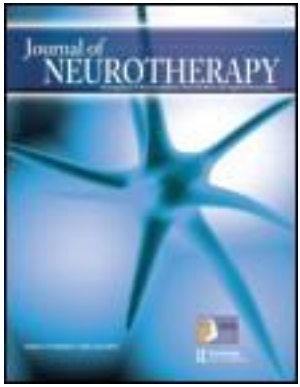

Journal of Neurotherapy: Investigations in Neuromodulation, Neurofeedback and Applied Neuroscience

Clinical Corner

D. Corydon Hammond Editor PhD Published online: 20 Oct 2008.

To cite this article: D. Corydon Hammond Editor PhD (2000) CLINICAL CORNER, Journal of Neurotherapy: Investigations in Neuromodulation, Neurofeedback and Applied Neuroscience, 4:3, 93-97, DOI: 10.1300/J184v04n03_07

To link to this article: http://dx.doi.org/10.1300/J184v04n03_07

CLINICAL CORNER

D. Corydon Hammond, PhD, Editor

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It is my impression that a large percentage of neurofeedback practitioners currently seem to be utilizing referential (single site) training. For example, someone might train at Cz or Fz. Even with systems such as the Procomp or the Roshi, where training occurs at two sites simultaneously, it is still referential training at two independent sites that is occurring simultaneously.

I have found it interesting, however, that Lubar's research (e.g., Lubar, 1995; Lubar, Swartwood, Swartwood & O'Donnell, 1995; Rasey, Lubar, McIntyre, Zoffuto & Abbott, 1996) Michael Linden's study (Linden, Habib, & Radojevic, 1996) and the Othmer's (Othmer, Othmer, & Kaiser, 1999) work with ADD/ADHD all focused on the use of bipolar training (training on the differences between two sites). In addition, Margaret Ayers relies on bipolar training. I also realized that although larger signals are obtained with referential (single electrode) training, this monopolar training is much more prone to artifact (e.g., contaminating eye movement, EKG, body or tongue movement) because of the lack of common mode rejection (the rejection of signals that are in phase and identical at the two different electrodes in a bipolar placement). Thus, it seems that bipolar training has received considerably more experimental validation than referential training.

In my experience I have only been aware of one practitioner, Joel Lubar, who has recently been presenting a thoughtful rationale for clinicians to decide whether to use bipolar or referential training. Therefore, I asked him to respond to the question below.

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RATIONALE FOR CHOOSING BIPOLAR VERSUS REFERENTIAL TRAINING

QUESTION: What factors can we take into consideration in neurofeedback in choosing to use sequential (bipolar) vs. referential training?

RESPONSE: Joel F. Lubar, PhD, Professor, Psychology Department, University of Tennessee, 310A Austin Peay Building, Knoxville, TN 37996-0900. E-mail address: jlubar@utk.edu

Over the past 25 years that we have been working with attention deficit hyperactivity disorder, we have done more training using a sequential (bipolar) configuration than a referential configuration. Our results have been outstanding and very enduring. We have followed many of our patients from 10 to 14 years after training and have shown that they have continued to do extremely well long after the treatment has ended. Although I cannot say that

this is because the bipolar configuration is better than the referential configuration, there are certain considerations that make it very appealing. Let me give a specific example. We do a great deal of our training for children with one electrode placed at FCZ, half way between FZ and CZ, and one at CPZ, half way between CZ and PZ with an ear reference.

Since these locations are on the midline, it doesn't matter whether the reference is the left ear lobe or the right ear lobe. Let me contrast this training with training at CZ only using either mathematically or physically linked ear references.

Before I engage in training with any individual, I make the following measurement. Using an assessment program (Autogenics A620 assessment), I measure the percentage power of activity at all three locations: FCZ, CZ, and PZ. I also take the measurements with the bipolar and the referential configuration. I look to see which configuration provides the largest spread between the percentage of theta and the percentage of beta, and then use that as the basis for training. For example, if the percentage of beta and theta measured with the bipolar configuration is 60% and 10%, respectively, and the percentage obtained referentially is 30% and 20%, respectively, I would then train with the bipolar configuration since it is easier to learn to reduce theta from a high percentage value to a lower one and beta from a lower percentage value to a higher one, than if the percentages are much closer as would be the case with the referential configuration. There is another consideration that is very important. If I were to actually measure the percentage or microvolt changes in theta and beta at all three locations (FCZ, CZ, and CPZ), there are many different possible outcomes. In a referential configuration, the only way one can learn is by changing what is happening specifically at or near the electrode site; that is, either increasing the percentage of beta or the microvolt levels of beta, or decreasing the percentage of theta or the microvolt levels of theta at that location. With the bipolar or sequential configuration, both parameter changes could take place at anywhere between the two electrodes or could take place at any one of the single locations (FCZ or CPZ) and the outcome would be a resultant decrease in the slow activity and an increase in the fast activity percentage or microvolt based since the sequential or bipolar configuration looks at the algebraic difference between the two sites.

A very interesting outcome would be as follows. Let us suppose that we could measure these parameters at FCZ and CPZ referentially and found that there was absolutely no change over sessions in either the microvolt levels or the percentages of activity in the reward or inhibit frequency, in this case, beta or theta. However, the resultant activity measured with the sequential configuration does show an increase in beta and a decrease in theta, microvolt levels or percentages. How can this come about and does it appear to be a

contradiction? The answer is no. All one has to do, is to somehow learn to change the phase relationships between the measured parameters at the two locations and the outcome would be exactly as expressed. For example, if the theta activity at the two measured locations FCZ and CPZ becomes more in phase, the resultant activity will be a decrease in the microvolt levels of theta. If the beta activity moves out of phase, there will be a resultant increase in the microvolt levels of beta. As a result, bipolar or sequential training has the advantage in that there are many more options for learning such as changing the activity at any one of the electrode sites, anywhere in between them, or changing the phase relationships between the two electrode sites. In contrast, with referential training there is only one way to learn and that is to change the parameters being trained at the electrode site. For this reason training over any locations within a hemisphere, whether it is on the midline or more lateral, will work and perhaps even better with bipolar than with referential configurations. For example, training an individual to change activity between F3 and P3 might work better with a bipolar configuration than training them to change those parameters at C3. One could measure what is happening at all three electrode sites to determine how they learned.

There is, however, one important warning. Bipolar training across the hemispheres is very difficult and probably counterproductive. For example, training an individual to increase alpha activity between O1 and O2 or P3 and P4 might be very difficult. Training an individual to change SMR activity with the electrode placements at C3 and C4 will be very difficult or to train beta activity between F3 and F4 will be difficult. The reason for this is because activity in many different frequency bands measured from homologous sites in left and right hemispheres tends to be very much in phase. As a result the amplitude of this activity will be very small. My recommendation would be, if one is to employ a bipolar montage for training, it should be done within a hemisphere whether it is lateral such as F7-F3, C3-T3, the same would hold for the right hemisphere, but not to use bilateral placements spanning the two hemispheres in homologous sites such as FP1 FP2, F3, F4 C3, C4, etc.

One other point is what I have said holds specifically for ear references. If one is using the alpha asymmetry protocol with one electrode at F3 and one electrode at F4 with a CZ reference, then shifting the alpha asymmetry seems to work fine. It might be much more difficult to accomplish this if one is using ear references where the frontal alpha asymmetry differences are usually not found.

In summary then, regardless of the instrument one is using, I recommend taking measurements both bipolar (sequentially) as well as referentially for the sites of interest and then determining which shows the greatest spread between the reward and inhibit frequency and go with that montage configu-

ration for training. Based on our experience, you will probably find that training occurs more rapidly if this measurement is done in advance. Sometimes the referential measurement indicates that it is the best approach, in which case, it should be employed. One other point is that the bipolar configuration often results in better common mode rejection of noise, which is often in phase, and therefore it is somewhat easier to learn. Graphs of the training parameters over sessions show less variability than with referential training. But again, this does not mean that all training should be done bipolar. The tests should be done in every case if one wants to optimize their results. The argument often used to discredit bipolar or sequential training is that one does not know what is happening under the electrodes. However, this argument is easily overcome by simply measuring what is happening at each site in the bipolar configuration as well as what is happening at the intermediate electrode between them. This allows one to determine how the learning took place, hence this argument no longer applies. I encourage us to have open discussion of this matter at meetings and to present data supporting different montages for different treatments to see if we can utilize this approach to increase the rate and stability of learning.