Brain-to-Brain interaction at a distance: a global or differential relationship?

William Girolini\textsuperscript{1,2}, Luciano Pederzoli\textsuperscript{1,2}, Marco Bilucaglia\textsuperscript{1}, Elena Prati\textsuperscript{1} and Patrizio Tressoldi\textsuperscript{2}

\textsuperscript{1}EvanLab, Firenze, Italy
\textsuperscript{2}Science of Consciousness Research Group, Dipartimento di Psicologia Generale, Università di Padova, Italy

Corresponding author:
Patrizio Tressoldi
Email: patrizio.tressoldi@unipd.it
Abstract

Background: The main objective of this exploratory study was a confirmation of the results obtained by Giroldini et al, 2016, relative to the possibility of identifying a long-distance connection between the EEG activities of two totally sensory shielded subjects, one of whom was stimulated with light and sounds. Furthermore, this study sought to answer the following questions:
- What is the relationship between the power of the EEG signal in the stimulated partner and that of the other distant partner?
- Is the relationship between the EEG activities of the stimulated and distant isolated partners global (i.e., an undifferentiated response), or is it differentiated and thus displays variations depending on the characteristics of the stimulation applied to the stimulated pair?

Methods: Five adults chosen for their experience in mind control techniques and their mutual friendships took part in this study. Each participant took turns in being both the stimulated partner and the isolated non-stimulated partner with each of the others, making a total of 20 pair combinations. The stimulated partner received three blocks of 32 visual-auditory stimulations lasting 1 second modulated at 10 Hz, 12 Hz, and 14 Hz respectively, with a constant inter-stimulus interval of 4 seconds. The EEG activity of each pair was recorded at 128 samples/sec over 14 channels and analyzed by measuring traditional steady-state potentials and the Pearson’s linear correlation between all possible signal pairs with an innovative algorithm.

Results: From the results of the twenty pairs, we found an increase in the correlation among the EEG channels of the isolated distant partners, corresponding to frequencies of the steady-state visual and auditory potentials used for the stimulated partner. Furthermore, we did not find a correlation between the response intensity elicited in the stimulated partners and that observed in the non-stimulated one suggesting that this physical characteristic cannot be transferred between isolated partners.

Discussion: A mental connection at distance can allow connection of informational rather than physical characteristics of the shared signals.

Keywords: EEG, Interaction at a distance, Generalized Quantum Theory, Steady-state potentials.
Introduction

The possibility that the brain activities of two physically distant, but emotionally and mentally connected individuals, display a correlation in the absence of any normal sensory connection, has been supported by Giroldini et al. (2016), independently confirmed by Radin (2017) and further approximately thirty studies (see Table S1 in the study of Giroldini et al., 2016a).

In a typical study of this kind, two members of a pair are separated (varying from meters to kilometers) and sensorially isolated from each other. One member is stimulated with either structured (e.g. images) or unstructured (e.g. lights and sounds) information, and the correlation between their respective EEG activities is measured. For example, if the sensorially isolated partner’s EEG shows a variation correlated to the stimulated partner’s EEG, we can assume (unless potential artefacts are discovered) that it is proof of a non-local (long-distance) connection between the two brains.

Even if, from a phenomenological point of view, this correlation seems to show a causal effect of the stimulated partner upon the sensorially isolated one, some authors believe it to be a form of biological entanglement similar to what occurs in quantum physics (see for example Walach, Tressoldi, & Pederzoli, 2016), and therefore is an expression of an acausal correlation.

However, to date, the relationship between the quality and intensity of the stimulated partner’s (SP) signal and the same parameters seen in the isolated non-stimulated distant partner (NSP) have yet to be examined in depth, except for the fact that the latter’s signal is much weaker (by approximately a factor of ten). This study is an exploratory contribution to better understand this relationship. We specifically sought to answer the following questions:

- What is the relationship between the intensity (or power) of the observed EEG signal between the stimulated partner and the isolated distant partner?
- Is the relationship between the EEG activities of the stimulated and distant isolated partners global (i.e., an undifferentiated response), or is it differentiated and therefore exhibits changes depending on the characteristics of the stimuli applied to one of the pair?

The first answer is important in understanding whether or not a correlation exists between the recorded EEG signal intensities of the stimulated partner and the isolated one, with all the related consequences of honing in on this relationship not just within groups but between pairs of subjects as well.

The second answer, however, is important in recognizing which physical characteristics of the signal can be identified from this strange distant correlation, for their possible future development and even technological application.

Materials and Methods

Participants

Five adults – two women and three men – took part in this study, with an average age of 38.3 years (SD = 7.5), chosen for their experience in mind control techniques (mainly meditation) and their mutual friendships. We consider these pre-requisites essential for an adequate “mental and emotional connection” between the pairs. Each participant took turns in being both the stimulated partner (SP) and the non-stimulated partner (NSP) with each of the others, making a total of 20 pair combinations.
Statement of Ethics
The use of experimental subjects is in accordance with ethical guidelines as outlined in the Declaration of Helsinki, and the study has been approved by the Ethical Committee of the University of Padova’s Department of General Psychology, prot. n. 63, 2012. Before taking part in the experiment, each subject gave his/her informed consent in writing after having read a description of the experiment.

EEG equipment
Two Emotiv Epoc™ EEG devices were used, modified to allow connection (via multi-contact connectors) to professional Bionen headsets (See Figure S1 in the Supplemental Information) to ensure high quality EEG signals. The system’s accuracy and signal quality were thoroughly checked and ascertained. The sample frequency was 128 samples/sec over 14 channels connected to locations Fp1, F3, C3, P3, O1, F7, T5, Fp2, F4, C4, P4, O2, F8, T6. The instruments were provided with a built-in fifth order low-pass digital filter (bandwidth from 0.2 to 45 Hz), as well as two notch filters at 50 and 60 Hz respectively as protection against noise produced by the local electricity network.

Signal acquisition by the two EEG devices was controlled by a specially designed software program with an acquisition synchronicity precision better than 1/128 second and which ensured total electrical independence and separation between the two devices (see Giroldini et al., 2016a).

The experiment was conducted at the EvanLab laboratory in Florence (Italy), which is comprised of two separate sound- and lightproof rooms with no electromagnetic disturbances (see Figure 1).

Visual-auditory stimulation
The visual-auditory stimulations were conducted in three blocks of 32 simultaneous stimulations lasting 1 second, at the same time on-off modulated at 10 Hz, 12 Hz, and 14 Hz respectively, with a constant inter-stimulus interval of 4 seconds. The audio modulation was performed on a 900 Hz sinusoidal carrier (80 dB). This method of stimulus administration, with a modulation frequency from 4 to 20 Hz, is also called “Steady-State” (Pastor, Artieda, Arbizu, Valencia, & Masdeu, 2003; Picton, John, Dimitrijevic, & Purcell, 2003).

The interval between the three blocks was randomly varied at between 40 and 90 seconds. The visual stimulus was provided by an array of 16 red LEDs positioned about 30 cm from the SP’s closed eyes, while the sound was sent directly to the ears via 32 ohms impedance earphones. The three frequency blocks were given randomly without repetition of the same frequency. The raw data are available at: http://tiny.cc/owzyly

Figure 1: floor plan of EvanLab laboratory.

Electronic copy available at: https://ssrn.com/abstract=2991977
**Procedure**

The SP was given the following instructions: “When you are ready, relax and be prepared to receive a visual and auditory stimulus connecting mentally and with positive emotions with your partner. Limit your body movements to prevent interference with your EEG activity. You will perceive three blocks of 32 stimulations of 1 second each, the blocks will be separated by long random pauses in order to avoid predictable rhythms. The experiment will last about 15 minutes.”

The NSP was given the following instructions: “When you are ready, relax and connect mentally with positive emotions with your partner, who is receiving visual and auditory stimulations. Keep your body still to prevent interference with your EEG activity. The experiment will last about 15 minutes.”

At the end of each trial involving pairs their roles were reversed.

**Timing of the stimuli**

Tests performed later on the data acquisition process showed a slight shift of the presentation of the stimulus with respect to the theoretical instant of stimulation. This shift is caused by the software program’s execution features due to the operating system (Windows 10). The shift is equal to around 10 samples (~0.08 secs) and can easily be compensated for during data analysis. In addition, this shift displays a jitter (equal to about 3 samples); this is because, since Windows is a multitasking operating system, programs and system services run simultaneously and compete with each other for the microprocessor. This jitter is small, however, and does not cause problems.

The image on the left in Figure 2 are obtained by measuring the signals from a photodiode in front of the stimulus LEDs to obtain time references, which are then fed back into the Emotiv Epoc™. From these measurements, it is possible to completely compensate for the shift.

![Figure 2](image-url)

Figure 2: The signal obtained from a BPW34 photodiode in front of the illuminator lights shows a delay between the stimulus command and its actualization (about 10 samples, or 0.08 secs). It is taken into account by adding up the time at the start of the stimulation period. In the image, the stimulus was at 12 Hz. On the right is a diagram showing placement of the EEG’s 14 electrodes.

**Data analyses**

Since each recording contained 32 stimulations for each of the three different frequencies, each of the three was processed the same way. One of the first types of analysis used was the FFT (Fast Fourier Transform), applied to a pre-stimulus 1 second period, a 1 second stimulus, and then a 1 second post-stimulus period, and then averaged over all stimuli (32 for each frequency in each of 20 files).

Next the FFT differentials were calculated – that is, the differences between the stimulus period and
the pre-stimulus period. The post-stimulus period was ignored.

**SP EEG data analysis**

Generally, in directly stimulated subjects, the FFT shows peaks very close to the stimulus frequencies (10, 12, and 14 Hz) and their potential harmonics although they are only 10 – 15% bigger than the baseline, see Figures 3, 4, and 5. This means the stimulation effect is not strong enough to be seen without appropriate processing. So as to better highlight the effects, the differences between the two situations (stimulus and pre-stimulus) were calculated and, once amplified, the stimulation frequencies became clear. All three stimulation frequencies show a strong reduction in the subjects’ spontaneous Alpha frequency (the well-known typical Alpha-block).

![Figure 3](image1.png)

**Figure 3:** On the left is the FFT (between 1 and 42 Hz) of the pre-stimulus, stimulus, and post-stimulus periods. On the right are differential graphs showing the loss of spontaneous Alpha and presence of stimulus frequency (10 Hz) including two of its harmonics, 20 Hz and 30 Hz. Note that the top right graph effectively represents the absolute value of the difference between the stimulus and pre-stimulus, whereas bottom right graph represents the signed difference.

![Figure 4](image2.png)

**Figure 4:** On the left is the FFT (between 1 and 42 Hz) of the pre-stimulus, stimulus, and post-stimulus periods. On the right are differential graphs showing loss of spontaneous Alpha and presence of stimulus frequency (12 Hz), as well as its first harmonic, 24 Hz.

Electronic copy available at: https://ssrn.com/abstract=2991977
Figure 5: On the left is the FFT (between 1 and 42 Hz) of the pre-stimulus, stimulus, and post-stimulus periods. On the right are differential graphs showing loss of spontaneous Alpha and presence of stimulus frequency (14 Hz) as well as its first harmonic, 28 Hz.

A small peak at 28 Hz appears only in SPs probably due to a weak disturbance at 50 Hz from the power source for the LED array used for visual stimuli or a second harmonic of 14 Hz. The 28 Hz peak is however eliminated by the differential FFT.

**Analysis of SP EEG data using the GW6 method.**

All EEG signals were pre-processed as outlined in Giroldini et al. (2016b), then narrow band filtered (1 Hz width) centered at the stimulation frequency (10 Hz, 12 Hz or 14 Hz - see Figure 6) by a fourth-order band-pass Butterworth filter. We chose to implement a time-reversal filter to ensure a zero phase delay: the effective filter order was 8. Therefore, the classic ERP was identified in SPs through simple averaging, calculating the power, and finally extracting a multiple correlation value between EEG channels in accordance with the GW6 method. A MatLab version is available at: [http://tiny.cc/owzyly](http://tiny.cc/owzyly)

To outline the fundamentals of this method, it is based on calculating Pearson’s linear correlation between all possible signal pairs, from which pairs of fixed duration data segments of about 250 ms are extracted. These segment pairs (sliding windows) are then slid along the time axis of the two signals, generating a series of curves $R(I, X)$, where I represents pair combinations ($I = 91$ in this case) and X is time. Subsequently this series of curves is processed to produce a single graph $Sync(x)$, that basically represents the global variations of correlation (or synchronisation) between all EEG channels, using suitable pre- and post-stimulus periods as a baseline.

This method was applied to each stimulus period, examining 4 seconds of data (1.5 s pre-stimulus, 1 second stimulus, 1.5 s post-stimulus).

The EEG signals were filtered in a narrow band (1 Hz width) centered at the stimulation frequency (i.e. 10 Hz, 12 Hz, 14 Hz - see Figure 6). The GW6 graph, the ERP's Power and the signal power were calculated as the average of all stimuli and all subjects.
Figure 6: Average ERP power of 32 stimuli over 20 files of SPs, with the signal filtered respectively in the band 9.5-10.5 Hz (left) 11.5-12.5 Hz (middle) and 13.5-14.5 Hz (right), therefore centered at 10 Hz, 12 Hz and 14 Hz.

Taking together all the graphs obtained with the GW6 method and shown in Figure 6, it is possible to clearly see the normal response to the stimuli, for example the power of classic ERP, or the signal power. It is also important to stress that the greatest SP response is obtained by effectively filtering the signal at the true stimulus frequency (e.g. 9.5-10.5 Hz for the steady-state frequency of 10 Hz). If we filter within a frequency range even slightly shifted (e.g. 10.0-11.0 Hz), the response is always reduced. In short, in the SPs the greatest steady-state response exactly coincides with the stimulus frequency.

From Figure 6, we note that the curve’s height increases as it moves from 10 to 14 Hz, probably because the stimulation frequency moves away from that of the spontaneous Alpha band frequencies (~ 8-12 Hz).

The continuous red line together with the green curve generated by GW6 represent the random expectation (calculated using a method described later). In all cases, we see that the GW6 graph greatly exceeds the random “zero curve”.

In particular, by simply calculating the power of the filtered signal within a narrow band (1 Hz bandwidth) at 10 Hz, 12 Hz, and 14 Hz, it is possible to classify – almost always correctly – the frequency of each of the three groups of stimuli given to the SPs.

Analysis of NSP EEG data.

Data analysis of the NSP data does not evidence any significant peaks at stimulation frequencies in differential FFT graphs equivalent to those in Figures 3, 4 and 5. Furthermore, on average there is no peak resembling a classic ERP, even when power is taken into account. In the EEG signal power, there are only weak and variable fluctuations and therefore there is no response which can be definitely correlated to that obtained in SPs.

The only graph showing any significant variation with respect to baseline EEG activity is that obtained using GW6, by filtering half a Hz below the stimulus one (see Figure 7). For example, in order to identify a more significant variation in the band around 10 Hz, it was necessary to filter (using the same band-pass filter described for SPs) in the range from 9.0 to 10.0 Hz. The same applies to other stimulation frequencies (e.g. 11-12 Hz for 12 Hz stimulus and 13-14 Hz for 14 Hz stimulus). This frequency shift in the NSPs response does not appear to be due to the software,
because the same program, when applied to SPs, shows the maximum response peak exactly at the stimulation frequency.

Figure 7: Averages of 32 stimuli for 20 files filtered in the 9-10 Hz band (top left); filtered in the 11-12 Hz band (top right); filtered in the 13-14 Hz band (bottom left) and average of the previous graphs (20 x 3 = 60 files, bottom right).

Note that the typical ERP curve and the ERP power curve are virtually flat.
Only the GW6 method reveals significant deviations from what is expected from chance alone (red curve), mainly in the global Sync1 curve. By applying the GW6 algorithm to each subject for each stimulus condition, a Sync1 curve was produced, making a total of 20 x 3 = 60 Sync1 curves. Then the average of the curves of each subject, relative to the same stimulation conditions, was calculated, producing 3 global Sync1 curves. Additionally, an overall Sync1 curve was obtained by averaging the 3 global Sync1 curves. From these resulting 4 curves, the maximum correlation value for each frequency was calculated, then from these values the average in the stimulation zone was determined. Furthermore, the accuracy (Standard Deviation and 95% Confidence Intervals) of the Sync1 curves was estimated with a bootstrap method using 10,000 resamples. The results are displayed in Table 1.

Table 1: Observed maximum correlation and their accuracy estimated with the bootstrap procedure for each frequency and their average.

| Frequency | Observed max correlation | Accuracy of max correlation | 95% CIs |
|-----------|--------------------------|-----------------------------|--------|
|           |                          | Mean and SD                 |        |
| 10 Hz     | 1.98                     | 2.24 ± .54                 | 1.26, 3.38 |
| 12 Hz     | 1.85                     | 1.98 ± .38                 | 1.28, 2.79 |
| 14 Hz     | 2.31                     | 2.39 ± .67                 | 1.21, 3.8  |
| Average   | 1.97                     | 2.01 ± .33                 | 1.39, 2.69 |

According to GW6 algorithm, the Sync1 curve is computed from epoched data with respect to the stimulus onset. In order to compare these observed values with a random estimate, for each subject and for each stimulus condition, on the raw datasets we created “fake” stimulus identifiers in the same quantity of real stimulus identifiers (32 identifiers for each stimulus condition), obtaining a so-called “random dataset”. The time-features of such “fake” identifiers are similar to real ones, that is, randomly distributed with minimal distance between adjacent identifiers greater than 10 s. The random dataset is processed in the same way as the real one, obtaining a “fake random max correlation” Sync1 curve. For each subject and for each stimulus condition we created 60 random Sync1 curves. As we did for the observed max correlation, for each frequency and their average, we estimated the precision of the random max correlation. The results are displayed in the following Table 2:

Table 2: Observed maximum correlation and accuracy of the “fake” random stimulus estimated with 10000 bootstrap resamplings.

| Frequency | Observed “fake” max correlation | Accuracy of “fake” max correlation | 95% CIs |
|-----------|---------------------------------|-----------------------------------|--------|
|           |                                 | Mean and SD                        |        |
| 10 Hz     | 1.37                            | 1.64 ± .43                        | 0.83, 2.57 |
| 12 Hz     | 1.39                            | 1.63 ± .42                        | 0.88, 2.51 |
| 14 Hz     | 1.45                            | 1.69 ± .41                        | 0.93, 2.67 |
| Average   | 1.40                            | 1.51 ± .26                        | 1.03, 2.04 |

Finally, using a Montecarlo method, we calculated the probability that the value of the random
maximum correlation would be equal to or greater than the observed one. The results are displayed in Table 3:

Table 3: Probability of the observed correlation compared to the random correlation

| Frequency | Observed max correlation | “fake” max correlation | Probability |
|-----------|--------------------------|------------------------|-------------|
| 10 Hz     | 1.98                     | 1.37                   | .20         |
| 12 Hz     | 1.85                     | 1.39                   | .29         |
| 14 Hz     | 2.31                     | 1.45                   | .084        |
| Average   | 1.97                     | 1.40                   | .043        |

The above results suggest that there is a probable global relationship between the EEG activity of the SPs and NSPs, associated with a less probable response in relation to the 14 Hz stimulation.

A comparison using Bayes Factors and paired t-test of the observed and fake max correlation, yielded the results presented in Table 4. Bayes Factors were estimated by using the software JASP 0.8.2.0 (Jasp Team, 2017), with a default Cauchy prior of .76.

Table 4: Paired t-test data of observed maximum correlations compared to ‘fake’ ones and their corresponding Bayes Factors.

| Frequency | Observed max correlation Means and SD | Fake max correlation Means and SD | Paired t-test | BF_{H1/H0} |
|-----------|--------------------------------------|-----------------------------------|---------------|------------|
| 10 Hz     | 2.24 ± .54                           | 1.64 ± .43                        | 2.72          | 7.8        |
| 12 Hz     | 1.98 ± .38                           | 1.63 ± .42                        | 1.75          | 1.58       |
| 14 Hz     | 2.39 ± .67                           | 1.69 ± .41                        | 3.01          | 13.4       |
| Average   | 2.01 ± .33                           | 1.51 ± .26                        | 2.9           | 10.9       |

The Bayes Factors values, suggest that the observed max correlation have a moderate level of probability to be higher than the fake ones for the 10 Hz, 14 Hz and average frequencies.

Another way of analyzing the results, is to compare the average of the observed maximum correlation of each of the 20 participants with the fake max correlation values. Raw data are available at: http://tiny.cc/owzyly
The results are presented in Table 5.
Table 5: Descriptive statistics and Bayes Factor H1/H0 related to the NSP max correlation estimated with the GW6 algorithm, compared with the fake max correlation estimated with the bootstrap procedure.

| Frequency | Observed max correlation | Fake max correlation | BF_{H1/H0} |
|-----------|--------------------------|----------------------|------------|
|           | Means and SD             |                      |            |
| 10 Hz     | 4.09 (2.47)              | 1.64                 | 210        |
| 12 Hz     | 3.26 (1.94)              | 1.63                 | 55         |
| 14 Hz     | 3.77 (3.03)              | 1.69                 | 14         |
| Average   | 2.7 (.96)                | 1.51                 | 2036       |

The Bayes Factors, confirmed by robustness checks, clearly suggest that for all three frequencies the probability that the mean values of the max correlation observed in the twenty participants is greater than the estimated fake max correlation, ranges from 14/1 for the 14 Hz frequency, to 210/1 for the 10 Hz frequency.

The differences between the results reported in Table 3, Table 4 and Table 5, suggest the importance of taking into account individual differences instead of the estimated overall averages.

As indicated in the introduction, the second aim of this study was to investigate the relationship between the strengths of the EEG signals between the stimulated partner and the isolated distant partner.

This relationship was analyzed by simple binary correlations between the values of the maximum correlations obtained with the GW6 algorithm of the SP and NSP pairs. The values of the Kendall’s tau-b correlations are presented in Table 6.

Table 6: Values of the Kendall’s tau-b correlations with corresponding credible intervals between the values of the maximum correlation of the SPs and NSPs, for each of the three frequencies.

|          | SPs 10 Hz | SPs 12 Hz | SPs 14 Hz |
|----------|-----------|-----------|-----------|
| NSPs 10 Hz | -.33 (-.56, -.006) |             |             |
| NSPs 12 Hz |             | .09 (-.2, .36) |             |
| NSPs 14 Hz |             |             | -.04 (-.32, .24) |

Is it evident that the values of the correlations are very low, ranging from a minimum of -0.04 to a maximum of -0.33, indicating an almost null correlation between the strength of the signals of the pairs of participants.

In evaluating the results, it is very important to determine not only the statistical significance, but also and especially the effect size, i.e., the quantitative measure of the strength of the phenomenon being examined.

Regarding the SP data, during the stimulus the variation in the Pearson correlation between the different electrode combinations is greater by about 10-15% with respect to the pre-stimulus period. Consequently, with regard to these steady state potentials induced by direct stimulations, no
statistical analysis is needed to understand this difference compared to the expected chance value.

In the case of a response in NSP EEG activity induced by a distant mental connection, it is instead normal to expect a decidedly smaller effect-size, which can be estimated as the difference between the experimental maximum and the random value, for example: $1.98 - 1.37 = .61$ (Table 1 and Table 2, line 1). The result varies roughly between .6% and 1.2%, but the value relative to the single NSP is greater than 2%.

This new experiment, conducted with the Steady-State method, confirms the results of Giroldini et al. (2016a) in which a sinusoidal sound frequency of 500 Hz and the same red LED array were used for stimulation, but neither of them was modulated.

Discussion

The primary objective of this study was to confirm that the brain activities of two physically distant but emotionally and mentally connected individuals display a correlation in the absence of any normal sensory connection, as well as to obtain more information on the characteristics of their EEG signals.

Specifically, as mentioned in the introduction, we aimed at acquiring more information on the relationship between the observed signal intensity in the EEG activities of the SPs and NSPs, as well as the possibility that this relationship between each partner’s EEG activity is either undifferentiated (i.e., global), or differentiated, thus varying depending on the type of stimulation applied to the SPs.

Regarding the relationship between the strength of the EEG activities of the SPs and NSPs, our results suggest that there is no such relationship and hence that this parameter cannot be communicated at a distance.

On the other hand, our results confirm the relationship between EEG signal characteristics of both the SP and NSP, at least regarding the frequency parameter in the 10 to 15 Hz band, when taking into consideration the maximum correlation values as estimated by applying the GW6 algorithm.

Indeed, in some preliminary tests SPs were stimulated with two frequencies, 15 and 18 Hz, repeated 100 times. From analysis of the NSP’s EEG recordings, we found significant results for both (see Supplemental Information).

At this stage of our studies we are unable to accurately determine which areas of the brain are the most sensitive to remote stimuli, even though we believe this may be due to the limitations of our mathematical analysis tools in distinguishing the actual signal from a strong background noise.

We emphasize that this is an exploratory study and results were obtained after a series of unplanned post hoc choices, such as the extension of the filtration band (1 Hz rather than 1.2 or .8 Hz), the size of the GW6 method’s sliding window, the choice of individual vs overall values, etc.

Conclusions

Nonetheless, despite its limits, the information that emerge from this study can, if confirmed, provide important details about the relationship between the EEG activities of two physically distant and mentally connected partners.

To summarize, we can tentatively affirm that the EEG activity in NSPs generates a weak response with a signal to noise ratio of around 1% that changes little as a function of the intensity of the response generated in the SPs.
We can also affirm that the NSP’s response seems to be specific to the frequency induced in the EEG activity of SPs.

The GW6 method as well similar ones based on the correlation of the EEG signals (e.g. Radin, 2017), seems suitable for this purpose, but we believe more refined tools are necessary, for example, those based on machine learning algorithms (Müller et al., 2008; Stober, Sternin, Owen, & Grahn, 2016), especially if we wish to detect signals after only a single stimulation and not, as we have done until now, after multiple repetitions of the same stimulation.

It seems right to theorize then that a mental connection at distance can allow connection of some informational, rather than physical, characteristics of the shared signals. This seems plausible, given that we cannot theorize about any information transmission based on conventional electromagnetic waves. This interpretation fits well with a quantum-like mental and biological entanglement as predicted by the Generalized Quantum Theory (Walach, Tressoldi, & Pederzoli, 2016) which predict quantum-like phenomena in areas outside quantum physics, such as biology and psychology.
Acknowledgements:
Thanks to C. Evangelista-Pannozzo for the English translation.
References

Giroldini, W., Pederzoli, L., Bilucaglia, M., Caini, P., Ferrini, A., Melloni, S., … Tressoldi, P. (2016). EEG correlates of social interaction at distance. F1000Research, 4, 457. https://doi.org/10.12688/f1000research.6755.5

Jasp Team. (2017). JASP (Version 0.8.2.0)[Computer software].

Müller, K.-R., Tangermann, M., Dornhege, G., Krauledat, M., Curio, G., & Blankertz, B. (2008). Machine learning for real-time single-trial EEG-analysis: From brain–computer interfacing to mental state monitoring. Journal of Neuroscience Methods, 167(1), 82–90. https://doi.org/10.1016/j.jneumeth.2007.09.022

Pastor, M. A., Artieda, J., Arbizu, J., Valencia, M., & Masdeu, J. C. (2003). Human Cerebral Activation during Steady-State Visual-Evoked Responses. Journal of Neuroscience, 23(37).

Picton, T. W., John, M. S., Dimitrijevic, A., & Purcell, D. (2003). Human auditory steady-state responses: Respuestas auditivas de estado estable en humanos. International Journal of Audiology, 42(4), 177–219. https://doi.org/10.3109/14992020309101316

Radin, D. (2017). Electro cortical correlations between pairs of isolated people: A reanalysis. F1000Research, 6, 676. https://doi.org/10.12688/f1000research.11537.1

Stober, S., Sternin, A., Owen, A. M., & Grahn, J. A. (2016). Deep Feature Learning for EEG Recordings. arXiv.

Walach, H., Tressoldi, P., & Pederzoli, L. (2016). Mental, behavioural and physiological nonlocal correlations within the Generalized Quantum Theory framework. Axiomathes, 26(3), 313–328. https://doi.org/10.1007/s10516-016-9290-6
Supplemental Information

Figure S1: EEG headset and modified Emotiv Epoc™

Pilot investigation using 15 and 18 Hz frequencies
This is a summary of the preliminary research in preparation for the study representing the aim of this work. This preliminary research allowed us to better choose the frequencies to use in the definitive study and to improve experimental conditions, so much so that the final data produced proved to be excellent quality.

The same experimental method as that described under Materials and Methods was used, but somewhat simplified, so that a higher number of tests could be performed in less time: in particular, only the EEG activity of the non-stimulated subjects were recorded. Furthermore, the stimuli (about 100 for each SP) were provided with the Steady-State modality at the modulation frequencies of 15 Hz and 18 Hz.

The sensory and electrical separation of the two subjects was good, but sometimes external noises could still reach them. Because the applied stimuli were numerous and on-off modulated, we believe these noises did not pose any significant influence on final results.

Data were collected from 20 pairs of subjects who all got along well (mostly friends) and the results are described in Figures S2 and S3, which only show graphs from the GW6 method, in that values relative to power and normal ERPs were shown to be insignificant (as in graphs from Figure 7).

Figure S2. Left: Average of 32 stimuli for 20 files filtred in the 14.5-15.5 Hz band. Right: Average of 100 stimuli for 20 files filtred in the 17.5-18.5 Hz band.
Graphs from Figures S2 and S3 show a large response (green curve) compared to what is expected by chance (red curve). The corresponding average values are presented in the Table S1.

Table S1 – Probability of the observed correlation compared to the random correlation.

| Stimulation Frequency | Observed max correlation | “Fake” max correlation | Number of stimuli | Probability |
|-----------------------|--------------------------|------------------------|-------------------|-------------|
| 15 Hz                 | 1.235                    | .715                   | 100 x 20          | .08         |
| 18 Hz                 | 1.207                    | .774                   | 100 x 20          | .06         |

Keeping these results in mind we decided to carry out the actual experiment at frequencies considerably less than 18 Hz, considering that the SP - NSP connection at this frequency becomes appreciably weaker.

We wanted to insert one frequency (10 Hz) which is well within the Alpha range, to see if it was discernable against the EEG ‘noise’ typical of this band.

The other two frequencies (12 and 14 Hz) are within a band thought to be relatively undisturbed by Alpha waves and low enough to not be seriously weakened in the SPs.