Searching for Neuronal Markers of Psi -

A summary of three studies measuring electrophysiology in distant participants

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Abstract

The search for correlations in the brain activities of distant pairs of participants has become a popular research method over the last decade. This method can be seen as a tool for investigating the physiology of a postulated extrasensory or telepathic connection between related people. Such correlations would also support the idea of an entanglement of brain functions. The report presented here summarizes the findings of three subsequent studies conducted by the author. In two of these, brain signals simultaneously recorded in remote laboratories at a distance of about 750 km were correlated. A comparison of the study outcome shows that each study bears significant correlations. The significances were weak and only replicable for the Alpha rhythm, which was increased in non-stimulated participants during the time the co-participants were exposed to pictures with affective content. After applying a potential correction for multiple testing, most significances would probably vanish. It is discussed whether the correlations might be artefacts and how far the results may support the theory of a generalized entanglement between the brain functions of the participants.

1. Introduction

During the last decade a number of studies have been conducted to test the hypothesis of whether under conditions of strict sensory isolation the electroencephalogram (EEG) of remote subjects can become correlated beyond chance levels (Grinberg-Zylberbaum et al. 1987, 1993; Fenwick et al. 1998; Standish et al. 2001; Radin 2004; Wackermann et al. 2003, 2004). These correlations have mainly measured in an experimental set up, often sloppily termed 'sender-receiver paradigm', a formulation we try to avoid for reasons mentioned below. One person, referred to as ‘sender’, was exposed to auditory or visual stimuli, while another person, the ‘receiver’, relaxed in a distant, mainly shielded room. The ‘receiver’ only or both participants were measured by EEG, skin conductance or even functional MRI. In this study, we focused on experiments with EEG. Using this technology, clearly visible event-related potentials (ERPs) in visually or auditory stimulated brains can be evoked. The hypothesis of these studies was that stimulation of the ‘sender’ persons also elicits some kind of ERP in the EEG of the ‘receiver’ co-participants.

2. History of studies

In the 1960s, two studies reported evidence for EEG correlations in pairs of subjects. In one of these studies, the pairs consisted of students and teachers (Tart 1963), and in the other of identical twins (Duane & Behrendt, 1965). About 20 years later, Grinberg- Zylberbaum (GZ) et al. reported the existence of what they called ‘transferred potentials’ in a number of experiments (TP) (GZ 1987, 1993, 1994).

The terms ‘sender’ and ‘receiver’, as well as ‘transferred potential’ imply the model of a signal transfer between the two participants, while one person is actually the causer and the other person is stimulated by its effect. Because such, a mechanism is not warranted, we avoided using this language in our own experiments preferring to use the term ‘correlation’ for the phenomenon, rather than referring to the participants as ‘stimulated’ and ‘non-stimulated’. This approach renders opportunities for a wider range of explanations, e.g., assuming a generalized entanglement as an explanatory model for the findings.

However, the TP reported by GZ could not be replicated. In fact, the experimental procedures used raise doubts, as to whether the reported effects were caused by electromagnetic effects of the stroboscopic lights used for triggering evoked potentials and the stimulation of the subjects. Yet, later experiments with a similar albeit refined design showed significant EEG correlations between pairs of isolated human subjects. (Fenwick et al. 1998, Standish et al. 2001, Wackermann et al. 2003, 2004, Radin 2004). In order to replicate the experiments of GZ, a number of important changes were introduced in most of these new experiments to overcome some of the shortcomings of the original design. Wackermann et al. (2003, 2004) used checkerboard reversals as computer animated stimuli, which provide a reliable visually evoked potential in an observer’s brain. Other major changes included the treatment of subject groups and data screening. Experimental and control groups were treated the same way and were equal in number. Artifact screening by means of measuring the electroocculogram (EOG) was conducted. Experimental rooms were electromagnetically and acoustically shielded. Appropriate statistical methods (non-parametric randomization statistics) were utilized that are sensitive enough and at the same time robust, because they do not depend on any distribution assumptions. Measurements to control for technical artifacts were taken. (Wackermann et al. 2003, 2004). For instance, the control situation was identical to the experimental situation with the only exception that the computer screen providing the stimulus was covered with a black, opaque piece of cardboard. So far, the original experiment (Wackermann et al. 2003) has been replicated twice with a larger number of subjects, a larger number of electrodes and other statistical methods. Although not published yet, informal presentations of the results show that the effect is stable in the sense that statistically significant deviations from randomness occur. The effect also seems to be non-classical in nature, because there is no stable pattern to these deviations.

For this reason, we propose to follow this experimental design and probe it for its robustness. At the same time, it seems necessary to elaborate on some critical points. For instance, in all the experiments conducted hitherto, the data-acquisition systems were internally connected to one system that provided the time stamp. Although electromagnetic crosstalk was not an issue, it would be more convincing if the effects could be seen in systems completely decoupled. Also, the question whether a signal theoretical approach is valid needs elaboration. This could not completely be excluded in previous studies. The studies by GZ, Standish et al. (2001) and Fenwick et al. (1998) did not use electromagnetic shielding. In the Wackermann et al. studies, electromagnetic shielding was present.

3. Approaches of our three replications

In order to independently replicate the effects found by Wackermann et al. (2003 and 2004), the author conducted a replication of this approach in Tübingen in two non-neighbouring laboratories (Hinterberger et al., 2006, 2007, in press). However, as an improvement, we disconnected the computer systems after starting the recording to avoid stimulus crosstalk. Another issue was which stimulus should be used. Radin (2004) observed that stronger potentials evoked in the sender were correlated with stronger effects in the receiver. We therefore addressed the question of different stimulus categories and used both: standard reversal checkerboard stimuli that should replicate Wackermann's study, and naturalistic pictures, which are likely to produce stronger reactions. The study design and the results are reported below.

To overcome the debate about non-perfect shielding and a conventional signal transfer, we set up two consecutive highly elaborate studies using a long distance as shielding that would make a signal theoretical approach implausible. On the other hand, long distances are not an issue, should the phenomenon fall in the class of generalised entanglement as predicted by Weak Quantum Theory (Atmanspacher et. al. 2002). Subjective case reports on telepathy would also suggest that telepathic connections are independent from distance. Therefore, in the last two of the three replication studies we used a distance between the participant pairs of 750 to 800 km, which would hardly allow for an electromagnetic signal transfer, but rather support the idea that the effect is driven by an entanglement process. These experiments were conducted in two laboratories, one being located either in Tübingen or Freiburg (two cities in southern Germany) the other being located in Northampton (UK). The computers in the two labs were synchronized by the DCF radio clock signal that could be received in both locations.

Another point in question was whether closeness of relationship is important or whether it is only the systemic setup of the experiment that establishes the effect. We attempted to clarify this question by using pairs of subjects with different personal relationships and using pictorial material reinforcing the relationship.

Finally, the method of the non-parametrical statistical analysis was further refined as reported below.

4. Experimental set up

In all three studies, we were using two identical EEG-recording systems (EEG8, Contact Precision Instruments, Inc., UK) which were placed in two different rooms. The first study was carried out in two non-neighbouring laboratories at the University of Tübingen. At the beginning of each recording run, the two computer systems were synchronized with a cable connection, which was cut after the run had started. The second study was carried out between Tübingen (Institute of Medical Psychology and Behavioural Neurobiology, University of Tübingen) and Northampton (School of Social Sciences, University of Northampton, approx. 800 km distance) and the third study between Freiburg (Institute of Environmental Medicine and Clinical Hygiene, University Medical Center Freiburg) and Northampton (approx. 750 km distance). In both studies, the computer systems were started simultaneously by synchronization with the DCF radio clock signal, which is broadcast from Frankfurt am Main/Germany reaching both laboratories. In all three experiments, the computers ran independently after recording started with a typical precision in synchronicity below 20 ms.

EEG was measured simultaneously in the stimulated and non-stimulated participants. Ag/AgCl electrodes were attached at the scalp locations Cz, C3, C4, Fz, Pz, Oz, A1, A2 (Int. 10/20 system). The vertical EOG was measured for correction of eye blink and movement artifacts. Data were filtered by hardware to a range of 0.01 Hz to 40 Hz and sampled at 512 samples/sec.

In study one, 10 related and 10 unrelated pairs of subjects were measured. Since the effects we found were mainly seen in the related participants, we decided to use closely related pairs of participants in study 2 (16 pairs) and study 3 (20 pairs), and assessed their relatedness with a questionnaire. Before each recording run, the related participants had to tune into each other for at least 5 minutes. As each one of the pairs could serve as stimulated and non-stimulated participant, study 2 and 3 provided data on 28 and 38 valid pairs.

In all three studies, pictures from the International Affective Picture System (IAPS) were used for stimulation. The pictures were categorized into affective pictures with negative valence, neutral pictures and positively rated pictures. Additionally, study 1 contained the checkerboard stimulus for replicating the design of Wackermann et al. (2003 and 2004). Study 2 additionally contained pictures of the partner and various self-selected photos (own emotional pictures, OEP). In study 3 we only used the three categories of the IAPS. No erotic stimuli were used. The pictures were presented in a pseudo-randomized order with random interstimulus intervals. The non-stimulated subject was seated in a comfortable reclining chair, and was instructed to relax while the EEG was taken. The parameters of the study design for each study are listed in Table 1.

Table 1: Overview of the three studies carried out by the author with similar equipment

Parameter	Tü-Tü	Nh-Tü	Nh-Fr
Stimulus Design	80 IAPS (40Neu+40 Aff) 80 checkerboard 80 IAPS (40Neu+40 Aff) ――― cov. 80 black screen cov. 80 IAPS (40Neu+40 Aff) cov. 80 checkerboard	80 partner 80 OEP 80 black ――― 80 IAPS (40neu+40aff) 40 partner	ca. 141 IAPS (47 aff+47 neu+47 pos) ――― ca. 141 IAPS (47 aff+47 neu+47 pos)
Electrodes	Cz, C3, C4, Fz, Pz, Oz, A1,A2, vEOG,	Cz, C3, C4, Fz, Pz, Oz, A1,A2, vEOG, SCR	Cz, C3, C4, Fz, Pz, Oz, A1,A2, vEOG, SCR(non-stim)
IS Duration	3-6 sec	4-7 sec	2-10 sec (mean 6sec)
Stimulus Duration	1 sec	2 sec	0.5-5 sec variable (mean 2s)
Participants	10 related pairs 10 unrelated pairs	16 pairs, closely related	20 pairs, closely related
Age of participants	24f/16m 18-51 (mean 27)	16f/14m 21-59 (mean 36)	28f/12m 21-81(mean 42)
Valid session pairs	10+10	28	38
Analysis	1 EEG (MastRef), EOG, 6 bands 56 spatial band CAR	SCP, 6 ch EEG (MastRef), EOG, SCR, SCL 7 bands	SCP, 6 ch EEG (MastRef), EOG, SCR, SCL 7 bands
Processing rate	256 Samples/s	32 Samples/s	32 Samples/s
Random Comparisons	1 000	10 000	5 000

Data Analysis

The entire data processing and statistical analysis was performed in Matlab 7.2. All the routines were developed and programmed by the author. In parts, analysis of the last two far-distant studies was similar to the analysis of the first study carried out in Tübingen (Hinterberger et al., 2006, 2007, in press). A detailed description of the analysis of the last two studies is given below.

Pre-processing

The data were visually inspected and checked for periods of artefacts, which were excluded from the analysis. The EEG was corrected for eye-movements and re-referenced to both mastoids resulting in 6 channels of EEG (Fz, Cz, Pz, Oz, C3, and C4). For extraction of different features, a number of band-pass filters were applied to each EEG channel as follows. The frequency range between 1 and 45 Hz was chosen for the analysis of event-related potentials (ERP). Additionally, to look for effects in specific frequency bands, each channel was filtered into 7 bands, namely the slow cortical potentials (SCP, 0.01-2 Hz), Delta (1-4 Hz), Theta (4-8 Hz), Alpha (8-12 Hz), Beta1 (12-20 Hz), Beta2 (20-30 Hz, and Gamma (30-45 Hz). To reduce the number of variables, the filtered EEG was averaged for each band over all cortical electrodes. The band power of the 6 bands from Delta to Gamma was calculated by squaring and smoothing of the signals. The SCP and the broadband EEG was analysed in their original time course. In order to avoid an excessive influence of possible remaining artefacts, the band power was limited to 10 times of its mean value. The EOG was also included in the further analysis after filtering to 0.01-2 Hz. This allowed for detection of possible startle reflexes of the non-stimulated participant contiguous with the stimulation times and resulted in 15 variables, namely 1 EOG, 6 broadband EEG for ERP analysis plus 8 channels with all electrodes merged. These signals were then down sampled to 32 samples/s for further analysis.

Statistical Analysis

All 15 channels were subject to the same statistical analysis. The analysis was applied to the data of the non-stimulated participants using the stimulus type and onset times from the stimulated participants. The stimulus epochs of the same conditions were averaged separately for each channel, sample and participant. For analysis of time series data such as SCP, EOG and the broadband EEG, a baseline value - taken from the 0.2 sec before stimulus onset - was subtracted. For the spectral data, a baseline consisting of the mean of the recording run was subtracted from the averaged spectra. Averaging was performed with respect to the pre-selected periods of artefacts.

Our non-parametrical statistical approach requires a comparison with 5 000-10 000 virtual sessions. Therefore, a randomised selection of 5 000-10 000 possible stimulus sequences was calculated using the same rules in terms of inter-stimulus intervals than the actual stimulus sequence. Those random epochs were averaged in the same way as the real stimulus epochs. Because we were only interested in the size of the response and not in its direction, the absolute values of the averages were calculated and filtered with a Savicki-Golay Filter of 2^{nd} order using a window of 5 samples which produces a 7 Hz low-pass filter. From the average over trials, the highest 3 samples (100 ms) were taken as a reduction from the whole time series (0 to 3 sec after stimulus onset) into one signal value. This maximum value of the average of the real stimulus onsets was then compared with all maxima of the random averages and ranked according to its amplitude. This rank can directly be interpreted as a probability of achieving a significantly heightened signal. On a 5 % level, the rank would have to be greater than 500. Using the inverse Gaussian cumulative distribution function Φ^{-1} the ranks can be transformed into z-scores according to

$$z^{rank} = \frac{1}{\sqrt{M}} \sum_{j=1}^{M} \Phi^{-1}(r_j) \qquad (1)$$

where r_j denotes the rank of the j-th participant rank and M the number of participants (M=28 or 38). The z-transformed values were averaged across all participants resulting in z^{rank}.

This leads to one z-score for each of the 5 conditions, each of 15 parameters, and each sample.

In a final step, we counted the significant time (z>1.65) in all channels and condition. This should be about 5 % according to the 5 % significance criterion.

Results

The ERP-analysis in the time range during the stimulation and one second after has been analysed for all non-stimulated participants. The global ERPs, including all electrodes and all picture categories, revealed no significant results in all three studies. The SCP and the EOG also remained non-significant. No significant variable could be found after analyzing each stimulus category separately. In contrast to the analysis of the evoked response time course, the responses in the spectral bands revealed some significant values, predominantly in the Delta, Theta, Alpha, and Gamma band. In the first study the unrelated participants remained non-significant for all bands and all stimulus categories. However, the related participants showed significant increase in the Theta (z=2.34, p=0.01) and Alpha band (z=2.14, p=0.02) for the affective pictures. The neutral pictures were significant for the Delta band (z=2.22, p<0.02). In the second study the 28 pairs could create a significant Alpha band increase for affective pictures (z=2.31, p=0.01) and the own emotional pictures (z=1.79, p=0.04). For the latter stimuli the Gamma band showed also a significant increase (z=2.08, p=0.02). In the third study the Theta band was increased when pooling all stimuli (z=2.48, p=0.01) and the increased Alpha band activity for negative affective pictures could be replicated the third time with z=2.52 (p=0.006) in a sample of 38 pair comparisons. A weak significant Delta band increase (z=1.89, p=0.03) and a Gamma band effect of z=2.50 (p<0.01) could be seen with positive emotional picture stimuli. As the p-values have to be corrected for multiple testing with an unknown factor most of the significances might not survive such a correction. However, the repeated Alpha band effect accumulates to a z-score of 4.0 (p=0.00003) which easily survives even a highly conservative correction. For a comparison of the results between the three studies Table 2 provides an overview.

Table 2: Overview of the results in all three studies. For the band power measures only significant bands are mentioned.

Analysis Parameter	Category	SepaCorr Unrelated	SepaCorr Related	DistCorr*	EntCorr*
Global ERP	All Pictures	n.s.	n.s.	n.s.	n.s.
	Affective	n.s.	n.s.	n.s.	n.s.
	Neutral	n.s.	n.s.	n.s.	n.s.
	Positive / Partner	-	-	n.s.	n.s.
	Checkerboard	n.s.	n.s.	-	-
	OEP	-	-	n.s.	-
Bandpower Analysis (significant results out of 7 bands)	All Pictures	n.s.	Theta: 2.34 Alpha: 2.14 Gamma: -2.95	n.s.	Theta: 2.48
	Affective	n.s.	Theta: 2.34 Alpha: 2.14	Alpha: 2.31	Alpha: 2.52
	Neutral	n.s.	Delta: 2.22	n.s.	Theta: 2.26
	Positive / Partner	-	-	n.s.	Delta: 1.89 Gamma: 2.50
	Checkerboard	n.s.	n.s.	-	-
	OEP	-	-	Alpha:1.79 Gamma: 2.08	-
SCP	All Pictures and all stimulus categories	-	-	n.s.	n.s.
EOG	All Pictures and all stimulus categories	n.s.	n.s.	n.s.	n.s.
Amount of significant values	All stimuli categories	6.25%		5.24% (Affective: 8.3% OEP: 8.3%)	6.05% (Affective: 5.96 % Neutral: 8.07%)

*Peak analysis in the time range; n.s. non significant; '-' means that the measure did not exist in this study

The Alpha effect in all three studies asked for a closer look. In case of the result being an artefact this could show up as outliers in a few participants only. On the other hand the literature gives many hints that there might be only a few gifted people who show strong telepathic abilities. If our Alpha effect would arise from such gifted participants some of them should be highly significant while most subjects would remain around chance distribution. As Figure 1 illustrates more than two third of all participants contribute to the effect. Therefore, we have to reject the hypothesis of gifted participants showing a kind of Alpha increase upon their partners' affective experiences. It is rather a small effect that got significant in 9/76 participants instead of only 4/76 and many others showed a tendency that supported the overall significance.

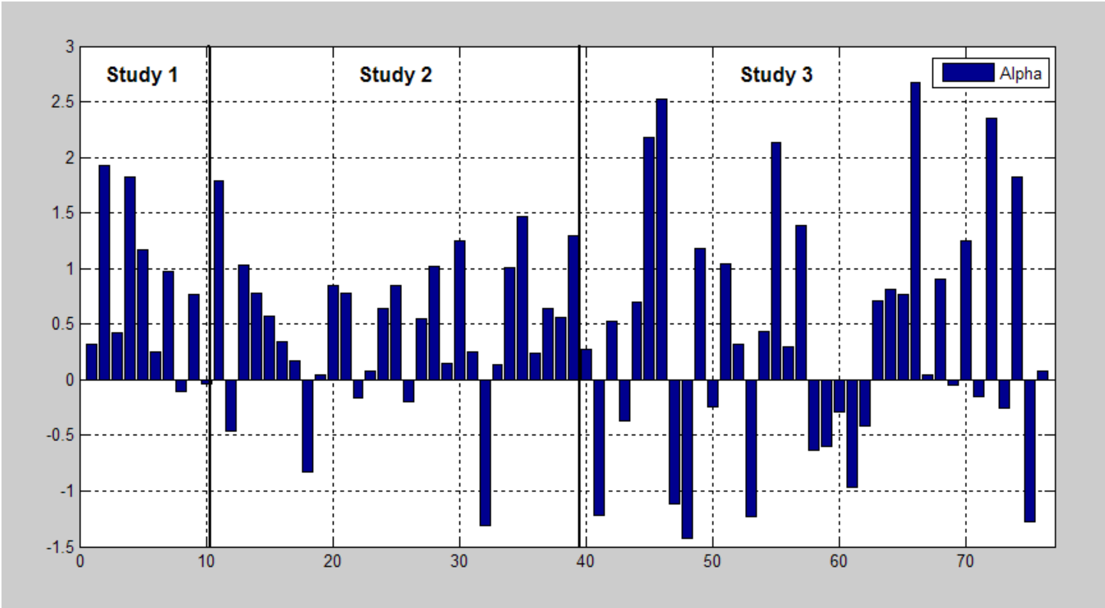

Figure 1. Each bar indicates the one non-stimulated participants' significance score in the Alpha band power deviation upon the stimulation of his/her partner with affective pictures. 76 participants of all three studies are shown not including the unrelated participants from study one.

Discussion

Considering all three experiments in each study, we found slightly more significant values when counting the significant parameters of all stimulus categories and all participants (final row in Table 2). This hints at a positive result, in terms of the EEG response in the non-stimulated participants being slightly modified by stimulation of a related person. However, the effect is rather small. The measures revealing significances remain in the range between z=1.65 and 2.5 or, in terms of p-values, between 0.05 and 0.005. However, we should also be aware that an unknown correction factor for multiple testing has to be applied to the p-values that has not been considered but which is also hard to predict. These results seem to be in line with other studies, such as those conducted by Wackermann et al. (2003, 2004). In contrast to Wackermann et al. (2004), who reported an increased amount of decreased activity in the non-stimulated participants, we found hardly any significant decreases in the activities in all stimulus categories and all 15 EEG measures. Despite having analyzed the signal decrease we focused predominantly on the increase, which is equivalent to the existence of an evoked response in the non-stimulated participant. However, if we decide to test the counterintuitive hypothesis of a decrease, it would be necessary to correct those significances for multiple testing. Similarly to our significances, which show up in only a few of the analyzed parameters, Wackermann et al. (2004) reported z-scores no larger than z=2.5 out of a set of 19 electrodes predominantly in the covered condition.

Yet, reporting such overall effects harbours the possibility of having smeared an effect which might be real and far more significant, e.g. for a certain stimulus condition, and/or for a specific EEG parameter, or for some especially gifted people, only. An individual analysis of the effect in the Alpha band could not identify such gifted participants. In other words, many participants contributed to the effect to become significant.

The different stimulus categories have been analyzed separately. In contrast to the findings of Wackermann et al., the results of the checkerboard stimulation remained non-significant. Thus, we can conclude that a replication of their approach failed.

At least two possible models could serve as explanation for the effects found in these and probably also in the earlier studies.

1) Artifact induced through analysis. The analysis of EEG signals usually leads to a multi-dimensional parameter space, i.e. several meaningful parameters can be derived from the EEG time signal, e.g. band power in various frequency bands. Furthermore, the way each parameter is determined offers a high degree of freedom. In our three studies, we attempted to focus on the most meaningful and most common methods. Still, there would be reasonable arguments for choosing different parameters. My experience with changing the analysis model slightly is that the results could change dramatically from significant to non-significant. As the human attention system is selective (and scientists are a human-like species) one might tend to focus more on positive outcomes and stop with analysis when an effect is found, or even change the parameter to optimize the effect. In my analyses, I was aware of this psychological phenomenon of tending to support significant results. Avoiding such tendencies could be achieved by optimizing the method first on the data from the stimulated participant and then applying it to the EEG data of the non-stimulated participants without any change. If similar physiological reactions occur in the non-stimulated participants the effect should then show up. This was actually found to be the case in the third study in which we found a significant ERP. However, when taking a closer look the significance turned out to be due to a potential shift during the 200ms baseline period before the button press. In this case it cannot be decided whether such a baseline shift already has its origin in a preparatory presentiment of the non-stimulated participant, or whether it happened arbitrarily exactly during the time span of the baseline.

2) Generalized entanglement between stimulation and EEG parameters of the non-stimulated person. In that case our measured parameters are correlates to complementary variables, i.e. variables which do not commute or which are independent, so that they do not carry information from each other. In quantum physics, such variables are measures in a so-called Bell-experiment. Here, e.g. the spin directions, which are measured alternatively, could be such variables. Transfer of the design to our EEG- correlation experiment to measure the Bell-inequation is not trivial. Statistically, many of the EEG-measures are not independent and therefore do not provide a set of complementary variables. However, different EEG measures could reflect correlations to different underlying variables which are complementary.

If those complementary variables are correlated with the same complementary variables in the brain of the stimulated participant, and in addition, if the stimulation influences those variables, then we could assume that the whole system behaves like an entangled system showing correlations between stimulation times and the non-stimulated EEG responses.

One property of the non-local generalized entanglement theory is the theorem of non-signal-transfer (NST). This means that it should not be possible to reconstruct the state at the stimulated participant from the EEG response in principle. One argument for the validity of the NST axiom in the present studies could be that the observed effects are not stable in the parameter in which they show up, but rather that they change their position from study to study (Walach, 2005). However, it is very important to note that fluctuating effects are a necessary condition to guarantee that a signal has not actually been transferred through such EEG correlations. However, it is not a condition that could serve as sufficient proof for the non-signal-transfer axiom that is valid in non-local correlations observed in entangled quantum states.

So far EEG correlation experiments have shown that unlike in stimulated persons there is no clearly visible and reproducible event-related potential in non-stimulated persons. The sensitivity for detection of such event-related signal changes in the EEG of the stimulated person in our final experiment was around 17 standard deviations away from noise, while the non-stimulated participant revealed z-scores smaller than 2.5 and often around zero. Therefore, we were able to conclude that if there is a correlation visible in the EEG activity, it must be very small. But this highly sensitive non-parametrical statistical approach probably was successful for detection of a very small increase in the Alpha band activity when exposing the related participant to affective pictures. However, because this has already been reproduced in three studies and the effect for affective picture material is also in line with our expectation, we found a pattern in the EEG that did not shift between the parameters as proposed by the theory of a generalized entanglement. The 'no signal transfer paradigm' would be violated if we could predict such Alpha increase successfully for a subsequent experiment in that style.

Even if we claim that the significant findings in the experiments simply reflect the random expectation, the hypothesis of possible EEG correlations between two closely related people is not thus disproved. All the experiments analyzed the event-related response to a visual stimulation. But what about correlations in the spontaneous EEGs between closely related pairs of subjects? We could expect that our EEGs might be to some extent correlated naturally (Standish et al. 2001). Therefore, it would be interesting to re-analyze our experiments and search for such correlations and test whether they are larger in the closer related pairs.

In conclusion, I would say that the paradigms we used in our experiments to test for so-called transferred EEG-potentials were very similar. Most other studies also aimed at the detection of an event-related response. Those similar approaches were important for replicating the reported effects. Now, after several replications I would like to encourage researchers to invent a new hypothesis for searching for a possible physiological connection, even in the existing data, or to develop new paradigms more suitable for uncovering a possible connection between people.

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