Correlation between Pineal Activation and Religious Meditation Observed by Functional Magnetic Resonance Imaging

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The human brain possesses plenty of functions but little is known about its scientific relationship with mind and spirit. Conferences[1,2] focused on the connection between science and religion were held very recently in which neuroscientists, Buddhist scholars and Dalai Lama discussed attention, mental imagery, emotion, mind, brain functions and meditation, suggesting religious meditation offers an effective means to investigate the mystery of mind and spirit. In the past decade, scientists struggled to obtain brain mappings for various meditation styles using different brain imaging techniques and stimulating results have been observed[3-17]. In this letter we report that, together with other brain regions, pineal body exhibit significant activation during meditation process, supporting the long lasting speculation that pineal plays an important role in the intrinsic awareness which might concern spirit or soul. Pineal is known as an endocrine organ which produces substrates including melatonin and has been ascribed numerous even mysterious functions but its activation during meditation has never been observed by brain imaging technique. In seventeenth century, based on anatomic observation, Descartes ventured to suggest that pineal serves as the principal seat of the soul[18-20]. Inspired by its geometric center in the brain, physiologists, psychologists, philosophers and religionists have been speculating for centuries about pineal's function relevant to spirit and soul. In this study, we chose Chinese Original Quiet Sitting, one style of meditation, to explore this long lasting speculation by functional magnetic resonance imaging technique. Our results demonstrate a correlation between pineal activation and religious meditation which might have profound implications in physiological understanding of the intrinsic awareness.

In 2003, Barinaga reported a conference called "Investigating the Mind", held at the Massachusetts Institute of Technology. Neuroscientists, Buddhist scholars and Dalai Lama discussed attention, mental imagery, emotion, and collaborations to test insights

gleaned from meditation. Wisconsin's Richard Davidson collaborating with Matthieu Ricard, using fMRI (functional magnetic resonance imaging), studied the brain activity associated with positive emotions in Buddhist monks[1]. Knight (2004) also reported another meeting - a research conference held at the Dalai Lama's headquarters in Dharamsala, India - including talks that suggested meditation can transform emotions and that daily experiences can alter the expression of genes. Fred Gage, a neuroscientist at the Salk Institute for Biological Studies in La Jolla, California, presented his research into how the brain can remake itself throughout life. As a key component of Buddhist belief is that meditation literally transforms the mind. Richard Davidson pointed that certain neural processes in the brain are more coordinated in people with extensive training in meditation[2]. There are many studies about meditation on the mental activation that employ different methods about brain mapping or detecting, such as: fMRI, PET (positron emission tomography), SPECT (single photon emission computed tomography), EEG (electroencephalogram), REG (rheoencephalography) and MEG (magnetoencephalography). Herzog (1991)[3], Lou (1999, 2005)[4,5] and Kjaer (2002)[6] had studied Yoga meditation by PET. Lazar (2000)[7] studied a simple type of meditation (Kundalini) by fMRI. Newberg studied Tibetan Buddhist meditation (2001)[8] and the "verbal" based meditation of Franciscan nuns (2003)[9] by SPECT. Lo (2003)[10], Lutz (2004)[11] and Takahashi (2005)[12] studied Buddhism or Zen meditation by EEG. Jevning (1996)[13] and Yamamoto (2006)[14] studied Transcendental Meditation by REG, MEG and EEG. Davidson (2003)[15] measured brain electrical activity in mindfulness meditation with healthy employees by EEG. Lazar (2005)[16] used MRI to assess cortical thickness in participants with extensive insight meditation experience. Hölzel (2007)[17] using fMRI found activations in the rostral anterior cingulate cortex and the dorsal medial prefrontal cortex bilaterally in Vipassana meditation. These studies showed that different meditation styles might arouse different brain activations and produce different physical affections.

Chinese Original Quiet Sitting (COQS) is essentially one kind of traditional Chinese meditation. In ancient China, meditation was the prime practice for Taoists to temper soul and body. The principal key of COQS is naturalness. Its working is allowed to proceed naturally as to come into subtle adjustment[21,22]. The overall COQS process is separated into two different parts: a short period, about several minutes, of silent recitation of specific religious phrase and mental imagination of receiving spiritual energy (which is named "Invitation of Primordial Qi": IPQ), and a long period of relaxation with no further action (named "Allow its Natural Workings": ANW). Chen (1997) had studied COQS by EEG and found that the brain theta-wave showed a marked increase, while the alpha- and beta-waves showed a decrease after practice[23]. We also had preceding fMRI studies[24,25]. In this paper, we showed how to investigate the brain activation region precisely by fMRI. We chose COQS to go into deep investigation since COQS includes a short period of IPQ stage, a specific mental operation, in the beginning of the whole meditation process.

Sixteen subjects with seven females and nine males participated in this fMRI study. Their mean age was 48.5±2.8 (32~70) with meditation experience 12.4±1.5 (4~21) years. Their regularly mean practice times every day was about 1.3±0.1 (1~3) with mean practice duration 54.7±5.7 (30~120) minutes each time. Fig. 1 showed the normalized fMRI signal intensity of the pineal area during the IPQ stage of COQS. Fig. 1a was the normalized fMRI signal intensity of each individual subject. Fig. 1b was the normalized and smoothed fMRI signal intensity of the 16 subjects. The data were smoothed by wavelet denoise package of LabVIEW™ (Haar wavelet, level 3). Variant activation strength and patterns were observed among these sixteen subjects probably due to the individual differences in meditation experience, age, physiological or physical conditions. We also obtained the fMRI images by SPM[26]. Fig. 2 showed the brain activation regions during the IPQ stage of COQS analyzed by fixed effect analysis in SPM with $p<10^{-5}$. These images showed that during the IPQ period the brain regions

such as: pineal body, corpora quadrigemina, thalamus, insula, claustrum, anterior cingulate, cingulate gyrus, Brodmann area 24, superior temporal gyrus, Brodmann area 47, middle temporal gyrus, right side inferior fontal gyrus, Brodmann area 37, putamen, and many other regions including cerebellum were also activated. We could find from the results of the other meditation researches which were mentioned above that different meditation styles may have the same activation regions as we have found in COQS, such as: anterior cingulate (Lazar[7], Yamamoto[14]), precentral gyrus (Lazar[7]), cingulate gyrus (Newberg[9]), inferior frontal gyrus (Newberg[8,9]), right anterior insula (Lazar[16]), temporal gyrus (Lazar[7]) and thalamus (Newberg[9]). The functions of these regions were interesting and should be paid more attention to. We discussed them in the following. For the inference into the population, we also performed the second level random effect analysis with SPM and showed the results in Fig. 3 ($p<10^{-3}$). It still appeared that pineal body was activated during the IPQ period.

In order to get the more accurate vision of the pineal activation, other fMRI images were obtained by FACT[27]. Four right handed subjects, two females and two males, were reported here and participated in nine experiments. Their mean age was 43 (range 33~52) years old with meditation experience from 10~21 years. The fMRI results reproducibly and precisely showed that special regions exhibited the same activation during the IPQ periods. Fig. 4 showed the best images of the consistent region of these experiments. Fig. 4a and 4b were the anatomic images of the slice including the pineal body which showed non-activated and activated. Fig. 4c was the relative signal intensity of the region shown in the green block region in Fig. 4b. Among these nine experiments, the cross correlation coefficient threshold was 0.30~0.79, the mean size of the active region was about three pixels (3.1±0.3) and the signal change was about 3.5 % (3.5±0.6). We had also dealt with the brain activation regions during the second stage - the ANW state - of COQS. Among the ANW state, hypothalamus showed positive activation after the IPQ period[25]. Besides, we knew that the fMRI images were based on

the BOLD (Blood Oxygenation Level Dependent) signal changes which were complex functions reflecting the changes in the balance of oxy- and deoxyhemoglobin, an indirect indicator for the activation status of nearby neurons. Since pineal is not a neuron but a gland, the elaborate reason which causes the signal changes in pineal body still need more study. Nevertheless, all our results distinctly pointed that: during the meditation process, especially the short period of phrase recitation of the mental operation, pineal body was aroused and showed activation, which meant that pineal body can be activated by the IPQ operation.

Some scientists found that, influenced by the meditation process, the melatonin level was elevated[28-30]. These studies might offer some chemical and quantitative evidences to the pineal activation concerned with meditation and should be proceeded to further examinations. Moreover, some meditators claimed that, during the IPQ process, special feelings occurred from the top of the head, down to the hairline and than to the middle point of two eyebrows. These kinds of self-observed description provide another aspect of understanding to the physical reaction coupled with mental operation or brain activity of this meditation and may inspire more studies in the future. Scrutinizing our fMRI results and comparing with other meditation researches[7,8,9,14,16], the brain activation regions exhibit profound significance between meditation and physiological reactions and adjustments. While keeping on reciting religious phrase in mind, the brain regions which are responsible for intonation, processing of syntax and sensation of sound, such as: the superior temporal gyrus, Brodmann area 47, middle temporal gyrus and right side inferior frontal gyrus, exhibit activation. Furthermore, some meditators claimed to see the inner light[10] or hear inner voice during the meditation process, perhaps these phenomena may be concerned with corpora quadrigemina. The upcoming physiological affections, such as regulating the autonomic function, visceral functions, motor systems and sensory systems, might activate thalamus and insula. As meditation is essentially such a complicated mental operation, it may also concern with the emotion and

cognitive functions, the anterior cingulate and cingulate gyrus might activate accordingly. Further, during the ANW stage, the hypothalamus was aroused and might get a secretive regulation during the second meditation period, which is a long period of relaxation with no further action in body or mind. This is the state which we named "Allow its Natural Workings" (ANW). Many other regions were also activated during the IPQ and ANW state and may need more study to find out their mysteries.

According to our fMRI results, we summarize and propose some view points here. Since pineal shows activation during the mental operation period of silent recitation of specific religious phrase and mental imagination of receiving spiritual energy, although the distinct internal process is still unknown, pineal seems to have certain or special functions here. These special functions may also have some interaction forms with the inner body which caused the physiological affections. Combining with the endocrine functions of pineal, it may vitalize or strengthen our corporeal existences. In summary, the religious meditation of receiving spiritual energy can cause correlated pineal activation and show clear brain imaging observed by fMRI, supporting the speculation that pineal plays an important role in the intrinsic awareness which might concern spirit or soul. Whether this correlation is merely a psychological effect or a real physical phenomenon remain to be further explored.

METHODS

Paradigm design. We designed the block type of paradigm to find out the BOLD (Blood Oxygenation Level Dependent) signal changes during the IPQ operation. There were two kinds of block-design paradigm adopted in this research. The first paradigm included two blocks of IPQ state, each with three minutes, and three control periods each also with three minutes put before, between and after the two meditation epoch. Total scan time was 15 minutes. The second paradigm contained four periods of IPQ

state, each with 1.5 minutes, and five control periods also with 1.5 minutes put before, between and after those four meditation epoch. Total scan time was 13.5 minutes.

Equipment and data acquisition. Experiments were performed on Bruker 3T ParaVision system with a birdcage head coil. Images were acquired using gradient-echo echo planar image (EPI) with matrix size of 128×128, TE of 35 ms, and TR of 6000 ms. All experiments had 12 continuous slices with slice thickness of 7 mm, field of view of 30×30 cm^2.

Data analysis and image performance. The SPM (Statistical Parametric Mapping, the popular MATLAB software package implementing statistical parametric mapping for neuroimaging data)[26] and the FACT (Functional MRI Analysis and Clustering Tools, on the Knoppix LINUX system)[27] were adopted for the data analysis and fMRI image performances.

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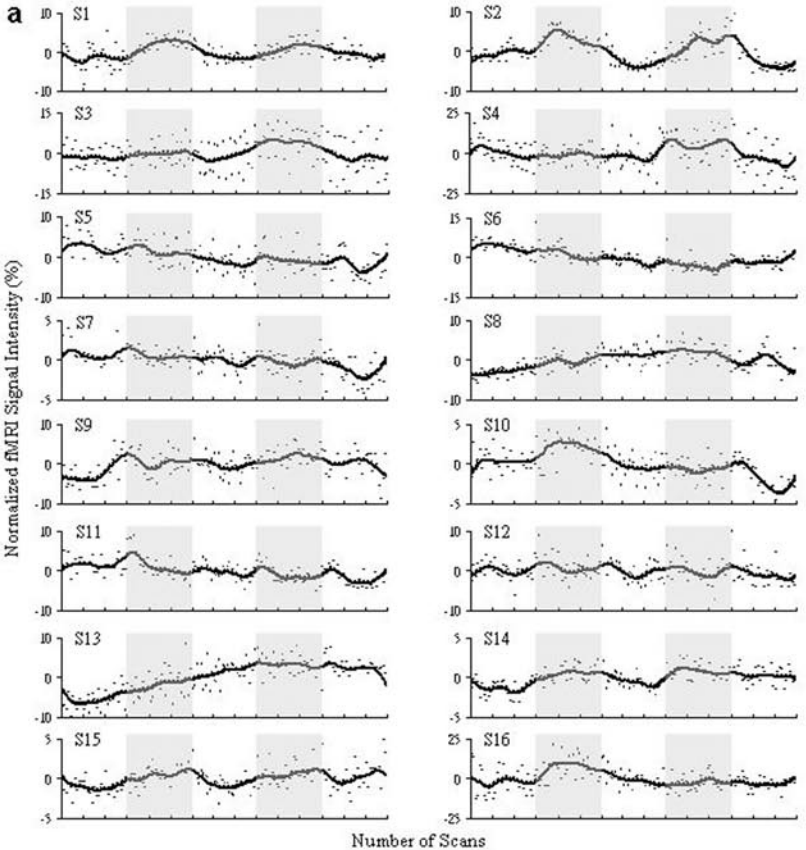
Figure legends

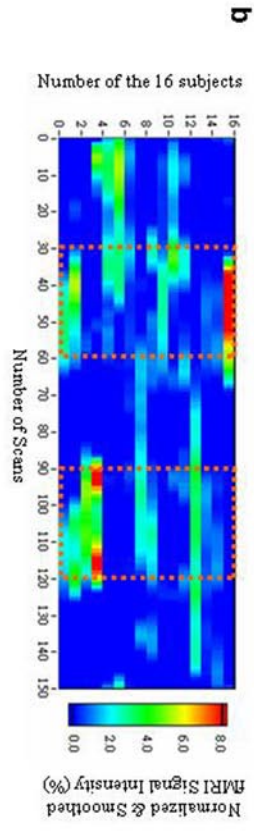
Figure 1 │ The normalized fMRI signal intensity of the pineal area during the COQS-IPQ stage. a, The normalized fMRI signal intensity of each individual subject. The solid lines are smoothed curve of the raw data. **b**, The normalized and smoothed fMRI signal intensity of the 16 subjects. The data were smoothed by wavelet denoise package of LabVIEW (Haar wavelet, level 3). All the horizontal axes of the diagrams in **a** and **b** show the number of scans. The blocked region shown by gray areas in **a** or red dashed line in **b** between 30-60 and 90-120 scans mean the meditation period whereas the other regions mean the control period.

Figure 2 │ The brain activation regions during the COQS-IPQ stage ($p < 10^{-5}$). L and R in the parentheses mean left and right of the brain area. The x, y, z Talairach coordinates of the center of the blue cross in these three views are [0 0 0].

Figure 3 │ The random effect analysis result of the brain activation regions during the COQS-IPQ atage ($p < 10^{-3}$). The pineal body (indicated by the arrow) still showed activation.

Figure 4 │ The best images and the signal intensity of the pineal activation area during the COQS-IPQ stage. a, the anatomic image of the slice including the pineal body, but not activated. From this image, we can see that the position of the pineal body is physiologically a little left-hand-side (right-hand-side in this image). **b,** the anatomic image of the slice showed the activation area of the pineal body, four pixels were seen been activated in this image, this image was produced by combining the activated EPI image with the anatomic raw image. **c,** the relative signal intensity of the region shown in the green block region of **b**. The horizontal axis shows the scan numbers with four meditation blocks.

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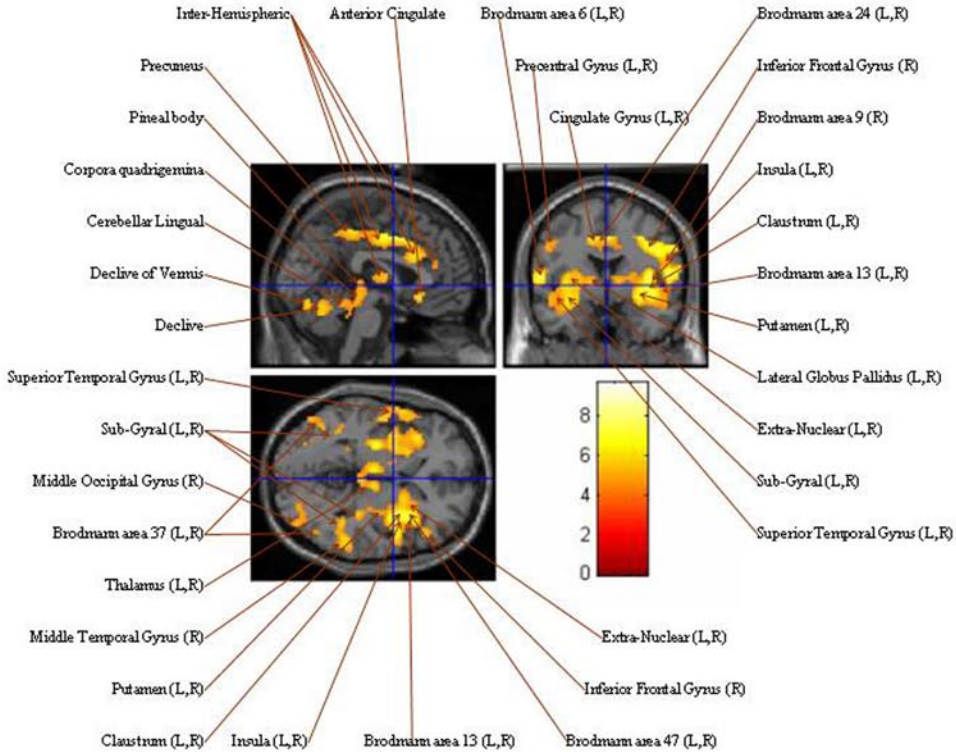

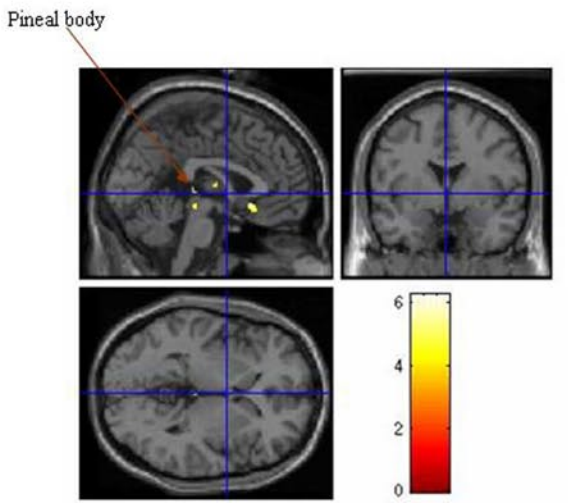

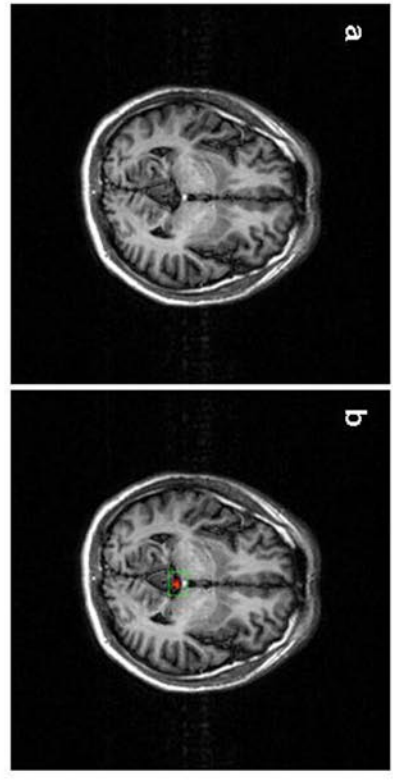
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