THE JOURNAL OF ALTERNATIVE AND COMPLEMENTARY MEDICINE
Volume 11, Number 6, 2005, pp. 955–963

ORIGINAL PAPERS

Replicable Functional Magnetic Resonance Imaging Evidence of Correlated Brain Signals Between Physically and Sensory Isolated Subjects

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ABSTRACT

Objectives: Previous electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) experiments have suggested that correlated neural signals may be detected in the brains of individuals who are physically and sensorily isolated from each other. Functional MRI and EEG methods were used in the present study in an attempt to replicate these findings.

Design/settings: Subjects were electrically and magnetically shielded because of the characteristic surroundings of the scanner room. During the experiment, the nonstimulated subject was placed in the scanner with sensory isolating goggles covering the subject's eyes. The stimulated subject was placed 30 feet away and sat in front of a video monitor that presented an alternating schedule of six stimulus-on/stimulus-off conditions. The stimulus-on condition consisted of a flickering checkerboard pattern whereas the stimulus-off condition consisted of a static checkerboard. Stimulus-on/-off conditions were presented in the sequence on/off/on/off/on/off. The duration of these intervals was randomly assigned but consistently provided a total of 150 seconds of flicker and 150 seconds of static. Sessions were repeated twice to assess possible replication of the phenomenon.

Outcome measures: Changes in fMRI brain activation (relating to blood oxygenation) and EEG signals were measured in the nonstimulated subjects. Changes occurring during stimulus-on conditions were statistically compared to changes occurring during the stimulus-off conditions.

Results: Statistically significant changes in fMRI brain activation and EEG signals were observed when comparing the stimulus-on condition to the stimulus-off condition in nonstimulated subjects ($p < 0.001$, corrected for multiple comparisons). For fMRI, these changes were observed in visual brain areas 18 and 19 (Brodmann areas). One of the subjects replicated the results.

Conclusions: These data replicate previous findings suggesting that correlated neural signals may be detected by fMRI and EEG in the brains of subjects who are physically and sensorily isolated from each other.

INTRODUCTION

Studies reporting the existence of anomalous correlated brain signals in pairs of physically and sensory isolated humans have appeared scarcely but consistently in the scientific literature for the last 40 years.[1–20] The first known report published by a biomedical journal of correlated signals between distant brains appeared in *Science* in 1965.[1] In this study, simultaneous EEG was recorded from 15 pairs of monozygotic human twins who were physically and sensorily isolated from each other. The study reported that EEG α rhythms were elicited in one member of the pair as a re-

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sult of evoking these rhythms in the other member, who was separated by 6 meters in a different room. This phenomenon, which the authors called "extrasensory induction," occurred in two of 15 pairs of twins tested and only when pairs of related twins were tested together.[1] In 1994 Grinberg-Zylberbaum et al.[3] reported that visual evoked potentials in one human brain produced by photostimulation to a single member of the pair could induce similar evoked potentials in the other member who was located 14.5 meters away in an electrically shielded room. Since 2000, at least three independent research groups have attempted to replicate these results. In these studies, simultaneous EEG was recorded in physically and sensorily isolated pairs in which one of the members was visually stimulated at random intervals.[14,18,20] These three groups reported that correlated brain signals were observed in 10%–20% of the pairs.[14,18,20] One of these EEG studies, carried out by the Bastyr University/University of Washington Consciousness Science Laboratory,[18] revealed "bursts" of brain activation in the nonstimulated subjects that were correlated ($p < 0.01$) with the "stimulus-on" condition of their stimulated partners in five of the 30 pairs. Four of the five significant pairs were invited to a replication experiment. Only one of those four pairs was able to replicate the results.[18] This pair was then invited to participate in the fMRI experiment described here.

Results from a pilot experiment to test the feasibility of using an EEG experimental design for an fMRI experiment have been published elsewhere.[17] This previous case report indicated that an increase in blood oxygenation significant at the $p < 0.001$ level was observed in the visual cortex of the nonstimulated subject, which was correlated to the stimulus-on condition of the stimulated partner. No such signal was observed when the stimulated partner was presented with the stimulus-off condition or when the subjects reversed their roles.[17] The experiment described below represents a second attempt to investigate the use of fMRI technology to investigate this phenomenon.

METHODS

Subjects

Two (2) healthy human subjects (CW and DW, subject identification only, not name initials) participated in our fMRI experiment. Subject CW was a 26-year-old white man. Subject DW was a 29-year-old white woman. The subjects had known each other for 6 years and had participated as a pair in a previous EEG experiment.[18] As previously discussed, subjects were selected because they were able to replicate statistically significant results in the EEG study.

fMRI experimental design and set-up

The experimental set-up was identical to that used in a previous fMRI study[17] except for minor improvements added to respond to reviewers' concerns, such as the inclusion of a replication trial and a physical barrier to achieve complete optical isolation between the control room and the scanner area. The experimental protocol is briefly described below.

fMRI experimental procedure

During the first experimental session Subject DW was designated as the nonstimulated subject and was placed in the MRI scanner, whereas Subject CW was designated as the stimulated subject and was placed in the scanner's control room 10 meters away from his partner. A diagram of the experimental set-up has been previously published.[17] The scanner room was electromagnetic field (EMF) shielded and therefore the two subjects were completely EMF shielded from one another. Each experimental session consisted of two trials: Trial 1 and Trial 2 (Replication). After the completion of the first experimental session, the subjects switched positions. Therefore, during the second experimental session subject CW was placed in the scanner (nonstimulated subject) while subject DW stayed in the control room (stimulated subject) and two other trials were recorded.

The nonstimulated subject was optically isolated from the control room and from the stimulated subject by two means: (1) goggles were placed that covered the visual fields of the nonstimulated subject's eyes, and (2) a black cardboard panel was added to the control room window to avoid any possible sensory leakage into the scanner area. The goggles were connected via high-resolution fiberoptic cables to two "Infocus" projectors (LP435z, Infocus, Wilsonville, OR), which were in turn connected to a personal computer.

Stimulus conditions

The stimulated subject was presented with an alternating schedule of six stimulus-on/stimulus-off conditions. The stimulus-on condition consisted of an 8×8 black-and-white checkerboard (0.12 cycles/degree) reversal stimuli presented at a rate of 6 Hz using Psyscope software (version 1.2.2, Cohen, MacWhinney, Flatt, Provost, Pittsburgh, PA). The stimulus-off condition consisted of a static fixation cross. The stimulus was presented on a 13-inch computer screen located 50 cm away from the subject's eyes. The nonstimulated subject was presented through the goggles with an unchanging static image that was considered "relaxing" or appealing to the subject. The image was chosen by the subject right before starting the experiment from a standard image catalog. This static image was introduced to act as a "built-in" control condition (i.e., the static image would not trigger visual evoked potentials).

The stimulated subject was instructed to fixate his or her eyes at the center of the video monitor screen and to attempt "sending an image or thought to his/her partner." The nonstimulated subject was instructed to watch the static image presented through goggles and to focus on feeling "connected" to his or her partner while "keeping open to receive any image or thought from him/her."

Data collection

The start of the stimulated subject's stimuli was synchronized to the start of the fMRI scan. Data were recorded during two trials for each of the subjects when acting as the nonstimulated partner. Each of the two trials rendered a total of 300 seconds of data. The 300 seconds of data acquisition yielded 100 sequentially collected brain volumes of which 50 (150 seconds) were collected during the stimulus-on condition (flicker) and 50 were collected during the stimulus-off condition (static). As in the previous experiment, the static flickering stimuli were alternated and presented in variable-length blocks ranging in duration from 18 to 33 seconds. For the stimulated subject, each experimental session began with a static condition. The start time of the static condition of the stimulated subject with respect to the nonstimulated subject's fMRI acquisition start time was randomly varied from 8.3 to 33 seconds.

fMRI scan acquisition

Blood oxygen level–dependent (BOLD) functional MRI scans were performed using echo planar images (EPI) to identify activation sites. Structural and functional MR imaging was performed on a 1.5 Tesla MR imaging system (version 5.8, General Electric, Waukesha, WI). Scanning included a 21-slice axial ("repetition time" (TR)/"echo time" (TE) 200/2.2 mseconds, fast spoiled gradient echo pulse sequence; 6 mm thick with 1 mm gap; 256×256 matrix). These anatomical series were followed by an fMRI series using two-dimensional gradient echo echoplanar pulse sequence (TR/TE 3000/50 mseconds, 21 slices; 6 mm thick with 1-mm gap, 64×64 matrix, 100 volumes total; time = 300 seconds). An additional three-dimensional, 124-slice anatomical MRI scan was performed with 1.4-mm sagittal slices using a three-dimensional fast spoiled gradient echo pulse sequence. Imaging parameters included a TR/TE of 11/2.2 mseconds, flip angle of 25 degrees, and a field of view was 24 cm (acquisition time was 4:36 minutes).

Image processing

Functional MRI scans were analyzed using BrainVoyager (version 4.8, Brain Innovation BV, Maastricht, The Netherlands). The data were motion corrected in three dimensions, smoothed in the spatial domain with a 4-mm Gaussian filter, smoothed in the temporal domain with a 4-second Gaussian filter, and linearly detrended. A general linear model regression (GLM) was used to generate statistical *p*-value maps based on the contrast between the "flicker-on" versus the "flicker-off" conditions. The expected response to changes in stimulation (i.e., stimulus-on versus stimulus-off) is known to follow the hemodynamic delay curve shown in Figures 1B, 2B, 3B,and 4B. The statistical process was used to determine the extent to which the observed MR responses were predicted by this model. A "goodness of fit" statistic (r^2) indicated the degree of fit between the hemodynamic model and the actual brain activity time course recording during 300-second fMRI scans. Both positive and negative β-coefficients can result. A positive β results when the fMRI signal positively correlates with the hemodynamic visual stimulus–brain response model. Negative β-coefficients result if the brain signal negatively correlates with the model.

The final display of fMRI superimposed on the structural MRI highlights only those areas of the brain in red that have *t* test values >4.4 corresponding to *p* values (Bonferroni corrected for masked 30,000 brain region elements) <0.01. The nonstimulated subject's activation map and three-dimensional structural MRI were converted to standard stereotaxic space of Talairach and Tournoux.[21] Stimulation typically energizes highly localized sites within the brain. The software examines brain regions within the mask and highlights only those brain areas in which the metabolic brain signal fits well with the model of stimulus presentation.

EEG methods used with same subjects

Subjects CW and DW also participated in a similar experiment using EEG (separately from the fMRI experiment). Briefly, two EEG systems (Lexicor, [Boulder, CO] Neurosearch-24) were combined to measure simultaneously the cortical EEG potentials from stimulated and nonstimulated subjects. Subjects were placed in different rooms separated by a distance of 30 feet. EEG was acquired using standard 19-channel Electrocap International (Eaton, OH) 10/20 electrode placements. Both Lexicor EEG systems were calibrated for the following parameters: visual evoked potential (VEP) mode, 512 points-per-second sampling rate; high-pass filter off; reversal of checkerboard once per second; 64 seconds per condition; four different conditions consisting of two flicker (on) and two static (off). Pattern reversal VEPs triggered by a flickering checkerboard pattern were recorded from O1 and O2 electrodes. The stimulus consisted of black-and-white checkerboard presented on a video monitor screen placed 50 cm from the subject, delivering checks of 10 pixels per cycle and 2.15 cycles per degree that reversed position at the rate of 0.5 Hz. Eye fixation was directed to the center of the screen where a red dot was placed. The EEG data for the nonstimulated subject was resorted again based on the exact sender's flicker timing. EEG α power was calculated for each 1 second epoch by Fourier transforming the EEG signal and integrating the EEG spectral power from 8 to 13 Hz. A Monte-Carlo randomization technique was used to compare α power values between the sender's flicker condition and the sender's static conditions.

RESULTS

EEG results

While acting as the nonstimulated partner, subject CW showed significantly lower alpha power for session 1 during the partner's stimulus on-condition flicker stimuli (χ^2

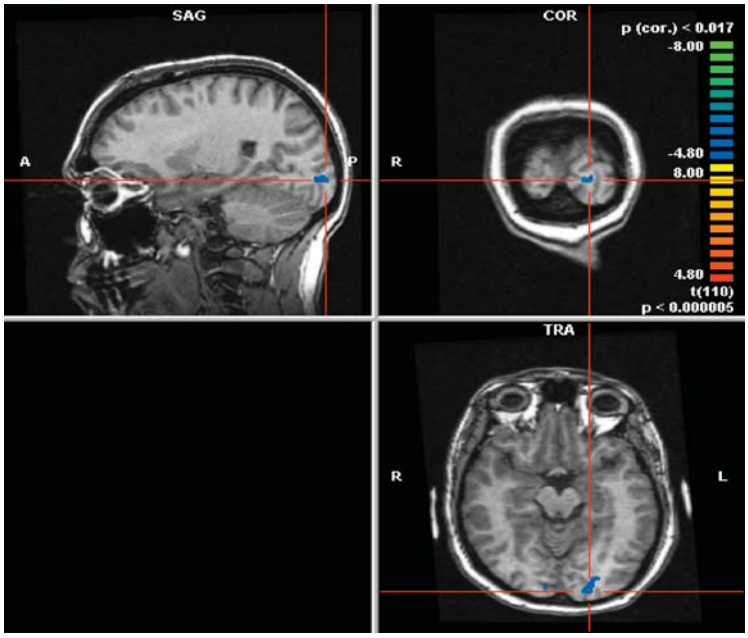
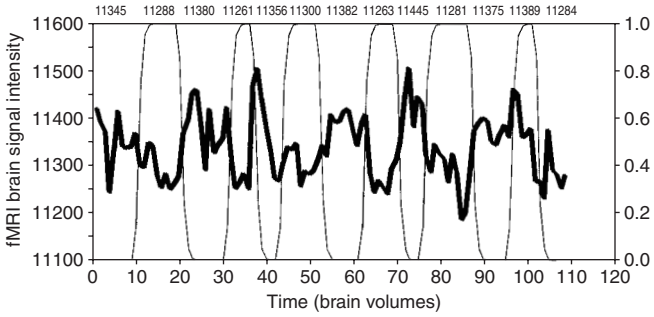


FIG. 1. Theoretical and actual functional magnetic resonance imagining (fMRI data obtained across 300-second experiment while subject DW was acting as "receiver." **A.** fMRI of subject DW acting as a "receiver" (first trial) with activation threshold set to $t = -4.8$, which corresponds to a p value of 0.017 (Bonferroni corrected). The blue areas overlaid onto the structural brain image indicate areas of statistically significant brain activation negatively correlated with the sender's stimuli. The cross-hairs are positioned over a significant cluster of brain activation in the left (occipital) visual cortex. **B.** Significant fMRI brain activation—negative correlation. Black bold lines indicate the actual fMRI brain signal (first trial) from the occipital region of subject DW during which the brain signal decreased in all six flicker conditions compared to the static conditions of the sender. Mean brain signal intensity for each stimulus condition is indicated at the top of each interval. **C.** fMRI z-score maps for subject DW during the first trial. The bright area is located in the left visual cortex.

B



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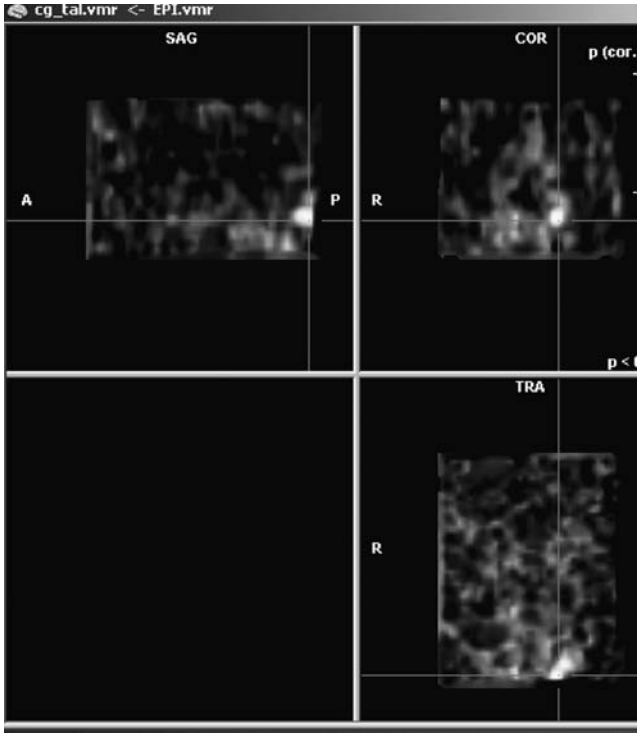


455.4; $p < .0001$) compared to the stimulus-off condition. However, no replication of these results was observed during a second trial. While acting as the nonstimulated partner, DW showed a significantly lower α power for session 2 during the partner's stimulus-on condition (χ^2, 317.4; $p < 0.005$) compared to the stimulus-off condition. However, results were not statistically significant for session 1.

fMRI results

As shown in Table 1, subject DW had significant fMRI brain activation which correlated with the stimulus-on condition of the stimulated partner in both the first and second trials in the left occipital regions (BA 17/18/19). Subject CW had significant fMRI brain activation, which correlated with the stimulus-on condition of the stimulated partner only in the second trial but not the first trial. In this case, significant activation was observed in the right occipital regions (BA 17/18).

Figures 1–4 show actual fMRI data, the time-course data for an activation cluster, and the z-score map from the two fMRI experiments for each subject. Results of all four fMRI experiments are summarized in Tables 1 and 2.

A significant decrease in fMRI brain activation, relating to blood oxygenation, at the $p < 0.017$ (Bonferroni corrected) level was observed in areas 18 and 19 of visual cortex in subject DW during the time intervals in which sub-

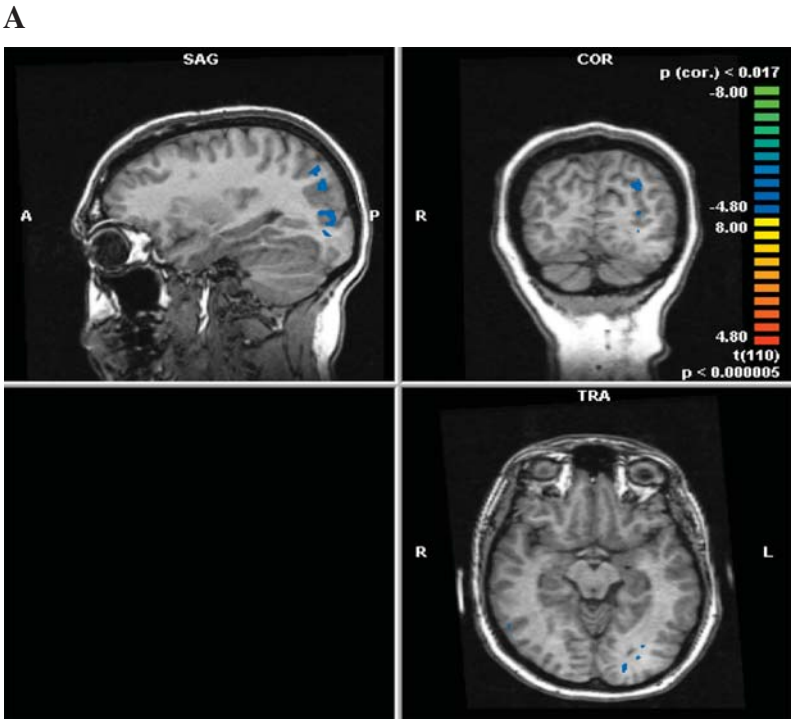
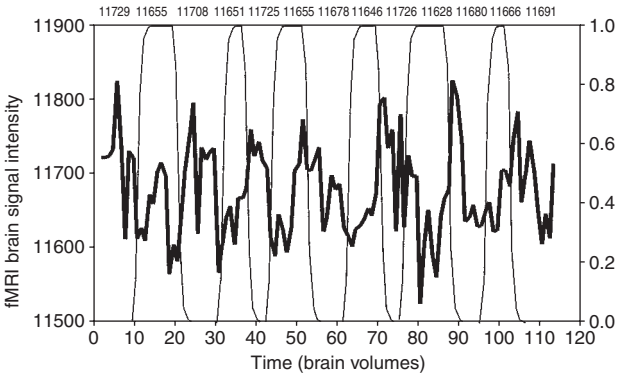
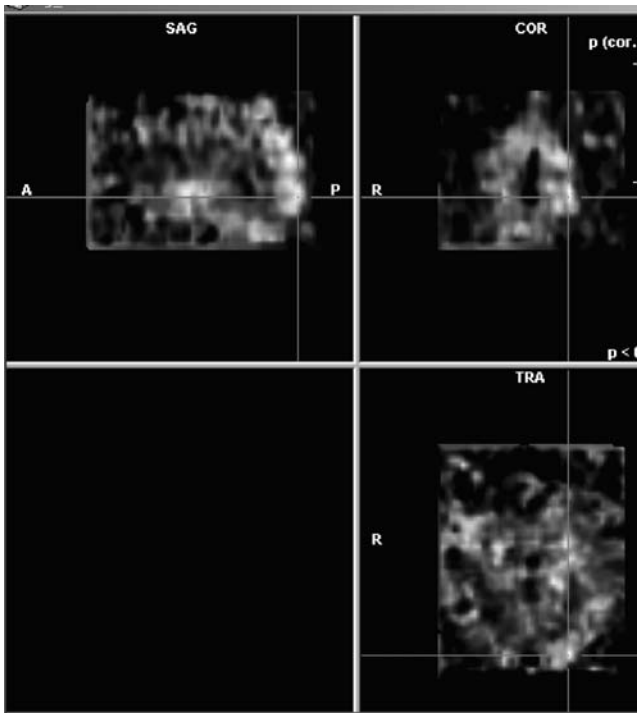


FIG. 2. Theoretical and actual fMRI data obtained across 300-second experiment while subject DW was acting as "receiver" (replication trial.). **A.** fMRI of subject DW acting as a "receiver" (second trial) with activation threshold set to $t = -4.8$, which corresponds to a p value of 0.017 (Bonferroni corrected). The blue areas overlaid onto the structural brain image indicate areas of statistically significant brain activation, which are negatively correlated with the sender's stimuli. Notice the consistent brain activation in the left visual cortex. **B.** Significant fMRI brain activation—negative correlation. Black bold lines indicates the actual fMRI brain signal from the occipital region of subject DW (replication trial) during which the brain signal decreased in all six flicker conditions compared to the static conditions of the sender. Mean brain-signal intensity for each stimulus condition is indicated at the top of each interval. **C.** fMRI z-score maps for subject DW during the replication trial. The crosshairs are positioned over an area depicting significant activation in the left visual cortex.





ject CW was presented with a flickering checkerboard stimulus (Fig. 1) compared to the control condition. Results were replicated in the following scan (Fig. 2).

When the roles were reversed (CW was placed in the brain scanner and DW acted as the stimulated partner), no significant changes in brain activation were observed in CW's brain during the first trial (Fig. 3). However, the brain signal increased in all six flicker conditions compared to the static conditions of the sender ($p < 0.017$, Bonferroni corrected) during the replication trial (Fig. 4).

DISCUSSION

This experiment was designed to test whether the stimulated partner's stimulus condition had an impact on the non-stimulated partner brain activation. To test this hypothesis various methodologic issues were taken in consideration, including: (1) a control condition (stimulus-off) was included in the protocol; (2) appropriate statistical techniques were used that controlled for individual variation and autocorrelation; (3) the nonstimulated partner was blinded (physically and sensorily isolated) to the stimulated partner's stimulus

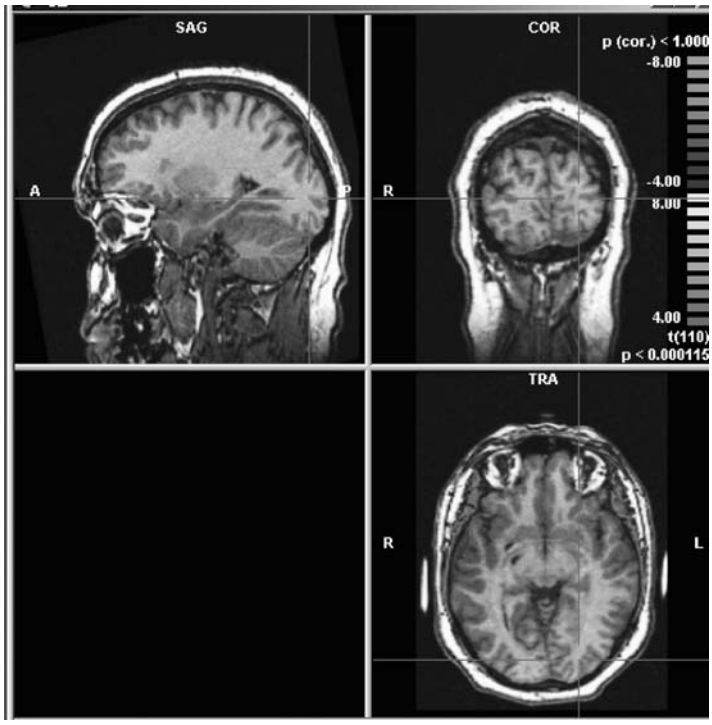
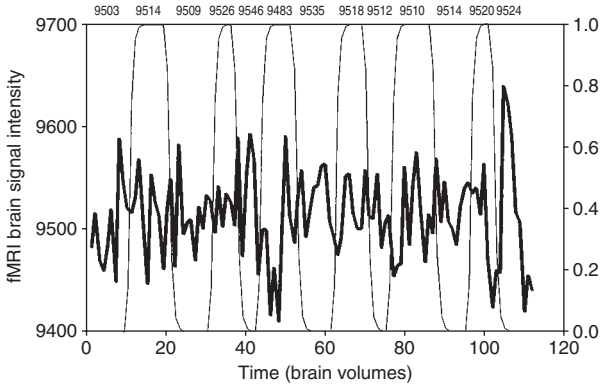
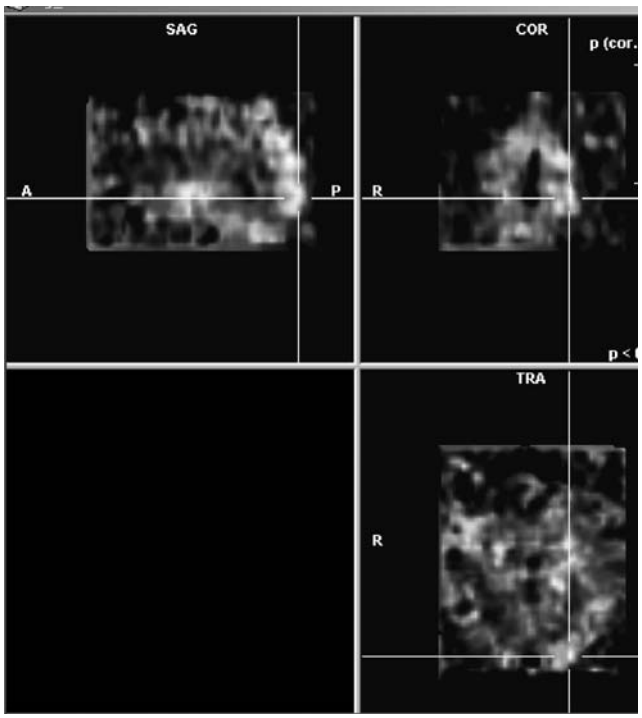


FIG. 3. Theoretical and actual functional magnetic resonance imaging (fMRI) data obtained across 300 second experiment while subject CW was acting as "receiver" (first trial). **A.** fMRI of subject CW acting as "receiver" with activation threshold set to $p < 0.01$. The absence of blue areas overlaid onto the structural brain image indicate areas that there has been no statistically significant brain activation correlated with the sender's stimuli. **B.** Black bold lines indicates the actual fMRI brain signal from the occipital region of subject CW, during which no significant changes were observed in brain activation when comparing flicker and static conditions of the sender. Mean brain-signal intensity for each stimulus condition is indicated at the top of each interval. Note that there was no significant receiver brain activaction. **C.** fMRI z-score maps for subject CW in first trial. No significant changes in activation were observed.





condition; (4) each subject served as his or her own autocorrelation control (see Methods section); and (5) a conservative threshold for significance ($t = -4.8$, which corresponds to a p value of <0.017) was chosen to protect against false-positive results. Under the null hypothesis there should be no correlation between the stimulated partner's stimulus condition and the nonstimulated partner's brain activation. If the null hypothesis is true, no brain regions should be detected at a p value <0.017 level when the statistics are corrected for multiple comparisons. Results suggest, however, that changes in fMRI brain activation in the nonstimulated partner's brain are correlated with the stimulus-on conditions of the stimulated partner. Furthermore, the correlated brain signals were observed in the occipital region of the brain in both subjects as would be expected for visual stimulation, and were not scattered throughout other brain regions, which suggests that the receiver subject is remotely receiving the timed visual stimuli. Although this may be interpreted as a validation that the signal is not an artifact or a false positive, there are currently no data indicating that a visual stimulus in the stimulated partner would necessarily have to correlate with a signal appearing in the visual cortex of the nonstimulated subject.

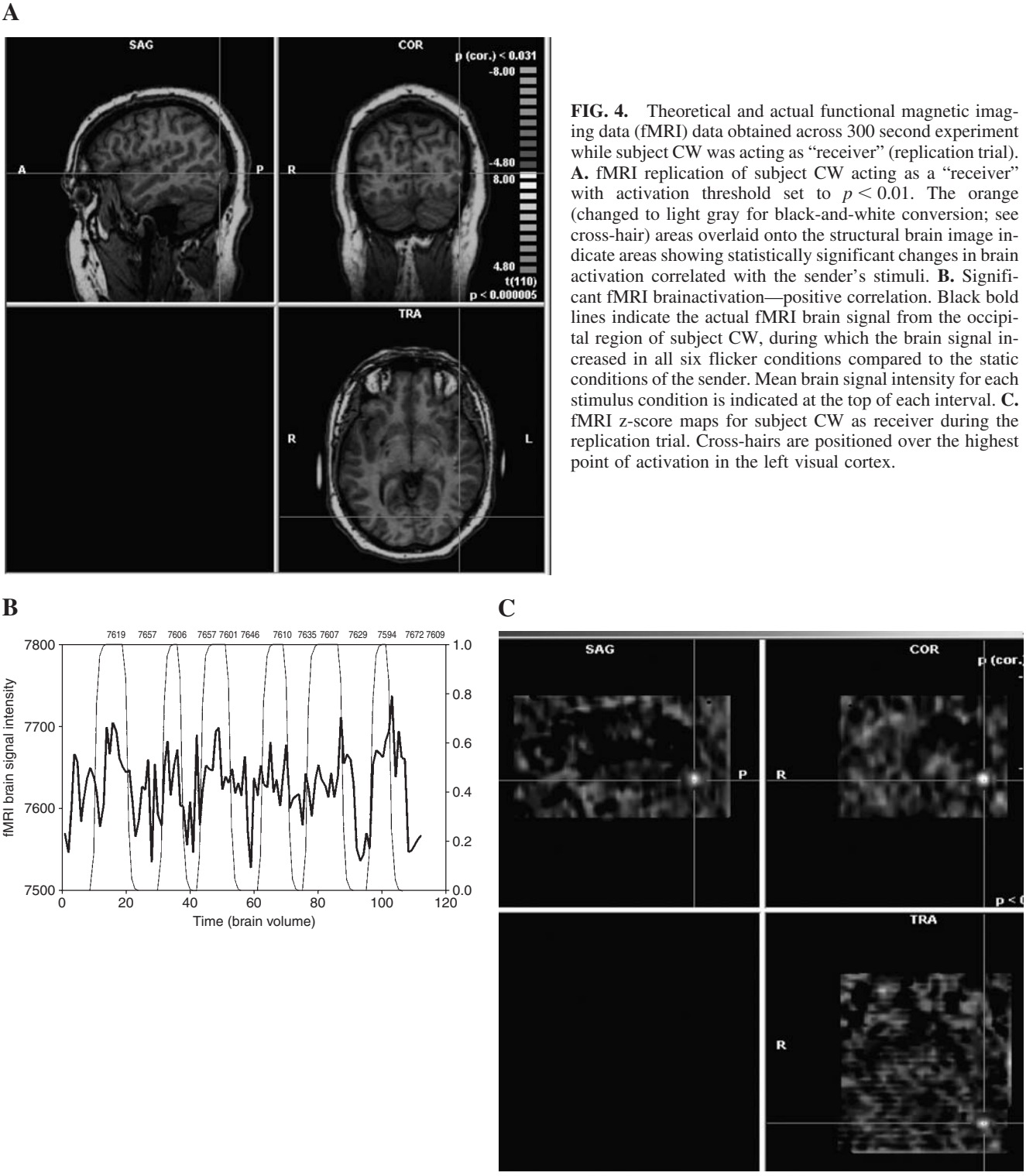


FIG. 4. Theoretical and actual functional magnetic imaging data (fMRI) data obtained across 300 second experiment while subject CW was acting as "receiver" (replication trial). **A.** fMRI replication of subject CW acting as a "receiver" with activation threshold set to $p < 0.01$. The orange (changed to light gray for black-and-white conversion; see cross-hair) areas overlaid onto the structural brain image indicate areas showing statistically significant changes in brain activation correlated with the sender's stimuli. **B.** Significant fMRI brainactivation—positive correlation. Black bold lines indicate the actual fMRI brain signal from the occipital region of subject CW, during which the brain signal increased in all six flicker conditions compared to the static conditions of the sender. Mean brain signal intensity for each stimulus condition is indicated at the top of each interval. **C.** fMRI z-score maps for subject CW as receiver during the replication trial. Cross-hairs are positioned over the highest point of activation in the left visual cortex.

CONCLUSIONS

The authors realize that these data refer to a highly controversial phenomenon and that the sample size is inadequate to draw any firm conclusions. However, the fact that a correlated signal could be detected and replicated in the nonstimulated partner by using two independent neurophysiologic measures of brain function (EEG and fMRI) provides evidence that an anomalous phenomenon (not just a recording artifact) may be at play. The authors realize, however, that even with the extreme care given to isolate the subjects from each other and to automate the experiment to avoid any added experimenter error, there is always a possibility that some artifacts could have been missed. A re-

Table 1. Summary of Data Analysis Results for First and Second Functional Magnetic Resonance Imaging (fMRI) Trials

Subject	*Broadman area*	*1st Trial*	*2nd Trial*
DW	BA 17	115[a] (L)	36 (L)
	BA 18	436 (L)	414 (L)
	BA 19	102 (L)	592 (L)
CW	BA 17	NA	29 (R)
	BA 18	NA	8 (R)
	BA 19	NA	NA

Note: Count of activated pixels ($t \geq 4.4$) in three areas of the visual cortex for the first and second fMRI trials.

[a]Count of pixels with t scores ≥ 4.4.

cently published meta-analysis reviewing distant intentionality data published until 2003 concluded that the meta-analysis yielded small but significant effects, and that "the existence of some anomaly related to distant intentions cannot be ruled out."[8]

Other possible explanation for the occurrence of such correlated signals is that the image presented to the nonstimulated subject through the goggles could flicker and therefore triggered VEPs in the nonstimulated subject. The experimenters, however, monitored the static image presentation to the goggles to make sure that the image did appear as visually static. The two visual stimuli were presented by two separate computers. The nonstimulated subject also had large ear phones to attenuate the scanner noise and would not have heard anything around the scanner room except the scanner noise.

To validate the existence of this phenomenon, further replication with a larger sample of subjects is warranted. The underlying mechanism of this phenomenon still remains to be elucidated[3] and no theoretical framework has yet been developed that allows incorporating these data into current neurophysiologic knowledge.[8] Some authors have suggested, however, that "quantum entanglement" properties of the human brain may be involved in such phenomena.[4,6,7] Future studies should include a variety of other control conditions to control further for false positives and/or other artifacts that may have been missed by this study. The authors acknowledge that this is a continuing case study of one particular pair of individuals and that these results cannot be generalized to the population as a whole.

ACKNOWLEDGMENTS

The authors gratefully acknowledge Michel Kliot, M.D., and Brent Stewart, Ph.D., for review of the manuscript and Heather King for her assistance in editing the manuscript. This research was supported through National Institutes of Health/National Center for Complementary and Alternative Medicine grant R21-AT00287.

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Table 2. Summary of Results for Region of Interest Analysis for Main Activation Cluster for First and Second Functional Magnetic Resonance Imaging (fMRI) Trials

	1st fMRI trial			*2nd fMRI trial (replication)*		
	*Region of interest analysis for main activation cluster**			*Region of interest analysis for main activation cluster*[a]		
	F *value*	T *value*	β	F *value*	T *value*	β
DW	37.4	−6.11	−70.2	30.217	−5.45	−48
CW				30.770	5.6	35.36

[a]First session stimulation time onset was delayed 1 minute relative to session 2 as a control for subject blinding.

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