The Einstein–Podolsky–Rosen Paradox in the Brain: The Transferred Potential

J. Grinberg-Zylberbaum, M. Delaflor, L. Attie, and A. Goswami

Abstract

Einstein-Podolsky-Rosen (EPR) correlations between human brains are studied to verify if the brain has a macroscopic quantum component. Pairs of subjects were allowed to interact and were then separated inside semisilent Faraday chambers 14.5 m apart when their EEG activity was registered. Only one subject of each pair was stimulated by 100 flashes. When the stimulated subject showed distinct evoked potentials, the nonstimulated subject showed "transferred potentials" similar to those evoked in the stimulated subject. Control subjects showed no such transferred potentials. The transferred potentials demonstrate brain-to-brain nonlocal EPR correlation between brains, supporting the brain's quantum nature at the macrolevel.

Key words: evoked potentials, transferred potentials, human nonlocal communication, EPR correlation

1. INTRODUCTION

In 1935 three renowned physicists, Einstein, Podolsky, and Rosen, published an article[1] in which they criticized quantum mechanics, claiming that if it were a complete model of reality, then nonlocal interactions between particles had to exist. Since that was clearly impossible, quantum mechanics had to be either wrong or at least incomplete. This critique is known as the EPR paradox.

For almost half a century, the EPR paradox remained without experimental tests, until in 1982 Aspect *et al.*[2] experimentally verified that nonlocal influences between particles indeed exist once these particles have interacted. Since nonlocality can never be simulated by a classical system,[3] EPR nonlocality can be used to test the explicit quantum nature of systems. The purpose of this paper is to demonstrate the existence of a macroscopic quantum system in the human brain through the demonstration of EPR nonlocal correlation between brains.

That the human brain may contain a quantum system in addition to its classical neuronal system is a decades-old idea.[4–8] What follows is a brief summary.

How does an electrical impulse pass from one neuron to another across a synaptic cleft? Conventional theory says that the synaptic transmission must be due to a chemical change. The evidence for this is somewhat circumstantial, however, and Walker has challenged it in favor of a quantum mechanical process.[4] Walker thinks that the synaptic cleft is so small that quantum tunneling may play a crucial role in the transmission of nerve signals. Eccles has discussed a similar mechanism for invoking the quantum in the brain.[9]

Bass and, more recently, Wolf have suggested that for intelligence to operate, the firing of one neuron must be accompanied by the firing of many correlated neurons at macroscopic distances, as much as 10 cm, which is the width of the cortical tissue. In order for this to happen, theorizes Wolf, we need nonlocal correlations (EPR-style, of course) existing at the molecular level in our brain, at our synapses. Thus even our ordinary thinking depends on the quantum nature of events in the brain.[5]

The crucial question is, How does the brain accommodate consciousness? Perhaps the brain accommodates consciousness because it has a quantum system sharing the job with its classical one, suggest Stuart *et al.*[6] and Stapp.[7] In this model, which Goswami has adapted into an idealist model of consciousness and quantum measurement,[8,10] the mind–brain is looked upon as two interacting classical and quantum systems. According to Goswami, the classical system acts as the measurement apparatus for the quantum system. And consciousness is accommodated because it is consciousness acting nonlocally and self-referentially that collapses the states of the dual quantum system/classical measurement apparatus.[11]

Grinberg-Zylberbaum's[12] ideas add further clarity to this picture. According to Grinberg-Zylberbaum's syntergic theory, the conjugated activity of all neuronal elements of a working brain forms an interaction matrix called the neuronal field. We posit that the neuronal field represents the effect of quantum measurement by the measurement apparatus of the brain. The neuronal field is thus the manifestation upon measurement of the state of the quantum system of the brain that exists in potentia before measurement. It is this neuronal field that is indicated locally in the EEG readings.

How does one test this quantum model of mind–brain–consciousness? Goswami and McCarthy have found evidence for such a model in the word-sense ambiguation data of Marcel[13] and have suggested further a quantum interference experiment — the analog of a double-slit experiment with the mind–brain.[14] Another equally convincing track toward evidence for the quantum in the macroscopic working of the brain is to demonstrate EPR nonlocality among brains directly.

There are already some indications that the EPR correlation may also occur at more complex levels (such as the human brain). Recently, changes were shown in the interhemispheric coherence of individual subjects who were located in a soundproof Faraday chamber while a meditation session was being held at a distance by a group of subjects.[15] Meditation produces an increase in coherence and interhemispheric correlation[16] in such a way that the changes over a distance were probably reflecting an interaction between the brains' coherences.

Another study[17] sheds light on this matter by showing that patterns of interhemispheric correlation in two subjects during nonverbal, empathic communication become similar. This communication refers to the capability of the subjects to feel mutual togetherness without the need of speech. We called this direct communication. The similarities in the morphologies of the interhemispheric correlation patterns hold a direct relation with the degree or intensity of direct communication[18] and is maintained even when the subjects concerned are separated in two individual Faraday chambers.[19] The previously mentioned studies show that a transference of EEG activity exists and that this transference is not the result of unspecific factors such as habituation, fatigue, or relaxation.[17] However, none of the aforementioned studies have tested the possibility of the existence of a transference of specific signals, such as the evoked potentials, with the exception of a recently published article[19] in which it was observed that an evoked potential in a stimulated subject is "transferred" to another subject once they have interacted. An evoked potential is an electrophysiological brain response produced by a sensory stimulus. This study was conducted in two Faraday chambers separated by a distance of approximately 3 m. The following experiment was designed precisely for exploring the possibility of replicating the former experiment but at a larger distance.

2. EXPERIMENTAL METHOD

According to Goswami,[20] the observation of quantum nonlocality in the human brain depends crucially on our ability to correlate brains. The earlier work of Grinberg-Zylberbaum and Ramos[17] suggests an experimental protocol to correlate brains. In this study it was found that if two people meditate together, their brains' EEG display phase coherence with respect to each other. Phase coherence is a well-known signature of quantum nonlocality. Accordingly, subjects of this study were correlated by meditating together for about 20 minutes.

A total of seven pairs of normal subjects of both sexes and of ages ranging from 20 – 44 years participated in this study. Two soundproof Faraday chambers were used, separated by a distance of 14.5 m. In all subjects, monopolar recordings in O1 and O2 derivations were conducted, keeping a reference electrode on the tip of the nose. In one of the chambers (the stimulation chamber) EEG activity was registered using a Beckman polygraph. In the other (the transference chamber), a Grass polygraph was used. In each chamber EEG activity was digitalized using a 12 byte A/D converter and was analyzed by two AT computers of different makes.

The analog filters used had a window between 5.3 Hz and 35 Hz. In addition, a digital filter was used to eliminate all EEG frequencies below 12.7 Hz. To each of the subjects in the stimulation chamber (Subject A) 100 flashes were applied at random intervals of 2 – 5 s while the subjects remained reclined and with eyes semiclosed. The other subject of the pair (Subject B) remained in the transference chamber in a reclined position and with eyes closed and received no stimulation, nor did he/she know when Subject A was being stimulated. One hundred samples of EEG activity were taken from each subject during 512 μs epochs, synchronized with the flashes during two different conditions: Condition 1: before interaction, and Condition 2: after interaction. In order to achieve Condition 1, the subjects in each pair were shown into the two chambers without having seen each other and without knowing that his/her partner was in the other chamber. Under these circumstances the averages of the 100 EEG samples were obtained from each subject. No data were discarded.

For Condition 2 the subjects were introduced to each other inside the stimulation chamber with instructions to get to know and then to feel one another in meditative silence for 20 minutes. [This protocol presumably established quantum correlation referred to as direct communication (DC); the data indicate that about 25% of subject pairs successfully attained DC.] Then Subject B went directly to the transference chamber on his own and *without interacting with anyone*, maintaining DC. Once there, he reclined with eyes closed. The subjects were instructed to maintain DC with their partners while Subject A was stimulated by a series of 100 flashes applied at random intervals by a Grass photostimulator on maximum power. In this condition (Condition 2) an average of EEG activity was taken as in Condition 1.

Furthermore, two blind control tests (without either subject's knowledge) were performed, consisting of an average of 100 EEG samplings without stimulation chosen at random (Control A) and an average of 100 EEG samples under stimulus but without a subject in the stimulation chamber (Control B). The averages obtained in both conditions and during the controls were compared to see if a potential similar to the evoked one (of Subject A) was recorded in Subject B. The recording program automatically rejected EEG segments of both subjects that were saturated (e.g., due to movement). The potential averages of both subjects were calculated taking into account every stimulation (flash) without eliminating any. In other words, for both the evoked and the transferred potential, the data are presented without any arbitrary selection.

The EEG activity of all the subjects was digitally filtered from 0 Hz – 12.7 Hz with the objective of eliminating all possibility that the potentials were chance results of alpha (or other slow wave) brain activity. Statistical analyses were performed using spectral analysis, correlation coefficient, and t-test in order to compare the EEG activities of the subjects in all the control and experimental conditions.

To achieve this goal, the EEG activity of each condition (1 and 2) was digitalized with a sampling speed of 8 μs. The value of statistical correlation between the electrical potentials of the two subjects was obtained every 128 μs (each 16 pairs of digits). The first correlation value was calculated for the first 16 pairs of digits. A second correlation value was obtained by shifting the analysis 8 μs in time to get a second set of 16 pairs of digits. In this manner, correlation values were calculated shifting each time 8 μs all the way to the total of 512 μs for each average. Thus we obtained a total of 48 Pearson correlations for each pair of potential averages. For each value of the correlation, we calculated the level of statistical significance.

In the following section we present our experimental results and the statistical analyses.

3. RESULTS

When interaction was deemed successful (in about one in four cases the subjects were able to attain and maintain direct communication while being apart) and when Subject A's average showed a distinct evoked potential (DEP), we found potentials of similar morphology in Subject B. These last we called *transferred potentials*, examples of which are shown in Figs. 1 and 2 for the O2 derivation. The 100-sample average of EEG activity in both subjects (A and B) shows a remarkable similarity. It is worth noting that in all our figures, the averages were calculated out of 100 segments with no arbitrary omissions.

In Fig. 1, the levels of high statistical correlation between 0.700 and 0.929 occurred in the first 132 μs. This corresponds to a statistical significance at a level where the probability of chance occurrence is less that 0.009 ($p < 0.009$). In Fig. 2, correlation levels were obtained with $p < 0.005$ between 0 and 73 μs. The correlation indexes between the evoked and transferred potentials fluctuated between 0.62 and 0.92.

In Figs. 3, 4, and 5 it can be noted that without interaction, *in the absence of a DEP*, and without stimulus, respectively, no clear potential signals were found in Subject B, and no statistically significant value for the correlation was obtained either.

4. DISCUSSION

Our results indicate that after a meditative interaction between two human beings in which both subjects are instructed to maintain direct communication (i.e., to feel each other's presence even at a distance), in about one in four cases when one of the subjects is stimulated in such a way that his/her brain responds clearly (with a distinct evoked potential), the brain of the nonstimulated subject also reacts and shows a transferred potential of a similar morphology. The transferred potentials never occur when the subjects do not interact, when the evoked potential is unclear, or when a signal (flash) is not applied.

The statistical analysis shows that the transferred potential is obtained from the moment of stimulation to about 132 μs. The striking similarity between the transferred and evoked potentials and the total absence of transferred potentials in the control experiments leaves no room for doubt about the existence of an unusual phenomenon, namely, propagation of influence without local signals. As noted already, the similarity of the evoked and transferred potentials could not be due to an unspecified low frequency EEG correspondence (alpha waves) because of the low frequency filters that we used.

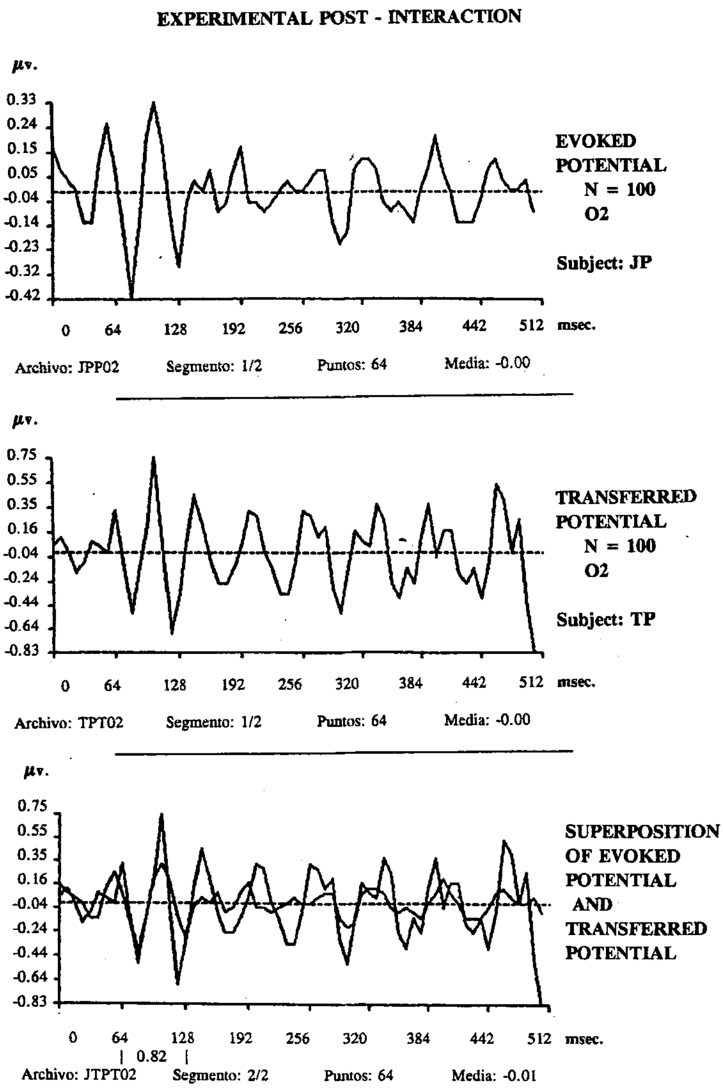
The data indicate that the human brain is capable of establishing close relationships with other brains (when it interacts with them appropriately) and may sustain such an interaction even at a distance. Our results cannot be explained as due to sensory communication between subjects (since the subjects were separated during the experiment and located in two semisilent, electromagnetically isolated chambers distant more than 14 m from one another) or as due to low frequency EEG chance correspondence.

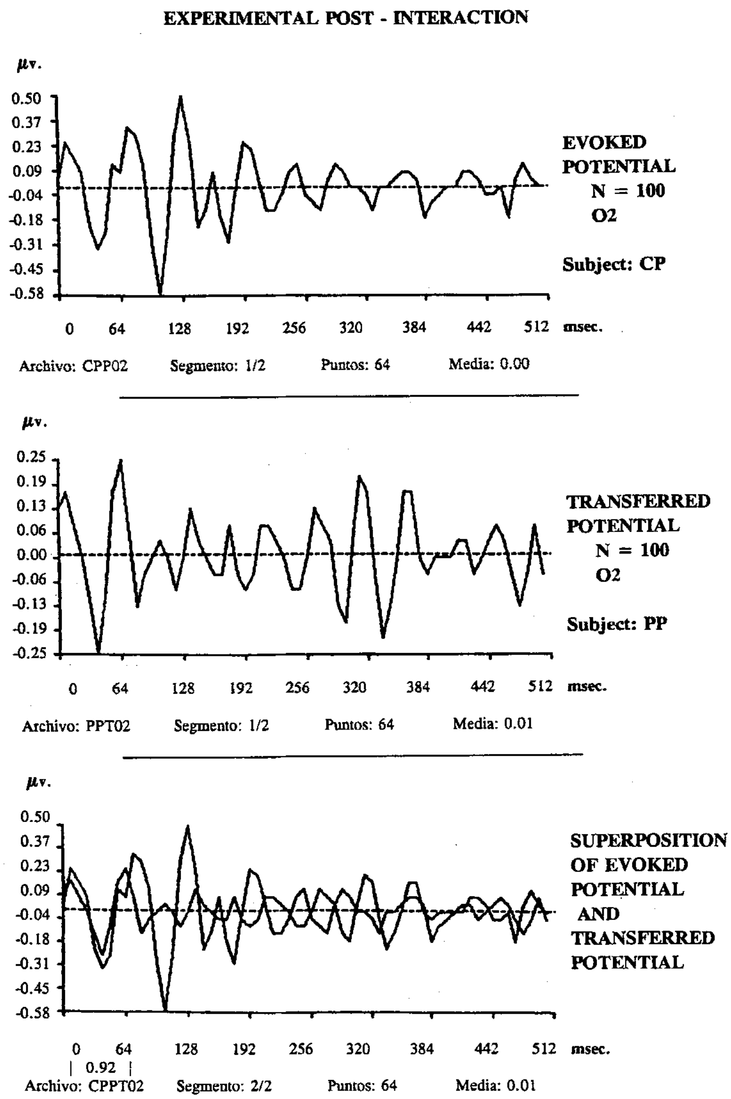
This means that neither sensory stimuli nor electromagnetic signals may be the means of communication. This point is further borne out by the fact that we have not seen any distance attenuation of the transference effect compared to our previous measurement which involved a shorter distance between the subjects. (Note that the present experiment thus serves as a replication of the previous experiment.) As is well known, local signals are always attenuated, and the absence of attenuation is a sure signature of nonlocality.

Encouraged by Bell's theorem[21] and the results of the Aspect *et al.* experiments[2] on elementary particles, we interpret the transferred potential as a manifestation of nonlocal interactions among "members" of a correlated quantum system whose parts, separated individual brains before interaction, become one system after interaction. Via the interaction, the quantum brains of the subjects become correlated; stimulation and collapse of one subject's wave function simultaneously collapses the wave function of the other in an identical state as indicated by the similarity of the DEP in the stimulated subject to the transferred potential in his/her nonstimulated partner. The similarity of the evoked and transferred potentials reflected in the EEG must be due to the close correspondence of the neuronal fields of the two correlated brains after collapse.

In other words, the phenomenon we are dealing with is the action of nonlocal collapse of the wave function of a unified system and not the result of a transmission using local signals from one brain to the other.

It is also extremely significant that the occurrence of trans-





Figures 1 (left) and 2. Figures 1 and 2 show in their upper portion the averages obtained from 100 evoked potentials. The middle portion shows the average of 100 epochs of EEG registered in Subject B synchronized to the stimuli presented to Subject A. The lower parts of the figures show both averages superimposed. These figures show the complete set of samples registered after subject interaction. The correlation index obtained in the first 132 μs for the potentials of Fig. 1 was meaningful with $p < 0.009$. The same for Fig. 2 for the first 73 μs was meaningful with $p < 0.005$. Note also the difference in the scales of the ordinate between the evoked and the transferred potentials.

ferred potential is always associated with the participants feeling that their interaction has been successfully completed (in contrast to the lack of transferred potential where there is no such feeling). The interaction that correlates the subjects under study is entirely an interaction via nonlocal consciousness. This indicates that consciousness is involved in the process of correlation, and thus the idealist interpretation that consciousness collapses the quantum wave function upon measurement is essential to make sense of the present data.

It is plain to see that when two brains interact, very peculiar effects are observed that closely resemble those observed in elementary particles — interaction correlates objects, and a measurement on one component of a correlated state collapses the other component as well, even at a distance.

Due to technical difficulties it was impossible for us to register more than two derivations at a time on each subject. So far, the

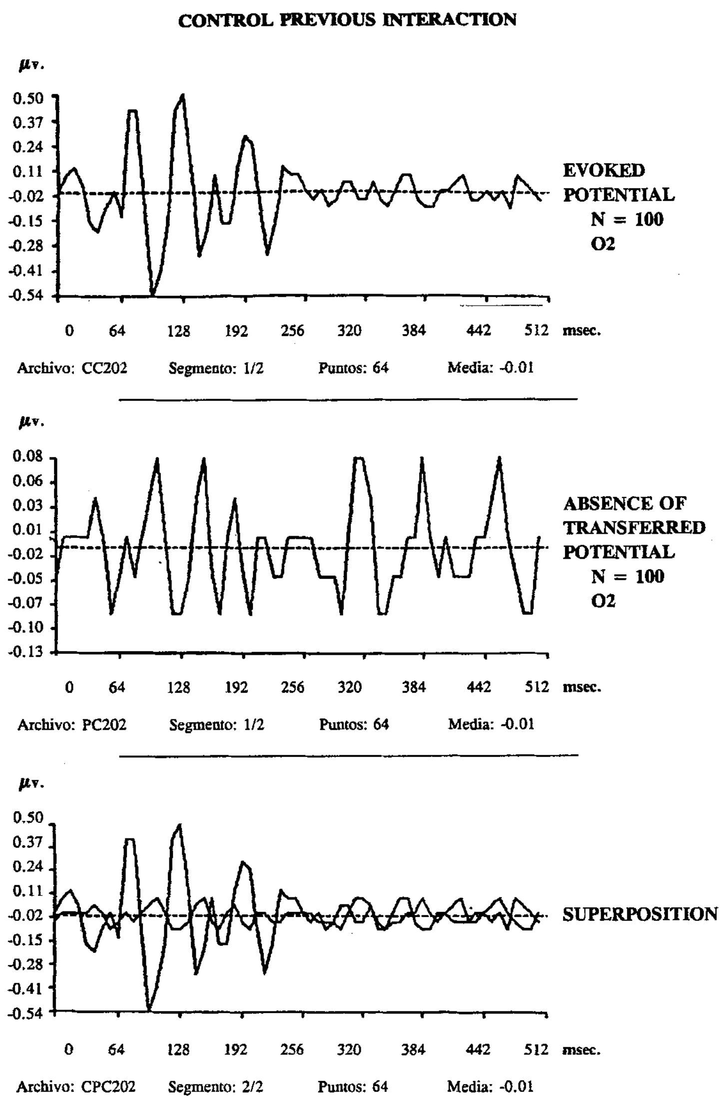


Figure 3. This figure, following the same arrangement as Figs. 1 and 2, shows the results of an experiment during Condition 1. Even though a DEP is observed in Subject A, no transferred potential is seen in his/her partner. Note scale as in Figs. 1 and 2.

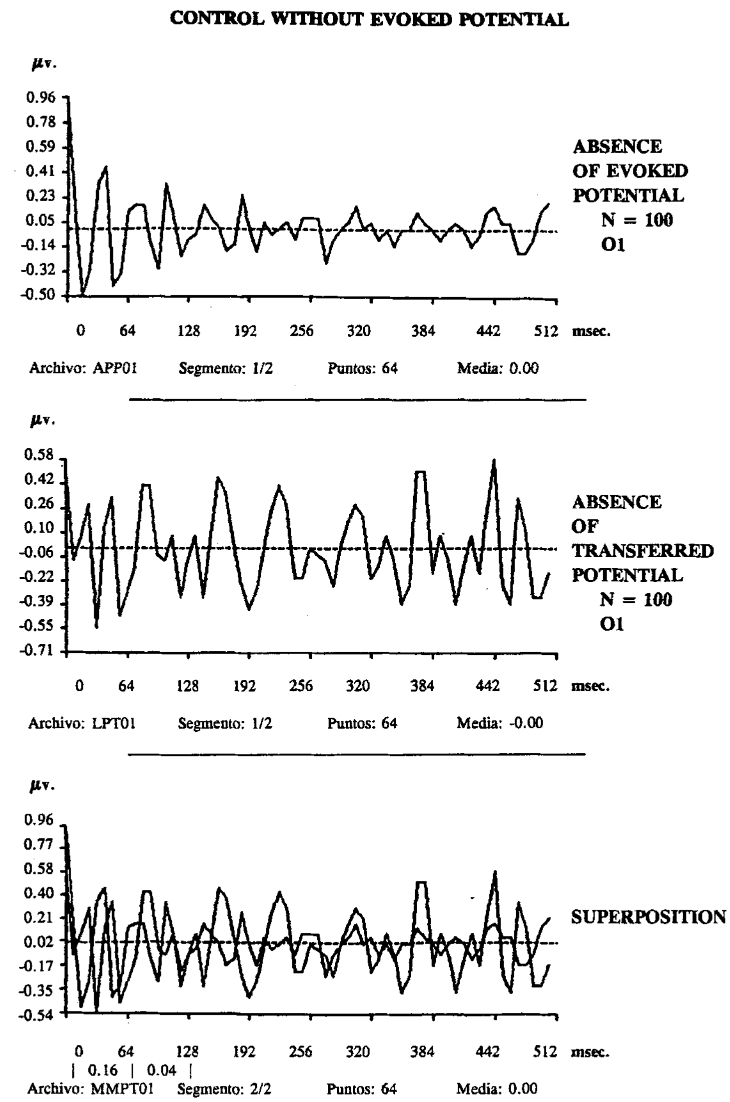


Figure 4. Same disposition as in Figs. 1, 2, and 3. This figure shows an experiment during Condition 2. No distinct evoked potential was elicited from the stimulated subject as can be observed. No transferred potential exists in the nonstimulated subject. Note scale.

anatomical locations of the transferred potential have not been studied, but it is worth mentioning that the O2 derivation (right occipital) seemed to offer a clearer transferred potential. At the moment we are beginning to conduct a study in which the complete cerebral cortex will be scanned using the 10–20 international system of electrode positions.

To close, it is important to note that none of the Subjects B ever reported realizing any type of conscious experience related to the appearance of the transferred potential. It is our view that this may be due to secondary processes (e.g., idle thought; see, also Ref. 8) in the Subject B. It is expected that with training, these subjects will be able to consciously experience the primary awareness process of correlated collapse.

Obviously, no information at the subjective level is being transferred and no violation of the causality principle is involved in the experiment. The nonlocal collapse and the subsequent similarity of the evoked and transferred potentials of the subjects must be seen as an act of synchronicity; the significance of the correlation is clear only after we compare the potentials. This is

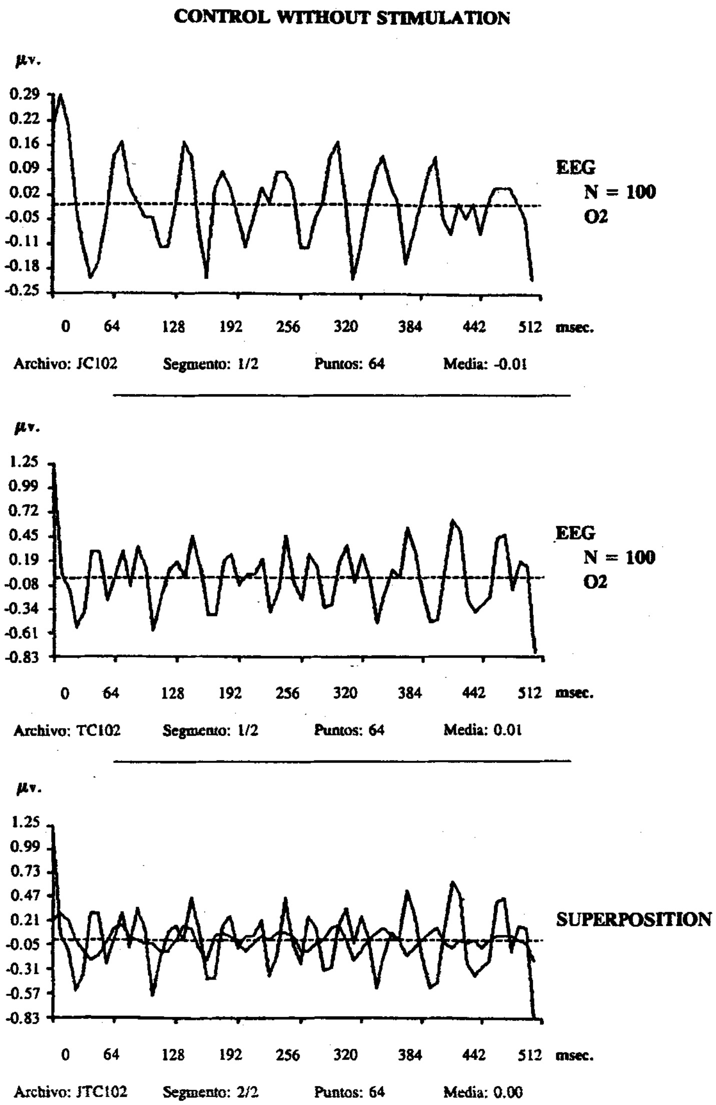


Figure 5. Same disposition as former figures. Averages obtained from 100 synchronized epochs of pure EEG activity in Subject A and Subject B prior to stimuli application. No evoked or transferred potentials are observed. Note scale.

similar to the Bell–Aspect situation; the meaning of the latter correlation is also clear only after we compare the individual data.[10] However, if we use a flickering light signal, the evoked potential often carries a frequency signature. To the extent that this frequency signature is also retained in the transferred potential, it may be possible to send a message, at least in principle, using a Morse code. This is now under study along with a very long-distance experiment in which the subjects will be separated by 12 000 km. In practice, of course, such message transfer will be very difficult because of the direct communication necessary between the subjects. It has been suggested that the brain obeys a nonlinear Schrödinger equation in order to include self-reference.[22] It is possible that for systems obeying nonlinear Schrödinger equations, message transfer via EPR correlation is permissible.[23]

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Résumé

On étudie les corrélations Einstein-Podolsky-Rosen (EPR) entre les cerveaux humains pour vérifier si le cerveau a des caractéristiques quantiques macroscopiques. On a permis que des paires de sujets réagissent réciproquement, puis qu'ils se séparent à l'intérieur de chambres de Faraday séparées de 14.5 m, à demi silencieuses où on a enregistré l'activité EEG de chacun. Seulement un sujet de chaque paire a été stimulé par 100 chocs. Quand le sujet stimulé a montré le potentiel distinct évoqué, le sujet non-stimulé a montré un "potentiel de transfert" similaire à celui évoqué par le sujet stimulé. Les sujets de contrôle n'ont montré aucun potentiel transféré. Le potentiel transféré démontre une corrélation EPR non-locale inter cerveaux soutenant la nature quantique au niveau macroscopique.

References

1. A. Einstein, B. Podolsky, and N. Rosen, Phys. Rev. **47**, 777 (1935).
2. A. Aspect, J. Dalibard, and G. Roger, Phys. Rev. Lett. **49**, 1804 (1982).
3. R.P. Feynman, Int. J. Theor. Phys. **21**, 467 (1982).
4. E.H. Walker, Math. Biosci. **7**, 131 (1970).
5. L. Bass, Found. Phys. **5**, 155 (1975); F.A. Wolf, *Starwave* (McMillan, NY, 1984).
6. C.I.J.M. Stuart, Y. Takahashi, and M. Umezawa, Found. Phys. **9**, 301 (1979).
7. H.P. Stapp, Found. Phys. **12**, 363 (1982).
8. A. Goswami, J. Mind Behav. **11**, 75 (1990).
9. J. Eccles, Proc. R. Soc. London, B **227**, 411 (1986).
10. A. Goswami, Phys. Essays, **2**, 385 (1989).
11. That consciousness collapses the quantum wave function was originally suggested by J. von Neumann, *The Mathematical Foundations of Quantum Mechanics* (Princeton University Press, Princeton, 1955) and by E.P. Wigner, in *The Scientist Speculates*, edited by I.J. Good (The Windmill Press, Kingswood, Surrey, UK, 1962). The dualistic connotations of this earlier work have been removed in Ref. 10.
12. J. Grinberg–Zylberbaum, *Creation of Experience* (INPEC, Mexico, 1988).
13. A.J. Marcel, in *Attention and Performance, VIII*, edited by R.S. Nickerson (Lawrence Erlbaum, Hillsdale, NJ, 1980), p. 435.
14. A. Goswami and K. McCarthy, J. Mind Behav. **14**, 13 (1993); see, also, C.H. Woo, Found. Phys. **11**, 933 (1981).
15. D.W. Orme–Johnson, M. Dillibeck, R.K. Wallace, and G.S. Landrith III, Int. J. Neurosci. **16**, 204 (1982).
16. D. Orme–Johnson, G. Clements, Ch. Haynes, and K. Badaoui, in *Scientific Research on the Transcendental Meditation Program*, edited by D. Orme–Johnson and J. Farrow (Maharishi European Research University Press, 1977), Vol. 1, p. 705.
17. J. Grinberg–Zylberbaum and J. Ramos, Int. J. Neurosci. **36**, 41 (1987).
18. J. Grinberg–Zylberbaum, J. Cueli, A. Riefkhol, and D. Szydlo, Enseñanza e Investigacion en Psicología **VII** (2), (1981).
19. J. Grinberg–Zylberbaum, M. Delaflor, and M.E. Sanchez, Rivista Intercontinental de Psicologia y Educacion **2**, 309 (1989).
20. A. Goswami, *The Self-Aware Universe* (Tarcher/Putnam, NY, 1993).
21. J.S. Bell, Physics **1**, 195 (1965); *idem*, Rev. Mod. Phys. **38**, 447 (1966).
22. M. Mitchell and A. Goswami, Phys. Essays, **5**, 526, (1992).
23. J. Polchinski, Phys. Rev. Lett. **66**, 397 (1991).

J. Grinberg–Zylberbaum, M. Delaflor, and L. Attie
Universidad Nacional Autónoma de México and
Instituto Nacional Para el Estudio de la Conciencia
Apartado Postal 22-836
Delegación Tlalpan
C.P. 14000 México, D.F.

A. Goswami
Department of Physics
and the Institute of Theoretical Science
University of Oregon
Eugene, Oregon 97403–5203 U.S.A.