Visualization of a stationary CPG-revealing spinal wave

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Background/Problem

Network Spinal Analysis (NSA) is a technique through which the practitioner applies light pressure at the dural attachment areas [1] in the cervical and sacral regions of the spine. When the areas are sensitized enough, the spine goes into spontaneous oscillations, first localized in the sacral area, then propagating to the occiput (level 1), eventually reaching the neck, itself going into oscillation (level 2a). When two oscillators are engaged, the subject is said to be in level 2. During the initial phase, the oscillators are out of synchronization, traveling wave patterns are moving in opposite directions, and the spine is in nonperiodic motion. However, after a few seconds, the sacral and cervical oscillators become synchronized at which time the spine goes into a stationary wave pattern (level 2b).

The goals are 1) to develop a neurophysiological model of this phenomenon, 2) to confirm the stationary wave pattern by sEMG analysis, 3) to link it with CPG theory, and 4) to visualize it.

Tools and Methods

The fundamental tool is the spatio-temporal analysis [4] of the signals recorded by an array of sEMG electrodes along the spine [3]. In this technique (not reported in [3]), the signals recorded at two different points of the spine are correlated with a time shift to capture the traveling and standing wave pattern of the bursts of accrued sEMG activity.

Results

If $X_i(t)$ are the signals recorded at many different points along the spine, and if $Y_i(t)$ are the signals restricted to their D8 subbands of the DB3 wavelet decomposition, the correlations $r_{ij}(s) = E(Y_i(t)Y_j(t+s))$ vanish ($r_{ij}(s) = 0, \forall i, j$) for some time shifts s as shown in the Figure. This is indicative of a stationary wave pattern. This standing wave property can be visualized by observing the wave pattern nodes during NSA entrainment. The results will be wrapped in a multimedia video demo.

Discussion/Conclusion

The neurosurgical foundation of the sensitization of the cervical area is Alf Breig's theory of dural vertebral attachments [1], which are conjectured to create sensory motor instabilities, themselves eliciting the oscillations. Another sensory motor instability occurs at the sacral level, via the attachment of the *filum terminale* to the coccyx. The neural pathways are hypothesized to remain in the spine without higher cerebral function involvement, as demonstrated on a quadriplegic subject who was able to sustain the wave despite a C5 burst fracture [3]. In conclusion, the NSA wave has all the features of a CPG [2]: it is a rhythmic motion sustained without external stimuli, its nervous pathways are localized in the spine, and it has wave pattern properties (stationary rather than traveling as in [2], because the subject is in the prone position on the table.)

References

1. A. Breig, *Adverse Mechanical Tension in the Central Nervous System*, John Wiley and Sons, New York, 1987
2. C. Eliasmith and C. H. Anderson, Rethinking central pattern generators: A general framework. *Neurocomputing*. 32-33(1-4): 735-740, 2000.
3. E. A. Jonckheere, P. Lohsoonthorn and V. Mahajan, ChiroSensor---An array of non-invasive sEMG electrodes, *The 13th Annual Medicine Meets Virtual Reality (MMVR 13) Conference*, Long Beach, CA, January 26-29, 2005.
4. E. A. Jonckheere and P. Lohsoonthorn, Spatio-temporal analysis of an electrophysiological wave phenomenon, *International Symposium on the Mathematical Theory of Network and Systems (MTNS2004)*, Leuven, Belgium, July 5-9, 2004.