Research Article

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The Variation of Geometrical Shapes of Reconstructed Attractors of HRV Data Before, During and After the Heart Lock-In® Experiment

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ABSTRACT

The algorithm of geometrical synchronization based on the optimal reconstruction of embedded attractors from heart rate variability (HRV) data is employed to detect temporary coherence between participants before, during, and after the Heart Lock-In experiment. The pairwise geometrical synchronization between individual participants help to detect the average coherence of the group. Geometrical shapes of the embedded attractors do provide an insight into the complexity of HRV data.

Keywords

Heart rate variability, Heart Lock-In® Technique, Attractor embedding

Introduction and the Description of the Experiment

The Heart Lock-In® Technique is a tool developed by Heart Math Institute [1]. It helps individuals and groups increase coherence in heart-rhythms of an individual and in a group setting as well [2,3].

The main objective of this manuscript is to investigate short-time changes in HRV data before, during, and after the Heart Lock-In® Technique. For instance, the length of the observation windows used to determine the influence of heart coherence on synchronization between human heart rate variability and geomagnetic activity in [3] was 24 hours. The objective of this paper is to use 5 minutes length observation windows – and to investigate any observable changes during such short periods of time.

The Heart Lock-In® experiment was executed at Heart Math Institute on 5 March, 2015. The group of participants comprised 20 persons. The Heart Lock-In® experiment continued for 5 minutes; all 20 persons were simultaneously executing the technique in the same room. 20 individual HRV meters were used to record HRV data of each participant 5 minutes before the Heart Lock-In® experiment, during the experiment, and 5 minutes after the experiment. The physical location of persons in the room is illustrated in the schematic diagram in Figure 1.

Note, that individual SC07 was excluded from the analysis, since his recorded HRV data series was too short. The coding of each individual HRV data file were organized in the following way (the code stands for the file name; the number represents the participant): SC25 – 1; SC13 – 2; SC17 – 3; SC01 – 4; SC30 – 5; SC20 – 6; SC12 – 7; SC27 – 8; SC24 – 9; SC26 – 10; SC36 – 11; SC29 – 12; SC02 – 13; SC23 – 14; SC35 – 15; SC16 – 16; SC03 – 17; SC22 – 18; SC31 – 19.

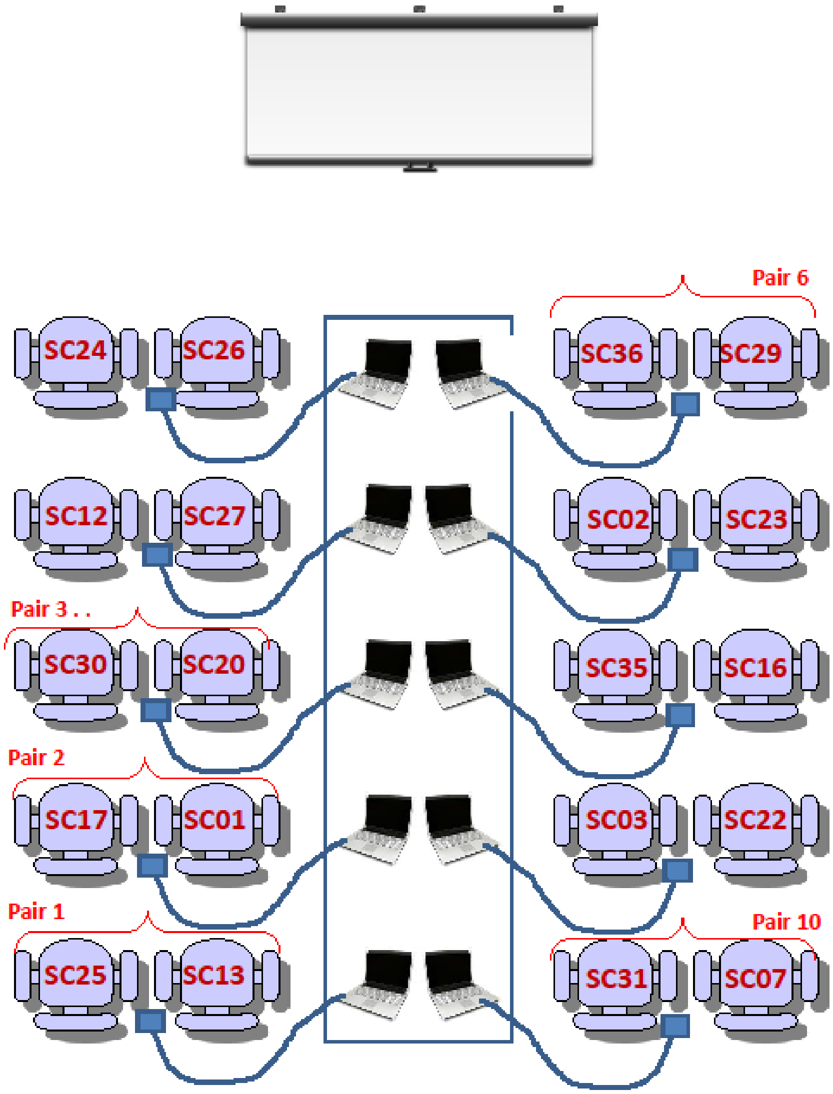

Figure 1: A schematic diagram illustrating the physical location of 20 participants during the Heart Lock-In® experiment.

Estimation of pairwise synchronization (coherence) between participants' HRV data

The first objective is to assess the pairwise synchronization between participants' HRV data; the algorithm introduced in [4] is used for that purpose. This technique uses an information reduction algorithm which represents a participant's HRV data series in a fixed observation window by a single number (the optimal time lag). 5 minutes length observation windows are used in [4]. However, since the present setup comprises three intervals each 5 minutes long, the length of the observation window is now set to 1 minute. That produces 5 discreet optimal time lags for each interval – 5 time lags before the Heart Lock-In® experiment; 5 time lags during the Heart Lock-In® experiment and 5 time lags after the Heart Lock-In® experiment.

In order to assess pairwise synchronization (coherence) between the participants' HRV data, we compute Euclidean distances between the obtained optimal time lags sequences for all participants according to this formula:

$$C_{kl} = \sqrt{\sum_{j=1}^{5}\left(\tau_j^{(k)} - \tau_j^{(l)}\right)^2}$$

Where C_{kl} is the pairwise synchronization (coherence) between the *k*-th and the *l*-th person; $\tau_j^{(k)}$ is the optimal time lag for the *k*-th person's HRV data during the *j*-th minute. Note that the pairwise synchronization (coherence) between the participants' HRV is computed separately for the three intervals (before, during and after the Heart Lock-In® experiment).

The obtained results are plotted in a matrix format in Figure 2. Each of the three plots do correspond to the 5 minutes intervals before, during and after the Heart Lock-In® experiment. Each square (*k,l*) represents the calculated Euclidean distance between them *k*-th and the *l*-th person. Colors close to red correspond to bigger Euclidean distance or lower level of synchronization (coherence) between participants. Colors close to blue correspond to smaller Euclidean distance or higher level of synchronization (coherence) between participants.

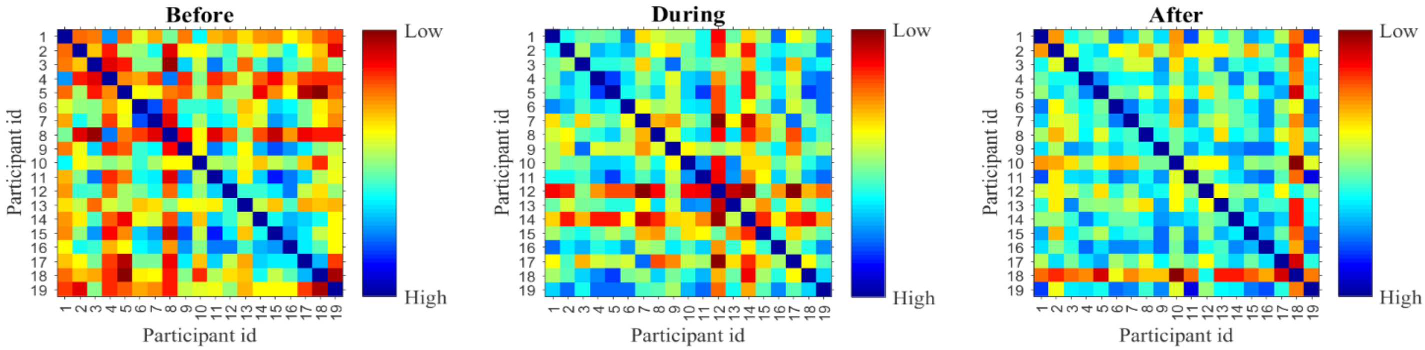

Figure 2: Pairwise synchronization (coherence) between the participants' HRV data before, during and after the Heart Lock-In® experiment.

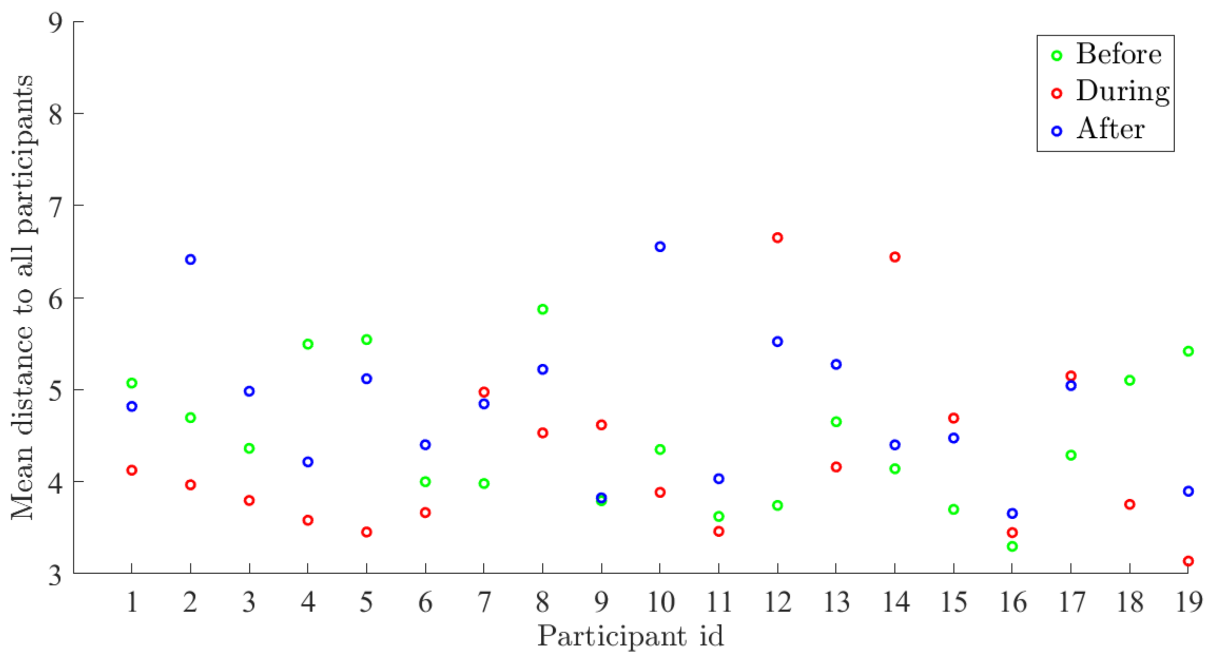

Figure 3: Synchronization (coherence) between each participant and all other persons in the group.

In can be seen from Figure 2 that average color for the plot corresponding to the data before the experiment is closer to red – meaning that participants were (mostly) not synchronized (coherent) with each other. However, the average color for the plot corresponding to the data during the Heart Lock-In® experiment is closer to blue – meaning that participants became more synchronized (coherent) with each other during the experiment. The plot corresponding to the 5 minutes data right after the Heart Lock-In® experiment is even more blue in average – meaning that participants were mostly coherent (compared to other intervals) during the 5 minutes period right after the experiment.

Estimation of synchronization (coherence) between each participant and all other persons in the group

In order to assess the synchronization (coherence) between each individual participant and all other persons in the group, the mean Euclidean distance between each participant and all other participants of the group must be calculated. The algorithms used in this Section are exactly the same as in Section 2. Again, the pairwise synchronization (coherence) between the participants' HRV is computed separately for the three intervals (before, during and after the Heart Lock-In® experiment).

Figure 3 depicts mean Euclidean distances between each participant and all other persons in the group. Green, red and blue circles correspond to the mean distance before, during and after the Heart Lock-In® experiment. Note that a smaller distance corresponds to a higher level of synchronization.

From the figure above we can see that 12 out of 19 participants became more synchronized (coherent) with the group during the Heart Lock-In® experiment. However, most individuals became less coherent with the group (as a whole), after the Heart Lock-In® experiment.

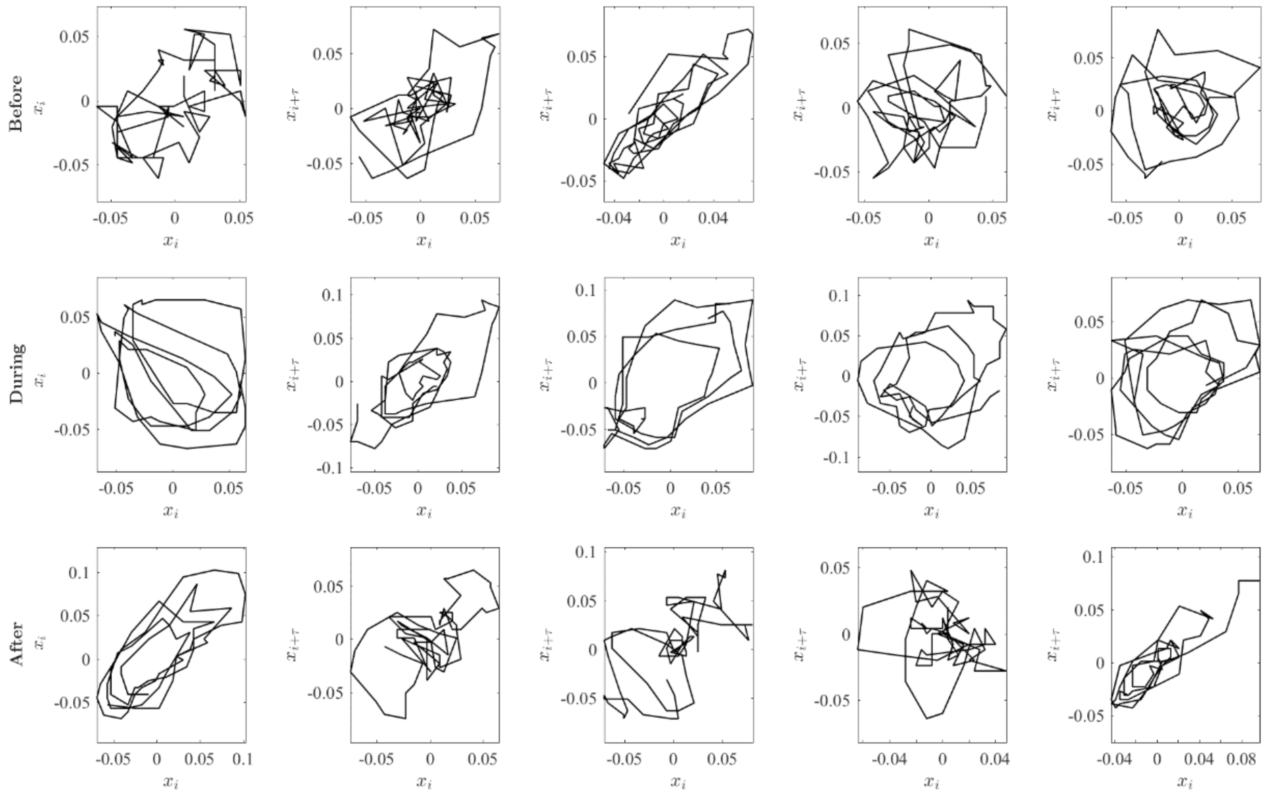

Figure 4: The variation of the shapes of attractors for the 1-st person before, during and after the Heart Lock-In® experiment. A single plot corresponds to the attractor reconstructed from one minute HRV data using the optimal time delay.

Geometrical shapes of reconstructed attractors from HRV data before, during and after the Heart Lock-In® experiment

Since the specific chaotic attractor embedding technique (the maximization of the state space occupied by the embedded attractor) is used in order to compute optimal time lags, it is interesting to look at the actual attractors generated by those optimal time delays in the reconstructed phase space.

Figure 4 depicts attractors generated by optimal time delays for one single individual. The first row corresponds to the data for 5 minutes before the Heart Lock-In® experiment, second row – 5 minutes during the experiment, third row – 5 minutes after the experiment. Note that each plot corresponds to one minute of HRV data.

From the figure above it can be observed that as the Heart Lock-In® experiment progresses, the form of the optimal embedded attractor becomes smoother and rounded. It is difficult to make any clinical conclusions on this phenomenon. However, this result is very interesting from the geometrical point of view.

Concluding remarks

Many previous studies have given convincing evidence that the Heart Lock-In® technique is an effective emotional restructuring technique which helps to withstand recurring stress or other depleting emotions. This study provides interesting data-based evidence that changes in the HRV data do happen also in short time observation windows. The presented results can be beneficial to further studies in the dynamics and self-organization of human cardiovascular system.

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