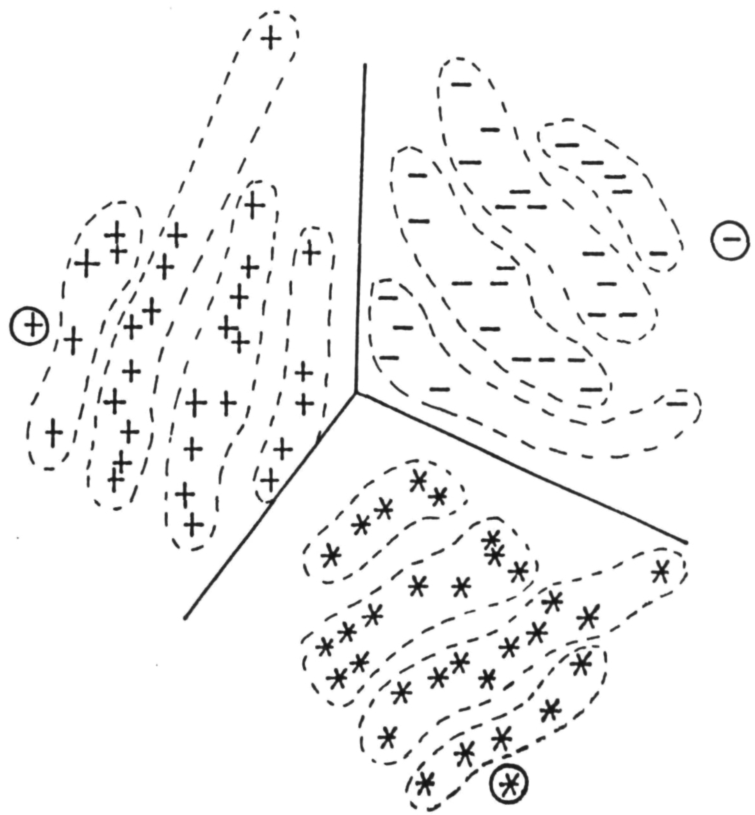
BURST AMPLITUDE
0
50
100
150
TIME, MSEC

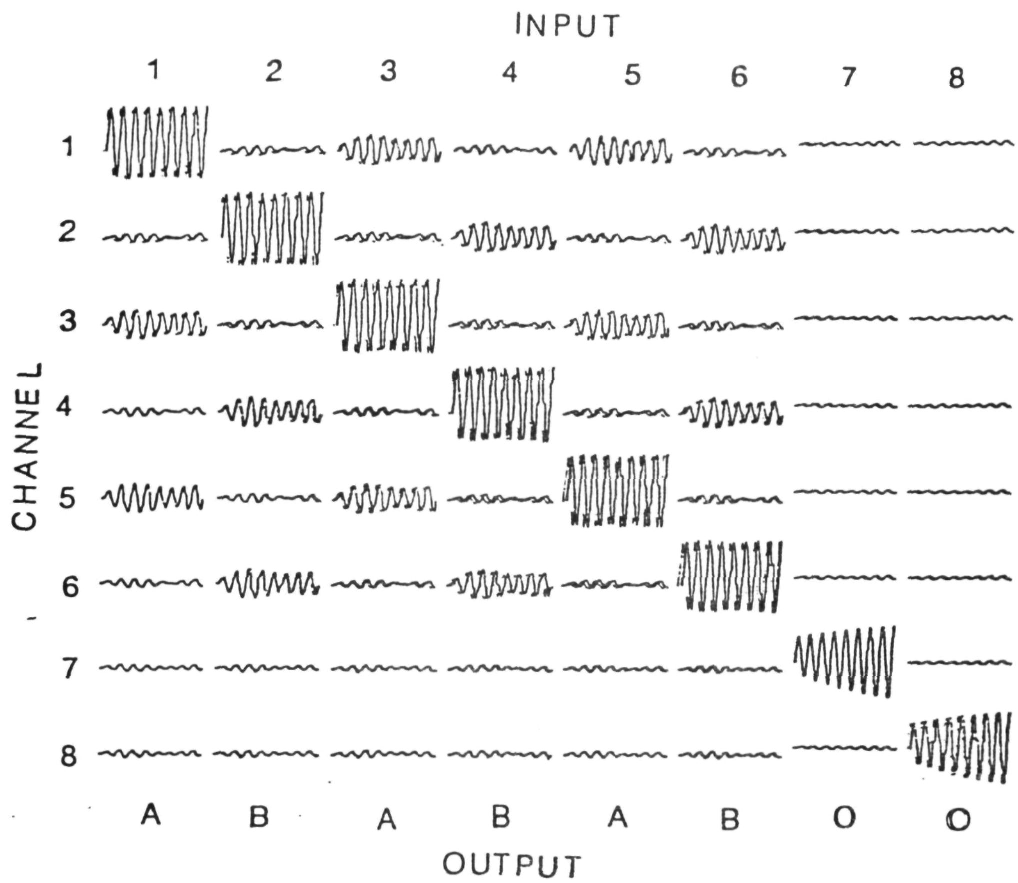
CORRELATION LEARNING RULE : a modified Hebb rule

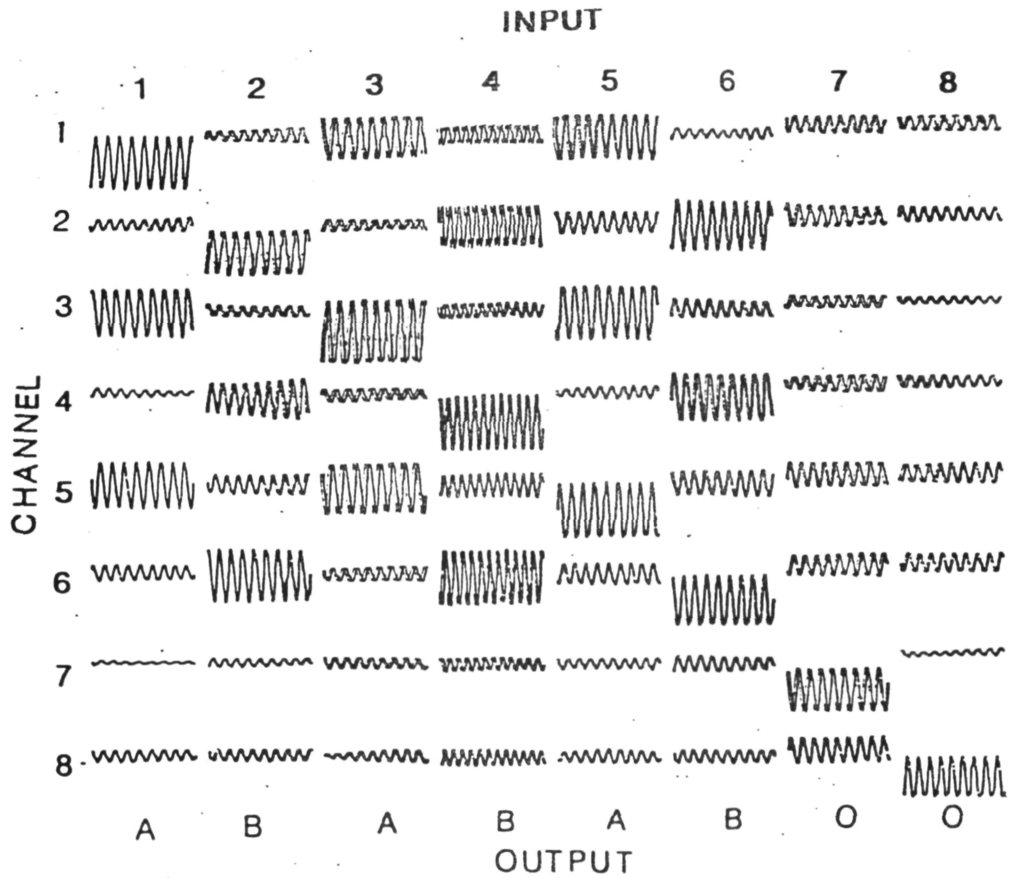
changing synapse in the following way:
if both channel j and k are on, Kee(j,k)= Kee(high), otherwise, unchanged.
The output waveform in the 64-channel case

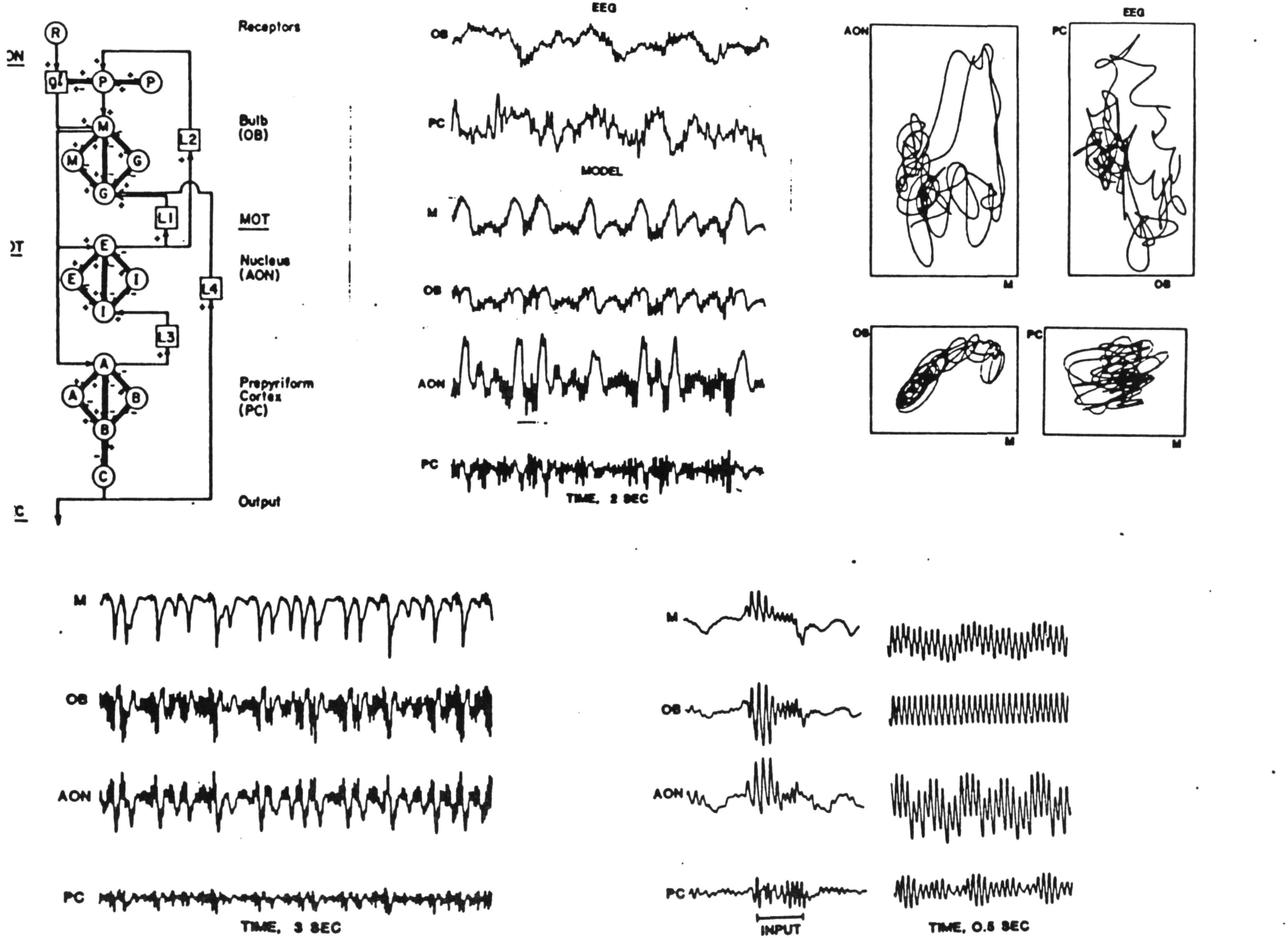
For the reduced interconnected KII set with 64-channel, the figure shows 100% clustering as well as perfect grouping.






INPUT
1 2 3 4 5 6 7 8
CHANNEL
1 2 3 4 5 6 7 8
A B A B A B O O
OUTPUT


INPUT
1 2 3 4 5 6 7 8
CHANNEL
1 2 3 4 5 6 7 8
A B A B A B O O
OUTPUT



Receptors
Bulb (OB)
MOT
Nucleus (AON)
Prepyriform Cortex (PC)
Output
R
P
M
G
E
I
A
B
C
L1
L2
L3
L4
EEG
OB
PC
MODEL
M
OB
AON
PC
TIME, 2 SEC
EEG
AON
PC
M
OB
PC
M
M
OB
AON
PC
TIME, 3 SEC
M
OB
AON
PC
INPUT
TIME, 0.5 SEC

Physiology of the Olfactory Bulb
1967-1987
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NOTES