EFFECTS OF PATTERN FOREARM STIMULATION ON THE HUMAN ELECTROENCEPHALOGRAM AND COGNITIVE NETWORKS

Thatcher, R. W[1]., DeBrincat, M.[2], and North, D. M.[1],

EEG and NeuroImaging Laboratory, Applied Neuroscience Research Institute. St. Petersburg, Fl[1]

Send Reprint Requests To:
Robert W. Thatcher, Ph.D.
Applied Neuroscience Res. Inst.
8200 Bryan Diary Rd., Suite 300
Largo, Florida 33777
(727) 244-0240, rwthatcher@yahoo.com

ABSTRACT

Objectives: The purpose of this study was to explore the effects on the human electroencephalogram (EEG) and cognitive networks by comparing a baseline EEG to the EEG after placing a patterned sleeve on the right forearm.

Methods: The electroencephalogram (EEG) was recorded from 19 scalp locations from 20 subjects ranging in age from 17.6 years to 41.9 years (Females = 7, males = 13). An approximate five minute baseline EEG was recorded with subjects sitting at rest with eyes closed. The eSmartr sleeve was then placed on the subject's dominant arm for 20 minutes and an approximate 5 minute EEG was recorded with the sleeve on. A power spectral analysis of the surface EEG as well as the LORETA inverse solution was computed. In addition, the current sources from 88 Brodmann areas were computed for 10 different networks. The variables were absolute power and absolute current density in 1 Hz increments in 10 frequency bands (delta, theta, alpha1, alpha2, beta1, beta2, beta3 and hi-beta). Paired t-tests between the baseline EEG and the EEG recorded after 20 minutes of wearing the eSmartr pattern sleeve were computed for each subject for all EEG measures as well as group paired t-tests.

Results: The results showed statistically significant t-test differences ($P < .01$) between the baseline condition vs the sleeves on condition in both the surface EEG and in the LORETA current sources. The largest differences were decreased alpha and beta frequency power at both the surface EEG and the LORETA current sources with the sleeve on vs the baseline. The largest effects of the sleeve on were in the left frontal and left temporal surface EEG and on the medial bank of the somatosensory cortex in the alpha frequency. Changes in the Default network and attention network were also prominent.

Conclusions: A strong effect size of the pattern sleeve on the EEG was present primarily in the alpha and beta frequency bands. Anatomical validation was evident because of the strong effects on the homuncular projection of the arm to the medial somatosensory cortex as well as the Default network. The mechanism of action of the pattern sleeves on the brain and the EEG is still under investigation.

Introduction

The peripheral nervous system (PNS) connects the central nervous system to environmental stimuli to gather sensory input and create motor output. The PNS coordinates action and responses by sending signals from one part of the body to another (From the various receptors such as mechano-receptors and dermatomes to the brainstem). The PNS includes all other sensory neurons, clusters of neurons called ganglia, and connector neurons that attach to the brainstem and other neurons (Hubbard, 1974). The brainstem connects the forebrain with the spinal cord. It consists of the midbrain, medulla oblongata, and the pons. The primary input into the brainstem are through the Area Postrema (AP) and Nucleus Tractus Solitarius (NTS). Motor and sensory neurons relay signals between the brain and spinal cord. Ascending neural pathways cross allowing the left hemisphere of the cerebrum to control the right side of the body and vice versa. The brainstem coordinates motor control signals sent from the brain to the body. It also controls several important functions of the body including pain management, alertness, arousal, breathing, blood pressure, digestion, heart rate, swallowing, walking, posture, stability and sensory and motor information integration.

Different PNS receptors have an integrative relationship between themselves and correlate to specific nervous stimulation and signals that can be sent through General Somatic Afferent (GSA) Pathways, Special Somatic Afferent (SSA) Pathways, General Visceral Afferent (GVA) Pathways, and Special Visceral Afferent (SVA) Pathways to the brainstem (Robertson and Biaggioni, 1995). These signals can be very specific and can help the brainstem reach homeostasis (equilibrium) and enhance the functions of the brainstem and the reticular nuclei, the monoaminergic and cholinergic nuclei as well as the parabrachial nucleus and periaqueductal gray.

The purpose of this study was to explore the effects on the human electroencephalogram (EEG) when subjects place specially designed sleeve that provide tactile pattern pressure on the forearm.

Methods

Subjects

A total population of 20 subjects ranging in age from 17.6 years to 41.9 years (Females = 7, males = 13). The pattern sleeve was placed on the dominant arm defined by the subject's handedness (left arm = 4, right arm = 16).

EEG Recording

The Wearable Sensing DSI-24 dry amplifier system was used to amplify and digitize the EEG recorded from 19 scalp electrodes according to the International 10/20 electrode locations. Approximately 2 to 5 minutes of EEG was recorded in the eyes closed condition with subjects sitting at rest with no sleeves on their arms. A second 2 to 5 minute recording in the eyes closed was recorded after placing the sleeves on each subject's dominant arm.

Power Spectral Analyses

Each EEG record was visually examined and manual deselection of segments containing artifact of any type were deleted from the record. Split-half reliability and test re-test reliability measures of the artifact free data were computed using the Neuroguide software program (NeuroGuide, v3.0.4). Split-half reliability tests were conducted on the edited artifact free EEG segments and records with > 90% reliability were entered into the spectral analyses. A Fast Fourier transform (FFT) auto-spectral and cross-spectral analysis was computed on 2 second epochs thus yielding a 0.5 Hz frequency resolution over the frequency range from 0 to 50 Hz for each epoch. A 75% sliding window method was used to compute the FFT in which successive two-second epochs (i.e., 256 points) were overlapped by 500 millisecond steps (64 points) in order to minimize the effects of the FFT windowing procedure.

LORETA Current Density

LORETA is a distributed EEG inverse solution where the currents at 3-dimensional gray matter voxels J are a linear combination of the signal S recorded at a scalp electrode:

$$J = T \bullet S$$

Where T is a minimum norm 3-dimensional matrix of 2,394 gray matter voxels with x, y and z coordinates in a generalized inverse that weights the solution to sources that are synchronous in local volumes or regions using the 3-dimensional Laplacian Operator (Pasqual-Marqui et al., 1994; Pasqual-Marqui, 1999). The T matrix is mathematically defined as:

$$T = \{inv(WB'BW)\}K'\{pinv(WB'BW)K'\}$$

Where B is the discrete Laplacian Operator and W is a weighting matrix (inv indicates inverse) and pinv(X) is the Moore-Penrouse pseudoinverse of X (Menke, 1984).

The Talairach Atlas coordinates of the Montreal Neurological Institute's MRI average of 305 brains (Lancaster et al, 2000; Pascual-Marqui, 1999) and the linkage to standard anatomical 7mm x 7mm x 7 mm voxels each with a distinct Talairach Atlas Coordinate. Groups of voxels are also defined by the clear anatomical landmarks established by von Brodmann in 1909 and referred to as Brodmann areas. The resultant current source vector at each voxel was computed as the square root of the sum of the squares for the x, y and z source moments for each 0.5 Hz frequency band. In order to reduce the number of variables, adjacent frequency 0.5 Hz bins were averaged to produce a 1 Hz bin from 1Hz to 40 Hz for each of the 2,394 gray matter voxels.

Results

Surface EEG Paired t-Tests

The results of the surface EEG paired t-tests between the baseline EEG and the EEG recorded during the post sleeve condition in different frequency bands is shown in Table I and in the topographic maps in Figure one. The largest differences were in the left hemisphere in the alpha frequency band (8 – 12 Hz).

Montage: LinkEars

FFT Absolute Power Group Paired t-Test (P-Value)

Intrahemispheric: LEFT

	DELTA	THETA	ALPHA	BETA	HIGH BETA	BETA 1	BETA 2	BETA 3
FP1 - LE	0.040	0.828	0.059	0.377	0.674	0.413	0.576	0.658
F3 - LE	0.873	0.231	0.004	0.086	0.198	0.146	0.237	0.089
C3 - LE	0.634	0.209	0.005	0.462	0.503	0.843	0.288	0.240
P3 - LE	0.752	0.474	0.047	0.453	0.925	0.381	0.596	0.772
O1 - LE	0.737	0.286	0.017	0.881	0.102	0.724	0.894	0.568
F7 - LE	0.064	0.148	0.037	0.192	0.961	0.582	0.279	0.151
T3 - LE	0.523	0.765	0.254	0.974	0.778	0.785	0.895	0.694
T5 - LE	0.725	0.333	0.014	0.216	0.589	0.177	0.213	0.623

Intrahemispheric: RIGHT

	DELTA	THETA	ALPHA	BETA	HIGH BETA	BETA 1	BETA 2	BETA 3
FP2 - LE	0.014	0.422	0.047	0.269	0.382	0.332	0.225	0.599
F4 - LE	0.557	0.590	0.069	0.303	0.731	0.196	0.621	0.818
C4 - LE	0.842	0.439	0.051	0.304	0.931	0.164	0.524	0.601
P4 - LE	0.507	0.337	0.082	0.621	0.858	0.601	0.592	0.794
O2 - LE	0.785	0.813	0.050	0.875	0.195	0.740	0.724	0.980
F8 - LE	0.020	0.238	0.087	0.346	0.732	0.506	0.287	0.511
T4 - LE	0.080	0.035	0.002	0.046	0.821	0.027	0.056	0.111
T6 - LE	0.279	0.147	0.011	0.134	0.831	0.145	0.076	0.149

Intrahemispheric: CENTER

	DELTA	THETA	ALPHA	BETA	HIGH BETA	BETA 1	BETA 2	BETA 3
Fz - LE	0.470	0.038	0.002	0.012	0.065	0.007	0.025	0.031
Cz - LE	0.197	0.227	0.019	0.152	0.187	0.112	0.286	0.467
Pz - LE	0.829	0.959	0.262	0.772	0.512	0.741	0.714	0.689

Table I – Results of paired t-tests from the 19 channel surface EEG between the baseline EEG and the EEG recorded during the post sleeve condition. The strongest effects were reduced power in the alpha frequency band (8 – 12 Hz) especially in the left hemisphere.

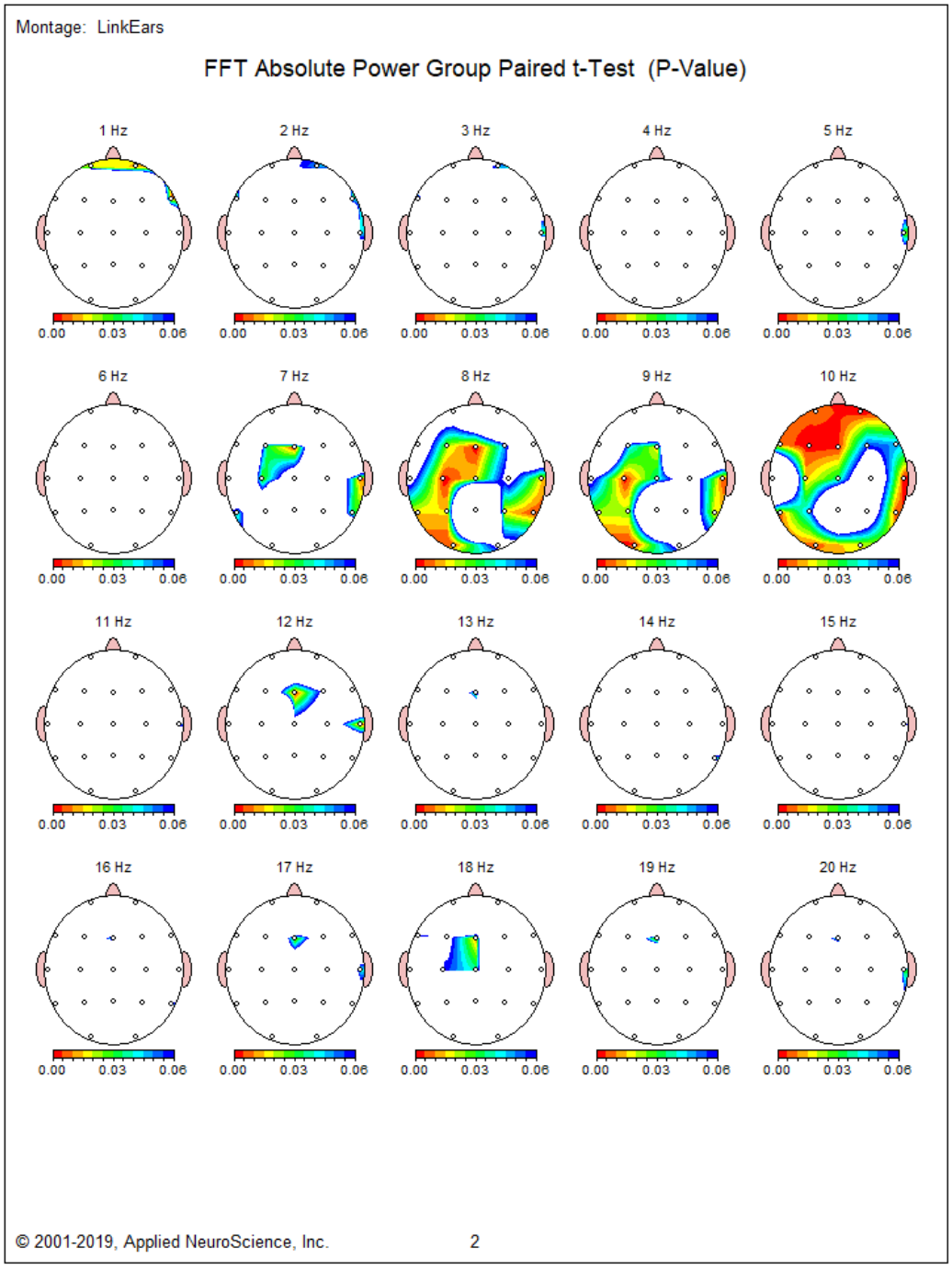


Fig. 1 – Topographic maps of paired t-tests from the 19 channel surface EEG between the baseline EEG and the EEG recorded during the post sleeve condition. The strongest effects were reduced power in the alpha frequency band (8 – 12 Hz) especially in the left central and frontal regions.

Figure two are EEG coherence paired t-tests that demonstrated reduced connectivity in the left hemisphere and elevated coherence in the right hemisphere in the Alpha frequency band.

Montage: LinkEars

FFT Coherence Group Paired t-Test (P-Value)

Intrahemispheric: LEFT

	DELTA	THETA	ALPHA	BETA
FP1 F3	0.437	0.770	0.782	0.605
FP1 C3	0.417	0.343	0.287	0.626
FP1 P3	0.577	0.976	0.391	0.940
FP1 O1	0.227	0.397	0.012	0.445
FP1 F7	0.576	0.444	0.875	0.743
FP1 T3	0.133	0.606	0.818	0.673
FP1 T5	0.367	0.542	0.086	0.503
F3 C3	0.898	0.896	0.633	0.747
F3 P3	0.549	0.884	0.204	0.755
F3 O1	0.073	0.367	0.370	0.638
F3 F7	0.154	0.816	0.754	0.658
F3 T3	0.240	0.374	0.785	0.442
F3 T5	0.622	0.957	0.924	0.615
C3 P3	0.705	0.716	0.080	0.423
C3 O1	0.593	0.758	0.156	0.289
C3 F7	0.807	0.110	0.301	0.973
C3 T3	0.745	0.712	0.729	0.610
C3 T5	0.304	0.853	0.203	0.291
P3 O1	0.709	0.629	0.226	0.636
P3 F7	0.626	0.341	0.390	0.885
P3 T3	0.639	0.505	0.360	0.614
P3 T5	0.511	0.896	0.529	0.795
O1 F7	0.418	0.834	0.527	0.720
O1 T3	0.970	0.980	0.731	0.836
O1 T5	0.824	0.729	0.193	0.942
F7 T3	0.761	0.343	0.818	0.976
F7 T5	0.246	0.873	0.690	0.657
T3 T5	0.981	0.997	0.908	0.789

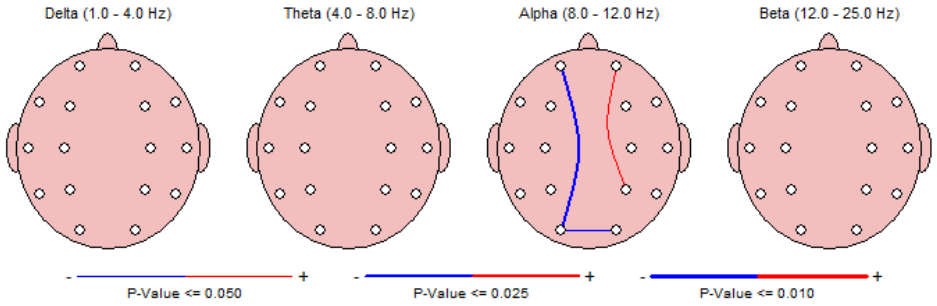
Intrahemispheric: RIGHT

	DELTA	THETA	ALPHA	BETA
FP2 F4	0.380	0.613	0.960	0.563
FP2 C4	0.608	0.451	0.856	0.685
FP2 P4	0.534	0.822	0.044	0.223
FP2 O2	0.500	0.096	0.408	0.745
FP2 F8	0.376	0.722	0.516	0.463
FP2 T4	0.151	0.936	0.321	0.443
FP2 T6	0.826	0.172	0.785	0.591
F4 C4	0.320	0.658	0.465	0.292
F4 P4	0.521	0.201	0.087	0.163
F4 O2	0.167	0.546	0.140	0.588
F4 F8	0.871	0.378	0.716	0.706
F4 T4	0.500	0.600	0.383	0.789
F4 T6	0.627	0.305	0.201	0.142
C4 P4	0.661	0.658	0.558	0.416
C4 O2	0.468	0.808	0.339	0.908
C4 F8	0.268	0.230	0.323	0.680
C4 T4	0.160	0.256	0.743	0.224
C4 T6	0.771	0.269	0.545	0.382
P4 O2	0.927	0.996	0.367	0.467
P4 F8	0.730	0.349	0.255	0.743
P4 T4	0.413	0.132	0.428	0.094
P4 T6	0.913	0.372	0.952	0.289
O2 F8	0.596	0.263	0.420	0.701
O2 T4	0.707	0.090	0.315	0.769
O2 T6	0.947	0.994	0.700	0.620
F8 T4	0.165	0.933	0.665	0.492
F8 T6	0.926	0.701	0.611	0.415
T4 T6	0.315	0.071	0.410	0.205

Interhemispheric: HOMOLOGOUS PAIRS

	DELTA	THETA	ALPHA	BETA
FP1 FP2	0.303	0.345	0.542	0.970
C3 C4	0.333	0.987	0.413	0.917
O1 O2	0.925	0.640	0.029	0.873
T3 T4	0.163	0.229	0.339	0.158

	DELTA	THETA	ALPHA	BETA
F3 F4	0.488	0.949	0.608	0.588
P3 P4	0.444	0.485	0.939	0.077
F7 F8	0.487	0.139	0.129	0.362
T5 T6	0.892	0.300	0.137	0.140



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Fig, 2 - EEG coherence paired t-tests that demonstrated reduced connectivity in the left hemisphere and elevated connectivity in the right hemisphere in the Alpha frequency band.

LORETA Current Density

Table II shows the results of paired t-tests in LORETA current density in the eyes closed condition between baseline vs sleeve on. The effects appeared to be widespread with statistically significant differences ($P < .05$) in all Brodmann areas except for right hemisphere BA 44, BA45 and BA 46. The statistical effect size was greater in the left hemisphere compared to the right. The alpha frequency band had more statistically significant differences than other frequency bands.

Left Hemisphere	Delta	Theta	Alpha	Beta	High Beta	Alpha 1	Alpha 2	Beta 1	Beta 2	Beta 3
Brodmann Area	1.0 - 4.0 Hz	4.0 - 8.0 Hz	8.0 - 12.0 Hz	12.0 - 25.0 Hz	25.0 - 30.0 Hz	8.0 - 10.0 Hz	10.0 - 12.0 Hz	12.0 - 15.0 Hz	15.0 - 18.0 Hz	18.0 - 25.0 Hz
BA1	0.3136	0.2703	0.0236	0.1261	0.0914	0.0236	0.0236	0.1836	0.1261	0.1261
BA2	0.3337	0.2905	0.0246	0.1324	0.1076	0.0246	0.0246	0.2861	0.1324	0.1324
BA3	0.2839	0.2462	0.0200	0.1184	0.0880	0.0200	0.0200	0.1399	0.1184	0.1184
BA4	0.1393	0.1279	0.0159	0.0448	0.0953	0.0159	0.0159	0.0828	0.1219	0.0448
BA5	0.1146	0.1038	0.0178	0.0841	0.2731	0.0178	0.0178	0.0841	0.2034	0.2209
BA6	0.0799	0.0533	0.0009	0.0244	0.0954	0.0009	0.0009	0.0358	0.0778	0.0244
BA7	0.1122	0.1089	0.0185	0.0845	0.2744	0.0185	0.0185	0.0845	0.1992	0.2090
BA8	0.1152	0.0611	0.0084	0.0722	0.1170	0.0084	0.0084	0.1654	0.1412	0.0722
BA9	0.1221	0.0753	0.0350	0.0853	0.1161	0.0350	0.0350	0.1478	0.1298	0.0853
BA10	0.0995	0.0672	0.0218	0.0264	0.1330	0.0218	0.0218	0.0264	0.0971	0.0656
BA11	0.0963	0.0963	0.0390	0.0584	0.1974	0.0390	0.0390	0.1499	0.1965	0.0584
BA13	0.2847	0.0561	0.0007	0.0085	0.1012	0.0007	0.0007	0.0350	0.0923	0.0085
BA17	0.2862	0.3644	0.2501	0.2675	0.2336	0.2501	0.2501	0.3244	0.2675	0.2675
BA18	0.2293	0.2985	0.0769	0.1855	0.2067	0.0769	0.0769	0.2752	0.2341	0.1855
BA19	0.1398	0.2043	0.0398	0.1610	0.2064	0.0398	0.0398	0.1610	0.2472	0.1928
BA20	0.1970	0.0508	0.0010	0.0261	0.1694	0.0010	0.0010	0.1344	0.1534	0.0261
BA21	0.1295	0.0782	0.0030	0.0086	0.1450	0.0030	0.0030	0.0607	0.0981	0.0086
BA22	0.1255	0.0779	0.0075	0.0211	0.1433	0.0075	0.0075	0.0581	0.1681	0.0211
BA23	0.0859	0.0271	0.0012	0.0124	0.1550	0.0012	0.0012	0.0124	0.0764	0.0661
BA24	0.0812	0.0263	0.0010	0.0144	0.0739	0.0010	0.0010	0.0144	0.0645	0.0662
BA25	0.2757	0.0705	0.0048	0.0439	0.2031	0.0048	0.0048	0.0439	0.1310	0.0641
BA27	0.4270	0.0582	0.0061	0.2477	0.3276	0.0061	0.0061	0.2571	0.2477	0.3157
BA28	0.3339	0.0497	0.0017	0.0357	0.1862	0.0017	0.0017	0.0902	0.1168	0.0357
BA29	0.2630	0.0795	0.0021	0.1052	0.1089	0.0021	0.0021	0.1059	0.1527	0.1052
BA30	0.2831	0.0509	0.0056	0.2358	0.2009	0.0056	0.0056	0.2523	0.2358	0.2763
BA31	0.0793	0.0484	0.0009	0.0244	0.1491	0.0009	0.0009	0.0244	0.0766	0.1003
BA32	0.1374	0.0448	0.0109	0.0247	0.0929	0.0109	0.0109	0.0247	0.0955	0.0667
BA33	0.1572	0.0382	0.0161	0.0861	0.0917	0.0161	0.0161	0.1133	0.1321	0.0861
BA34	0.3114	0.0652	0.0034	0.0298	0.1750	0.0034	0.0034	0.0395	0.1303	0.0298
BA35	0.3361	0.0346	0.0011	0.0362	0.1940	0.0011	0.0011	0.1090	0.1068	0.0362
BA36	0.3341	0.0396	0.0012	0.0367	0.1917	0.0012	0.0012	0.1027	0.1502	0.0367
BA37	0.2927	0.0613	0.0034	0.0384	0.1943	0.0034	0.0034	0.0534	0.1264	0.0384
BA38	0.2539	0.1319	0.0174	0.0259	0.1628	0.0174	0.0174	0.0672	0.1864	0.0259
BA39	0.3086	0.2472	0.0391	0.1641	0.2801	0.0391	0.0391	0.1941	0.3237	0.1641
BA40	0.2647	0.1633	0.0080	0.0915	0.0945	0.0080	0.0080	0.1198	0.1289	0.0915
BA41	0.1682	0.1073	0.0018	0.0925	0.1041	0.0018	0.0018	0.1068	0.1502	0.0925
BA42	0.1519	0.1367	0.0112	0.0842	0.1227	0.0112	0.0112	0.1278	0.1931	0.0842
BA43	0.2545	0.2061	0.0096	0.0983	0.1021	0.0096	0.0096	0.1261	0.1461	0.0983
BA44	0.2881	0.1218	0.0161	0.0136	0.1296	0.0161	0.0161	0.0493	0.1394	0.0136
BA45	0.2267	0.1638	0.0616	0.0496	0.1284	0.0616	0.0616	0.0889	0.1248	0.0496
BA46	0.1941	0.1801	0.0793	0.0783	0.1260	0.0793	0.0793	0.1341	0.1392	0.0783
BA47	0.2974	0.1380	0.0204	0.0347	0.1620	0.0204	0.0204	0.0570	0.1614	0.0347
Amygdala	0.3360	0.0617	0.0029	0.0262	0.1698	0.0029	0.0029	0.0654	0.1221	0.0262
Hippocampus	0.3364	0.0356	0.0011	0.0335	0.1896	0.0011	0.0011	0.0988	0.1171	0.0335

Right Hemisphere	Delta	Theta	Alpha	Beta	High Beta	Alpha 1	Alpha 2	Beta 1	Beta 2	Beta 3
Brodmann Area	1.0 - 4.0 Hz	4.0 - 8.0 Hz	8.0 - 12.0 Hz	12.0 - 25.0 Hz	25.0 - 30.0 Hz	8.0 - 10.0 Hz	10.0 - 12.0 Hz	12.0 - 15.0 Hz	15.0 - 18.0 Hz	18.0 - 25.0 Hz
BA1	0.0916	0.1645	0.0332	0.1501	0.2754	0.0332	0.0332	0.2524	0.1857	0.1501
BA2	0.0965	0.1721	0.0352	0.1562	0.2817	0.0352	0.0352	0.2623	0.1896	0.1562
BA3	0.0758	0.0978	0.0126	0.1217	0.2428	0.0126	0.0126	0.1445	0.1496	0.1217
BA4	0.0825	0.0803	0.0189	0.0510	0.2072	0.0189	0.0189	0.0510	0.1247	0.0748
BA5	0.1307	0.1042	0.0143	0.0689	0.2713	0.0143	0.0143	0.0689	0.2094	0.1982
BA6	0.0800	0.0439	0.0009	0.0282	0.0955	0.0009	0.0009	0.0282	0.0785	0.0551
BA7	0.1296	0.1120	0.0181	0.0870	0.2602	0.0181	0.0181	0.0870	0.1924	0.2290
BA8	0.1205	0.0614	0.0086	0.0969	0.1175	0.0086	0.0086	0.1627	0.1489	0.0969
BA9	0.1096	0.0747	0.0361	0.0885	0.1241	0.0361	0.0361	0.1386	0.1496	0.0885
BA10	0.1067	0.0540	0.0237	0.0253	0.1626	0.0237	0.0237	0.0253	0.0925	0.0718
BA11	0.1182	0.1227	0.0470	0.1420	0.2438	0.0470	0.0470	0.1420	0.2291	0.1538
BA13	0.0794	0.0157	0.0013	0.0194	0.1845	0.0013	0.0013	0.0194	0.0534	0.0468
BA17	0.2878	0.3845	0.2458	0.2848	0.2368	0.2458	0.2458	0.3259	0.2960	0.2848
BA18	0.2065	0.1915	0.1152	0.2227	0.2136	0.1152	0.1152	0.2420	0.2227	0.2454
BA19	0.1769	0.0831	0.0213	0.1100	0.2036	0.0213	0.0213	0.1288	0.1100	0.2129
BA20	0.0210	0.0071	0.0002	0.0043	0.1025	0.0002	0.0002	0.0043	0.0273	0.0128
BA21	0.0179	0.0049	0.0002	0.0073	0.1262	0.0002	0.0002	0.0073	0.0242	0.0140
BA22	0.0182	0.0055	0.0002	0.0070	0.1257	0.0002	0.0002	0.0070	0.0263	0.0151
BA23	0.0833	0.0272	0.0012	0.0124	0.1551	0.0012	0.0012	0.0124	0.0767	0.0665
BA24	0.0798	0.0263	0.0010	0.0144	0.0739	0.0010	0.0010	0.0144	0.0647	0.0690
BA25	0.2622	0.0881	0.0069	0.0553	0.2097	0.0069	0.0069	0.0553	0.1448	0.0938
BA27	0.2463	0.0772	0.0333	0.1895	0.4021	0.0333	0.0333	0.1895	0.2360	0.3086
BA28	0.2979	0.0285	0.0047	0.0657	0.2218	0.0047	0.0047	0.0657	0.1522	0.1241
BA29	0.0663	0.0150	0.0009	0.0410	0.1861	0.0009	0.0009	0.0410	0.0727	0.0665
BA30	0.2474	0.1233	0.0276	0.2288	0.1974	0.0276	0.0276	0.2811	0.3095	0.2288
BA31	0.0791	0.0484	0.0009	0.0247	0.1492	0.0009	0.0009	0.0247	0.0767	0.1005
BA32	0.1364	0.0402	0.0106	0.0255	0.0868	0.0106	0.0106	0.0255	0.0931	0.0693
BA33	0.1576	0.0375	0.0154	0.0857	0.0912	0.0154	0.0154	0.1105	0.1309	0.0857
BA34	0.3093	0.0550	0.0087	0.0923	0.2416	0.0087	0.0087	0.0923	0.2160	0.1262
BA35	0.2415	0.0185	0.0034	0.0440	0.1845	0.0034	0.0034	0.0440	0.0969	0.1060
BA36	0.1096	0.0169	0.0026	0.0226	0.1325	0.0026	0.0026	0.0226	0.0480	0.0522
BA37	0.0681	0.0108	0.0004	0.0167	0.1363	0.0004	0.0004	0.0167	0.0252	0.0237
BA38	0.1192	0.0379	0.0272	0.0505	0.2478	0.0272	0.0272	0.0505	0.0777	0.0789
BA39	0.1884	0.0761	0.0207	0.0902	0.2180	0.0207	0.0207	0.1036	0.0902	0.2563
BA40	0.0454	0.0221	0.0016	0.0419	0.1893	0.0016	0.0016	0.0419	0.0635	0.0714
BA41	0.0377	0.0084	0.0010	0.0211	0.1556	0.0010	0.0010	0.0211	0.0325	0.0459
BA42	0.0232	0.0065	0.0004	0.0118	0.1442	0.0004	0.0004	0.0118	0.0393	0.0297
BA43	0.0471	0.0568	0.0035	0.0433	0.1864	0.0035	0.0035	0.0433	0.1081	0.0686
BA44	0.1077	0.0671	0.0661	0.0709	0.2334	0.0661	0.0661	0.1199	0.1528	0.0709
BA45	0.1187	0.1075	0.1119	0.1064	0.2586	0.1119	0.1119	0.2751	0.2751	0.1064
BA46	0.1347	0.1416	0.1449	0.2125	0.3050	0.1449	0.1509	0.3571	0.3648	0.2125
BA47	0.0976	0.0865	0.0363	0.1413	0.2731	0.0363	0.0363	0.1917	0.2843	0.1413
Amygdala	0.3073	0.0611	0.0103	0.0949	0.2473	0.0103	0.0103	0.0949	0.1880	0.1322
Hippocampus	0.2366	0.0187	0.0033	0.0364	0.1713	0.0033	0.0033	0.0364	0.0624	0.0967

Table II – Group Paired t-test results for Loreta Current Source Density Between the Baseline EEG vs Post Sleeve EEG in all frequency bands and all Brodmann areas.

Figure three shows the results of the paired t-tests between the baseline EEG and the EEG recorded after wearing the pattern sleeve. The MRI slices at 7mm and are sequentially displayed starting at the lowest slice (top left) and advancing in 15 steps to the upper MRI cortical regions. Bilaterally significant differences were present especially in the frontal and temporal lobes and the midline areas of the default network hubs with the largest effects on the medial banks of the two hemispheres.

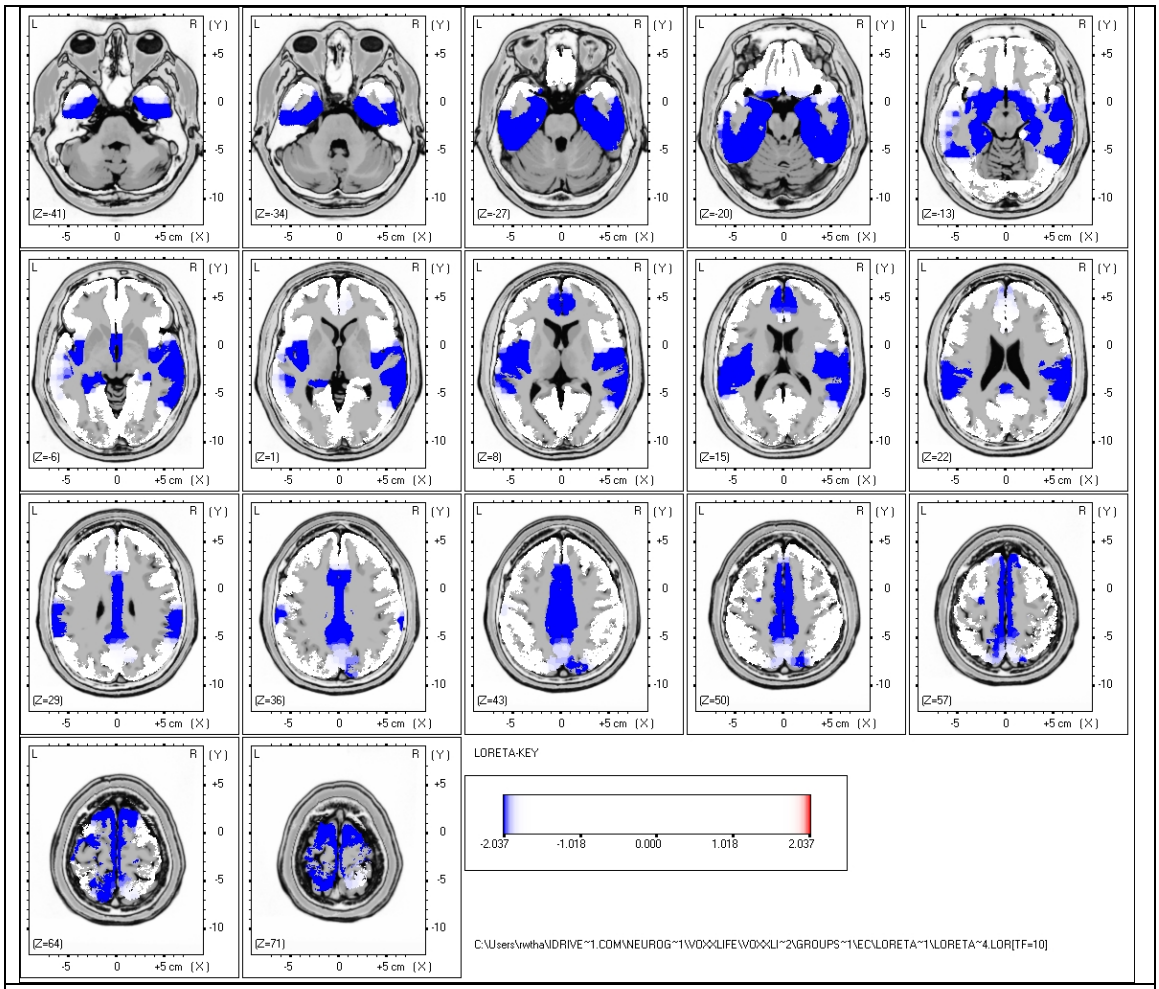

Fig. -3 LORETA paired t-test results from all of the 7 mm slices from the lower cortex (upper left) to the highest cortical slice (lower left) at 10 Hz from P < .05 to P <.0001

Figure four shows paired t-test (P < .0.05 to P < 0.0001) results in the comparison of cortical current densities between the baseline EEG and the EEG recorded during the post sleeve condition. Bilateral significant differences were present. The bilateral frontal lobes, including the sensory motor strip on the dorsal surface as well as the medial wall of the somatosensory projection regions of the arm (Homunculus) is shown at 10 Hz. The

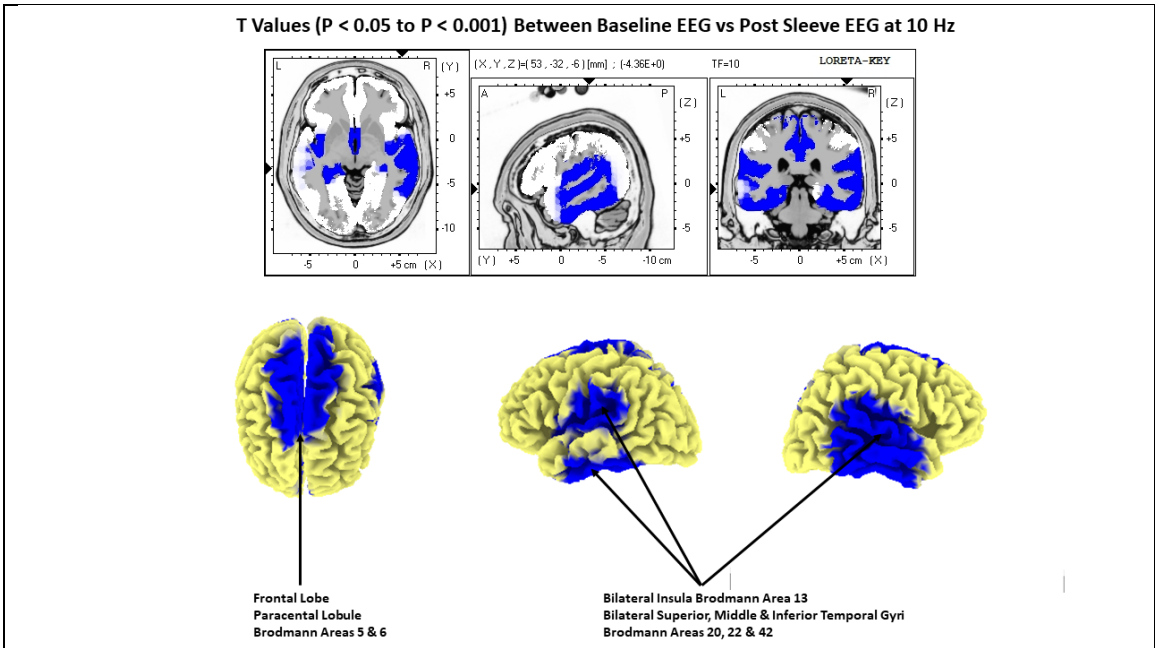

Fig. 4 – Paired t-test (P < 0.05 to P < 0.0001) differences in current density between the baseline EEG and the EEG recorded during the post sleeve condition.

Brain Networks

Table III is a list of the Brodmann areas that comprised the regions of interest as the 10 networks. The Brodmann areas that comprise a given network are based on the fMRI and PET scientific literature which is reviewed in Thatcher (2016).

Lobular Regions				Networks										
FRONTAL	TEMPORAL	PARIETAL	OCCIPITAL	Pain	Attn Dorsal	Attn Ventral	Default Mode	Reward	Mood	Work Mem	Anxiety	Executive	Fr-Occ	Facial Rec
BA4	BA13	BA1	BA17	BA1	BA6	BA10	BA2	BA8	BA10	BA7	BA4	BA5	BA8	BA7
BA6	BA20	BA2	BA18	BA2	BA7	BA11	BA7	BA9	BA11	BA8	BA6	BA7	BA9	BA9
BA8	BA21	BA3	BA19	BA3	BA8	BA19	BA10	BA10	BA13	BA9	BA7	BA8	BA10	BA10
BA9	BA22	BA5		BA4	BA9	BA21	BA11	BA24	BA23	BA24	BA10	BA9	BA11	BA11
BA10	BA27	BA7		BA5	BA19	BA37	BA19	BA30	BA24	BA30	BA13	BA10	BA17	BA17
BA11	BA28	BA23		BA13	BA39	BA44	BA29	BA32	BA32	BA31	BA21	BA11	BA18	BA18
BA24	BA29	BA31		BA24	BA40	BA45	BA30	BA33	BA33	BA32	AMYG	BA46	BA19	BA19
BA25	BA30	BA39		BA32		AMYG	BA31	BA44	BA44	BA33		BA47	BA37	BA20
BA32	BA34	BA40		BA33			BA35	BA45	BA45	BA40			BA45	BA21
BA33	BA35	BA43					BA39	BA47	BA47	HIPP			BA46	BA27
BA44	BA36						BA40	AMYG						BA38
BA45	BA37							HIPP						BA40
BA46	BA38													
BA47	BA41													
	BA42													
	Amygdala													
	Hippocampus													

Table III – List of the Brodmann areas that comprise regions of interest (Lobular Regions) and Networks.

The results of group paired t-tests between the baseline EEG and the EEG recorded with the sleeve on. Table IV shows the percent of subjects that exhibited statistically significant differences. The alpha frequency demonstrated the strongest effects where the Chi Square is statistically significant with 70% or higher. All networks exhibited a statically significant Chi Square ($P < 0.05$) except for the Frontal-Occipital network.

% of Significant T-TESTs Brodmann Areas per LORETA Network @ p<=.05

LORETA Eyes Closed		DELTA	THETA	ALPHA	BETA	HI-BETA	ALPHA1	ALPHA2	BETA1	BETA2	BETA3
LOBEs:	FRONTAL	0%	25%	82%	46%	0%	82%	82%	36%	0%	18%
	TEMPORAL	15%	50%	100%	68%	0%	100%	100%	38%	21%	56%
	PARIETAL	10%	25%	100%	30%	0%	100%	100%	30%	0%	0%
	OCCIPITAL	0%	0%	33%	0%	0%	33%	33%	0%	0%	0%
NETWORKs:	Pain	0%	39%	100%	39%	0%	100%	100%	33%	0%	17%
	Attn Dorsal	7%	14%	100%	21%	0%	100%	100%	21%	0%	7%
	Attn Ventral	6%	13%	81%	56%	0%	81%	81%	31%	13%	44%
	Default Mode	5%	27%	100%	36%	0%	100%	100%	32%	0%	5%
	Reward	0%	33%	88%	50%	0%	88%	88%	33%	0%	21%
	Mood	0%	45%	85%	65%	0%	85%	85%	55%	0%	25%
	Memory	5%	55%	100%	45%	0%	100%	100%	40%	0%	5%
	Anxiety	7%	21%	100%	71%	0%	100%	100%	50%	7%	50%
	Executive	0%	0%	88%	19%	0%	88%	88%	13%	0%	6%
	Front-Occ	0%	5%	60%	25%	0%	60%	60%	15%	5%	15%
	Facial Rec	13%	17%	83%	33%	0%	83%	83%	21%	8%	21%

Table IV – List of the percentage of subjects that demonstrated statistically significant differences in lobules and brain networks between the baseline EEG and EEG recorded with a sleeve on the forearm. The alpha frequency band exhibited the strongest effects.

Discussion

The results of this study showed that the EEG auto and cross-spectrum is effected when a pattern sleeve is placed on a person's arm as compared to a baseline EEG with no patterned sleeve. Twenty out of 20 subjects exhibited statistically significant changes in several brain networks and group statistics were significant for both the surface EEG power and LORETA current density in the alpha frequency band from 9 out of 10 networks.

There was generally a decrease in EEG absolute power in the alpha frequency band (8 – 12 Hz). There were bilateral hemispheric differences, however, the differences were strongest in the left hemisphere compared to the right hemisphere. Surface EEG coherence demonstrated a hemispheric effect of reduced connectivity in the left frontal-occipital locations and elevated coherence in the right frontal-occipital locations. This indicates increased left hemisphere differentiation and increased right hemisphere integration.

Validation of the effects of the somatosensory arm stimulation on the central nervous system was further provided by the finding that LORETA current density consistently increased in the somatosensory projection areas on the medial surface of the somatosensory cortex. Bilateral frontal lobe Brodmann areas exhibited the largest t-test differences (99.9%) in the alpha frequency range (e.g., 8 Hz – 12 Hz) and especially in left hemisphere Brodmann areas. The effects of the arm sleeve on the electrical energies of the brain were evident especially in frontal and temporal and parietal lobes.

Another finding is the sleeve is correlated with reduced current density of the EEG in the default network which is important in directed attention. The default network is most active when one is alone and ruminating one's self-narrative and is inhibited when one attends to the outside world (Fox et al, 2005; Sridharan et al, 2009). This indicates that the sleeves reciprocally turn off or reduce one's self narrative which is important for enhanced attention to objects and events located in the external world.

The exact mechanisms of action of the arm sleeve pattern on the somatosensory system are currently unknown. At least three hypotheses are: 1- The process of placing a sleeve on the arm effects the EEG spectrum independent of the pattern, 2- Dishabituation occurs because of the novelty of a sequence of edges that stimulate the forearm, 3- The specific properties and nature of the pattern making contact on the forearm is responsible for the EEG effects. Future studies are planned to compare a sleeve with no pattern to a patterned sleeve and also to compare different patterns to further understand the nature of the somatosensory effects of patterns on the brain.

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