A Multidimensional Quantum Model of Brain Activity: The Exploration of Increased Neural Energy States in Daoist Meditation

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ABSTRACT

In the study of high energy physics, as subatomic particles are in different energy states, a suitable accelerator is needed to explore information inside the atom at deeper and deeper levels. Particularly, there are different neural energy patterns or neuro-quantum states within the brain associated with meditative practices; to find out certain information inside the body, it is necessary to reach a meditative state having increased energy levels. Here we report that Chinese Original Quiet Sitting (COQS)—one style of Chinese Daoist meditation— exhibits noticeable results about different neural energy levels or quantum types using functional magnetic resonance imaging technique. Two different states within COQS were examined. Firstly, a prolonged rest-like meditative state, maintaining a relatively low energy level and showing both activation and deactivation of certain brain regions, was observed. Secondly, a higher energy state was found, showing different pattern with only positive activation of certain brain regions. In particular, it appears that there is a correlation between pineal activation and this high energy meditation practice. Also, the pineal body seems concerning with the "upper elixir field" which is an important region in Daoist meditation. Our results provide new evidence for a seldom studied aspect of human physiological performance which has life science implications. Also, a multidimensional quantum model of brain activity is established to offer a scientific description more properly.

Key Words: Qi, *Ch'i*, quantum, pineal body, upper elixir field, spirit, awareness,-multidimensional quantum model
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1. Introduction

In ancient China, meditation was the prime practice for Daoists to temper body and spirit. "Qi" and "*Ch'i*" are terms which were regularly used in teaching and practicing of Daoist meditation. Till now, the natures or scientific properties of "Qi" and "*Ch'i*" are still unknown and may be supposed as certain quantum states or forms. Besides, it is generally believed that meditation can benefit both physical health and spiritual performance (Manocha, 2000; Pettinati, 2001; Edwards, 2003; Tacon, 2003; Cardoso *et al*., 2004; NCCAM-NIH, 2007). Meditation practices can positively influence chronic illness and can serve as a primary, secondary and/or tertiary prevention strategy (Bonadonna, 2003) Luskin studied a variety of religious practices, including prayer, meditation, mantra, affirmation, tai chi and yoga, and stated that the purpose of these practices was to lead the practitioner to a long-term spiritual

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transformation toward an enhanced awareness of the spirit (Luskin, 2004). However, meditation is somewhat unique and distinctive in that it is difficult to standardize, quantify and authenticate for a given sample of research subjects (Caspi and Burleson, 2005). Over the past decade, scientists have attempted to perform neuroimaging studies to obtain brain mappings for various meditation styles (Lou *et al.*, 1999; Lazar *et al*., 2000; Newberg *et al*., 2001; Yamamoto *et al*., 2006; Hölzel *et al*., 2007; Engström *et al*., 2010; Short *et al*., 2010). Many interesting results have been observed. Meanwhile, it revealed that different meditation styles activated various brain regions, which implied different forms of meditation might affect various functions in the body.

We first define those two terms which mentioned above -"Qi" and "*Ch'i*"- as essential bases for the coming studies and discussions which may relate to the different energy states of meditation. "Qi" can be regard as the coarse or crude vitality or bioenergy with a lower energy state; whereas "*Ch'i*" is a fine or subtle vitality or bioenergy with a higher energy state. Both "Qi" and "*Ch'i*" can be viewed as certain states with different energy levels of quantum existences which their actual forms are still unknown. Over the course of training in *Traditional Chinese Daoist Meditation* (TCDM), there are three main progressive statuses having different energy levels through protracted TCDM practice, which are "refining vital *Essence* into *Qi*", "refining *Qi* into *Shen*" and "refining *Shen* into *Void*". Here, "*Shen*" is a functional entity which equilibrates and animates organic systems and "*Void*" is a relative description which roughly represents the non-physical existence. It should be noted that each of those three statuses possesses an operating center or field—similar to "Chakra" of Yoga—which are named "lower elixir field", "middle elixir field" and "upper elixir field", corresponding to low, middle and high energy level, respectively. Figure 1(a) shows the three meditating statuses, energy levels and their relationships within TCDM. Till now, there are no physiological definitions about these three elixir fields. Also, the scientific characterizations of the physiological reactions pertaining to these three meditation statuses still need to be established. In this study, we try to give a preliminary description on some aspects of these phenomena.

Chinese Original Quiet Sitting (COQS) is essentially one kind of Chinese Daoist meditation. Two main processes are involved in COQS. The first, initial process mainly focuses on the high energy level: it is a means to promote "direct process of refining *Shen* into *Void*" by a special mental operation. This is a several-minute interval of silently reciting a specific mantra along with mental imagination of receiving spiritual energy—referred to as "Invitation of Primordial *Ch'i*" (IPC). The second, subsequent process is a "non-purposive" or "rest-like" mode and is a middle to low energy state. It is an operation involving a longer period, often a few dozen minutes or longer, of observant relaxation with no further intentional mental action—termed "Allow its Natural Workings" (ANW). As the initial process in COQS mainly focuses on the head but not the whole body, relative to general TCDM and other meditation styles, COQS should be more convenient and effective for examining brain activation in law and high energy meditation states through neuro-imaging techniques. Two kinds of paradigms in fMRI (functional magnetic resonance imaging) study were set to examine the two different processes involved in COQS. Figure 1(b) shows the main contents of COQS. Figure 1(c) shows the experimental scheme for brain study paradigms in fMRI examinations (refer to Material and Methods).

2. Material and Methods

2.1 Paradigm design

Paradigm for the COQS-ANW study

As ANW is a long relaxation process following the IPC process, a paradigm was designed to analyze its BOLD (Blood Oxygenation Level Dependent) signal changes during the ANW operation. The COQS-ANW paradigm (shown in Figure 1(c)) was separated into three segments: three minutes of the "off" state—the control period, three minutes of the IPC state—as the initiating process, and then nine minutes of the ANW state. The total scan time was 15 min with a total scan number of 150. The instructor, outside the scan room, controlled each period by giving short orders through the microphone. The first segment—the control state, served as a comparison or a background compared with the meditation state. During the control states, subjects were asked to silently keep a short poem—very different from the specific mantra as in the IPC group—in mind. The second segment—the IPC state, leading into the third segment, was set to mark off a consistent meditation practice as a reproducible practice. The third segment—the ANW state, compared to the first segment—the control state, was set for the consequent data analysis.

Paradigm for the COQS-IPC study

A block-type paradigm (also shown in Figure 1(c)) was designed to determine the BOLD signal

changes during the IPC operation. The paradigm included two blocks of the "on" state—the IPC state—for 3 min each, and three "off" state—the control state—also for 3 min each, set before, between and after the two "on" states. The total scan time was also 15 min with a total scan number of 150. Another block-type paradigm (also shown in Figure 1(c)) was used which included four blocks of the "on" state—the IPC state—for 1.5 min each, and five "off" state—the control state—also for 1.5 min each, set before, between and after the four "on" states. The total scan time was 13.5 min with a total scan number of 135.

2.2 Equipment and data acquisition

Experiments were performed on Bruker MEDSPEC 3T system (Bruker, Ettlingen, Germany) with a birdcage head coil. A forehead-fixation-belt and a jaw-holder were adopted for preventing from head motion artifact. The subject, lying on the patient bed, was moved into the bore of the magnet without tying the fingers of both hands to avoid arousing induced current during scanning. Subject kept eyes closed during the scanning process. Images were acquired using gradient-echo *echo planar image* (EPI) with matrix size of 128×128, effective echo time (TE) of 35 ms, and repetition time (TR) of 6000 ms. All experiments had 12 continuous slices with slice thickness of 7 mm and field of view of 30×30 cm^2.

2.3 Experimental Ethics

Before all of the experiments, all subjects were first asked to read the experimental instructions and were given an explanation of the test. Each subject was asked to provide written consent, and the study protocol was approved by the Interdisciplinary MRI/MRS Lab Group. The experimental methods were also carried out in accordance with the approved guidelines by this Lab Group. After each test, a short discussion was held for collecting the information pertaining to each subject's situation and condition of the scanning process.

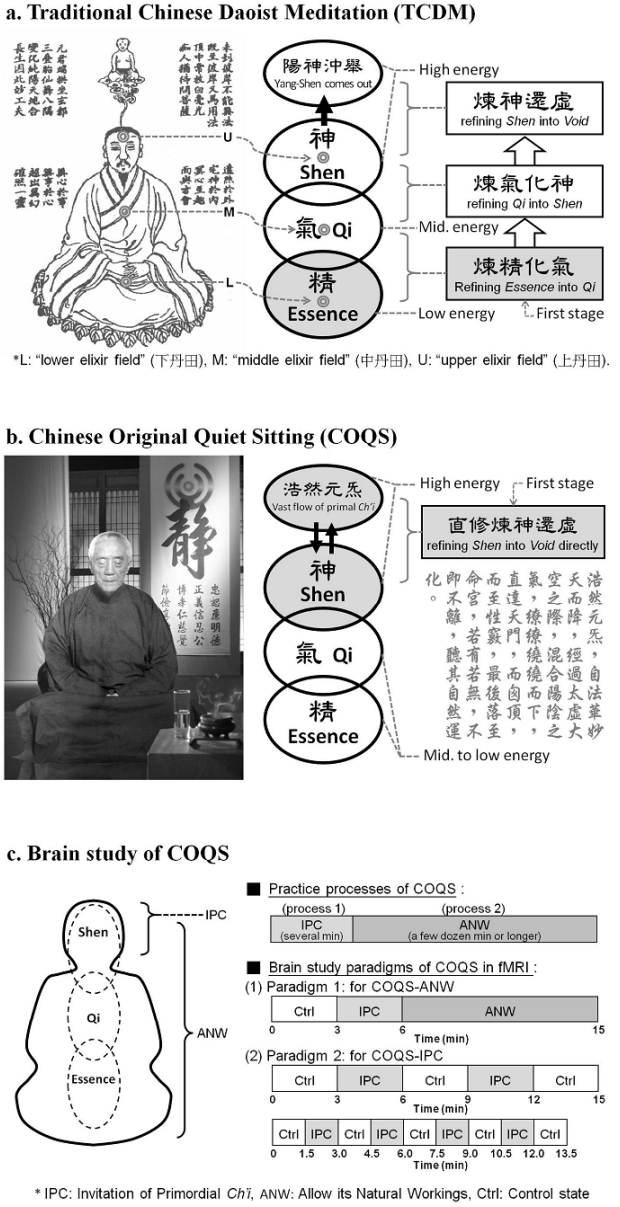

Figure 1. Energy levels of Daoist meditation and experimental scheme of brain study. (a) Progressive statuses and energy levels of TCDM. Three progressive statuses: refining vital Essence into Qi (煉精化氣), refining Qi into Shen (煉氣化神) and refining Shen into Void (煉神還虛)—in a very special situation, the Yang-Shen (a spiritual body with very high energy) may come out of the body. The left part of this figure was adopted from an important book in ancient China for "inner alchemy practicing" of Daoism named in Chinese "Xing-ming gui-zhi" (性命圭旨). Also, each of these three statuses possesses an operating center or field which are named "lower elixir field" (下丹田), "middle elixir field" (中丹田) and "upper elixir field" (上丹田), corresponding to low, middle and high energy level, respectively. (b) Energy levels and practice processes of COQS. Two main processes are involved in COQS. The first process of COQS mainly focuses on the high energy level—which is a "direct process of refining Shen into Void" (直修煉神還虛) by a special mental operation. The second process is a middle to low energy state—an operation involving a longer period of relaxation with no further intentional action. (c) Brain study of COQS. Two kinds of paradigms in fMRI study were set to examine the two different processes involved in COQS: paradigm 1, to examine the COQS-ANW state; paradigm 2, to examine the COQS-IPC state.

2.4 Data analysis and image performance for COQS-ANW & COQS-IPC

The SPM (Statistical Parametric Mapping, http://www.fil.ion.ucl.ac.uk/spm/) was adopted for the data analysis and fMRI image performances. Experimental data were first checked by *centre-of-mass* (COM) analysis with the criteria that all x, y, z drifts should be less than 2 mm, whereupon realignments were performed to modify the COM drift. The data were analyzed by the general linear model (GLM) on SPM. The pre-processing processes for the raw data were realignment, co-registration, normalization of Talairach space and smoothness with full width at half maximum (FWHM) of 8 mm. For the inference into the population, second-level random-effects (RFX) analysis was adopted for the data analysis and the fMRI image performance executing process.

2.5 Subject demographics

The meditators who participated in the test as the subjects were all in good health; exclusion criteria included epilepsy, psychosis, diseases of the nervous system and a history of head trauma. Owing to the arrangement of the use of scan room and the testing duration, the fMRI tests for the ANW study and the IPC study were executed separately. Seventeen subjects (seven females) participated in the ANW study. The mean age of these subjects was 47.5 ± 2.8 (mean ± SEM, 31.7-70.3) years old with a meditation experience of 12.4 ± 1.4 (3.4–20.8) years. The subjects practiced regularly 1.3 ± 0.1 (1–3) times per day with a mean practice duration of 53.8 ± 5.4 (30–120) minutes. Sixteen subjects (seven females) participated in the IPC study. The mean age of the subjects was 48.5 ± 2.8 (range 31.8-70.3) years old with a meditation experience of 12.4 ± 1.5 (3.4–20.8) years. Their mean practice time was 1.3 ± 0.1 (1–3) times each day, with a mean practice duration of 54.7 ± 5.7 (30–120) minutes per time. As the pineal body was found to be activated during the IPC stage, eight subjects (two females) were invited for the detailed study, with a mean age of 48.4 ± 4.7 (31.7-70.3) years old and meditation experience of 15.3 ± 1.5 (12.0–20.8) years. The subjects practiced 1.3 ± 0.1 (1–2) times per day with a mean practice duration of 51.9 ± 3.8 (40–65) minutes.

2.6 Statistical analysis for detailed study of pineal activation in COQS-IPC

For the detailed check of pineal activation, data and images were managed and obtained by FACT (Functional MRI Analysis and Clustering Tools[2]). Raw data were also checked at first by COM analysis with all x, y, z drifts less than 2 mm. Realignment was performed accordingly to modify the COM drift.

The main study outcomes were pixel size, percentage of signal changes and cross-correlation coefficient threshold. Student t test was used to compare the mean difference of outcome variable from the zero mean null hypothesis. The choice of zero mean null hypothesis is based on two reasons: first, 8 participants were all skillful in meditation—with the mean (± Standard Error of the Mean, SEM) meditation experience of 15.3 (± 1.5) years, and second, another 3 subjects as the control tests in this study—all of these 3 controls have zero response of all our three main study outcomes. As the repeated measurements of outcome were from 1 to 9 (in 22 replicates) for subjects in our study, average within subject was first used to represent each subject's outcome value. Besides, a sensitive analysis by using minimum within subject was used to represent each subject's outcome value for comparison purpose. Mean, standard error of the mean and T test p value were reported. Statistical analyses were performed using SAS 9.4 software (SAS Institute Inc., Cary, NC). All tests with one-tailed and P values <0.05 were considered statistically significant.

3. Results

3.1 The fMRI results of the COQS-ANW stage

Group analysis of the general linear model (GLM) on SPM showed significant performances of the brain regions with activation and deactivation during the COQS-ANW stage as shown in Table 1 and Figure 2 (n=17, $p<0.05$, $T>1.75$, degree of freedom=16, and number of clusters>25). Figure 2(a) shows the 3-D images, whereas Figure 2(b) shows the sagittal, coronal and axial views of the activation regions during the COQS-ANW period. The mainly activation regions were the ventral anterior cingulate cortex (vACC), declive, culmen, thalamus and hypothalamus. The deactivation regions were the dorsal anterior cingulate cortex (dACC), superior frontal gyrus, caudate body, amygdala and superior temporal gyrus.

[2] https://sites.google.com/site/chuanglab/software/fact

Table 1. The activated regions of the brain during COQS-ANW stage[a]

Activation [b]	Brain regions	Voxels [c]	Talairach coordinates	T-value
+	vACC	711	-6 22 -4	4.51
+	Declive	506 [d]	-6 -56 -16	2.89
+	Culmen		-6 -54 -16	2.74
+	Thalamus	44	4 -8 10	2.57
+	Hypothalamus	25	-4 6 -24	2.38
-	dACC	7256 [d]	4 42 12	-5.89
-	Superior Frontal Gyrus		-22 44 22	-4.83
-	Caudate body		-6 12 14	-2.60
-	Amygdala		26 -12 -28	-5.07
-	Amygdala	5309 [d]	-30 -8 -30	-4.69
-	Superior Temporal Gyrus		-50 -42 6	-4.53
-	Superior Temporal Gyrus	2464 [d]	68 -24 6	-4.10

[a] Seventeen subjects (seven females) participated in this COQS-ANW study. Paradigm 1 with a long ANW state (shown in Figure 1(c)) was adopted. The data and images (shown in Figure 2) were obtained by SPM. Statistical parameters: n=17, $p<0.05$, $T>1.75$, degree of freedom=16, and number of clusters>25.

[b] "+" represents activation, "-" represents deactivation.

[c] Voxel size = 2*2*2 mm^3.

[d] The voxel numbers including several brain regions.

Table 2. The activated regions of the brain during the COQS-IPC stage [a]

Brain regions	Voxels [b]	Talairach coordinates	T-value
Anterior Cingulate (vACC)	119	0 24 -12	6.25
Left Cerebellum, Declive	25	-26 -72 -18	4.55
Middle Occipital Gyrus	117	48 -70 -8	4.54
Midbrain (Corpora quadrigemina)	339 [c]	0 -26 -10	4.40
Thalamus		6 -20 12	4.31
Pineal body		0 -28 4	4.03
Occipital Lobe, Fusiform Gyrus	25	-28 -84 -12	4.38
Hippocampus	131	32 -24 -8	4.28
Superior Temporal Gyrus	54	58 -40 18	4.26
Parietal Lobe, Precuneus	18	18 -50 44	3.73
Frontal Lobe, Precentral Gyrus	68	44 -6 40	3.71
Insula	18	-46 6 12	3.67
Middle Temporal Gyrus	15	-60 -44 -8	3.50
Left Cerebellum, Culmen	39	-10 -38 -12	3.35
Cingulate Gyrus	23	-2 20 26	3.22

[a] Sixteen subjects (seven females) participated in this COQS-IPC study. Paradigm 2 with 2 IPC states (shown in Figure 1(c)) was adopted. The data and images (shown in Figure 3) were obtained by SPM. Statistical parameters: n=16, $p<0.005$, $T>2.95$, degree of freedom=15, number of clusters>15, and all with positive activations.

[b] Voxel size = 2*2*2 mm^3.

[c] The voxel numbers including several brain regions.

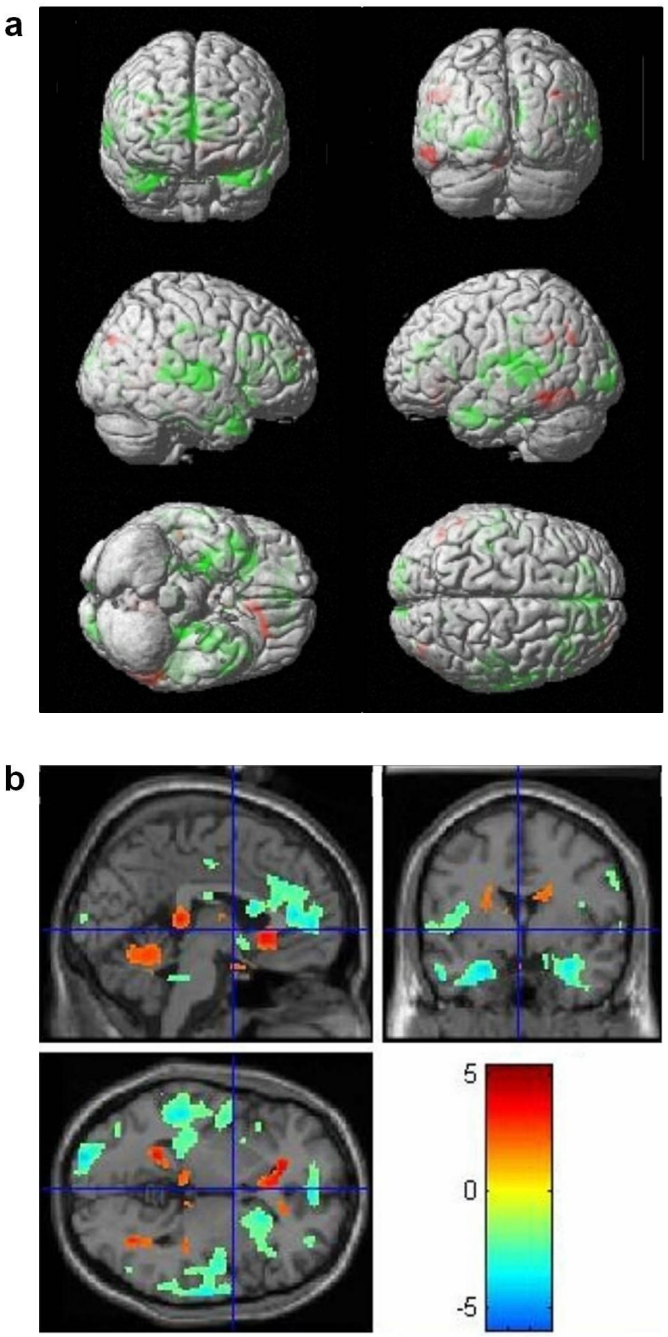

Figure 2. Group analysis results of the brain activation regions during the COQS-ANW stage of all 17 subjects. (n=17, p<0.05, T>1.75, degree of freedom=16, and number of clusters>25, refer to Table 1 for detailed data). (a) The 3-D images. (b) The images of sagittal, coronal and axial views. The x, y, z Talairach coordinates of the center of the blue cross in these three views are [-2 0 0]. The color bar indicates T-values.

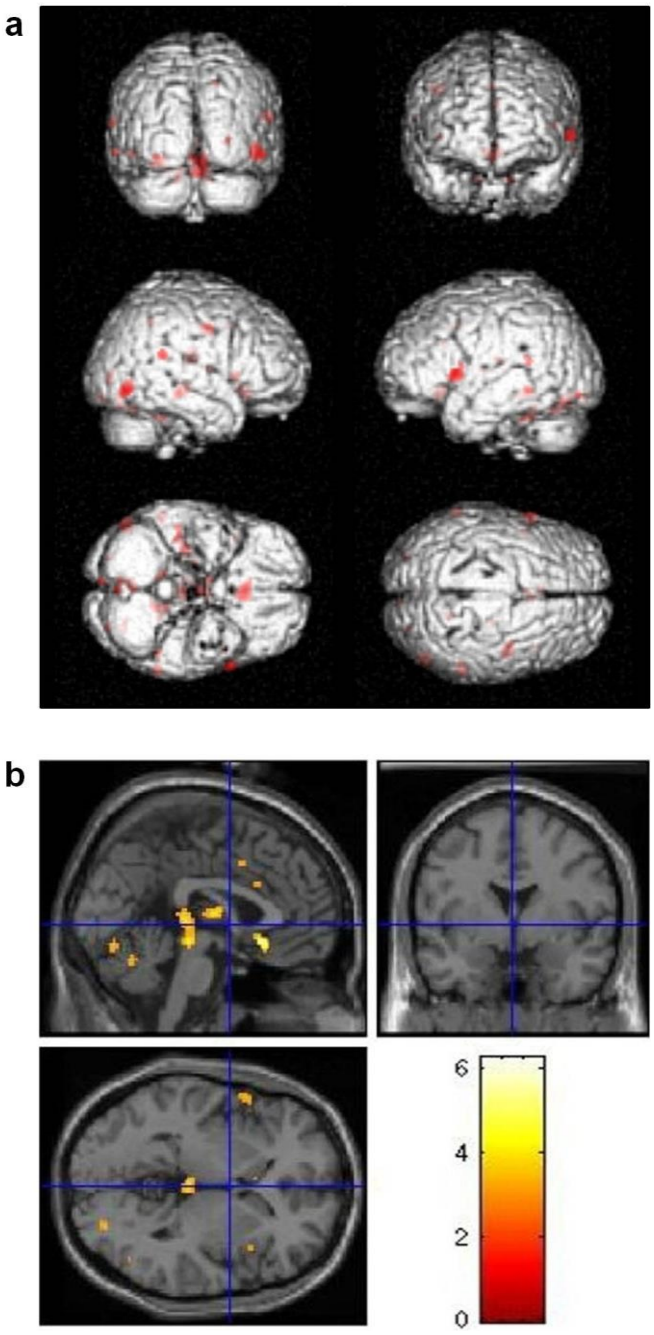

Figure 3. Group analysis results of the brain activation regions during the COQS-IPC stage of all 16 subjects. (n=16, p<0.005, T>2.95, degree of freedom=15, and number of clusters>15, refer to Table 2 for detailed data). **(a)** The 3-D images. **(b)** The images of sagittal, coronal and axial views. The x, y, z Talairach coordinates of the center of the blue cross in these three views are [0 0 0]. The color bar indicates *T*-values.

3.2 The fMRI results of the COQS-IPC stage

Group analysis of GLM on SPM also showed significant results during the COQS-IPC stage. Table 2 and Figure 3 reveal the brain activation regions (n=16 with p<0.005, T>2.95, degree of freedom=15, and number of clusters>15). Figure 3(a) shows the 3-D images, and Figure 3(b) shows the sagittal, coronal and axial views of the activated regions during the COQS-IPC period. The brain regions such as the vACC, declive, middle occipital gyrus, corpora quadrigemina, thalamus, pineal body, fusiform gyrus, hippocampus, superior temporal gyrus, precuneus, precentral gyrus, insula, middle temporal gyrus, culmen, and

cingulate gyrus were activated positively. It is notable that no deactivation region was observed.

3.3 Results of detailed study of pineal activation in COQS-IPC

As the pineal body was found to be activated during the COQS-IPC practice, a further study to check the pineal activation was executed. Eight subjects (two females) participated in this test in 22 replicates. Data and images were managed and obtained by FACT. Table 3 is the preliminarily processed data of the detailed examination of pineal activation during the COQS-IPC stage which reveals pixel size, percentage of signal changes and cross-correlation coefficient threshold. Table 4 summarizes the outcomes of these preliminarily processed data. For the analysis of average measurement within subject, the mean of the outcomes: pixel size, percentage of signal changes and cross-correlation coefficient were all significantly larger than zero, respectively. Even we choice the minimum measurements within subject, the mean of all main outcomes were still significantly larger than zero, respectively. In this one-arm experiment, we found the mean of the outcomes were all significantly larger than zero. Because the non-response was considered as the assumption for general population, we concluded that COQS-IPC may induce the signal of the pineal body. The mean size of the active region was approximately 3 pixels (3.07 ± 0.91, p=0.006) and the mean signal change was approximately 2.37 % (2.37 ± 0.45, p<0.001) with cross-correlation coefficient threshold of 0.38 ± 0.06 (range 0.24-0.65, p<0.001). As the images obtained by FACT of all eight subjects were not merged together but were shown individually, we chose the best image and its BOLD signal intensity of the pineal activation area from single subject as shown in Figure 4.

Table 3. Preliminarily processed data of the detailed examination of pineal activation during the COQS-IPC stage [a]

Test	Subject	Pixels [b]	ΔS/S (%) [c]	CC [d]	Paradigm [e]
1	S1	5	4.68	0.56	2B
2	S2	3	5.31	0.74	2B
3	S1	3	3.66	0.54	2B
4	S2	4	2.92	0.62	2B
5	S1	4	3.43	0.54	2B
6	S1	4	5.91	0.64	2B
7	S2	2	3.49	0.70	2B
8	S1	3	3.81	0.57	2B
9	S1	3	2.32	0.44	2B
10	S1	2	3.33	0.57	2B
11	S3	2	2.75	0.32	2B
12	S1	3	1.66	0.30	4B
13	S4	2	3.26	0.42	2B
14	S5	3	0.90	0.24	2B
15	S6	1	3.32	0.49	2B
16	S7	2	2.24	0.30	2B
17	S1	3	3.30	0.56	4B
18	S7	2	1.15	0.30	4B
19	S2	3	1.70	0.41	4B
20	S3	0	0.00	0.00	4B
21 [f]	S2	4	6.29	0.79	4B
22	S8	9	0.88	0.24	4B

[a] Eight subjects (two females) were invited for this study in 22 replicates. [b] Pixel size = 2.34*2.34 mm^2. [c] ΔS/S (%): Percentage of Signal Changes. [d] CC: Cross-correlation Coefficient threshold. [e] The block-type paradigms with 2 and 4 IPC states (shown in Figure 1(c)) were adopted in this test and were remarked by 2B (with 2-IPC states) and 4B (with 4-IPC states). Data and images were managed and obtained by FACT. [f] Image and data of this test were chosen and shown in Figure 4.

Table 4. T test outcome variables of the detailed examination of pineal activation during the COQS-IPC stage

Subject [a]	Replicates	Average within subject			Minimum within subject		
		Pixels [b]	ΔS/S (%)[c]	CC [d]	Pixels [b]	ΔS/S (%)[c]	CC [d]
S1	9	3.33	3.57	0.52	2.00	1.66	0.30
S2	5	3.20	3.94	0.65	2.00	1.70	0.41
S3	2	1.00	1.38	0.16	0.00	0.00	0.00
S4	1	2.00	3.26	0.42	2.00	3.26	0.42
S5	1	3.00	0.90	0.24	3.00	0.90	0.24
S6	1	1.00	3.32	0.49	1.00	3.32	0.49
S7	2	2.00	1.70	0.30	2.00	1.15	0.30
S8	1	9.00	0.88	0.24	9.00	0.88	0.24
Mean ± SEM [e]		3.07±0.91	2.37±0.45	0.38±0.06	2.63±0.96	1.61±0.41	0.30±0.05
T test [f] p value		0.006	<0.001	<0.001	0.015	0.003	<0.001

[a] Eight subjects (two females) were invited for this study in 22 replicates. Preliminarily processed data were listed in Table 3.
[b] Pixel size = 2.34*2.34 mm^2.
[c] ΔS/S (%): Percentage of Signal Changes.
[d] CC: Cross-correlation Coefficient threshold.
[e] SEM: Standard Error of the Mean.
[f] One-tailed t test, null hypothesis: population mean is zero.

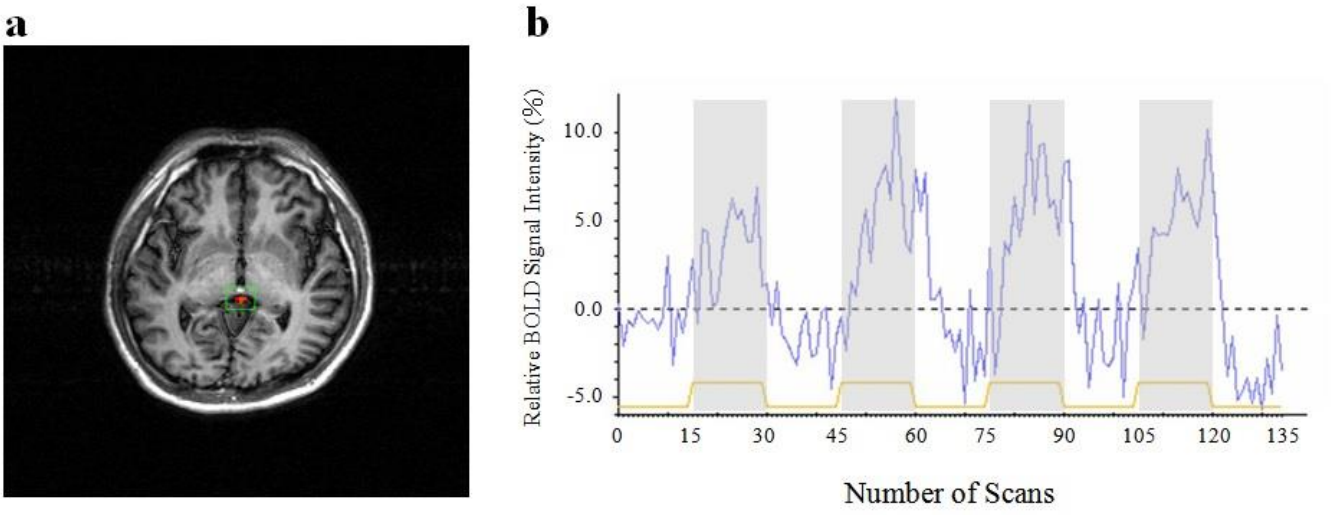

Figure 4. The best image and the BOLD signal intensity of the pineal activation area from single subject during the COQS-IPC stage (As the images obtained by FACT of all eight subjects were not merged together but were acquired individually, the best one was chosen and shown here. For detailed data please refer to Table 3). (**a)** The anatomic image of the slice showed the activation area of the pineal body, 4 pixels were seen been activated in this image. (**b)** The relative BOLD signal intensity of the region shown in the green block region of (**a)**. The horizontal axis shows the scan numbers with four IPC blocks. The mean of this relative BOLD signal intensity is 6.29 % with Cross-correlation Coefficient threshold of 0.79.

4. Discussion

4.1 The physiological connotation of COQS-IPC and COQS-ANW practice

Generally speaking, fMRI measures the BOLD contrast in the brain, which is the increased or decreased BOLD signal relative to the control state. By this way, it shows the activation or deactivation brain regions according to the mental or body process been performing. During the initial COQS-IPC process while performing the "invitation" process, the brain activation organs (as listed in the following parentheses) might possibly be

concerned with certain physiological effects such as intonation, processing of syntax and sensation of sound and words, memory, word meaning and recognition (superior temporal gyrus, middle temporal gyrus, hippocampus, fusiform gyrus), emotion, cognition and memory functions (vACC, cingulate gyrus), arousal, awareness, autonomic and visceral functions, motor and sensory functions (thalamus, insula) and subtle regulation of motor functions (declive, culmen). The function of the activation of corpora quadrigemina is hard to confirm, some meditators claimed to see the inner light (Lo *et al*., 2003) or hear an inner voice; whether this related to corpora quadrigemina still need more examination. Also, during the subsequent COQS-ANW process, the main activated organs—except the hypothalamus—all carried over from their activated state in the COQS-IPC process, including vACC, declive, culmen and thalamus. As the hypothalamus is a collecting center which congregates physiological and psychological information concerning the internal well-being of the body to control the secretions of the pituitary hormones (Guyton and Hall, 2011[a]), its activation following the COQS-IPC process implies that our body may subsequently proceed to carry out a secretory regulation process during the COQS-ANW state. In contrast, the deactivation of the dACC, superior frontal gyrus, superior temporal gyrus, amygdala and caudate body exhibited "reduced activity" of the brain function concerning body awareness, cognition or sensory systems. These imply that the lower energy level of the "relaxation situation" is proceeding and dominating on those brain regions during the "COQS-ANW state".

The pineal body is known to be an endocrine gland which produces precursors such as melatonin and to which numerous functions have been ascribed including enhancing sex, staving off infection, promoting sleep, enhancing mood, and increasing longevity (Guyton and Hall, 2011[b]). Nighttime salivary melatonin analysis has revealed that melatonin levels are significantly elevated after meditation in the meditation group and are almost unchanged in the control group (Liou *et al*., 2010). This implies that pineal body may be activated during the meditation process, which coincides with these fMRI results. Moreover, referring to a number of other studies about the functions of the pineal body, e.g. morphological and histological studies (Jangir *et al*., 2005), light spectra correlated properties (Daniel *et al*., 1972), and neuronal photo responses (Engbretson and Lent, 1976), etc., it seems that pineal body is somehow related to the visual sense—as the eyes—and may be restrained by light impulses, to which it responds with secretion feedback. These results imply that pineal body seems to have quantum responses or certain interactions.

4.2 The "multidimensional quantum model" of the brain activity during COQS-IPC practice

Comparing Figure 2 and Figure 3 may reveal at least two main points. First, based on the definitions of "*Ch'i*" and "Qi", those different brain activation patterns coincide with the high energy state (as COQS-IPC practice) and the middle to low energy state (as COQS-ANW practice). Second, it seems that the pineal body is concerned both with the high energy "*Ch'i*" state and the "upper elixir field" as mentioned above in TCDM practice. For an ideally controlled COQS-IPC process, we would like to provide a conceptual model as in the following equation:

$$F\left(pineal\ activation\right) \equiv$$
$$f_1\left(upper\ elixir\ field\right) \Leftrightarrow f_2\left(pineal\ body\right) \qquad \text{(A)}$$

In which, F represents the detectable results of the pineal activation by fMRI, f_1 represents the functions of the high energy quantum state of the "upper elixir field" and f_2 represents the physiological functions—also a lower energy state—of the pineal body. The symbol " $\Leftrightarrow$ " represents some kinds of quantum, awareness or even consciousness interactions, which are still unknown, between f_1 and f_2. We do not intend to develop a numerical equation here, yet concerning the properties of the high energy "*Ch'i*" or quantum state, we would like to draw out a special connotation of this equation. Let us suppose that the pineal activation—induced by COQS-IPC process—should not be interpreted only by a three-dimensional model. The concept of multiple dimensions in mathematics would be proper to be adopted to develop a high-energy, multidimensional interpretation. Consequently, the concise meaning of equation (A) should be: *If an experimental condition can be accurately controlled, the pineal activation (F) induced by COQS-IPC process can be regarded as the results of the interaction of the "high-energy high-dimensional quantum state" of function f_1 and the "low-energy three-dimensional state" of function f_2.* Equation (A) serves as a "multidimensional quantum model" of the brain activity, which is related to the interaction of "upper elixir field" and pineal body during COQS-IPC practice. Moreover, whether f_1 or f_2 is concerned with the modality of inner sensation or even intrinsic awareness is worthy of further exploration.

5. Conclusion and Outlook

Our study exhibits noticeable results about different neural energy patterns or neuro-quantum states on COQS-ANW and COQS-IPC practices by fMRI. COQS-ANW—a prolonged rest-like meditative state, also a relatively low energy level— showing both activation and deactivation of certain brain regions, whereas COQS-IPC—a higher energy state— showing only activation of certain brain regions. The physiological connotations of both COQS-IPC and COQS-ANW are also revealed. In particular, it appears that there is a correlation between the high energy state of COQS-IPC practice and the pineal activation (concerning with the "upper elixir field"). The "multidimensional quantum model" of brain activity is also established to offer a scientific description more properly for the pineal activation.

Our results provide new evidences for a seldom studied aspect of human physiological performance which has life science implications. For other meditation styles yielding high energy states, the activations of brain regions and phenomena are also worthy of examination. By studying practices which involve body, mind and spirit, the physiological interpretations of the performance of living beings shall be improved. It may also enrich the contents of the discipline of neuroscience, quantum physics and life science.

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References

Bonadonna R. Meditation's impact on chronic illness. Holistic Nursing Practice 2003; 17(6): 309-319.

Cardoso R, de Souza E, Camano L, Leite JR. Meditation in health: an operational definition. Brain Research. Brain Research Protocols 2004; 14(1): 58-60.

Caspi O and Burleson KO. Methodological challenges in meditation research. Advances in Mind-Body Medicine 2005; 21(1): 4-11.

Daniel PC, Frances L, Richard JW. Control of the Rat Pineal Gland by Light Spectra. Proceedings of the National Academy of Sciences of the USA 1972; 69(8): 2003-2005.

Edwards L. Meditation as medicine: benefits go beyond relaxation. Advance for Nurse Practitioners 2003; 11(5): 49-52.

Engbretson GA and Lent CM. Parietal eye of the lizard: neuronal photoresponses and feedback from the pineal gland. Proceedings of the National Academy of Sciences of the USA 1976; 73(2): 654-657.

Engström M, Pihlsgård J, Lundberg P, Söderfeldt B. Functional Magnetic Resonance Imaging of Hippocampal Activation During Silent Mantra Meditation. Journal of Alternative and Complementary Medicine 2010; 16(12): 1253-1258.

Guyton AC and Hall JE. Ch. 75 Pituitary Hormones and Their Control by the Hypothalamus. In: Textbook of Medical Physiology. W. B. Saunders Company, Pennsylvania, 12th ed., pp.897, 2011a.

Guyton AC and Hall JE. Ch. 80 Reproductive and Hormonal Functions of the Male (and Function of the Pineal Gland). In: Textbook of Medical Physiology. W. B. Saunders Company, Pennsylvania, 12th ed., pp.986, 2011b.

Hölzel BK, Ott U, Hempel H, Hackl A, Wolf K, Stark R, Vaitl D. Differential engagement of anterior cingulate and adjacent medial frontal cortex in adept meditators and non-meditators. Neuroscience Letters 2007; 421(1): 16-21.

Jangir OP, Suthar P, Shekhawat DV, Acharya P, Swami KK, Sharma M. The "third eye"—a new concept of trans-differentiation of pineal gland into median eye in amphibian tadpoles of Bufo melanostictus. Indian Journal of Experimental Biology 2005; 43(8): 671-678.

Lazar SW, Bush G, Gollub RL, Fricchione GL, Khalsa G, Benson H. Functional brain mapping of the relaxation response and meditation. Neuroreport 2000; 11(7): 1581-1585.

Liou CH, Hsieh CW, Hsieh CH, Chen DY, Wang CH, Chen JH, Lee SC. Detection of nighttime melatonin level in Chinese Original Quiet Sitting. Journal of the Formosan Medical Association 2010; 109(10): 694-701.

Lo PC, Huang ML, Chang KM. EEG alpha blocking correlated with perception of inner light during Zen meditation. The American journal of Chinese medicine 2003; 31(4): 629-642.

Lou HC, Kjaer TW, Friberg L, Wildschiodtz G, Holm S, Nowak M. A ^{15}O-H_2O PET study of meditation and the resting state of normal consciousness. Human Brain Mapping 1999; 7(2): 98-105.

Luskin F. Transformative practices for integrating mind-body-spirit. Journal of Alternative and Complementary Medicine 2004; 10(Suppl 1):S15-23.

Manocha R. Why meditation? Australian Family Physician 2000; 29(12): 1135-1138.

National Center for Complementary and Alternative Medicine, National Institutes of Health. Meditation for Health Purposes.
http://img.thebody.com/nccam/meditation.pdf
(Reviewed June 2007)

Newberg A, Alavi A, Baime M, Pourdehnad M, Santanna J, d'Aquili E. The measurement of regional cerebral blood flow during the complex cognitive task of meditation: a preliminary SPECT study. Psychiatry Research. Neuroimaging 2001; 106(2): 113-122.

Pettinati PM. Meditation, yoga, and guided imagery. Nursing Clinics of North America 2001; 36(1): 47-56.

Short EB, Kose S, Mu Q, Borckardt J, Newberg A, George MS, Kozel FA. Regional Brain Activation during Meditation Shows Time and Practice Effects: An Exploratory fMRI Study. Evidence-Based Complementary and Alternative Medicine 2010; 7(1): 121-127.

Tacon, AM. Meditation as a complementary therapy in cancer. Family & Community Health 2003; 26(1): 64-73.

Yamamoto S, Kitamura Y, Yamada N, Nakashima Y, Kuroda S. Medial prefrontal cortex and anterior cingulate cortex in the generation of alpha activity induced by transcendental meditation: a magnetoencephalographic study. Acta Medica Okayama 2006; 60(1): 51-58.