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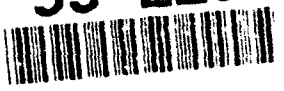

13. ABSTRACT (Maximum 200 words)

The primary objective of this research project was to carry out a behavioral cellular and computational analysis of operant conditioning of the head-waving response in the marine mollusc *Aplysia*. The major motor components of the operant response (head-waving) were revealed with detailed kinematic analysis; the biomechanical principles underlying the operant response have been elucidated and a fluid-hydrostat model of head-waving was constructed; the critical muscle groups involved in the generation and maintenance of the operant response have been identified; the timing and pattern of muscle interactions and their relationship both to motor neuron activity and to behavioral generation of the operant response have been specified; the endogenous firing rates of single identified motor neurons can be operantly conditioned using behaviorally relevant stimuli; the interganglionic connections responsible for coordinating the operant response have been identified; the reinforcement pathway necessary for operant conditioning has been identified and, techniques have now been developed to generate a network model for information processing involved in operant conditioning, as well as other forms of plasticity, in the CNS of *Aplysia*. One hallmark for a successful project is that it opens new and exciting areas of inquiry at the same time that it satisfies the basic project mission.

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FINAL TECHNICAL REPORT
AFOSR-89-0362

A CIRCUIT ANALYSIS AND COMPUTATIONAL MODEL OF OPERANT CONDITIONING IN *APLYSIA*

THOMAS J. CAREW

The primary objective of this research project was to carry out a behavioral, cellular and computational analysis of operant conditioning of the head-waving response in the marine mollusc *Aplysia*. The overall project was divided into three basic endeavors: (i) a detailed analysis of the operant response (head-waving); (ii) an analysis of the reinforcement pathways that modify the response (primarily a visual pathway); and (iii) the construction of a quantitative model of operant conditioning. Significant progress was made in all aspects of the project reflected by the 11 primary publications and 8 published abstracts over the award period.

The fundamental observations made during the project include:

- The major motor components of the operant response (head-waving) were revealed with a detailed kinematic analysis

- The biomechanical principles underlying the operant response have been elucidated and a fluid-hydrostat model of head-waving was constructed

- The critical muscle groups involved in the generation and maintenance of the operant response have been identified

- The timing and pattern of muscle interactions and their relationship both to motor neuron activity and to behavioral generation of the operant response have been specified

- The endogenous firing rates of single identified motor neurons can be operantly conditioned using behaviorally relevant stimuli

- The interganglionic connections responsible for coordinating the operant response have been identified

- The reinforcement pathway necessary for operant conditioning has been identified

- Techniques have now been developed to generate a network model for information processing involved in operant conditioning, as well as other forms of plasticity, in the CNS of *Aplysia*

One hallmark for a successful project is that it opens new and exciting areas of inquiry at the same time that it satisfies the basic project mission. From this perspective, the project's success is underscored by the continuation of active research on each level of analysis (behavioral, cellular and computational), currently ongoing in the laboratory in the hands of two graduate students and two post-doctoral fellows.

In the pages that follow I will provide an overview of the published research resulting from the award and the primary personnel supported by the project.

1. ORIGINAL PUBLICATIONS RESULTING FROM THE AWARD

Blazis, D.E.J., Fischer, T.M. and Carew, T.J. (1993) A neural network model of inhibitory information processing in *Aplysia*. *Neural Computation*, **5**: 213-227.

Cook, D.G. and Carew, T.J. (1989) Operant conditioning of head-waving in *Aplysia* I: Identified muscles involved in the operant response. *J. Neurosci.*, **9**: 3097-3106.

Cook, D.G. and Carew, T.J. (1989) Operant conditioning of head-waving in*Aplysia* II: contingent modification of electromyographic activity in identified muscles. *J. Neurosci.*, **9**: 3107-3114.

Cook, D.G. and Carew, T.J. (1989) Operant conditioning of head-waving in *Aplysia* III: Cellular analysis of possible reinforcement pathways in *Aplysia J. Neurosci.*, **9**: 3115-3122.

Emptage, N.J. and T.J. Carew (1993) Long-term synaptic facilitation in the absence of short-term facilitation in *Aplysia* sensory neurons. *Science* (in press).

Fischer, T.M. and Carew, T.J. (1993) Activity dependent potentiation of recurrent inhibition: A mechanism for dynamic gain control in the siphon withdrawal reflex of *Aplysia*. *J. Neurosci.*, **13**: 1302-1314.

Fitzgerald, K. and Carew, T.J. (1991) Serotonin mimics tail shock in producing transient inhibition in the siphon withdrawal reflex of *Aplysia*. *J. Neurosci.*, **11**: 2510-2518.

Kuenzi, F.M. and T.J. Carew (1993) Head waving in *Aplysia californica*. I. Behavioral characterization of searching movements. *J. Exp. Biol.* (in press).

Kuenzi, F.M. and T.J. Carew (1993) Head waving in *Aplysia californica*. II. Functional anatomy and muscular activity during searching behavior. *J. Exp. Biol.* (in press).

Kuenzi, F.M. and T.J. Carew (1993) Head waving in *Aplysia californica*. III. Interganglionic pathways underlying the coordination and control of searching movements. *J. Exp. Biol.* (in press).

Wright , W.G., Marcus, E.A. and Carew, T.J. (1991) A cellular analysis of inhibition in the siphon withdrawal reflex of *Aplysia*. *J. Neurosci.*, **11**: 2498-2509.

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Baxter, D.A., Buonomano D.V., Raymond, J.L., Cook, D.G., Kuenzi, F.M., Carew, T.J and Byrne, J.H. (1991) Empirically derived adaptive elements and networks simulate associative learning; In: *Quantitative Analysis of Behavior Volume XII: Neural Network Models of Conditioning and Action*. Hillsdale: Lawrence Erlbaum & Assoc. New Jersey, pp. 13-51.

Blazis, D.E.J., Berkowicz, D.A., Kairiss, E.W. and Carew, T.J. (1991) A network model of inhibitory information processing in the siphon withdrawal reflex of *Aplysia*. *Soc. Neurosci.*, **17**: 1302.

Blazis, D.E.J., Fischer, T.M., and Carew, T.J. (1992) A neural network model of use-dependent gain control in the siphon withdrawal reflex of *Aplysia*. *Soc. Neurosci*. **18**: 713.

Fischer, T.M. and Carew, T.J. (1991) Activation of the facilitatory interneuron L29 produces inhibition of reflex input to siphon motor neurons in *Aplysia*. *Soc. Neurosci.*, **17**: 1302.

Fitzgerald, K., Wright, W.G., Marcus, E.A. and Carew, T.J. (1990) Multiple forms of non-associative plasticity in *Aplysia*: A behavioral, cellular and pharmacological analysis. *Phil. Trans. R. Soc. Lond.* **329**: 171-1

Marcus, E.A., Mercer, A.R., Emptage, N.J. and Carew, T.J. (1991) Sensory neuron spike broadening induced by tail nerve stimulation in *Aplysia* is blocked by cyproheptadine. *Soc. Neurosci.*, **17**: 1592.

Mercer, A.R. and Carew, T.J. (1991) Cyproheptadine blocks 5-HT-induced spike broadening but not 5-HT-induced anti-accomodation: Evidence for multiple 5-HT receptors in *Aplysia* sensory neurons. *Soc. Neurosci.*, **17**: 1591.

Wright, W.G., Marcus E.A. and Carew, T.J. (1989) Facilitation and inhibition in the siphon withdrawal reflex of *Aplysia*: A behavioral and cellular analysis; In: *Perspectives in Neural Systems and Behavior*, T.J. Carew and D.B. Kelley (eds) Alan R. Liss Inc, N.Y., pp 93-103.

3. PERSONNEL SUPPORTED BY AWARD

A. David G. Cook	Graduate Student
B. Frederick M. Kuenzi	Graduate Student
C. Kent Fitzgerald	Graduate Student
D. Diana Blazis	Post-Doctoral Fellow
E. Thomas Fischer	Post-Doctoral Fellow
F. Tina Agentis	Laboratory Technician
G. Paul Hofstadter	Laboratory Technician