Clinical Neurophysiology 128 (2017) 512–519

Contents lists available at ScienceDirect

Clinical Neurophysiology

journal homepage: www.elsevier.com/locate/clinph

DC-EEG recordings of mindfulness

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ARTICLE INFO

Article history:
Accepted 29 December 2016
Available online 26 January 2017

Keywords:
DC-EEG
Mindfulness
Infraslow
DC-shifts
Delta
Independent component analysis
Yoga Nidra

HIGHLIGHTS

- DC-EEG recordings revealed, in normal subjects, rhythmic waves lasting tens of minutes.
- Some channels did not return to the baseline within one hour indicating the presence of even slower activity.
- Archived EEG data that were obtained with DC amplifiers should be assessed for ultra-long wave durations.

ABSTRACT

Objective: To assess the frequency spectrum of the normal waking human eyes-closed EEG while concentrating on a mental task.
Methods: Ten adult normal volunteers listened to a CD encouraging mindfulness for one hour and five minutes while their EEG was recorded on a 128 channel DC based ANT system. The software package BESA Research version 6.1 was used for data analysis. The data were subjected to topographic display, frequency as well as independent component analysis.
Results: Near-DC activity that extended beyond one hour, as well as rhythmic wave durations ranging from about 10 to 35 min, was observed in all subjects. For this task the major topographic distribution was mainly in frontal near midline areas and the inferior portions of the hemispheres.
Conclusions: The study demonstrated that rhythms below the infraslow band, as well as a near-DC component, exist in the normal human EEG. Their significance for health and disease now needs to be explored.
Significance: Since DC-based EEG/MEG systems are already in use by some laboratories, investigators are encouraged to include the exploration of these ultra-slow waves in the review of their data.

1. Introduction

The advent of digital EEG systems with input filters ranging from 0.1, 0.03, and 0.012 Hz have allowed the investigation of cerebral electrical activity below the previous analog systems limit of 0.5 Hz. It has been shown that infraslow activity in the range of 0.01–0.1 Hz (ISA) can provide additional valuable clinical information especially in regard to seizure onset in epilepsy patients. A recent review of the topic contains the major references (Rodin, 2015). Several additional clinical studies have subsequently been published (Myers et al., 2014; Wu et al., 2014; Kanazawa et al., 2015; Bello-Espinosa, 2015; van Putten et al., 2015; Thompson et al., 2016; Rodin et al., 2016).

Nearly all of these studies used conventional AC-coupled amplifiers and even when DC-coupled amplifiers were employed the investigators limited themselves to the infraslow range and presented data with analysis epochs of several seconds or up to 4 min. Yet, extensive experimental animal studies that had been carried out during the middle of the past century with DC amplifiers, had shown important changes in the EEG that could not have been observed with AC systems. O'Leary and Goldring provided a detailed review of the literature up to 1964 which is a valuable resource (O'Leary and Goldring, 1964). Among these were: ictal onset negative baseline shifts that preceded changes in the

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http://dx.doi.org/10.1016/j.clinph.2016.12.031
1388-2457/

conventional frequency band by several minutes, as well as baseline shift changes, from negative to positive, related to the waking alert, relaxed, drowsy and sleeping state and brief negative shifts in the appropriate area with sensory stimulation. The article also contained an extensive review of Aladjalova's work on rhythmic activity in the infraslow range (Rodin, 2015).

Since DC amplifiers showed slow drifts, which intermittently necessitated resetting the baseline, clinical DC-EEG studies were not pursued with the exception of Cohn who demonstrated a negative baseline shift at the onset and for the duration of absence seizures (Cohn, 1954, 1964). The finding was subsequently confirmed by Bates (1963) as well as Chatrian et al. (1968). The only DC studies that described rhythmic activity with wave durations of "decaminutes" were carried out by Aladjalova and co-workers in the Soviet Union. These investigations, involving animals, were first reported in an English language publication in 1957 (Aladjalova, 1957) and subsequently summarized in a monograph, which also included preliminary human observations (Aladjalova, 1964). The only detailed English language report on human subjects dealt with the effects of hypnosis in 15 "neurotic" patients (Aladzhalova et al., 1978). With increasing depth of hypnosis rhythms lasting tens of seconds ("decaseconds") as well as those with wave duration between 2 and 4 min became apparent. A PubMed search failed to reveal a replication of this study or other investigations of DC-EEG studies in patients or normal subjects with file length of more than 5 min.

In 2013 the Psychiatry Department of the University of Utah acquired a DC based 128 channel ANT system and preliminary investigations dealing with a variety of evoked response paradigms were undertaken on a number of normal volunteers. When the background EEG of these studies was viewed with different frequency bandwidths it became apparent that with file lengths of up to 30 min the curves showed shifts in most channels that did not return to the baseline over this time span. Since the software used for our investigations (BESA Research version 6.1) had an upper limit of 60 min display time it was decided to use a test paradigm that extended over this period and only required mental attention without any physical movement. A commercially available CD on Yoga Nidra – Yogic Sleep (YN) was chosen for this purpose (Swami Jnaneshvara Bharati). It is advertised as inducing "conscious deep sleep" and plays for one hour, five minutes and 36 seconds. The purpose of the investigation was to determine the frequency spectrum of the relaxed but attentive adult waking human EEG during the mentioned time period with emphasis on what the longest wave duration might be. Possible specific Yoga Nidra effects were regarded as a byproduct that will be investigated in the future.

2. Materials and methods

The subject pool consisted of 10 normal volunteers who had expressed interest in meditation practices. An informed consent was signed, the data were anonymized at the source and the study design was consistent with the ethical standards of the Belmont Report, and the Declaration of Helsinki. There were 5 females and 5 males in the cohort ranging in age from 26 to 90 years, with an average age of 41.2 years.

A 128 channel DC based ANT system was used to register the data and amplifier drift, after a warming up period, was certified by the company as not exceeding about 5 μV. The amplifiers were turned on one hour before the subjects were tested to allow adequate warm up. The subjects were fitted with an ANT *Waveguard* cap consisting of 128 sintered Ag/AgCl electrodes connected to shielded wires. An additional set of 2 bipolar electrodes were connected with one lead below and one above the right eye to measure eye movements. The cap was positioned using standardized 10–20 measurements with Cz serving as the primary reference point and the symmetrical distribution of the remaining electrodes was checked. The electrodes were attached to the scalp using Grass EC2 Electrode Cream slightly diluted with 10 ml of water to 100 g of paste to allow slightly decreased viscosity for application into the electrode port. The electrode impedance values were checked and adjusted using light abrasion until all impedance values were at 50k Ohm or less. The subjects were asked to position themselves comfortably and were allowed as much time as needed for adjustments to ensure maximal comfort with a relaxed posture while sit-

Table 1
Amplitude and localization comparison of delta, ISA and near-DC activity for the three highest regions.

1			
Delta	FpM 14.7	TAL 9.6	TAR 6.2
ISA I	FpM 270	TAL 258;	TAL 169
ISA II	FpM 1340	TPL 1257	CL 1257
ISA III	FpM 12857	TPL 10791	CM 9167
2			
Delta	FpM 3.9	TAL 2.8	FL 1.9
ISA I	FpM 164	TAL 119	CL 112
ISA II	FpM 11695	TAL 1022	FM 872
ISA III	FpM 20058	CR 15135	FR 12153
3			
Delta	FpM 4.3	TAR 2.4	TAL 2.3
ISA I	FpM 103	TAL 79	TAR 68
ISA II	TAL 1288	FpM 610	FR 452
ISA III	TPL 6528	TAL 6524	TAR 4729
4			
Delta	FpM 3.7	TAL 3.0	OpM 3.0
ISA I	FpM 107	TAL 88	FL 60
ISA II	TPR 541	TAR 486	FFL 384
ISA III	FpM 12389	TAR 11205	CR 7347
5			
Delta	TAR 4.4	FpM 4.2	TAL 3.9
ISA I	FpM 155	TAL165	TAL 137
ISA II	FpM 3008	FR 1386	TPL 1249
ISA III	TAL 10691	FpM 7761	FM 11864
6			
Delta	FpM 3.3	TAL 2.4	TAR 2.4
ISA I	FpM 111	TAL 58	TAR 53
ISA II	TAR 621	FpM 537	TPR 354
ISA III	TAL 10387	FL 5463	TPL 5545
7			
Delta	FpM 9.5	TAL 7.1	TAR 6.7
ISA I	FpM 1227	TAL 760	TPL 745
ISA II	TAR 3243	FpM 2982	TPL 1838
ISA III	FpM 24554	FL 13038	TAL 10155
8			
Delta	TAR 4.9	TAL 3.9	FpM 3.9
ISA I	TPR 243	FpM 109	PL 89
ISA II	TPR 798	TAR 766	FpM 572
ISA III	TAR 13277	TPR 10743	TAL 10687
9			
Delta	TPR 3.1	TAL 2.9	FpM 2.7
ISA I	TPR 90	TAR 84	FpM 81
ISA II	FpM 673	TAL 639	TAR 612
ISA III	TPR 8526	CR 7929	FPM 7354
10			
Delta	FpM 3.8	TAL 3.3	TAR 2.8
ISA I	FpM 159	TAR 124	TPL 112
ISA II	FpM 991	TAL 961	OpM 696
ISA III	FpM 27715	TAL 10750	FL 10050

Amplitudes reflect source strength in nAm for a one hour recording.
Delta 0.5–3 Hz, ISA I 0.01–0.1 Hz, ISA II 0.001–0.1 Hz, ISA III 0.0002–0.001 Hz.
Abbreviations: CM central midline, CL central left, CR central right, FpM frontopolar midline, FL frontal left, FR frontal right, FM frontal midline, OpM occipital midline, PL parietal left, PR parietal right, TAL temporal anterior left, TAR temporal anterior right, TPL temporal posterior left, TPR temporal posterior right.