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Personnel
Faculty
Zafra Lerman Head, Institute for Science Education and Communication
(Columbia College)
Nestor A. Schmajuk Associate Professor (Duke University) and
Adjunct Professor (Columbia College)
Geof Goldbogen Chairman, Academic Computing (Columbia College)

Students
Hugh T. Blair Graduate Student (Northwestern University)
David Morton Undergraduate Student (Columbia College)
Silvano Zanutto Post-doctoral Student (Duke University)

BOOKS
1. Schmajuk, N.A. Animal learning and cognition: A neural network approach. Cambridge University
Press. In press

PUBLICATIONS


5. Christiansen, B.A., and Schmajuk, N.A. Hippocampectomy disrupts the topography of the rat eyeblink
conditioned response during acquisition and extinction of classical conditioning. Brain Research, 595, 206-


7. Schmajuk, N.A., and Blair, H.T. Dynamics of spatial navigation: An adaptive neural network. In From

8. Schmajuk, N.A., and Blair, H.T. Place learning and the dynamics of spatial navigation: An adaptive


**PAPERS SUBMITTED**


22. Christiansen, B.A., and Schmajuk, N.A. Haloperidol reinstates latent inhibition impaired by
hippocampal lesions. Behavioral Neuroscience


COMMUNICATIONS TO SCIENTIFIC MEETINGS


15. Schmajuk, N.A. Modeling the effect of aspiration and ibotenic acid lesions of the hippocampus. Fifth Midwestern Hippocampal Meeting, Northwestern University, Evanston, IL, June 4, 1993.


19. Schmajuk, N.A. Stimulus configuration, classical conditioning, and spatial learning: Role of the hippocampus. Invited talk at the World Congress on Neural Networks. San Diego, June 4-9, 1994.


**COMPUTER SOFTWARE**


BOOKS

Schmajuk, N.A. ANIMAL LEARNING AND COGNITION: A NEURAL NETWORK APPROACH
Cambridge University Press, in press.

This book describes several connectionist theories of animal learning and cognition. Starting at
the simple assumption that psychological associations are represented by the strength of neural synaptic
connections, mechanistic descriptions of complex cognitive behaviors are provided. Part I describes neural
network theories of classical conditioning and discusses the concepts of models of the environment,
prediction of future events, reliable and salient predictors, redundancy reduction, competition for limited
capacity short-term memory, mismatch between predicted and observed events, stimulus configuration,
inference generation, modulation of attention by novelty, storage and retrieval processes, and timing. Part
II describes neural networks of operant conditioning, specifically avoidance, introduces the concept of
response-selection mechanisms, and applies operant conditioning principles to the description of animal
communication. Part III describes goal-directed mechanisms, spatial mapping, and cognitive mapping.
Finally, Part IV shows how neural network models permit to simultaneously develop psychological
theories and models of the brain.

ABSTRACTS OF SOME PUBLICATIONS SUPPORTED BY ONR

1. Schmajuk, N.A. and DiCarlo, J.J. Stimulus configuration, classical conditioning, and the

This study describes hippocampal participation in classical conditioning in terms of a multilayer
network that portrays stimulus configuration. The network (a) describes behavior in real time, (b)
incorporates a layer of "hidden" units positioned between input and output units, (c) includes inputs that
are connected to the output directly as well as indirectly through the hidden-unit layer, and (d) employs
a biologically plausible backpropagation procedure to train the hidden-unit layer. The model correctly
describes the effect of hippocampal and cortical lesions in the following paradigms: (1) acquisition of
delay and trace conditioning, (2) extinction, (3) acquisition-extinction series of delay conditioning, (4)
blocking, (5) overshadowing, (6) discrimination acquisition, (7) discrimination reversal, (8) feature-positive
discrimination, (9) conditioned inhibition, (10) negative patterning, (11) positive patterning, and (12)
generalization. Some of these results might be extended to the description of anterograde amnesia in
human patients.


This study presents a real-time, biologically plausible neural network approach to purposive
behavior and cognitive mapping. The system is composed of (a) an action system, consisting of a goal-
seeking neural mechanism controlled by a motivational system; and (b) a cognitive system, involving a
neural cognitive map. The goal-seeking mechanism displays exploratory behavior until either (a) the goal
is found or (b) an adequate prediction of the goal is generated. The cognitive map built by the network
is a topological map, i.e., it represents only the adjacency, but not distances or directions, between places.
The network has recurrent and non-recurrent properties that allow the reading of the cognitive map without
modifying it. Computer simulations show that the network successfully describes latent learning and detour
behavior in rats. In addition, simulations demonstrate that the network can be applied to problem-solving
paradigms such as the Tower of Hanoi puzzle.

The effects of hippocampal lesions (HL) on acquisition and extinction of eyeblink *conditioning* were analyzed. Although HL affected neither acquisition nor extinction rates, HL animals showed significantly shorter CR onset latency during acquisition and extinction, and larger CR peak amplitude during acquisition.


In "The Perception of Multiple Objects", Michael Mozer offers a connectionist model capable of Multiple Object Recognition and Attentional Selection (MORSEL). In general, as prescribed by the connectionist approach, the book presents precise mathematical descriptions and quantitative computer simulations of the model's most important functions. Sometimes, however, the accounts are qualitative and simply justified in terms of single examples. The balance between both strategies is adequately maintained throughout the book. In the tradition of connectionist models, MORSEL provides valuable intuitions into the problem of visual perception, recognition, and attention. Because it offers a mechanistic description of psychological processes, it contributes a basis for the study of the neurophysiological foundations of word recognition. In addition, when quantitative descriptions are provided, they can be strictly compared with experimental data. In sum, the books offers an impressive contribution to the field.


We present a real-time neural network capable of describing place learning and the dynamics of spatial navigation. The network generates spatial generalization surfaces that can guide navigation from any location that is within view of familiar landmark cues, even if that location has never been visited before.


We present a real-time neural network capable of describing place learning and the dynamics of spatial navigation. The network generates spatial generalization surfaces that can guide navigation from any location that is within view of familiar landmark cues, even if that location has never been visited before. Spatial navigation is accomplished by adopting a "stimulus-approach" principle, that is, by approaching appetitive places and avoiding aversive places. When generalization surfaces are assumed to represent forces driving animal's behavior, the dynamics of spatial movements can be described. Computer simulations were carried out for appetitive, aversive, and aversive-appetitive place learning. The paper shows that the network correctly describes the navigational trajectories and dynamics of many spatial learning tasks.


This study describes hippocampal participation in maze navigation in terms of a real-time, biologically plausible neural network. The system incorporates a cognitive map system and a route system. The cognitive map is a topological map that stores associations between Places and Views of accessible Places, and between Places and reward. The route system establishes associations between Cues and reward. Both systems compete with each other to establish associations with the reward, with the
cognitive system generally overshadowing the route system.

In agreement with previous models (Schmajuk, 1989; Schmajuk and DiCarlo, 1992), it is assumed that the hippocampus modulates the storage of cognitive maps in cortical areas, and mediates the competition between cognitive maps and route systems. After hippocampal lesions, animals navigate through mazes making use of the route system. Computer simulations show that the network effectively describes latent learning, detour behavior, and place learning in normal, hippocampal and cortical lesioned animals.


The effect of hippocampal aspiration lesions on latent inhibition of eyelink conditioning in the restrained rat preparation was examined. Rats received either sham, cortical control, or hippocampal aspiration lesions. Control animals, but not animals with hippocampal lesions, showed slower conditioning after being preexposed to the conditioned stimulus (latent inhibition). Together with previous results regarding the effect of hippocampal lesions in acquisition and extinction of delay conditioning, the present study suggests that the restrained rat preparation may serve as a reliable way of investigating hippocampal participation in different classical conditioning paradigms.


Schmajuk and DiCarlo (1992) introduced a neural network, which utilizes a biologically plausible model. It is important to notice that this extension does not modify the model's learning rules for the CR, but only the computation of the responses for the different systems. Backpropagation procedure, to describe compound conditioning, feature-positive patterning, negative patterning, and positive patterning during classical conditioning. The model correctly describes many experimental results under the assumption that aspiration lesions of the hippocampus eliminate (a) the competition between simple and configural stimuli to gain association with the unconditioned stimulus and (b) stimulus configuration.

The present study extends the network to describe place learning. Under the assumption that ibotenic acid lesions of the hippocampus only impair stimulus configuration, the model correctly shows that ibotenic acid lesions might spare simultaneous negative and positive patterning but impair place learning. In general, the results are taken to support a hippocampal role in stimulus configuration.


Schmajuk and DiCarlo (1992) and Schmajuk and Blair (1993) presented a neural network model capable of generating predictions of future events in time and space. In the context of this model, accurate generation of predictions depends on the processes of configuration and competition. Configuration refers to the combination of simple stimuli into a complex stimulus, which represents a pattern of stimuli that better predicts the future than its individual constituents. Competition refers to the selection of the stimulus best predicting the future from among different simple and complex stimuli.

In the context of the network, the hippocampus is assumed to provide error signals that control the formation of configurations in cortical regions, and to compute the "aggregate prediction" signal that regulates competition in subcortical areas. According to the model, whereas aspiration lesions of the hippocampus eliminate both cortical configuration and subcortical competition, ibotenic acid lesions of the hippocampus abolish only cortical configuration. The model correctly describes the effects of hippocampal aspiration and ibotenic acid lesions on several temporal (classical conditioning) and spatial learning paradigms.


We present a novel, real-time two-process theory of escape and avoidance that closely integrates classical and operant conditioning processes. In cognitive terms, the model assumes that through classical conditioning animals build an internal model of their environment and that through operant conditioning animals learn alternative behavioral strategies. The internal model provides predictions of what environmental events precede other environmental events, such as the US. Behavioral strategies refer to the responses generated in different environmental circumstances. Whenever there is a mismatch between predicted and actual environmental events (a) the internal model is modified and (b) the behavioral strategies are adjusted. Specifically, the classical conditioning process generates associations between the warning stimulus (WS), the unconditioned stimulus (US), and the responses (R) generated by the animal with the US. Whereas the WS and the US become predictors of the US, the escape response (Re) and the avoidance response (Ra) become predictors of the absence of the US. The operant conditioning process associates the US and US with those responses that predict the absence (or the reduction) of the aversive US (Re and Ra). The classical conditioning process (a) provides predictions of the presence or absence of the US used by the operant conditioning process to generate WS-R and US-R associations, and (b) controls the strength of the responses. Because the WS and the US can become associated with different available responses, animals can learn distinct escape and avoidance responses. Since the model describes behavior in real time, it is able to capture the effects of using different temporal WS and US arrangements and to describe the latency of avoidance and escape responses. The model describes many of the features that characterize avoidance behavior in shuttle-box, running wheel, leg-flexion, and Sidman avoidance tasks.


Latent inhibition is a phenomenon in which the association of a conditioned stimulus with an unconditioned stimulus is retarded by preexposing the conditioned stimulus alone. This study describes a novel theory of latent inhibition in the context of a real-time neural network. The network assumes that animals build an internal model of the world to generate predictions of environmental events (Sokolov, 1960). Whenever predicted and observed events differ, orienting responses are emitted, ongoing behaviors are inhibited, and attention to stimuli is increased, in proportion to the total novelty detected (Gray, 1971).

In the model, environmental stimuli activate internal representations. An attentional system enhances internal representations of events active at a time when the total environmental novelty is large (by increasing attention), and decreases internal representations of those events active at a time when the total novelty is small (by decreasing attention or increasing inattention). The magnitude of the internal representations control the storage of information into the model of the environment (associability) and the retrieval of information from the model (retrievability).

The amplitude of the conditioned response is proportional to the magnitude of the prediction of the unconditioned stimulus. The amplitude of the conditioned response is inhibited by the orienting response, which is assumed to be proportional to total novelty.

According to the model, latent inhibition reflects the decreased internal representation of a CS as a consequence of decreased attention or increased inattention after preexposure to that CS. Computer simulations show that the neural network correctly describes many features that characterize latent inhibition.

Schmajuk and DiCarlo (SD) (1992) presented a neural network model of classical conditioning that successfully describes complex classical conditioning paradigms such as negative patterning, positive patterning, feature positive patterning, feature negative patterning, and compound conditioning. The present paper introduces an extension of the SD model that (a) simultaneously describes the output of multiple response systems in real time, (b) incorporates "hidden" units that represent configural stimuli and generalization between input stimuli, (c) includes inputs directly and indirectly connected to the output, and (d) employs a biologically plausible backpropagation procedure. The model characterizes occasion setting as the result of the interaction between simple CS-US and configural CS-US associations.

The model is able to describe most paradigms that distinguish simple conditioning from occasion setting: (1) response form during simultaneous and serial feature-positive discrimination, (2) feature-positive discrimination and extinction effects, (3) feature-negative discrimination and counterconditioning effects, (4) transfer effects during feature-positive and feature-negative discriminations, (5) within-category transfer, temporal factors such as (6) X-A and X-US intervals effects, (7) effects of X-A, X-US and A-US intervals, (8) termination asynchrony effects, (9) relation of within- and between-trial time intervals, nontemporal factors such as (10) target intensity, (11) feature-target similarity, and (12) pretraining of separate elements. In addition, the model correctly describes the effects of hippocampal aspiration and ibotenic acid lesions on occasion setting.


The communicative aspects of the contents of consciousness are analyzed in the framework of a neural network model of animal communication. We discuss some issues raised by Gray, such as the control of the contents of consciousness, the adaptive value of consciousness, conscious and unconscious behaviors, and the nature of a model's consciousness.


The effect of the quality of a visual representation on computers on improving learning of a computer-simulated maze has been studied. The maze was modelled and scripted on a Silicon Graphics Personal Iris using TDI (Thomson Digital Image) software to incorporate both color and texture. The test of the maze task was done on a Macintosh computer using Micromind Director software. Subjects were students of Columbia College that live in urban and suburban areas. It was found that subjects living in urban areas performed better in the maze task than subjects living in suburban areas.
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