Co-Evolution Among Bodies: An Investigation With Brain Signals

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Abstract

This article aims at using a specific artificial neural network , the KSON (Kohonen Self-organized Network), as a means of observing the brain signal patterns acquired as a result of training that network with several visual stimuli subjects induced respectively by observing and imagining a small set of specific dance and daily movements.

The signals used were gathered using an EEG equipment with sixteen channels and two groups of subjects: artists and non-artists, both exposed to exactly the same stimuli.

Two different experiments were carried out based on the results produced by the artificial neural network: from all the available signals regardless of the groups, and from the two groups. The first experiment compared the KSON's outputs produced respectively by three different stimuli processes from the same movement: observation, imagination and basal; the second one compared the KSON's outputs produced respectively by the two groups, i.e. artists and non-artists.

Three arithmetic indexes were determined from the results obtained and these indexes led to the following conclusion :

- Artists and non-artists presented different perceptions of the exhibited movements, but the amount of information obtained from those movements, mainly from the daily ones, was more significant for the artists' group than the non-artists' one;
- For certain movements the differences among the observation, imagination and basal brain signals were greater than for others. Nevertheless, there was no clear pattern for those differences which could point to an evident distinction between the dance and daily movements;
- Dance and daily movements are not distinct in the brain processes here analyzed.

Keywords: Dance, Brain Signals, Artificial Neural Net, Art, Science, Technology.

1. Introduction

There is a popular supposition among philosophers, still polluted by Cartesian thought, that the brain processes responsible for cognition belong to one category and the brain processes responsible for motor control belong to a completely different one. [CHUR,97]

However, from the neurobiological and evolutionary point of view , 30% of the fibers that compose the spinal-cortical and bulbar-cortical treatments come from the motor cortex, 30% from the pre-motor cortex and 40% from the parietal lobe, especially of the somatic sensorial area. [GANO,95]

Stimulation in the cortical areas, where the spinal-cortical and bulbar-cortical systems originate, immediately produces a different movement . Of these areas, the motor cortex is the best-known . However, there is a supplemental motor area on the medial side of the hemisphere that reaches the pre-motor cortex on the lateral surface of the brain.

Because of this , motor answers are also produced by the stimulation of the first sensorial somatic area in the post -central turn, and for stimulation of the second somatic sensorial area, in the wall of the Sylvius fissure. [GANO, 95]

In this sense and allied to this point of view, this research used the digital processing signals techniques applied to the interface brain computer (BCI - Brain Computer Interface) to investigate the mental representations, starting from the reflexes of the neural activities that occurred during the observation and imagination processes of the execution of dance and daily movements, in sixteen points on the scalp, distributed among the frontal, temporal, central, parietal, and occipital areas.

For this , brain signals were acquired from the two groups of volunteers, formed by five artists and six non- artists, during visual stimuli caused by images of dance and daily movements, and sensorimotor stimuli caused by the thought of the volunteer when imagining himself executing the movement seen.

The patterns of these signals were learned by an artificial neural network of the KSON (Kohonen Self-Organizing Network) type that with a reduced number of artificial neurons simulates the brain phenomena [KOHO,90] and uses the competition among these neurons to reach the self-organization of the system. The winning neurons and their respective neighborhoods, being constituted of specific attracting areas for the entrance signals after the self-organization of the net, caused the appearance of clusters in different parts of the artificial space, and in that way they evidenced the categories present in the analyzed brain signals. Such concentrations could be visualized and analyzed through the maps generated by KSON, that recall the topologically organized maps found in the cortex of the most highly developed animal brain [KOHO,82].

The results obtained in [COST,00] - by which we validated the method and procedures used in the experiment proposed by this research - demonstrated a prominent separability of the brain signals when a person imagines a movement for the left or a movement for the right, making it possible to classify those signals by using Artificial Neural Networks (ANN).

Based on this, the investigation of a possible classification of the dance and daily movements starting from the identification of patterns in the acquired signals during the observation and imagination of those movements using the methodology of digital processing of signals and a self-organized ANN, has become the object of this research.

2. Materials and Methods

Materials

The system developed for the performance of the experiment used:

- Audiometric Cabin: cabin with acoustic isolation and transparent viewfinder through which the images of the movements exhibited the volunteer on a 14-inch TV monitor , attached/connected to the external part of the cabin.

- Hardware:

Microcomputer - Pentium III 650MHz Processor, 128Mb of RAM memory, 10 Gb of hard disk, operating system Windows 95 (due to the need and facility of the system to acquire the brain signals).

MindSet MS - 1000 EEG System - Hardware for the acquisition of the brain signals. Connected to the microcomputer by the SCSI door, which has thirty two cables with silver electrodes at the extremities and extending cable that allows the volunteer-MindSet setup connection.

- Conductive cream for electroencephalography : its basic components are non-ionic self emulsifiers, alcohol-derived emollients and consistence-giving fatty acids, special esters, neutral oily components, viscosity stabilizers, high conductivity salts and conserving bacteriostatic agents . Non - toxic .

- Exhibited images: the experiment proposed the visualization of two groups of movements: six artistic (dance movements) and six daily (movements of routine activities). These two groups were subdivided into two others thereby constituting four groups of movements:

Movements of dance 1, 2 and 3: artistic movements that just go ahead, not returning to the initial position.
Movements of dance 4, 5 and 6: artistic movements that go and do return to the initial position.
Daily movements 1, 2 and 3: almost static daily movements.
Daily movements 4, 5 and 6: dynamic daily movements

All the movements last an average of 7 seconds, being executed by the same person.

- Softwares:

Electroencephalography Neuromapping Software, divided into two applications:

MindLab - application used for the acquisition of data and analysis of said data in real time. It allows the acquisition and recording of EEG data in real time and subsequent visualization of the recorded data, besides several visual analysis tools.

WaveLab - application used for off-line analysis, in other words, subsequent to the acquisition of the EEG data . It permits the visualization of the acquired EEG files, channel to channel, and it supplies the FFT function analysis .

MatLab 5.2.: used for the development of the programs " Filt ", Filt2 ", size " and of the Kohonen Network.

Methods

Acquisition of the Brain Signals

They were acquired and analyzed the eleven volunteers' brain signals, six of the masculine sex and five of the feminine sex, divided into two groups, all in the 20 to 35 age group, Brazilian, (attesting) perfect physical and mental health.

The experiment to which the volunteers were submitted involved four phases:

I. Placing of the electrode: this was done with the volunteer seated in a chair outside the audiometric cabin. Sixteen silver electrodes were placed on the volunteer´s scalp , obeying the positions established by the 10-20 international convention for the acquisition of brain signals. All the electrodes were placed in potential difference to an only electrode distant from the cortex - the reference electrode - generating unipolar registrations .
The location, asepsis and application of the conductive cream - with wooden spatula and in small amounts not to modify the focus of the electrode - in the positions determined by the convention were performed in sequence before the placement of the electrodes.

II. Connection Volunteer/MindSet setup: with the volunteer inside the audiometric cabin, the connection of the electrodes applied to the scalp to the MindSet setup is done by the extending cable.

III. Acquisition of the Brain Signals: for each volunteer a total of 60 acquisitions was performed. For each visualized movement, 5 acquisitions of signals were gathered:

- Basal brain signal, always acquired before the first exhibition of each movement, with the volunteer looking at the screen of the monitor, black without image. Duration of the acquisition: average of 35 seconds.
- Brain signal of observation, acquired with the volunteer just observing the execution of the artistic or daily movement. Duration of the acquisition: average of 7 seconds.
- Brain signals of imagination 1, 2 and 3, acquired with the volunteer observing and imagining himself executing the artistic or daily movement for the first, second and third time. Duration of the acquisition: average of 7 seconds.

The acquisition of each volunteer's brain signals involved seven stages:

1st stage: The volunteer was asked to observe the screen of the monitor exhibiting a black screen without images, for approximately 35 seconds. Thjs is when the acquisition of the basal brain signals took place.
2nd stage: The volunteer was asked to observe the movement being executed completely and in its real time, approximately 7 seconds . During this process the acquisition of the brain signals of observation took place.
3rd stage: The slow movement in the initial position was shown to the volunteer for 10 seconds. The volunteer was then asked to imagine the same position of the image.

4th stage: The decelerated movement was shown to the volunteer. . He was then asked to pay attention to the execution of the movement during the visualization.
5th stage: The complete movement was exhibited , without pauses and in real time. The volunteer was asked to observe and imagine himself executing the movement shown on the screen. During this process the first acquisition of the brain signals of imagination was accomplished.
6th stage: The movement was exhibited again, in the same way. The second acquisition of brain signals of imagination was accomplished.
7th stage: The movement was exhibited again, in the same way. The third acquisition of brain signals of imagination was accomplished.

For a better representation of the brain signals, all the frequency zones within the EEG signal were considered in the pre-processing stage. While other related works in the literature, that deal with the brain-computer interface, use a certain frequency zone of the EEG signals for analysis and classification.

IV. Removal of the electrodes: after the end of the experiment, the electrodes as well as the conductive cream are easily removed from the volunteer´s scalp. All the electrodes go through the cleansing and asepsis process again so that they may be used on another volunteer.

Filtering of the 60 Hz noise and .eeg in .txt Transformation

Developed in MatLab 5.2, the programs " to Filter " and " Filt2 " were used after the digitalization of the signals to filter the 60 Hz noise , caused by the interference of the electric net during the acquisition of the signals, and to transform the EEG files (generated by MindSet during the acquisition of the signals) in .txt (the format used for the entrance of the data into the Kohonen Network).

Calculation of the dimensions of the acquired brain signals per volunteer

Developed in MatLab 5.2., the program " size " supplied the exact numbers of points contained in each brain signal.

Calculation of the minimum dimensions of the acquired brain signals for each movement

The minimum dimensions of the brain signals were always obtained by selecting the smallest value among the dimensions of all the volunteers' brain signals for each movement.

Configuration of the Kohonen Network for the proposed experiment

By using the initsm function of MatLab 5.2, a network was created with the following configuration:

Dimension of the samples for training: x, where x is the minimum dimension of each acquired brain signal.
Number of signals for training: the quantity of acquired brain signals of the artists and non-artists groups.
Size of the net: 100 neurons in a flat,square topology of 10x10.

The nbgrid function was used to define the function of calculating the distances between the neurons.
The net was trained using the trainsm function. The number of times used to train the net was 600, because that was the value as of which the net presented a low value of error and the learning rate became constant.
The surrounding area of the net was configured in such a way as to exponentially decrease during the training times , beginning with an approximate value of N, where NxN are all the neurons of the net.
The net was tested with the simusm function using the same training files, since the purpose was to observe the groupings formed.

3. Obtained Results

Interpretation of the obtained results

For the interpretation of the results generated by KSON, two types of comparisons were proposed:

- Comparison among Signals: among brain signals of different types from a same group of volunteers ex. imagination signal 1 with observation signal, observation signal with imagination signal 3, basal signal with imagination signal 2, and so forth - acquired for each movement visualized by the two groups of volunteers - artists and non artists;

- Comparison between Groups: among brain signals of the same type, however from different groups ex. imagination signal 1, acquired from the artists group of volunteers, with imagination signal 1, acquired from the non- artists group of volunteers, and so forth.

The comparison of signals was done with the intention of observing and comparing the distribution of space of the winning neurons for each type of brain signal in the Kohonen Network, while the comparison among groups tried to compare the behavior of the same signal type for different groups. A total of 276 comparisons among the acquired brain signals was analyzed.

Interpretation of the comparisons among signals and inter-groups

For the interpretation of the results obtained from the comparisons among signals and inter-groups, matrixes of correlated percentages were generated to relate the resulting percentages of the nine comparisons made among the brain signals. They were associated to the matrixes´ three indexes: average individual percentage for each brain signal (MS), general average percentage of the five types of brain signals (MG) and inter-cluster dispersion measure (ICDM):
- MS indicates the individual percentage of likeness to the other brain signals that each signal obtained during the exhibition of the movement, of dance or daily, for a certain group of volunteers (artists and non-artists);
- MG indicates the general average of MSs, pointing out the general percentage of similarity among the acquired brain signals for a certain movement and group;
- ICDM indicates the value of the city block distance among the groupings formed in the space of ANN, calculated by the formula: $ICDM = \sum \frac{|S_i - S_{i-1}|}{9}$, with i being = 2.

These indexes made possible the analysis of the comparisons among the signals and between the groups, to which we applied the following criteria:

Comparatively:

- MS values closer to each other indicate little distance differentiation among the space distribution of the analyzed brain signals. We consider that the values resulting from the difference between the highest and the lowest percentage , inferior to the average of that difference, characterizes a low differentiation among the analyzed brain signals, for values equal or superior to the higher average differentiation among the patterns of the brain signals.
- Higher MG values indicate that the intersection among the five types of brain signals, analyzed in this experiment, is higher . In other words, proportionally, the degree of likeness among them is higher .
- Higher ICDM values indicate that the dispersion of the clusters for the space of KSON is also proportionally higher.

Starting from the analysis of the MS, MG and ICDM percentages for the six dance movements and for the six daily movements, it was observed that:

1 - they presented the same MS indexes or higher than the average - in this case, 8,16 for the daily movements and 7,5 for the dance movements - the following movements: daily 3 and 5 for the artists' and non- artists' groups, daily 1 and 6 just the artists' group; of dance 1 for the non- artists' group, of dance 3 for the artists' group and of dance 2, 4 and 5 for the two groups.

2 - for all the dance movements, the MG percentages are considerably lower for the artists' group than for the non- artists' group;

3 - for all the daily movements, the same applies ;

4 - ICDM percentages for the daily movements, except for the daily movement 3 that presents identical values for the two groups, are considerably higher for the artists' group than for the non- artists' group;

5 - for the dance movements, however, the ICDM values don't remain constantly high for the artists' group; for instance, for the movement of dance 1 the ICDM is higher for the non- artists' group than for the artists' group and for the movement of dance 4 this value is identical for the two groups.

6 no pattern was detected in the space distribution in KSON of the acquired brain signals during the observation and imagination of the execution of dance and daily movements.

4. Discussions

1 - for daily movements 3 and 5 - artists' and non- artists' groups -, daily 1 and 6 - artists' group -, of dance 1 - non artists´ group - of dance 3 - artists' group - and of dance 2, 4 and 5 - the two groups -, the differentiation among the brain signals of imagination, observation and basal is larger than for the other movements. In other words, the brain processes involved in the observation and imagination are more differentiated for certain movements than for others. However, there was no pattern for those differentiations that could characterize an evident distinction between the dance and daily movements;

2 / 3 - the higher MG indexes , as much for the dance movements as for the daily movements, indicate for the non artists' group that artists and non- artists noticed the exhibited movements in a different way. In other words, for the artists' group the percentage of likeness among the five types of acquired brain signals is smaller than for the non- artists' group. In such a way that the processes of imagination of the execution of a movement and of the observation of a movement, for the artists's group, are more differentiated than for the non- artists' group. The results of the comparisons obtained among the same type of brain signal of different groups, demonstrates the percentage of likeness between the artists' brain signals and those of the non-artist acquired for each exhibited movement.

4 - for high ICDM indexes a proportionally higher dispersion of the groupings for the space of the net was observed. That higher dispersion among the clusters means that KSON identified a greater amount of information in that movement, than in the movements that presented a more compact distribution of the groupings. In other words, the higher the dispersion of the groupings for KSON, the greater the amount of information that the movement possesses for a certain group.

5 From this , and associated to the obtained values, it can be concluded that the daily movements possess a larger amount of information for the artists' group, or even , that the artists' group identifies a greater amount of information in the daily movements than the non- artists' group. Except for daily movement 3 that, because it presents the same ICDM percentage for the two groups, indicates that, both for artists and non- artists, the movement contains the same percentage of information.

For the dance movements, due to the differentiated ICDM values for each movement, it can be concluded that for certain dance movements, such as movements 3, 5 and 6, the amount of information contained is greater for the artists' group than for the non- artists'. However, in the movement of dance 1 we observed the opposite, i.e. a higher ICDM for the non- artists' group than for the artists' group. In movement 4, on the other hand, the ICDM percentage is identical for the two groups, and for movement 2 these percentages are very close. In other words, of the dance movements exhibited, for four movements the artists' group extracted more information than the non- artists's group, for one the percentage of information was the same and for the other it was higher for the non- artists' group than for the artists' group.

It can also be verified that the artists's group presents a higher ICDM percentage for the daily movements when compared to the ICDM values for the dance movements. In other words, for the artists' group some of the daily movements bring a larger amount of information than some dance movements.

The movements that bring a greater amount of information according to KSON when observed and imagined are the daily 1,5 and 6 and the dance 3 and 5. With daily movement 1 of the almost static movements´s group, and daily movements 5 and 6 of the dynamic movements´ group. Dance movement 3 of the movements group that don't return to the initial position, and dance movement 5 of the group that does . And for all these movements the average of the MS percentages characterize a greater differentiation among the brain signals.

6 - the non- detection of a pattern in the distribution of the acquired brain signals for the dance and daily movements demonstrates that in the brain processes analyzed by this experiment, the dance and daily movements are not differentiated.

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