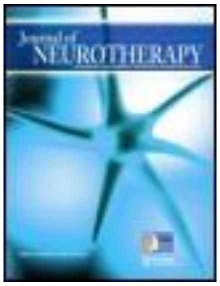

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Behaviorism and Neurofeedback: Still Married

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CURRENT CONCEPTS IN NEUROTHERAPY

Articles appearing in "Current Concepts" advance hypotheses, descriptions, and reviews of techniques important to clinical neurotherapy. The techniques described are not necessarily supported by clinical research, and opinions expressed regarding the effectiveness or efficacies of these techniques are solely those of the authors.

Behaviorism and Neurofeedback: Still Married

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ABSTRACT. Many behavioral science practitioners do not appear to understand basic behavioral concepts and may easily misuse and misunderstand behavioral language. The notion that the non-linear nature of

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the neural system requires a perspective based on either general systems theory or chaos theory in order to describe EEG training, and that a behavioral conceptualization is inadequate, is unjustified. All aspects of effective EEG training programs can be described in behavioral terms. Behavioral language is particularly useful for identifying and describing important components of the training procedure.

KEYWORDS. Behavioral, behaviorism, non-linear, equilibrium, neurofeedback, neurotherapy

A recent conversation with a prominent neurotherapist left this author taken aback and irritated. A particular neurotherapy procedure had been described in behavioral terms and the therapist began to stridently denounce the behavioral model with the assertion that behavioral language and conceptualization were absolutely inadequate for understanding this particular procedure. In fact, the therapist could not accurately define even basic behavioral terms (e.g., "reinforcement" and "punishment") and pejoratively represented the behavioral framework as "linear," "archaic," and "simplistic," typically involving only one stimulus, one response and one consequence. This incident may not be unique. An alarming number of practitioners educated in the "behavioral sciences" do not appear to know basic behavioral concepts beyond a "pop psychology" level, and often seem to have placed the approach in their mental museum alongside relics of the "brass instruments" era. The nonlinear dynamics model of cerebral activity has been heralded as the new bride of the brain training enterprise, but this may be due to deficiencies in practitioner's understanding and articulation of the behavioral model. Regarding those who believe that nonlinear dynamic systems theory, or in particular chaos theory, is superior to the behavioral model for understanding the dynamics of effective neurotherapy, some clarification of basic behavioral concepts may serve to challenge this belief. A brief overview of both models is presented here, but the present article is primarily intended to enhance behavioral fluency and understanding of the behavioral model among neurotherapy practitioners whose induction into the field may have involved limited behavioral training.

THE SYSTEMS APPROACH

Systems thinking involves both a philosophy (involving holism and interconnectedness) and particular methods of inquiry, such as loop diagrams and computer simulations. From the presentation of general system theory by Bertalanffy (1967) to the more recent popularizations of Chaos theory by Gleick (1987) and Briggs and Peat (1989), systemic conceptualization is, in part, a reaction to the hegemony of linear, reductionistic or parts-oriented science based on a Newtonian universe in which basic cause-and-effect laws are systematically discovered and employed. It is a view of the universe (and all subentities like the human neural system) that is holistic, and it has been instrumental in aiding our understanding of the interconnectedness of nature's parts and processes. Mathematicians and physicists, astronomers, sociologists, psychologists and biologists have begun to look closely at one another's disciplines to find that nonlinear dynamic models across fields look eerily similar. One central feature of nonlinear dynamics is the "attractor," the dynamic state or behavior toward which the system settles. Brain research has consistently supported models of memory and information processing that involve the whole brain. In these models, attractors have been identified in personality and persistent behaviors (Goetz & Walters, 1997), schizophrenia and epilepsy (Briggs & Peat, 1989), and human cognitive development (Novak, 1998). These are just a few examples of the application of this language to the EEG.

Senge (1990) has argued that systems thinking is a powerful problem-solving tool. He has suggested that its heuristic value may rest primarily in its power as a language, a way of augmenting and changing the way we think and talk about complex entities like the brain. The fractalian imagery evoked by the recursive nature of neurofeedback (the brain watching itself watch itself) for example, may be a beguiling representation of the experience. Recently there have been many fine syntheses of systems and behavioral models in the psychophysiological research literature (Hoyert, 1992; Viken & McFall, 1994; Efremova & Kulikov, 1998) an endeavor that may seem to some as the epitome of "cultural diversity."

THE BEHAVIORAL APPROACH

The foundation of the behavioral framework is the notion of adaptation to an environment. All living organisms adapt. That is their primary function. Organisms and their immediate contexts are continually engaged in a fluid dance with one another; the movements of the organism can all be seen as "responses," and all relevant, consequent movements of the environment are seen as either reinforcing or punishing. The behavior of organisms is a constructive, functional or "adaptive," dynamic process, and behavior is a neural event.

Some basic definitions must be clarified. "Reinforcement" whether positive (when a stimulus is contingently administered) or negative (when a stimulus is contingently withdrawn or removed), is traditionally defined as that contingent consequence of a target behavior that strengthens or increases that behavior. "Punishment" is defined as any contingent consequence that serves to weaken or decrease a targeted behavior. The "pop" version of these definitions generally uses words like "pleasant" or "desirable" to describe reinforcers and "noxious," "painful," or "unwanted" to describe punishers, when in fact these subjective characteristics are entirely irrelevant to the identity of these classes of stimuli. The word "reward" is often used to indicate a stimulus that is intended to be reinforcing, but in fact, the word refers more to the intention of the administrator than to the effectiveness of the stimulus. One can reward a behavior without actually reinforcing it. One can also experience pain and be subject to extreme noxiousness without being effectively punished, a phenomenon witnessed increasingly often in cold climates. Those hatless people huddled against the winter wind and sub-zero temperature in their shirtsleeves outside public buildings are not in a time out; they are merely enjoying a cigarette.

Much of the research into the neurobiology of behavior involves simple learning tasks using relatively simple organisms. Complexity, both structural and behavioral, is often merely an elaboration of the simple (this observation may seem to have distinctly different meanings from a strictly holistic and nonlinear to a reductionistic and linear perspective). Discoveries that have involved the marine mollusk, Aplysia, for example, have provided great insight into the functions of human neurobiology (for examples, see Byrne et al., 1991; Hawkins, Green, & Kandel, 1998).

Because all behavior (both overt and covert) consists of neural activity, reinforcement and punishment are neural phenomena. Organisms develop behaviorally within an environment by expanding upon certain neural tendencies while minimizing others, based on consequent feedback from the environment. Individual neurons exhibit specific nerve energies. That is, they fire with about the same amount of force all the time. Environmental feedback does not affect the strength of discharge by individual neurons. Rather, the organism's behavior appears to adapt via an adjustment of the firing threshold, based upon changes in synaptic transmission (Nargeot, Baxter, & Byrne, 1999) or the shape of the neural pattern or receptive field (Mehta, Quirk, & Wilson, 2000). Punishing consequences are those that cause the threshold to be raised so that under the same antecedent conditions the individual neuron (with its now higher threshold) does not fire as easily. The neural pattern (or "behavior") that is dependent on this threshold is now inhibited. Reinforcement, of course, works in a similar fashion but neural thresholds are lowered as the behavior-feedback dance commences, serving to augment or strengthen the pattern. By definition, any feedback that results in threshold lowering or augmentation is "reinforcing," whereas that which results in inhibition is "punishing." The relative permanence of effective training is explained by Abarbanel (1995), who offers an articulate description of the influence of conditioning on the process of long-term potentiation.

It must be acknowledged that in traditional behavioral language, a particular stimulus cannot be identified as reinforcing or punishing until its effect on prior behavior is determined. As Meehl (1950) pointed out, the circularity of this approach or "post hoc definition" problem has created some difficulties for the prescriptive application or identification of a stimulus. That said, many proponents of the early "functionalist" perspective in psychology, and many proponents of the Darwinian model of biological evolution, have lived with the same problem without feeling compromised, and so it would not appear to preclude the conceptual utility of the behavioral model.

BEHAVIORAL DESCRIPTION OF NEUROFEEDBACK

The environment to which the brain is adapting during neurotherapy is often complex, and may require a complex response pattern. In behavioral terms, one has a compound stimulus and expects to reinforce a compound response. It is an easy task for the brain to simultaneously inhibit some rhythms while increasing others, in the same manner in which one quickly learns to step *up* while simultaneously ducking one's head when entering a darkened attic. The typical feedback protocol used in EEG training involves both audio and visual stimuli. Portions of the feedback array brighten, move, expand, crescendo, or stabilize as a particular frequency pattern is approximated. To the extent that this EEG configuration is strengthened and repeated, the stimulus array is said to provide reinforcement. Similarly, parts of the array slow, dim, or become more dissonant as the EEG pattern moves away from the inhibit-augment parameters, ideally effectively punishing such movement so that the tendency to do so is decreased. Both reinforcement and punishment parameters may be engaged simultaneously. Again, words like "noxious," "unpleasant," or "painful" are irrelevant.

BEHAVIORAL SYSTEMS DESCRIPTION

In systems theory language, the behavior-feedback loop is completed hundreds of times per second, across many cortical sites per second, and represents a system that is dynamically equilibrating within its environment, or adapting. Abarbanel (1995) described this process as neuromodulation of the attentional system into an attractor state. Nicolis and Tsuda (1999) describe the same process as the "capture" of environmental stimuli bringing about change in the brain through "chaotic itinerancy" which may ultimately affect (change) the reigning attractor. A stable system, whether linear or nonlinear, is characterized by dynamic mechanisms that influence the system toward its default equilibrium set. A very tidy integration of the systems and behavioral perspectives is proposed by Viken and McFall (1994). They support the notion that the neural system of each human being is unique, in the sense that we appear to tend toward our own idiosyncratic, "free baseline" equilibrium that is the brain's "preferred" state. Both the emotional valence of a stimulus and the empirical effect of a stimulus upon behavior are dependent upon the context, the dance floor upon which the organism and environment are engaged, and to its advantage, systems language inherently accounts for an individual's baseline equilibrium. This conceptualization is useful; I am not suggesting that we dispense with it.

HEURISTIC MERITS OF EACH APPROACH

From a treatment perspective the nonlinear dynamics approach may claim greater parsimony. The simple input of information-rich feedback into the complex neural system is intended to mobilize the system's adaptive nature, such that the problematic spikes and drop-offs in the EEG are constrained over time. The effect is said to be general in the sense that the brain is seen as renormalizing or "resetting" itself, by itself. This seems analogous in many ways to solving a mechanical problem by the clinically validated method of shaking the box or jiggling the lock. With minimal training and minimal understanding of the mechanism, a practitioner may begin providing neurotherapy. The quality of the treatment may possibly be seen as entirely a function of the quality of the feedback. Although it may be tempting to simply "let the brain figure it out" (V.W. Brown, personal communication, Sept. 25, 2000), in fact, the nature of feedback that is described as "inhibiting" or "augmenting" some aspect of the EEG array is probably better described in behavioral language.

A behavioral conceptualization of EEG training has several advantages, for both treatment and research endeavors. As Kazdin (2001) points out, the behavioral approach alone provides a structure for operationalizing both the problem and the intended target behavior, in EEG terms of course, when describing brain behavior. The establishment of goals (consider ratios, power, percent of time within or over threshold, frequency of spikes and drop-offs, etc.) and consistent, built-in assessment and evaluation components allow both provider and client to monitor progress, purposefully change tactics, and to begin to identify specific tactics for particular problems. Nearly a century of behavioral research and widespread applications of this treatment modality have furnished the creative practitioner or researcher with a rich palette of serviceable techniques and principles.

Some behavioral researchers appear to be comfortable using both conceptualizations. For example, Hoyert (1992) used a nonlinear dynamic model to predict pigeons' response rates on a fixed-interval reinforcement schedule, and Efremova and Kulikov (1998) observed changes in their measure of a high frequency attractor in the rabbit EEG during behavioral training. Mpitsos (2000) has echoed the comments of many theorists in his recent portrayal of the learning process as a producer of the architecture that generates the attractor.

In behavioral terms, the evolution of neural structures that enhance individual equilibrium because of the brain's adaptation to feedback is the goal of neurotherapy. It is proposed here that our conditional or at least referential feedback can *always* be conceptualized as providing reinforcement and punishment, goals may be set, progress may be monitored, and this conceptualization does not contradict or undermine a systemic framework. Rather, behavioral language will continue to be a useful vehicle for describing characteristics of any neurofeedback intervention.

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