The Role of Mind-Body Medicine in the Mind-Body Problem

Jon A. Frederick, Ph.D., Director of Clinical Research, Quietmind Foundation, Lafayette Hill, PA

The mind-body problem, as it is usually stated, is the question of how the properties of the mind interact with or can be explained by the properties of the body. Most discussions of the problem begin with Descartes, who conceived of the mind as purely spiritual, and outside of space and time, and the body as material and mechanical. The problem Descartes never solved was, given that we do mentally perceive or exert our will upon the material world, exactly how do these distinct substances interact?

Kupfermann and Weiss (1978) described how scientific research can only demonstrate three types of relationships between biology and psychology. *Correlation* between biology and behavior can be shown by recording experiments, such as fMRI, EEG, or single-cell studies. Meanwhile, stimulation experiments, whether stimulating electrically or with an agonist drug, can demonstrate that activity in some region or system is *sufficient* to evoke a given behavior or experience. Finally, lesion studies, by removing a brain region or administering an antagonist drug, can show that some physiological system is *necessary* for some psychological process to occur.

Modern science has succeeded in showing many causal relationships between the mind and the brain. However, philosophers like David Chalmers (1995) argue that showing causal relationships doesn't solve the "hard problem" of explaining qualitative phenomena or *qualia.* Qualia are defined as "what it is like" to experience particular feelings or perceptions, such as pain, or the color yellow. "It is widely agreed that experience arises from a physical basis," Chalmers argues, "but we have no good explanation of why and how it so arises."

For example, suppose we noticed that a 40 Hz evoked rhythm was always observed in the visual cortex EEG when "yellow" was experienced (correlation); that applying a 40 Hz stimulus to the visual cortex evoked an experience of yellow (sufficiency); and that blocking all 40 Hz waves in the visual cortex prevented every subject tested from experiencing yellow (necessity). Would we really have a complete explanation? Something still seems to be missing. In Maxwell's reduction of heat to molecular motion, it is easy to imagine how boiling water feels painfully hot to the touch because rapidly moving water molecules are damaging the skin. There is, however, nothing intuitively obvious about why neuronal membranes depolarizing 40 times per second is somehow "exactly the same as" the experience of yellow—even if this neuronal process is correlated, necessary, and sufficient for the experience. The "yellowness" seems to be missing!

Given that the goal of biofeedback is to increase conscious awareness and voluntary control of otherwise subconscious and involuntary physiological processes, it is surprising how unpretentious workers in this field are about the potential for biofeedback as a research method, to advance our understanding of the mind-body relationship. How do mental processes arise from a material substrate without possessing innate knowledge of that substrate? The mysterious and often pathological nature of this transition is what creates demand for biofeedback therapists, who are uniquely trained and equipped to study this essential question.

In *Beyond Biofeedback*, Elmer and Alyce Green (1977) made an important contribution when they proposed the Psychophysiological Principle. They said, "Every change in the physiological state is accompanied by an appropriate change in the mental-emotional state, conscious or unconscious; and, conversely, every change in the mental-emotional state, conscious or unconscious, is accompanied by an appropriate change in the physiological state. . . this principle, when coupled with volition, allows a natural process—psychosomatic self-regulation—to unfold." Green and Green documented the diversity of physiological processes that were known to be trainable through biofeedback at the time, supporting an optimistic view that essentially any bodily process which can be measured can be subject to some degree of self-regulation. This view continues to influence the field to this day, where every clinical practitioner has their favorite physiological measurement or measurements along with some rationale for why training its self-regulation helps their particular clients. In fact, most published research in biofeedback is focused on the problem of demonstrating its efficacy as a therapy. This emphasis is understandable, but I think that more basic research into biofeedback's mechanism of action could potentially pay off in the form of more precise and targeted therapies.

To me, the most important contribution the biofeedback field can make both theoretically and clinically would be to characterize not just how the mind and brain are related, but the mechanistic details of how this relationship is limited. A variety of considerations lead me to believe that what awaits us is not just more effective behavioral medicine, but the discovery a specific organ system that regulates the flow of information between conscious and subconscious systems, where the permeability to specific kinds of transmission is determined by learning, development and evolution. I postulate the existence of a "mind-brain barrier," whose functional existence is no less real than the "blood-brain barrier" that regulates the flow of dissolved substances between the blood and cerebrospinal fluid.

In an influential essay, Ramachandran and Hirstein (1997) argued that qualitative phenomena or *qualia* have three properties: (1) they are irrevocable on the input side; (2) they are flexible on the output side; and (3) they must last long enough to be maintained in short term memory.

By *irrevocable*, they meant that qualia have an involuntary nature. While we might be able to imagine how our sensations might be different, all existential optimism aside, we can't willfully change our visual percept of a red fire truck into a yellow one. This property of qualia, their involuntary construction by preconscious systems, makes it clear how conscious and subconscious processes are not mutually exclusive, but inextricably linked. The most successful "reduction" of qualia would simply represent them in terms of other, more interesting, preconsciously-generated qualia. Similarly, "self-control" is paradoxical because volition itself arises involuntarily.

The second property of qualia is that their *output is flexible*. We can choose any

Continued on page 32

The Role of Mind-Body Medicine
Continued from page 15

of a wide variety of responses to most stimulus situations. By contrast, reflex reactions have only one possible output. Consciousness appears to have evolved, among other reasons, as a system for making choices in situations for which reflex reactions do not present adequate options.

Finally, qualia *must be present in short term memory long enough for executive processes to act upon them.* These two properties help us to understand why qualia have the property of irrevocability on the input side. Executive processes, like attention and working memory, are famously limited in their capacity. For executive processes to make effective decisions, they must at some level have premises that are not subject to further questioning and uncertainty.

Bernard Baars (1993) explained how consciousness is a limited resource. For instance, studies have shown that most people can only hold "seven plus or minus two" independent items in working memory. You can only attend to a subset of your sensory field. It is generally accepted that attention has a "center" and a "surround," or a focus on the most important or relevant information and a periphery of less important information that can become the focus if internal or external factors warrant a shift of attention.

Secondly, consciousness operates serially. Divided attention experiments have shown that even the most skilled individuals are not truly "multitasking" but rapidly shifting their attention between tasks.

Finally, consciousness is integrated—we seamlessly attribute the many different aspects of an object to the same object. The subconscious nervous system, by contrast, is a distributed, parallel system of enormous capacity. Hundreds of millions of receptors simultaneously represent discrete pieces of the sensory field, of which only a tiny fraction are processed consciously. One of the essential functions of sensory systems, then, is to *exclude* information from consciousness. Studies comparing the sensory neurophysiology of different animal species have shown that the phenomenal field of animals is specifically limited to forms of energy that are relevant to survival.

So, the irrevocability of qualia is a clue to their adaptive function. The limited capacity of consciousness as an executive system creates an adaptive requirement for it to operate on finite number of assumptions, and to orient, allocate, and focus on novel problems whose solution is not already hardwired by millions of years of evolution. So, one could argue that our preconscious systems construct our qualitative experience more from a perspective of "efficiency" than from a concept of "reality."

Meanwhile, the flexibility of qualia on the output side suggests another reason to insulate physiological processes from mental ones. That is, if a system is designed to specialize in open-ended problems, then it is adaptive to prevent that system from controlling processes requiring regular, predictable operation. There is a reason why we pass out if we hold our breath long enough. The wide-open flexibility of consciousness makes its reflection back on its physiological basis not only perplexing, but in some ways, dangerous. I claim, then, that the boundaries between the mind and brain are too mission-critical to be left to chance. I predict that psychophysiologists will discover a system policing this boundary whose intricacy and elegance will rival that of known organ systems.

To understand this system, we need to systematically study and document which physiological processes can be subjectively discriminated and controlled, and why some are easier to discriminate and control than others. The first step would be to measure how many training sessions are required to achieve a minimal level of discrimination or control, and what mean and maximal levels can be achieved for each physiological variable of interest. The next step would be to measure which physiological discrimination and control skills would generalize to each other, such that training in one would result in a shorter required training time in the other. Such discriminative stimulus generalization experiments would generate taxonomies or maps of the relationships among the internal representations of the varieties of physiological signals that can be fed back externally (similar to the way psychoactive drugs are categorized based on discriminative stimulus generalization studies in laboratory animals). The interesting question would be, how do the similarities and differences in the discriminative stimulus properties of various physiological signals relate to their structural (location, time and frequency) and other functional similarities and differences. For instance, would 18 Hz amplitude discrimination at FP1 generalize better with (a) 18 Hz amplitude discrimination at O2; (b) 25 Hz amplitude discrimination at FP1; or (c) 18 Hz coherence discrimination between FP1 and O1? Prior knowledge will inform this research, but we should expect some results to be provocatively hard to reconcile with what standard neuropsychological experiments would suggest.

My contributions to this program of research began two years ago when I started my study of the "Psychophysics of EEG State Discrimination" at the University of Minnesota (Viebrock and Frederick, *in press*; Frederick, 2006). One of the earliest and often cited studies in neurofeedback was a discrimination learning experiment by Joe Kamiya (1968), who reported success in training human subjects to discriminate alpha from non alpha states. In this study, subjects were asked to respond "A" for alpha and "B" for non alpha when the experimenter rang a bell. The experimenter waited for distinct alpha and non-alpha states, in random order, to appear in the raw EEG and then rang the bell when they appeared. Kamiya reported that 9 out of 12 subjects reached a significant proportion of correct within seven one-hour sessions.

Interestingly, nearly all research on human learning of brainwave states since this study have focused on training and measuring voluntary control of EEG constructs, rather than discrimation. However, given the frequent assertion by biofeedback therapists that training people to control their EEG increases perceptual acuity for subtle internal signals about their EEG state, it is remarkable how few EEG biofeedback studies have actually measured whether trainees can correctly identify their internal state. One study (Cott, Pavlski, and Black, 1981) failed to demonstrate discriminative learning of the alpha rhythm, but differed substantially from Kamiya's original study in defining an alpha state as one-half second of high alpha power. Kamiya (personal communication) suggested to me that a half second was too short for subjects to discriminate from the background variability. Therefore, we attempted to demonstrate alpha state discrimination using one-, two- and four second intervals.

With the approval of the University of Minnesota Institutional Review Board, we studied 22 participants, age 18-55. A 150-second eyes-closed baseline EEG was recorded at frontal (F3 or Fz) or posterior locations (Pz, O1, or O2) with a linked ears reference. Each epoch was ranked among a percentile distribution of alpha powers of the most recent 150 seconds initially derived from the baseline recording. A tone sounded whenever the alpha band power exceeded a critical difference from the median of the baseline. This critical difference varied continuously between 0 and the 30th percentile for "low" alpha trials, and between the 70th and 100th percentiles for high alpha trials. Subjects responded "high" or "low," and received feedback about whether the response was correct or incorrect after each trial.

Only sessions where performance exceeded a criterion of binomial $p<.01$ for percentage correct were included for analysis. Eleven subjects had at least one session above criterion with a median of four sessions to reach criterion. The remaining eleven subjects did not reach criterion with a median of three total sessions. The graph of average session performance showed a clear pattern of improvement from over the course of 13 sessions ($R^2 = 0.736$).

When trials were segregated into 10-percentile bins, an analysis of variance clearly showed differences between performance at different signal intensities ($F=3.99$; $p=.004$). Post-hoc tests showed that participants performed significantly better in the "very low" 10th and "very high" 100th percentile bins compared to the more moderate 30th and 80th percentile bins.

The duration of the discriminative stimulus interval also affected performance, where participants scored significantly higher on four second epochs (mean 71%) than one second epochs (63%; $p=.005$), with an intermediate performance on two second epochs (66%).

Given that discrimination accuracy increased with both the duration and intensity (percentile difference from the median), it is tantalizingly hard not to conclude that we have characterized the psychophysical properties of an introspective sensory modality. The word "interoception" is used to describe the brain's reception of signals from the visceral organs, where the primary sensory cortex for interoception is on the insula (Cameron, 2001). However, there is not yet a word for the mind's discrimination of the brain's electrical state. It would be of interest, however, to do fMRI and quantitative EEG studies to see if this sensory modality has a primary sensory cortex and, if so, whether there is a anato-topical map like the somatosensory cortex or a frequency-topical map like the primary auditory cortex.

The interactions between discrimination and control (awareness vs. volition) in EEG biofeedback are vastly unknown, and may have important clinical implications. Insofar as discrimination and control are related, measuring discrimination could serve as a more precise experimental model of control training. Learning is difficult to measure in EEG control training because therapists often adjust thresholds to maintain an optimum percentage of reward, and effects of training are often smaller than the baseline variation. By contrast, a direct measurement of success is intrinsic to every trial in discrimination learning. Thus, if control and discrimination skills generalize to each other, taking EEG state discrimination measurements could be a useful method of assessing client progress for neurotherapists who train control, and discrimination training could potentially improve the extent and rate of learning in control training. Meanwhile, training discrimination could also have therapeutic value in its own right, just as insight-oriented psychotherapy can have value above and beyond behavior-modification psychotherapy.

Future studies should utilize this method to characterize the psychophysics of other EEG constructs, including coherence, phase, ERP amplitudes, peak frequency, and amplitude in frequencies other than alpha. Identifying the discriminative stimulus properties of physiological states and their relationship to control of these states is, in my view, essential to the development of more specific and efficacious therapies and—while I don't believe the Hard Problem of consciousness can be solved empirically, I do think that the practical insight gained by the use of biofeedback toward an introspective science of neurophysiology will make the problem less problematic. My software, *Introspect,* is available to any Brainmaster user who wishes to join me in this mission.

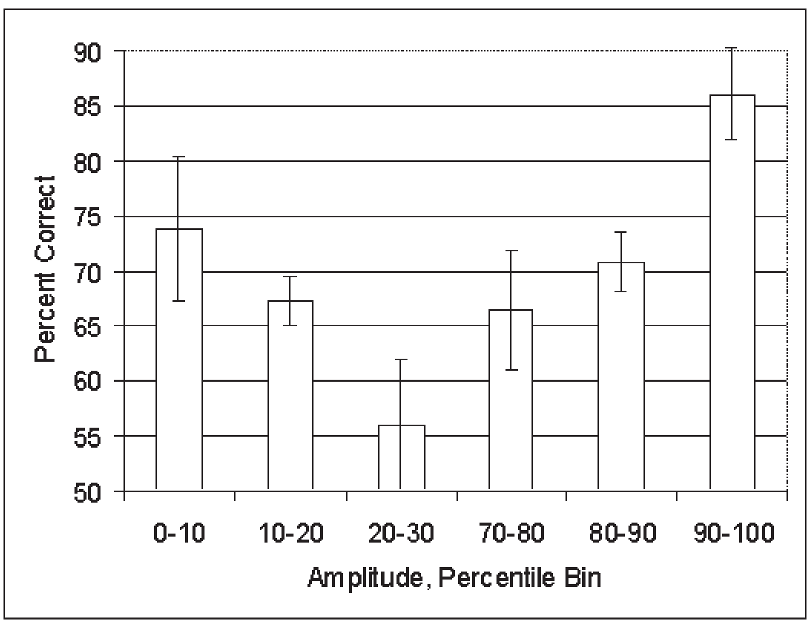

Figure 1. Effect of signal intensity on EEG alpha state discrimination performance

Acknowledgment

I am grateful to Seth Viebrock for his excellent work as lab manager and research assistant in the EEG state discrimination study. This study was supported in part by NIH Training Grant T32-MH-17069.

References

Baars, B. J. (1993). How does a serial, integrated and very limited stream of consciousness emerge from a nervous system that is mostly unconscious, distributed, parallel and of enormous capacity? Theoretical and Experimental Studies of Consciousness, *Ciba Foundation Symposium* 174 (282): 282-90; 291-303.

Cameron, O.G. (2001). Interoception: The Inside Story—A Model for Psychosomatic Processes. *Psychosomatic Medicine* 63:697-710.

Chalmers, D.J. (1995). Facing Up to the Problem of Consciousness. *Journal of Consciousness Studies* 2(3), 1995, pp. 200-219

Cott, A., Pavloski, R.P. and Black, A.H. (1981). Operant conditioning and discrimination of alpha: some methodological limitations inherent in response-discrimination experiments. Journal of Experimental Psychology: General, 110(3):398-414.

Frederick, J.A. (2006). Psychophysics of EEG state discrimination *Journal of Neurotherapy,* 9(4):107-108.

Green, E. & Green A. (1977). *Beyond Biofeedback.* Dell Publishing Co., Inc., New York, N.Y.

Kamiya, J. (1968). Conscious control of brain waves. *Psychology Today*, 1:57-60.

Kupfermann, I. & Weiss, K.R. (1978). The command neuron concept. *The Behavioral and Brain Sciences, 1, 3-39.*

Ramachandran, V.S. & Hirstein, W. (1997). Three Laws of Qualia: What Neurology Tells Us about the Biological Functions of Consciousness, Qualia, and the Self. *Journal of Consciousness Studies*, 4(5-6): 429-58.

Viebrock, S.O. & Frederick, J.A (*in press*). Optimizing dimensions for EEG alpha state discrimination (conference abstract). *Journal of Neurotherapy.*