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# A new experimental method to verify psycho-physiological phenomena

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**Abstract.** The relaxation methods and in general the body expression techniques (massage, reflex therapy, shiatsu, gymnastics, stretching, yoga, meditation, autogenic training and more), have beneficial effects on the state of health. The measurement of some electrical properties of the skin is able to verify the effectiveness of the techniques indicated in the Anglo-Saxon literature with the generic term of Wellness. William A. Tiller, lecturer emeritus at Stanford University (CA), has created a circuit, referred to in the literature as the Tiller Relaxation Circuit, capable of inducing a state of well-being and relaxation in human subjects. It's the first time that relaxation methods are tested with a device of advanced electronics able to quantify biophysical or psychological response in terms of the values of a function – the electrocutaneous potential – directly measured on consenting subjects; and that the relationship between special aspects of the state of health and values of a function are obtained by means of a reproducible experiment in which is well known what we measure.

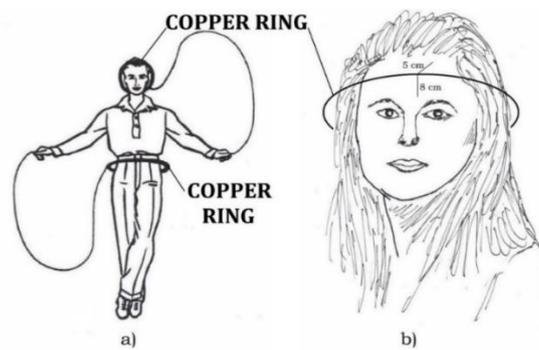
## 1. Introduction

William A. Tiller (b. 1930), was a researcher at the Westinghouse laboratories until 1964 and later was a Professor of Materials Science at Stanford University, California, until 1992, the year of his retirement. He is currently professor emeritus of the latter university. Tiller has written texts and articles on the physics of semiconductors and insulators [1]. Tiller's research work is summarized in [2, 3]. In the September 2018 Tiller published an interesting article [4] in which he describes a circuit indicated in the literature as the *Tiller Relaxation Circuit* (Figure 1).

With reference to Figure 1, the Tiller Relaxation Circuit consists of two copper rings. The first, which wraps the head diagonally, is in contact with the base of the neck and is about two inches (5.08 cm) from the face. It passes 3 inches (7.62 cm) above the eyebrows (Figure 1b). The second copper ring is located around the waist and is in contact with the base of the spine. The diameter of the ring must be large enough to easily pass over shoes and trousers. The ring, in the upper part, is 2-3 inches (5.08-7.62 cm) from the body. According to Tiller, using, lying on a bed, with the head not necessarily oriented to the north, the arrangement of Figure 1a, there is a strong sensation of energy flowing in the body. The intensity of this energy is sometimes very intense in some parts of the body. After half an hour "in the circuit" you feel very relaxed, energetically charged and mentally concentrated for the next 6-10 hours. Tiller suggests using relaxation circuit early in the afternoon. Tiller, in an "unorthodox" way, used a clairvoyant friend to scrutinize and examine what happens in his relaxation circuit. The latter described what happens when a tired and mentally exhausted person (in the specific



case of Tiller) uses copper rings. The clairvoyant “saw” a bright spot forming first on the left shoulder and then on the left coxa; subsequently some form of energy, in the form of a shiny strip, began to flow between the shoulder and the coxa. Later, the energy began to flow into the legs and the right coxa lit up. Eventually, the whole body glowed with a pink light. Tiller had the *psychosensory experience* of feeling an “energy flow” moving up and down rhythmically. The whole phenomenon was accompanied by relaxation of the body and the sensation of being energetically charged.



**Figure 1.** a) Tiller Relaxation Circuit; b) Detail of the ring that wraps the head.

## 2. The purpose of the research

Tiller generally believes that most of the different relaxation and self-healing techniques are valid. These practices are most effective only if performed after a session with the rings. The positive influence of rings requires further experimental evidence and the interpretation of why it is effective. Without expecting an interpretative theory of the phenomenon in question, which sometimes requires generations of scientists, we have submitted the hypothesized “cause-effect” correlation to experimental verification, that is, to measurements performed by the group of researchers of CIRPS engaged in the project Quantitative analysis of the bioelectrical potential and impedance that characterize particularly active skin points in normal subjects. Therefore, we have experimentally verified the possible action of the Tiller rings on the skin potential in the general picture of the state of health, following a measurement protocol prepared by the coordinator of BEM section of CIRPS, Prof. Massimo Scalia, who together Prof. Sperini have designed the device of advanced electronics used for the experimental tests: APEC 300 (see below) [5]. The latter was created by the electronic engineer Mauro Santilli<sup>b</sup>. All these three researchers have followed with us the phase of measurements, given their operational delicacy.

In order to verify whether the use of the “Tiller rings” shows any effect on our body, the connection between the sensations experienced during the use of the circles and an important physiological parameter was examined: EDA, that in the international scientific literature is the acronym of Electro-Dermal Activity and indicates the electrical properties of the skin.

The sweat activity of the palm of the hand modulates change in electrical conductance of the skin. The variation in conductivity is directly proportional to the skin potential. Electrical conductance and

Psycho-sensory phenomena are sensations comparable to perceptions, but without the presence of an object. They include both mental images and hallucinations; they can be considered as illusions or external realities from our consciousness.

CEO of Metro-Calibration-Service (MCS) skin potential are the electrodermal activity (EDA) signal. EDA since 1879 has a history in psychophysiological study, including emotional or cognitive stress. EDA has applications like the assessment of fatigue, pain, sleepiness, state of relaxation, exercise recovery, diagnosis of epilepsy, neuropathies, depression, and so forth [6, 7].

The advent of new devices like APEC]has increased the development of novel signal processing techniques to provide a more sophisticated analysis of EDA, beyond the traditional tonic/phasic decomposition of the signal [8, 9, 10].

The possibility to detect whether an individual is becoming relaxed is important and of interest when considering the relaxation techniques as a tool to improve personal welfare. These techniques are based on interpreting the physiological signals of the subject. When a person relaxes there are certain physiological changes that take place in the organism. There exist several physiological signals that can be useful to evaluate the state of relaxation, between these respiration, cardiac activity, sweating and other [11].

The EDA determines the state of relaxation of the subject using sweating, revealed as the change in conductivity or the skin potential [12, 13]. A new method of skin potential analysis is presented in this article for the first time. In addition to its capability to show relaxation, skin potential has the advantage that it can be collected noninvasively using skin contact electrodes.

### 3. APEC 300: electro-cutaneous parameters analyzer

The “protagonist” of the present research is a device of advanced electronics, APEC-300 (Figure 2), which is able to perform on biological and non-biological materials, two fundamental types of measurement:

- exceedingly small potential differences;
- impedance at low frequencies.

These two measures can be performed, besides that on human body districts, also on biological systems up to the cell cultures.

In general, differently from the measurement of the potential, the impedance measurement is performed by applying an electrical stimulation. Furthermore, APEC-300 is an electronic device capable of stressing biological and non-biological materials, with current and voltage waveforms.

The first two types of measurement can be performed on water and aqueous solutions, inorganic solid bodies, on districts of the human body and cell cultures.

In particular, in biological systems, in the field of electrophysiology, the skin potential is the expression of the electrical activity of the skin organ (epidermis + dermis + subcutaneous) and its measurement can be performed directly with APEC-300, recording through of the electrodes the signals of this activity with the same modalities with which one proceeds with the electrocardiogram (ECG) and the electroencephalogram (EEG). The skin impedance characterizes the electrical properties of the skin organ (resistance and capacity) and the measurement is performed with particular electrodes to which an electrical voltage or current is applied.

In the potential configuration we can measure a) the potential difference (p.d.) between two areas of a body (solid or liquid); b) between two areas of a body related to the mass; c) the potential of an area of the body. In particular APEC-300 is able to measure the bioelectric signals detected on the surface of a biological system (plants, animals, cell cultures, etc.); and skin.



**Figure 2.** Image of APEC 300, by the company MCS s.r.l. of Pomezia, Rome, Italy.

In summary, APEC-300 has been designed, built and calibrated in order to perform the measurements of p.d. and impedance not only on areas of the human body but also on water and aqueous solutions, cell cultures, solid inorganic bodies.

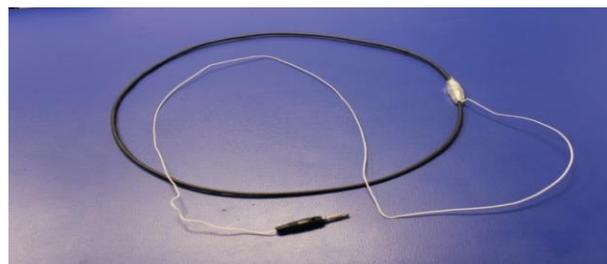
The measurement frequency extends in the range from 0 to 30 Hz and the minimum detectable voltage value is 100 nV ( $1\text{nV} = 1 \text{ nanovolt} = 10^{-9} \text{ Volt}$ , i.e. one billionth of a Volt). The duration time of the single recording can be adjusted up to a maximum of 300 s and is stored.

APEC-300 is endowed with an its internal software able of producing, for each measurement of the potential level as a function of time, a frequency analysis, that is, the Fourier components to the different orders. This particular performance allows to associate to each measure a kind of electromagnetic footprint, typical of an inanimate body, an aqueous solution, of the body district, of the organism, – animal, vegetable – or the cell culture, which are under examination.

#### 4. Materials and methods

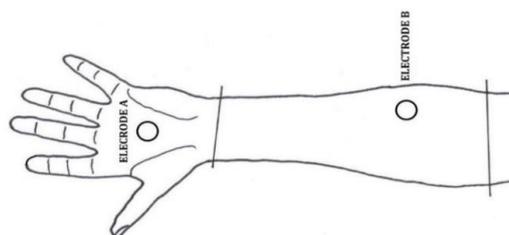
The experimental tests were carried out in the period February-July 2019. The rings used were made, as already indicated, by Mauro Santilli (Figure 3). The potential difference was measured between two points on the skin surface, respectively the palm and forearm of the left hand (Figure 4).

We report below the values of the environmental parameters of the laboratory where the measurements were made, more in homage to the correct experimental protocol than to a real need. In fact, if there are no drastic changes in the laboratory conditions, the experience of countless measurements carried out over decades in conditions of significant variation in temperature, humidity, pressure, etc., have confirmed that these variations are not of particular significance with regard to the quantities which translate a bioelectrical activity of our organs. This phenomenon is also true for the EEG and the ECG.



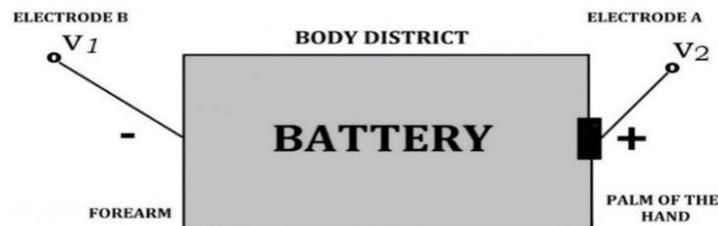
**Figure 3.** Image of the ring made by MCS s.r.l. of Pomezia, Rome, Italy.

The environmental parameters of the laboratory where the measurements were carried out were checked. The ambient temperature  $T$  remained in the range (21.2-26.1) °C; the temperature gradient  $\Delta T$  during each single measurement never exceeded the value of 1.2 °C. The relative humidity  $U\%$  varied from 44.8 to 57.3. The lighting was included in the range (17–33) lux. The average value of the electric field at 50 Hz, present in the room, was for the whole duration of the measurements of 2 V/m (with fluctuations, positive and negative, lower than 5%) while the magnetic one was 0.01  $\mu\text{T}$  (with value of the fluctuations similar to the electrical one). The average value of the electrical component of the electromagnetic field, in the range 50 MHz - 3.5 GHz, varied in the range (71.0 - 82.0) mV/m, values twenty times higher than the maximum deviation recorded in each single measurement.



**Figure 4.** Position of the electrodes on the left hand. The two electrodes (A and B), model for ECG, are connected to the APEC-300 by means of shielded cables (BNC – BNC). With this arrangement, the output voltage is the measure of the potential difference (p.d.) between the two points of the skin under examination.

We can imagine the potential difference  $\Delta V$  that we measure between the palm of the hand and forearm as a battery (Figure 5), in which the positive (+) pole is the palm ( $V_2$ ) and the negative (-) the forearm ( $V_1$ ). In the skin of the hand, unlike that of the forearm, there are many endings of the vegetative nervous system (VNS). The hypothesis to be verified is: if the VNS is influenced by the use of the rings: any change in the skin potential must be experimentally observable.



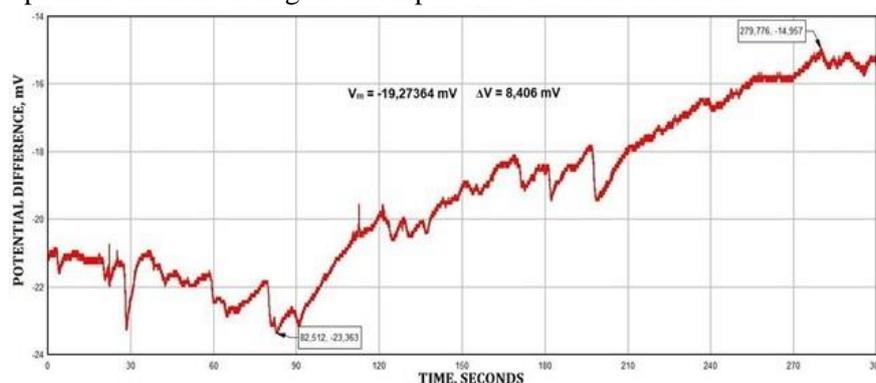
**Figure 5.** Analogy between the battery and two points on the skin surface.

Eight subjects, three males and five females, aged between 37 and 67 years, were examined several times, for a total of 12 measurements. The latter lasted 300 s (5 minutes). The first series of measurements was performed in the absence of observable external stresses, the second series in the same conditions as the previous one but after using the rings for twenty minutes.

How we proceeded on each of the subjects who participated in the experimentation will be shown for only one of them - Figure 6, Figure 7 and Figure 8, Table I and II - which will be conventionally indicated as "number 1".

There are several parameters to be taken into consideration when measuring the p.d., Figure 6 examines the time course of the skin potential of subject number one (MEASURE 1), before the use of the Tiller rings.

By analyzing Figure 6 it is possible to determine, in the absence of stimulation (BEFORE USING RINGS), the average value  $V_m$  (the average of all the individual readings of the potential in the 300 s of measurement) and the difference  $\Delta V$  between the maximum and minimum value of the potential skin between hand and forearm detected during the measurement. This last value provides an indication of how much the skin potential fluctuates during the measurement. In particular, we obtain  $V_m = -19.27364$  mV and (in absolute value)  $\Delta V = 8.406$  mV. The minus sign indicates that the potential of the palm of the hand is negative compared to that of the forearm.



**Figure 6.** Subject 1. Time course of skin potential. Full scale 50 mV. Duration Measurement between palm and forearm before stimulation 300 s.

After using the rings, or after stimulation, a new measurement is performed (AFTER USING THE RINGS), in the same way as the previous one. In this way it was possible to collect for all 12 measurements (eight subjects) the data reported in Table I. The trend over time of the skin potential in the absence of stimulation (Figure 6) was then studied in relation to the frequency (Figure 7 and 8).

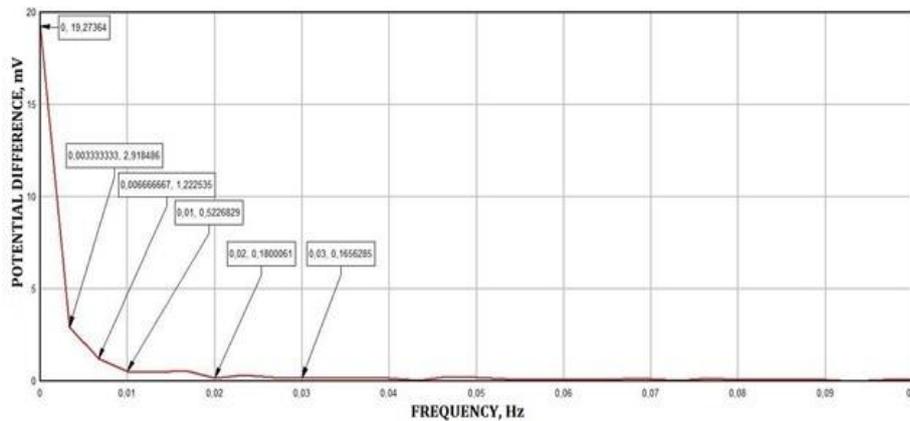
**Table 1.** Skin potential.

MEA SURE	BEFORE USING RINGS		AFTER USING RINGS		V %	OSC	C
	V <sub>m</sub> mV	ΔV mV	V <sub>m</sub> mV	ΔV mV			
1	-19.27	8.41	-15.41	4.88	+ 20	D	R
2	-24.06	4.20	-9.83	3.91	+ 59	D	R
3	-6.71	8.11	-7.46	6.26	- 10	D	R
4	-5.66	3.03	18.99	32.26	+ 81	A	R
5	-1.45	5.28	-9.58	3.23	- 88	D	R
6	24.33	25.03	-15.68	5.67	- 61	D	R
7	-5.45	13.92	-5.94	9.97	- 8	D	R
8	-4.07	4.11	-6.80	5.96	- 40	A	
9	-8.40	14.27	-2.20	14.96	+ 74	A	
10	-7.98	18.48	-4.65	0.09	+ 42	D	R
11	-7.81	12.90	-13.19	9.78	- 41	D	R
12	-7.59	15.35	17.64	35.68	+ 70	A	

Notes: V<sub>m</sub>, indicates the measure of the average value of the skin potential; ΔV, is the extent of the oscillation of the skin potential in absolute value. In the sixth column, the + sign indicates that the use of rings has resulted in a decrease in the average negative value of the potential of the palm of the hand (expressed as a percentage); the - sign, on the other hand, means an increase in the negative potential of the palm of the hand. In the seventh column OSC indicates the excursions of the skin potential (D means that they decrease, A, that they increase). The eighth column, marked with the symbol C, indicates the sensation felt by the subject after staying in the rings: the presence of the letter R indicates a state of relaxation.

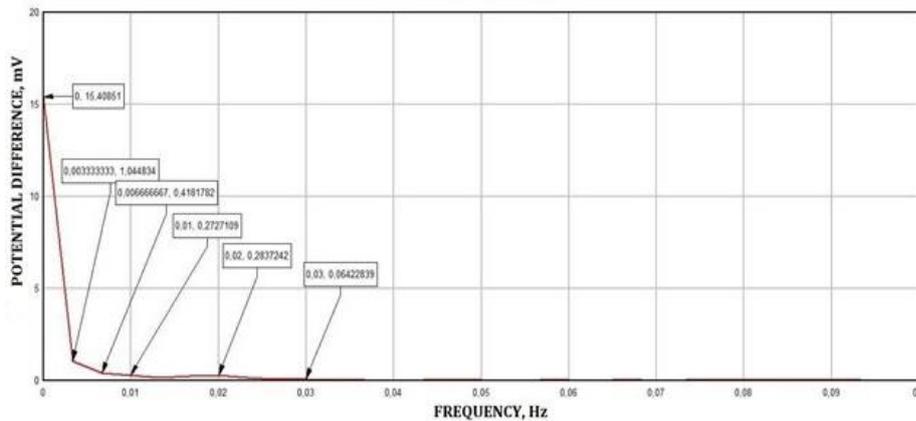
This “frequency spectrum”, as the graph of Figures 7 and 8 is mathematically called, is made possible by a sophisticated software inside APEC-300 which is able to produce the “Fourier transform”, that is the spectrum in frequency, of the curve of Figure 6. It is the “electromagnetic footprint” mentioned at the beginning. Known the meaning that we attribute to them, in the graphs of Figures 7 and 8 are shown the Fourier transforms of the time course respectively before and after stimulation (USE OF RINGS), referring for the data of the two figures to Table II.

Figures 7 and 8 are the graph of the frequency spectrum, from 0 to 0.1 Hz of subject number one: respectively before the use of the rings and immediately after the use of the rings. Before stimulation (Figure 7) the zero-frequency potential value was about 19 mV and the first three frequency components were 2.92 - 1.22 - 0.52 mV. After stimulation (Figure 8) the value of the potential at zero frequency decreased, passing from 19 mV to about 15 mV. The first three frequency components also decreased, passing to 1.05 - 0.42 - 0.27 mV.



**Figure 7.** Subject 1. Spectrum of skin potential. Full scale 50 mV; Duration Measurement between palm and forearm before stimulation 300 s.

It is important to immediately note that in Fig. 7 and 8 the frequency spectrum ranges from 0 to 0.1 Hz. The maximum information is obtained only in such a limited range and, above all, in an extremely low frequency range (Ultra Low Frequencies). In fact, the part of the spectrum for frequencies above 0.1 Hz does not provide interesting data for any of the eight subjects examined.



**Figure 8.** Subject 1. Spectrum of skin potential. Full scale 50 mV; Duration Measure between palm and forearm after stimulation 300 s.

**Table 2.** Frequency analysis of skin potential.

FREQUENCY Hz	PEAK VALUE mV before stimulation	PEAK VALUE mV after stimulation	MEAN VALUE mV before stimulation	MEAN VALUE mV after stimulation
0	19.27364	15.408510		
0.00333	2.918486	1.044834		
0.00666	1.222535	0.418178		
0.01	0.522683	0.272711		
0.02	0.180006	0.283724		
0.03	0.165629	0.064228		
GRAPHIC STUDIED 0 - 0,1 Hz				
0.00 - 0.01			5.984336	4.286057
0.01 - 0.02			0.440146	0.225567
0.02 - 0.03			0.221592	0.176409
0.03 - 0.1			0.112293	0.032706

Notes: [0 - 0.1] Hz frequency spectrum for subject number one. The lower part shows the average values of the potential per frequency range of the spectrum, which decrease in all ranges.

**Table 3.** Frequency spectrum data for 0 - 0.0033 - 0.0066 - 0.01 Hz for all the tests performed.

MIS	Before using rings				After using rings			
	Peak Value V [mV]							
	Frequency [Hz]							
	0	0.0033	0.0066	0.01	0	0.0033	0.0066	0.01
1	19.27	2.91	1.22	0.52	15.41	1.05	0.42	0.27
2	24.06	1.11	0.39	0.30	9.83	0.23	0.35	0.32
3	6.71	2.34	1.36	0.63	7.46	1.23	0.99	0.36
4	5.66	0.89	0.35	0.10	18.99	16.07	6.19	1.89
5	1.45	1.02	0.62	0.42	9.58	0.11	0.11	0.11
6	24.33	7.45	3.37	0.94	15.68	0.91	0.26	0.31
7	5.45	2.39	1.44	0.94	5.94	2.36	1.34	0.79
8	4.07	0.37	0.59	0.46	6.80	0.55	0.93	0.78
9	8.40	3.73	2.01	1.35	2.20	5.29	0.56	1.01
10	7.98	4.90	3.08	1.78	4.65	0.02	-----	0.02
11	7.81	2.56	1.14	1.04	13.19	1.33	2.18	0.86
12	7.59	6.01	2.02	1.08	17.64	7.58	4.37	2.65

## 5. Results and discussion

The Table 3 reports the values of the spectral components, with two significant figures, for the 12 measurements performed.

The use of the rings in three out of twelve tests resulted in a variation in the value of the modulus of the p.d. average ( $V_m$ ) of the subject, not exceeding  $\pm 20\%$ . In all other cases the variation was equal to or greater than 40%. The use of the rings in eight out of twelve tests (sizes from 1 to 3, from 5 to 7 and 10 and 11) determined the decrease in the amplitude of the excursions over time of the skin potential - (the oscillations; in Table 1 the OSC column). In two cases the increase in oscillations is contained, while in the other two there is a significant increase (57% and 90%).

In general, the eight subjects in which the excursion of the skin potential decreases, regardless of whether the palm potential after the use of the circles becomes more or less negative, show a tendency towards a decrease in the amplitude of the first three components of the spectrum (0.00333, 0.00666 and 0.01 Hz); in particular of the first component. The opposite occurs for cases in which the range of variation of the skin potential increases.

In two measures (8 and 11) the first component of the spectrum has the smaller amplitude of the next (in gray in Table 3). The significance of this "particular" trend is not known at the moment. In measures 1 to 7 and 10-11, after staying in the Tiller rings, the subjects felt relaxed (letter R in the eighth column of Table 1). In measures 8 and 9, the subjects experienced a sense of chest tightness when using the rings. In measure 12 the subject, in the three days preceding the test, had suffered from pain due to inflammation of the cervical. Finally, in test 4, the subject had vivid "daydreams" during the stimulation with the rings.

## 6. Conclusions

It has been hypothesized that the use of copper rings is able to modify our psychophysiological parameters, in particular the electrical activity of the skin. The scientific literature we refer to motivates why measurements of skin parameters are more reliable to verify psychophysiological response when the electrodes are in position of Figure 4 (palm of hand/forearm): an increase in the

level of skin resistance in states of relaxation and a decrease in alertness. In psychophysiology, it was preferred to study the VNS through measurements of skin impedance at zero frequency, while, for historical and mainly for technical reasons, the measurement of skin potential has been little used. On the contrary, we believe that the latter, especially the frequency spectrum of the skin potential, are tools capable of reproducing the two different states of alertness and relaxation more faithfully than measuring impedance; and we present in this paper the first ever skin potential spectrum experiments.

This preliminary study with APEC-300, in the case in which external stimulation is realized by the Tiller rings, indicates that in the transition from the physiological state of alertness to that of relaxation it is possible to measure: a change in the modulus of the amplitude of the skin potential  $V_m$  (between the palm and forearm of the left hand);

- a decrease in the change in the skin potential  $\Delta V$  in the time course of the measurements;
- a decrease in the amplitude of the peak value  $V$  of the first component (0.00333 Hz) of the skin potential spectrum.

The number of tests performed is low to adequately support the statistical validity of the association between the presence, or absence, of the “stimulation”, the rings, and a measurable difference in skin potential or in skin potential spectrum between “before” and “after” stimulation. Anyway, even if our results are statistically limited, they are more rigorously drawn than the comparable ones in literature and our conclusion are generally in line with those of the articles [9, 11, 12] and [13].

All the results provided in this article have not yet been published in scientific journals.

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