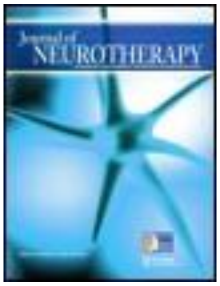

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Clinical Corner

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CLINICAL CORNER

D. Corydon Hammond, PhD, Editor

The purpose of the Clinical Corner is to provide responses to clinically oriented questions which may not, in many cases, have been evaluated yet by research. Therefore, the personal opinions expressed in the column are exactly that, the opinions of the individual authors, often based on their clinical experience. The opinions shared belong to the authors and are not necessarily those of the Society for Neuronal Regualtion (SNR) or the Journal of Neurotherapy. Nonetheless, it is hoped that the diversity of opinion expressed in this column will stimulate thought and the further exchange of ideas.

Readers are invited to send questions for consideration to: D. Corydon Hammond, PhD, University of Utah School of Medicine, PM&R, 30 No. 1900 East, Salt Lake City, UT 84132. E-mail address: D.C.Hammond@m.cc.utah.edu

In this Clinical Corner feature, we pose a question about conducting neurofeedback training at multiple sites simultaneously using Lexicor's Linear Channel Combination (LCC) montage. Our respondents include an academic researcher with extensive clinical experience, and one of our most experienced neurofeedback clinicians in using Lexicor equipment.

SIMULTANEOUS NEUROFEEDBACK TRAINING AT MULTIPLE SITES: USING LEXICOR'S LCC MONTAGE

QUESTION: I have heard about being able to do neurofeedback training simultaneously at multiple sites using the Linear Channel Combina-

Journal of Neurotherapy, Vol. 6(2) 2002

tion (LCC) files with Lexicor's NRS-24 equipment. How is this done, when may it be used, and is there any risk associated with its use?

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Linear channel combination (LCC) files are possible through the Lexicor Biolex programs. This technique refers to algebraically adding the relative contributions of a number of electrodes to provide feedback over larger areas of the scalp. On page 54 of the NRS-24 software manual, a number of LCC file combinations are shown. These involve combining features from channels in the left or right hemispheres, from anterior and posterior positions, from different quadrants, across the sensory motor strip, and across the midline. It is important to realize that when channels are combined together, whether it is truly linear or some weighted average of each channel, that the resultant EEG pattern exhibits a very complex relationship to the individual recorded EEGs because harmonics are produced that may not be present in the original individual recordings. When using this LCC montage, one has to be aware of the effect of phase. For example, if two regions are producing a frequency of equal amplitudes and these are combined together by algebraic addition that are in phase, the resulting amplitude for that frequency will be twice that of each channel. If more channels are in phase, the LCC amplitude for that frequency will result in a very large signal. If some of the channels are out of phase by various phase angles not only will the resulting signal be intermediate or reduced but harmonics will be produced that were not originally part of the initial signals. If one has access to three or more wave form generators, they can see that the combination of signals of a particular frequency with different phase and amplitude relationships leads to very complex patterns. For this reason one must be aware that simplistic assumptions such as combining alpha, beta, theta or activity in any frequency band from multiple regions is going to result in a larger signal. This would only be true in cases where the phase relationships are identical in each of the channels.

At the present time, I know of no studies that compare the results of LCC training with training individual locations. This is not to say that LCC training would be more or less effective, we just don't know. One investigator (Tansey, 1990) in the 1980s used an electrode which was 6 cm long and approximately 1 cm wide placed over the medial cortex from approximately CZ to PZ. He claimed that this electrode resulted in the ability for individuals to train SMR over large regions and was particularly helpful for dealing with a variety of disorders including attentional disorders and seizure disorders. However, he never showed a raw signal from this combined electrode so we had no idea what was actually trained. The extreme case would be to fit a device over the entire scalp such as a sponge soaked single electrode and record from the summation of all scalp locations simultaneously. What would be the relationship between such a bizarre full scalp recording and individual recording sites? One approach to solving the problem of what the LCC really means would be to record from an LCC montage of three or four or even five channels simultaneously and to also display underneath the recordings from each of these channels separately. Once done we could compare the wave forms in the LCC montage with those from individual channels to see which events in the raw signals from the different channels influenced the LCC recording the most or the least. We could also compare each channel and the LCC using Fourier analysis. For instance, how would artifact be handled if it were, for example, an eye blink on one channel and muscle activity in another channel all averaged together with the EEG activity from the remaining channels, and how does one deal with the very difficult problem of artifact blocking by inhibitory circuits? A large transient may actually be a result of a combination of EEG activity as opposed to EEG contaminated with eye blinks or body movements.

For these reasons, I cannot say that LCC approaches are good or bad, it's just that we don't know what they really mean and until we look at the relationship between linear channel combinations and individual channels we will not be able to understand what we are recording even if we get good clinical results. We won't even know exactly which channel combinations in the LCC were most responsible and which contributed the least to a good clinical outcome. My caveat then is to study this montage systematically and try to understand what an algebraic addition of multiple channels really means in terms of the relationship to the individual sites recorded.

REFERENCE

Tansey, M. A., (1990). Righting the rhythms of reason: EEG biofeedback training as a therapeutic modality in the clinical office setting. *Medical Psychotherapy 3*, 57-68.

RESPONSE: Marvin W. Sams, ND, Neurofeedback Centers of America, P.O. Box 153644, Irving, TX 75015. E-mail: drmsams@aol.com

I became interested in LCC training after learning about the importance of 40 Hz frequencies (20-50 Hz) in memory and learning several years ago (Sams, 1995). After experimenting with 40 Hz training at various electrode sites with both ear reference and bipolar (scalp to scalp) montages, I didn't see obvious EEG changes or improvement in the trainee's attentional and cognitive abilities. I was about to give up on the idea when I remembered the Linear Channel Combination (LCC) training available on the Lexicor 20- and 24-channel systems. As the 40 Hz research demonstrated that specific cognitive activities (such as visual scanning) activated "zero lag" (synchronous) 40 Hz pulses in multiple cortical and subcortical areas, LCC training seemed to be a logical "last-ditch" choice. The LCC montages yielded positive EEG, attentional, and behavioral changes, so I focused on LCC montages to develop my 40 Hz protocols.

The LCC capability, standard on the Lexicor 20- and 24-channel equipment, allows multiple (3 to 19) electrode sites to be trained simultaneously. For example, the frontal electrodes Fp1, Fp2, F7, F3, Fz, F4, and F8 may be selected as a group, the Lexicor software mathematically combining the selected electrodes to create a single channel of EEG data. The software allows any frequency band to be selected and magnitude, coherence, and phase training is easily done. Several standard LCC montages are available (see the Lexicor User's Manual for information), but the user can create custom files if desired.

My remediation neurofeedback training model requires favorable changes in the Delta, Theta, Alpha, and Beta bands for a particular type of training to be included in my training repertoire. Delta (0.5-3 Hz), Theta (3-6 Hz), and Alpha-a (8-10 Hz) must decrease as a result of a particular training, while 13 Hz (11.5-14.5 Hz), Alpha-b (10-12 Hz), Beta1 (12-18 Hz), and Beta2 (18-24 Hz) increase. These frequency bands are analyzed at five electrode sites (Cz, F3, F4, P3, P4) on pre-training baselines, comparing the data from the previous session's baseline to that of the present session. I have used both the standard Lexicor montages based in this model, and created and experimented with several other combinations.

The Lexicor LCC montages giving the most robust and reproducible results have been the anterior and posterior montages (labeled "AP" in the LCC files), and one of my own creation I call "CPO" (for centro-parieto-occipital): C3, Cz, C4, P3, Pz, P4, O1, O2. I have found that best results are achieved if 13 Hz training precedes the 40 Hz training (five minutes each). With the CPO montage, I found it helpful to intersperse Beta2 between the 13 Hz and 40 Hz segments. It is important to note that a minimum sampling rate of 256 is required for 40 Hz training.

A few months ago, I circled back to some of my early experiments with referential and bipolar montages. I found that 40 Hz is effectively trained with non-LCC montages if 5 minutes of 13 Hz training is done before 5 minutes of 40 Hz training. Scalp to scalp montages are preferred (for example P3-P4) over ear reference training. No untoward reactions have been noted. The risks are that some electrode combinations cause inappropriate movement in some frequency bands, for example, an increase in Alpha or Delta magnitude, or a decrease in Beta.

REFERENCE

Sams, M. W. (1995). Mathematically derived frequency correlates in cerebral function: Theoretical and clinical implications for neurofeedback training. *Journal of Neurotherapy*, *1* (2), 1-14.