NEURAL CORRELATES OF RELIGIOUS AND SPIRITUAL EXPERIENCES

The human brain during religious and spiritual experiences is where God and Science meet.

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ABSTRACT

A literature review was undertaken with the aim of understanding the relationship between human brain and religious and spiritual experiences (RSEs). The most common features ascribed to RSEs include a "sense of having encountered ultimate reality", "a sense of unity or totality", "a state of no mind – pure consciousness" and "a state of bliss", which may be experienced during a wide range of spiritual practices such as prayer, yoga and meditation. Scientists previously believed that RSEs were "artifacts" of temporal lobe function, thus the temporal lobe was thought to be the only part of the brain involved in those experiences. Can RSEs predominantly be related to a single region of the brain? Or are there many parts of the brain involved simultaneously during RSEs?

A search was conducted using the PubMed database to retrieve articles related to neural (anatomical) correlates of RSEs that were investigated using functional neuroimaging techniques, such as SPECT, PET and fMRI. Search terms included brain, religion, spirituality and neurotheology.

11 relevant articles were reviewed. Perhaps the most striking finding observed in these studies is that there exists no single specific neural correlate of RSEs. This finding should not come as a surprise, given that these experiences, like many other higher cortical functions, are complex and multidimensional, combining perception, cognition and emotion. Accordingly, RSEs are not merely irrational or delusions, they are rather based in the observable functions of the brain. The studies have also revealed some discrepancies, which are predominantly attributed to the diversity of meditative practices included in the studies.

Still, there are some consistent findings within the frontal lobes, parietal lobes, basal ganglia and limbic system, which appears to be frequently related in a network associated with RSEs. However, these findings are only correlative in nature, they tell us nothing about cause and effect. In other words, it is not clear whether a change in regional brain activity caused that experience or responded to that experience.

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INTRODUCTION

In 1885, Philosopher Friedrich Nietzsche made a famous declaration; "God is dead", and what he was saying is that God had never really lived at all. It was the great expectation of many in that world-changing generation of thinkers that, as educational levels rose and science provided more realistic explanations for the mysteries of existence, the irrational appeal of religion would simply fade, and God, in all his incarnations, would simply go away. God, however, has not disappeared, and as we enter an age of prodigious scientific and technological development, religion and spirituality continue to thrive.

RELIGION VS SPIRITUALITY

The word religion derives from the Latin *religio*, meaning *to reconnect*, *re-* again + *ligo-* bind, connect. There are many definitions of religion, as many as the number of existing religions in the world. However psychiatrist Harold Koenig's definition includes several aspects and the one which will be mentioned here, he defines religion as *a system of beliefs and practices observed by a community, supported by rituals that acknowledge, worship, communicate with, or approach the Sacred, the Divine, God (in Western cultures), or Ultimate Truth, Reality, or nirvana (in Eastern cultures)*. (26,46)

While religion is an organized belief system promoted and sustained by a human institution, ethnic group or culture and involves definite rules of behavior, practices and rituals. (21,36) Spirituality, in contrast, is a personal, experiential and thoughtful dynamic process, searching for meaning, unity, connectedness, transcendence, for the highest of human potential. (8,27,47)

Spirituality is an individual's experience of and relationship with a nonmaterial aspect of the universe that may be referred to in many ways – God, Higher Power, Mystery and the Transcendent and forms the way by which an individual finds meaning and relates to the life and universe. (21,36,48)

Spirituality and religion are not interchangeable or always linked. Therefore a person may have religion without spirituality or spirituality without religion.

WHY DO WE HAVE RELIGION?

In an evolutionary perspective

Religious and spiritual phenomena are highly complex, involving emotions, thoughts, perceptions, and behaviors, so they probably require a highly complex brain.

Religious ideas can be traced to the evolution of brains large enough to make possible the kind of abstract thought necessary to formulate religious and philosophical ideas. Neanderthals, who lived 70 000-100 000 years ago, had a much larger brain than prior human ancestors, particularly the neocortex, part of the brain involved in processing higher order cognitive functions. Anthropologist Robin Dunbar found a correlation between the neocortex size and the level of social complexity, which include social group size and complexity of mating behaviors of the particular species. It is however not clear if the correlation is causal. Neuroscientists argues that the size does not necessarily relate to complexity, even though there usually is a relationship. (7,16,44)

Researchers have proposed specific psychological processes which may explain religion's roots in our minds. Such mechanisms may include (33,38,39,40,42,43):

[1]*agency detection* – the ability to infer the presence of organisms that might do harm. Scientists argue that this module is biased toward *overdetection*, which were highly adaptive for ancestral environments. In situations where one is unsure of the presence of a potential threat in environment, it is far better to overdetect than to underdetect, in a survival perspective, so the precautions can be taken. For example, a curly tree branch in the nighttime may be mistaken for a snake, however this 'detection error' have positive effects in an evolutionary viewpoint. In contrast, the cost of not detecting the snake when that is actually around could be very high.

[2]*theory of mind* – the understanding that another being has a mind with intentions, desires, and beliefs that are different from one's own. If you suspect that an agent was responsible for some mysterious event, it's a short step to think that the agent has a mind like your own.

[3]*"Hypersensitive Agency Detection Device",* a cognitive module that readily ascribes events in the environment to the behavior of agents. HADD could contribute to the formation of religious concepts by making people identify ambiguous objects as intentional agents (e.g., spirits), or by causing objects correctly identified as such to be perceived as invested with agency (e.g., seeing a thunderstorm as manifestation of a deity's will).

[4]*causal attribution* – people seek to explain experiences and events by attributing them to causes. The attribution process is motivated by a general desire to understand and seek meaning in the world, and an attempt to control and predict events, as well as maintaining or enhancing our self-esteem.

These adaptations allow human beings to imagine purposeful agents behind many observations that could not readily be explained otherwise; e.g. thunder, lightning, complexity of life etc. Belief in supernatural agents, for example, appears to be acquired relatively effortlessly by children. Children do not need to be force-fed religion, they naturally develop religion's basic component processes. (13,42)

The human mind is, first and foremost, a highly social mind with an elaborated set of emotions that promote interpersonal bonding. Frans de Waal contends that all social animals have to restrain or alter their behavior for group living to be worthwhile. Moreover, for any social species, the benefits of being part of an altruistic group should outweigh the benefits of individualism. For example, lack of group cohesion could make individuals more vulnerable to attack from outsiders. (4,14,32)

Some scientists have suggested that religion is genetically "hardwired" into the human brain, the God gene hypothesis states that some variants of a specific gene, the VMAT2 gene, predispose to spirituality. Geneticist Dean Hamer in his book, *The God Gene: How faith is hardwired into our Genes*, contends that one's predisposition toward spirituality is influenced by genetic factors. VMAT2 encodes a transporter protein that imports several monoamine neurotransmitters (dopamine, serotonin, norepinephrine) into vesicles in the brain. Thus, an alteration in the transporter could potentially affect the levels of multiple types of neurotransmitters, resulting in altered brain function. (35)

Religion – a by-product or evolved adaptation?

By-product theories describe religion as a dysfunctional product or by-product of specific mental processes. In the evolution of the human brain there was no specific evolutionary selection for religious concepts. Thus there is no special religious center in the brain, no network of neurons that is specialized for handling thoughts about supernatural entities. Many of the human behaviors are outcome of psychological adaptations that evolved to solve problems in human ancestral environments long time ago. People want to understand events and processes – that is, to explain, predict and perhaps control over them. These very general, indeed universal intellectual needs gave rise to religious concepts at some point during human cultural evolution. (4,14,33,37)

Adaptive theories describe religion as an adaptation to certain human needs and conditions during the evolution of social behavior, providing solutions for cooperation problems in complex communities. They include the improved ability to cope with crises, as well as to overcome the allurement of personal gain by exploiting others or harming the common, furthermore improving cooperation and moral solidarity within groups and improving competitiveness with other groups. Religiosity (mysticism, ethics, myth, and ritual) describe a modular structure of cognitive skills in a network of brain, body, language, and culture, providing an architecture underlying the human capacity for religion. (14,33)

WHY DO WE NEED RELIGION?

Aspects of religion

Religion provides social order: religion holds society together, perpetuates a particular social order. Religion is not just something that is added to social life, it very often organizes social life. "If God did not exist, he would have to be invented", in this famous quote by Voltaire, he means that the society would not hold together if people did not have some central set of beliefs that bind them together and make social group work as organic wholes rather than aggregates of self-interested individuals. Primary functions of religion is promotion of group solidarity. Collective rituals enable the expression and reaffirmation of shared belief, norms and values, and are thus essential for maintaining communal stability and group harmony, which also may provide a sense of control and comfort. (4,22,37)

Religion supports morality: No society could work without moral prescriptions that bind people together and thwart crime, theft, treachery etc. Religious people believe that the fear of God is a better incentive to moral behavior since it assumes that the monitoring is constant and the sanctions eternal. (4,22) Maybe it works for some societies, but still a poor way if a man's ethical behavior is based on fear of punishment or hope of reward after death, rather than on sympathy and respect for human beings.

Religion provides explanations: Aristotle opened his Metaphysics with the assertion that "all men by nature desire to know". Human nature is to be curious, to search for meaning of life and to seek deeper understanding of the experiences we have in our life. Religion provides answers to questions that otherwise might seem unanswerable.

Religion provides comfort: Mortality is unbearable or makes human existence intrinsically pointless is a culture-specific speculation and by no means provides universal motivation. Religious explanations make mortality less unbearable, religion allays anxiety and makes for a comfortable world. (4)

However, religion has not only led to positive outcomes, as we all know the other side of the coin is very dark. In the name of religion, nearly a billion people have been killed throughout the history. Yet, the "holy" war has not come to an end. Daniel Dennett suggests that many religious adherents are more loyal to "faith" than to God. "Believe in belief in God" seems to be more important than "believe in God". Another viewpoint among scientists are also that religion – rather than being a tool by which an individual can get use of, for its own growth and to discover the highest potential of being a human – has become a more static and stagnant "faith".

NEUROSCIENCE

"*Once upon a time, I dreamt I was a butterfly, fluttering hither and thither, to all intents and purposes a butterfly. I was conscious only of my happiness as a butterfly, unaware that I was myself. Soon I awaked, and there I was, veritably myself again. Now I do not know whether I was then a man dreaming I was a butterfly, or whether I am now a butterfly, dreaming I am a man.*" – Chuang Tzu

Nothing is certain! No wonder one of the wisest men to walk the Earth, Socrates, lived by the principle that all he knew was that he knew nothing at all. *It has been said that beauty is in the eye of the beholder. The world of experience is produced by the man who experiences it* – Ulric Neisser. It is apparent that the world as we know is shaped by the sensory impressions, as well as the manner in which our brains then process that information. Let us begin with a glance into how we perceive our world.

The brain reaches out to the environment via our sense organs, highly specialized nerve cells called sensory receptors (afferent neurons) convert the energy associated with mechanical forces, light, sound waves, odorant molecules, or ingested chemicals into neural signals. The process by which a sensory receptor converts a stimulus from environment to a generator potential, is called transduction. The information is transmitted as electrical signals to specialized areas of the cerebral cortex (the outer layer of the cerebrum) to be processed into sensations such as touch, vision, hearing, smell and taste. (5,28,29)

The way we interpret these sensations and make sense of the environment around us, is what we call perception. It is the mental process or state that is representing awareness or understanding of the world delivered by sensory input. Even though we receive electromagnetic waves of different frequencies, we perceive them as the colors red, blue, and green. Similarly, we receive pressure waves from objects vibrating at different frequencies, but we hear sounds, words, and music. The goal of sensation is detection and the goal of perception is to create appropriate information of the surroundings. (17,49,50)

A large amount of information is being sensed at any one time such as room temperature, brightness of lights, someone talking, a distant train, or the smell of perfume. With all this information coming into our senses, the majority of our world never gets recognized. In fact, what we perceive is very much influenced by attention, memory, the emotional and motivational state of the perceiver. Cognitive psychologists distinguish between two types of processes in perception; "top-down" processing and "bottom-up" processing. Cortical association areas integrate the qualities of a given modality (e.g., color, brightness and form in vision) as well as information from other sensory

modalities and from brain regions carrying out other functions such as attention, memory and emotions. Such processing is referred to as "top-down" processing, to indicate that the influences of these areas on perception are broader than the influence of sensory processing alone. Bottom-up processing is a type of information processing based on incoming data or sensory input from the environment to form a perception. Physiological differences can affect bottom-up processing. One person's color-processing area in the brain may be highly sensitive, for example, so colors for them are more vibrant than average. Bear in mind that colors, tones, smells, and tastes are mental creations constructed by the brain out of sensory experience. They do not exist, as such, outside the brain. (28,50,51)

The Brain – basic structure and function

The cerebrum, the largest portion of the human brain, is divided into two halves, the right and left cerebral hemispheres. Although the hemispheres are similar in appearance, they are not completely symmetrical in structure nor equivalent in function. For example, each hemisphere is concerned primarily with sensory and motor processes on the contralateral side of the body. The left hemisphere receives and analyzes sensations from the right side of the body and governs right-side motor activity, while the right hemisphere does the same for the body's left side. Further, each hemisphere is composed of a thin outer shell of gray matter, the cerebral cortex, which is generally considered to be the seat of higher-level cognitive functions as well as sensory and motor control. The vast majority of the cerebral cortex is also called the neocortex (the "new" cortex) because it is the most recently developed part of the brain from an evolutionary perspective. (5,16,28)
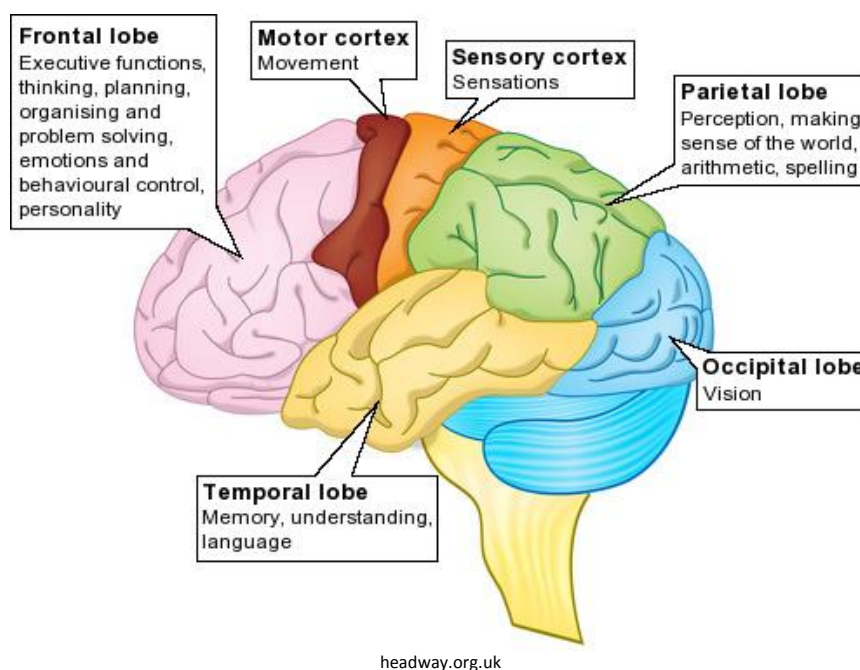
By anatomical landmarks each half of the cortex is further divided into four major lobes: *the occipital, temporal, parietal,* and *frontal* lobes. The occipital lobes, located posteriorly carry out the initial processing of visual input. Auditory sensation is initially received by the temporal lobes, which are also associated with language and conceptual thinking, are located laterally. Through temporal lobe's deep structures, the hippocampus and the amygdala, are related to aspects of learning, memory, and emotion. The parietal lobes are primarily responsible for receiving and processing sensory input, visual-spatial tasks, and body orientation. The frontal lobes are largely concerned with attention, planning and with the control of movements. (5,10,17,28)

For instance, a visual image originates in the electrochemical impulses streaming into the brain along the optic nerve. The first stop for these impulses once they arrive in the cortex is the primary visual cortex, located in the occipital lobe. Analyses of visual system shows that information arrives in the primary visual cortex from retina in separate, parallel pathways, each dedicated to analyzing a different aspect of the visual image (lines, shapes, colors and movements). Processing at this level of sensory reception does not allow for a conscious understanding and identification of the actual image. The processing that goes on at the level of the primary sensory cortex in all sensory systems occurs in conjunction with processing in what are usually referred to as "higher-order" cortical areas, also called *cortical association areas*. They are thought to be the anatomical substrates of the highest brain functions, such as conscious thought, perception, and goal-directed action. These are called association areas because they gather together, or "associate," neural information from various parts of the brain. At this level, information are sorted, amplified or inhibited, integrated with input from emotional centers and other senses. At each successive stage of this stream more complex analysis is achieved and finally assembled into a perception that has a useful, individual meaning to the perceiver. (30,45,50)

The Association Cortices

Cortical Association Areas receive and analyze signals simultaneously from multiple regions of both the motor and sensory cortices, as well as from subcortical structures. Their enrichment in projections from other cortical areas, called corticocortical connections, are not only within the same hemisphere, but also arise from other corresponding and noncorresponding cortical regions in the opposite hemisphere via the corpus callosum and anterior commissure. (5,28,29)

Important association areas include [1] *the temporal association cortex,* [2] *the prefrontal association cortex,* and [3] *the parietal association cortex.* Initial insight into the function of these cortical regions came primarily from observations of human patients with damage to specific brain regions, noninvasive brain imaging of normal subjects during the performance of various cognitive tasks, functional mapping at neurosurgery, and electrophysiological analysis of comparable brain regions in animals. (12,17)

Frontal lobe
Executive functions, thinking, planning, organising and problem solving, emotions and behavioural control, personality

Motor cortex
Movement

Sensory cortex
Sensations

Parietal lobe
Perception, making sense of the world, arithmetic, spelling

Occipital lobe
Vision

Temporal lobe
Memory, understanding, language

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- *1) The temporal association cortex*: are particularly concerned with high-level processing of auditory and visual information, through its connections with the auditory cortex and the extrastriate visual areas. Patients with lesions in this part of the brain indicate that one of the major functions related to this area is recognition and identification of highly processed sensory information. Thus, damage to either temporal lobe can result in difficulty recognizing, identifying, and naming different categories of objects, collectively called *agnosias*. Patients with for example, prosopagnosia (*prosopo-* the Greek term meaning "face") have difficulty in identifying individuals by their facial features, due to lesion in typically the right temporal lobe. They may also fail to recognize the faces of friends and family members, though they can identify people by their voices. (5,11,17)

  Wernicke's area, which spans the region between temporal and parietal lobe in dominant hemisphere (which is the left hemisphere in about 95% of right handed individuals), plays a key role in interpreting language input arriving from the nearby auditory and visual areas.

When Wernicke's area is damaged, the person has trouble understanding speech or writing (*receptive aphasia*), the person can still speak, but the speech is mostly meaningless. *Broca's area* situated in frontal lobe carry out initiation and execution of plans and motor patterns for expressing individual words or short phrases. Persons with damage to Broca's area can understand language, but cannot properly form words or produce speech (*expressive aphasia*). Broca's area is particularly important for the expressive aspects of speech, while the Wernicke's area is more concerned with the sensory aspects. (5,10,11)

- 2) *The prefrontal association cortex:* is the front portion of the frontal lobe just anterior to the premotor cortex, receives information about all sensory modalities and also about the motivational and emotional state of the individual. The main difference between the brains of the monkeys and of human beings is the great prominence of the human prefrontal areas, which shows the crucial role these areas are playing in higher cognitive functions, such as planning complex cognitive behavior, personality expression, decision making, and moderating social behavior. The prefrontal cortex is additionally important for planning and initiation of goal-oriented sequential behavior. For instance, this area helps the body organize the behaviors necessary for reaching desired objects or moving toward some chosen destination. More specifically, this part of the brain is important for attention, for selection of specific behavior among several possible, planning and execution of appropriate behavior (also suppression of unwanted behavior), particularly in social contexts. Even if you are angry at someone and your body is internally preparing for attack, you can usually judge whether an attack is appropriate and can consciously suppress the external manifestation of this basic emotional behavior. (5,9,16,17)

  Another function that has been ascribed to the prefrontal areas is elaboration of thought. This means simply an increase in depth and abstractness of the different thoughts put together from multiple sources of information. To carry out these highest of neural functions, the prefrontal cortex is thought to store a short-term basis "working memories", a temporary storing of information that are used to combine new thoughts while they are entering the brain and thereby guiding our future actions. fMRI studies indicate that we remember words or pictures only if their presentation also activates the prefrontal cortex. Damage to this area of the brain results in a loss of the ability to concentrate, plan future behavior, and carry out complex perceptual tasks that require sharp mental focus or sustained attention. Victims of such damage, for example, are often unable to complete long sentences or plan a schedule for the day. They also frequently exhibit emotional flatness, a lack of will, and a profound indifference to events in the environment. (5,9,12,17)

- 3) *The parietal association cortex*: situated at the posterior section of the parietal lobe, receives somatosensory information as well as information from other sensory modalities, especially vision and hearing. Integration of these various information gives the ability to become aware of one's body, a three-dimensional sense of body and to orient that body in space, in other words spatial orientation and visually guided behavior. Patients with strokes or tumors in the right parietal association area have deficiencies involving depth perception and the ability to determine location, distance, spatial orientation, and object size. Further, many of these patients suffer from contralateral neglect syndrome, an inability to perceive objects, activities or people, even one's own body, on the side opposite the damage. Such patients are unable to "see" the left side of their body, despite the fact that all the sensory functions remain intact. For example, the patient may fail to shave or apply makeup on the left side of the face. In some cases, a person with a paralyzed arm or leg will deny that anything is wrong and even claim that the affected limb belongs to someone else, because

the idea of having a left limb is completely foreign to them. They may also have difficulty performing complex motor tasks on the neglected side, including dressing themselves, reaching for objects, writing, drawing, and to a lesser extent, orienting to sounds, collectively referred to as apraxia. (5,11,12,17,28)

Collectively, the association cortices mediate these intricate cognitive functions of the brain – broadly defined as the ability to attend to, identify, and act meaningfully in response to complex external or internal stimuli. (17,28)

The Limbic System

The limbic system is that part of the brain that generates and modulates our emotions (such as anger, fear and happiness), as well as long-term memories. The primary structures of the limbic system are the amygdala, the hippocampus, the thalamus, the hypothalamus and several other nearby areas. Stimulating specific regions of the limbic system during brain surgery produces vague subjective sensations that the patient may describe as joy, satisfaction, or pleasure in one region and discouragement, fear, or anxiety in another. (5,12)

In humans, feelings are consciously experienced emotions that give our lives meaning, motivation and value. They are characterized primarily by psychophysiological expressions, biological reactions, and mental states. Without emotions, we would move through the world like very intelligent robots. In fact, most animals with central nervous systems have a limbic system even if they have no cerebral cortex for higher-lever thinking, thus many other species are also probably capable of emotions. (16,41)

The concept of emotion encompasses subjective emotional feelings and moods plus the overt physical responses associated with these feelings. When frightened we not only feel afraid but also experience increased heart rate and respiration, dryness of the mouth, tense muscles, and sweaty palms, due to increased activity of the sympathetic nervous system regulated by the hypothalamus. Apparently the involvement of the hypothalamus in the limbic system governs the involuntary internal responses of various body systems in preparation for appropriate actions in challenging or threatening situations. These preparatory changes in the internal state require no conscious control. (16,17,34)

Even though emotions are generated constantly, most of the time we are not aware of them. The unconscious physiological component of emotion is generated by limbic activity, while the conscious recognition of the emotion is mediated by the cerebral cortex, in part by the cingulate cortex and by the frontal lobes. The sight of a snake, for example, indicating a danger is first sent to the thalamus, where all sensory information passes through (except olfaction). From there, the information is sent out over two parallel pathways: the thalamo-amygdala pathway (the "short route") and the thalamo-cortico-amygdala pathway (the "long route"). Through the "short route", the sensory information from thalamus is directed to the amygdala, which registers the emotional stimuli before we are even conscious of it. Subsequently, the amygdala sends messages to the hypothalamus, which prepares the body for flight-or-fight response. Thus, the short and quick route generates emotional responses before recognition of the emotions have even occurred. The "long route" takes the information through the sensory- and the association –cortices, where the perceptual integration occurs (as we have seen earlier) and allow us to become conscious of the emotion and consequently give a more

thoughtful response. Subsequently, the information that has travelled via the long route reaches the amygdala and tells it whether or not the stimulus represents a real threat. The amygdala is especially important in processing inputs that give rise to the sensation of fear. (5,17,52)

Further, the amygdala participates in several higher-order emotional and motivational functions. The amygdala helps to store memories of events and emotions so that an individual may be able to recognize similar events in the future. When a stimulus requiring our attention is presented, the amygdala acts to analyze its significance in a very basic way, then directs the mind to pay attention by assigning emotional value to the stimulus. It is believed that due to its role in processing of emotional significance of the stimulus, it might be involved in perception. It also plays a key role in expression of emotions and recognition of emotional expression in faces. (1,5,12,16)
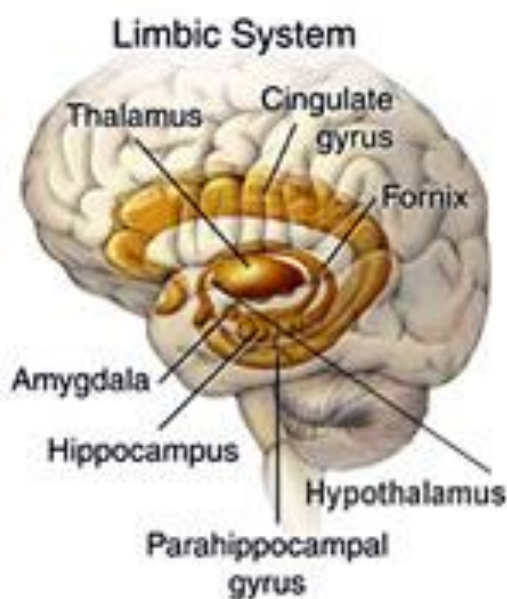
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The brief description of the brain structures and functions here are merely a guide to thinking about how complex cognitive information is represented and processed in the brain, as well as how relevant brain areas and their neurons contribute to such important cognitive functions.

METHODS

A literature search was conducted using PubMed database in an iterative manner during October-December 2014 to retrieve articles related to neural (anatomical) correlates of spiritual and religious experiences that were investigated using functional neuroimaging techniques. Search terms included "brain AND religion", "neurotheology", "spirituality AND brain" and "neural correlates AND religion". No specific key words were required as inclusion or exclusion criteria, a relatively small number of studies exist on the topic, so a "bottom-up" search strategy was required. The reference lists of each relevant article were reviewed in detail to find additional articles. The final yield was 11 relevant articles, including a MRI study on Buddhist Insight meditation; PET studies on Protestant Christian prayer, Yoga meditative relaxation and Yoga Nidra; SPECT studies on Tibetan Buddhist meditation and Franciscan Christian prayer; and fMRI studies on Kundalini meditation, Zen meditation and Christian Carmelite nuns during a religious experience.

RESULTS

A number of studies have revealed an association between temporal lobe epilepsy and religious experiences. Many scientists believed that religious and mystical experiences were "artifacts" of temporal lobe function, thus temporal lobe was thought to be the only part of the brain involved in Religious and Spiritual Experiences (RSEs). However, recent imaging studies have shown that many parts of the brain are activated during RSEs. The neurological substrates of these experiences would provide them as convincingly real as any other of the brain's perception. Thus, RSEs are not merely irrational or delusions, they are based in observable functions of the brain.

A diverse variety of experiences fall under the general rubric of RSEs, which may be attained through a wide range of religious and spiritual practices such as prayer, religious singing, rituals, meditation, yoga, mantra chanting, sufi dancing, tai chi etc. Some of the most common features of RSEs are "a sense of having encountered ultimate reality", "a sense of sacredness", "feelings of unity or totality", " a sense of timelessness and spacelessness", "a state of no-mind" and "pure consciousness". (21,36,52) Furthermore, such experiences are usually described as evoking positive feelings such as happiness, blissfulness, peace and joy. Most studies that have explored RSEs thus far have focused mainly on prayers and meditative practices.

Most of the studies examining RSEs used functional neuroimaging as the investigation tool, to delineate the neural mechanisms involved in spiritual or religious practices. These neuroimaging techniques include positron emission tomography (PET), single photon emission computed tomography (SPECT), and functional magnetic resonance imaging (fMRI).

By understanding which brain regions are engaged during RSEs we can get some clues as to what types of information are being processed there, according to current knowledge we have about the (specific) functions related to those areas. Keep in mind that even though a discrete activity is ultimately attributed to a particular region of the brain, no part of the brain functions in isolation. Each part depends on complex interactions with numerous other regions for both incoming and outgoing messages, as we already have seen in earlier part of this review.

The results of the included studies are summarized in table 1 and table 2 below.

Activation of frontal lobe regions

Most of the included studies show increased activity in the frontal lobe regions, particularly the prefrontal cortex when an individual performs a meditation or prayer practice in which there is intense concentration on the particular practice. This finding should not come as a surprise when we recall the complex functions related to the prefrontal cortex, which include attention, elaboration of thought, goal-oriented behavior etc.

Using PET scan, Herzog et al. (1990) measured the regional cerebral metabolic rate of glucose (rCMRGlc) in eight members of a yoga meditation group during self-induced yoga meditative relaxation and in the resting state (control condition). Each subject had minimum 1 year of experience in yoga meditation. The meditators reported feeling relaxed, at peace and detached during meditation but not during the control condition. In all conditions eyes remained open. During the meditative state, measurements were started after a hand signal from subjects which indicated that each have reached the peak state of yoga meditative relaxation. The results showed a significant

increase in the frontal:occipital ratio of rCMRGlc during the meditation compared to the resting state. These altered ratios were caused by a mild increase of frontal rCMRGlc and a more pronounced *decrease* in metabolism in the parietal and occipital lobes (primary and secondary visual areas). Herzog and colleagues suggest that the decrease in the occipital cortical areas may reflect a reduced visual input and processing during meditation, whereas the increase in the frontal cortex may reflect the sustained attention required for meditation. (15)

Another study to detect the increased activation in the prefrontal cortex was conducted by Lazar et al. (2000), who used fMRI to identify the brain regions that are active during a form of Kundalini meditation. Five subjects participated in this study and each had practiced Kundalini meditation daily for at least 4 years. Subjects performed a simple form of Kundalini meditation in which they passively observed their breathing and silently repeated the phrase 'sat nam' during inhalations and 'wahe guru' during exhalations (experimental condition). During the control state they silently generated a random list of animals and did not observe their breathing. Significant *increases* were detected in the dorsolateral prefrontal and parietal cortices, hippocampus/parahippocampus, temporal lobe, pregenual anterior cingulate cortex, striatum, and pre- and post- central gyri during meditation compared to the control condition. A global decrease in blood oxygen level was also noted, however these changes were explained to be secondary to cardiorespiratory changes that often accompany meditation. The results are interpreted as reflecting that the practice of meditation activates neural structures involved in attention (frontal and parietal cortex) and control of the autonomic nervous system (pregenual anterior cingulate, amygdala, midbrain and hypothalamus). (18)
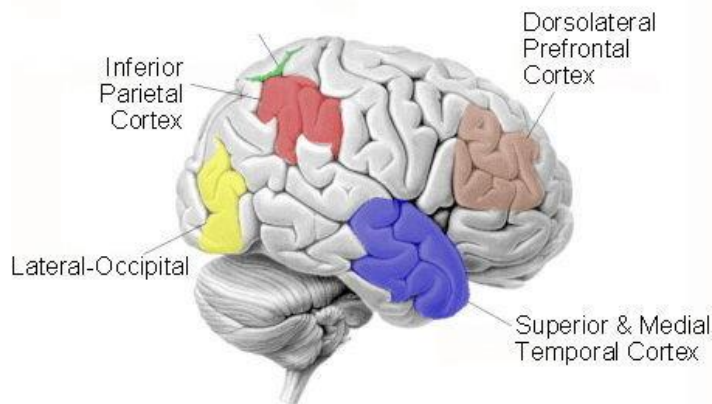
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Increased prefrontal activity appears to be common in both meditation and prayer practices. Azari et al. (2001) used PET scan to study a group of six self-identified religious subjects, who were Protestant Christians, and a group of six control subjects, who were self-identified as nonreligious. Subjects were PET-scanned in six conditions; (1) reading silently or (2) reciting biblical Psalm 23, (3) reading silently or (4) reciting the children nursery rhyme, (5) reading silently the set of phone card instructions and (6) lying quietly. During religious recitation, self-identified religious subjects reported achieving a religious state and showed *peak blood flow activation* in a frontal-parietal circuit, composed of the dorsolateral prefrontal, dorsomedial frontal and medial parietal cortex - compared with other readings and with nonreligious control individuals. Accordingly, Azari et al. suggest that religious experience may be a cognitive attributional phenomenon, mediated by this frontal-parietal circuit. The experience becomes religious when people consciously identify the experience as consistent with their own religious schema. A religious schema is – a mental representation

containing organized knowledge or information about the religious concepts – that facilitates religious attributions. Consequently, self-initiated religious actions will reinforce the subject's personal religious schema. This cognitive process most probably involves the dorsolateral prefrontal and medial parietal cortex. (2)

Ritskes et al. (2003) also demonstrated increased activity in the prefrontal cortex in a study of Zen meditators. A group of 11 experienced Zen meditation practitioners were scanned with fMRI as they switched from normal consciousness to a meditative state of mind. These subjects had on average 8 years of daily Zen-meditation experience. During fMRI scanning an on-off design was used, in which 3 periods of 45 seconds meditation where all 11 subjects focused on silently counting their breaths (experimental condition) - were alternated by 3 periods of 45 seconds of random thoughts (control condition). Comparing meditation with the control condition revealed *increased* activity in the right medial prefrontal cortex (BA 10) and basal ganglia. *Decreased* activity was noted in the superior occipital gyrus and anterior cingulate cortex. Reduced activation were attributed to decreased experience of will and less awareness of self-orientation in the meditative state. (31)

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15 Carmelite nuns were asked to recall their religious experiences under a fMRI study by Beauregard & Paquette (2006). Blood oxygen level dependent (BOLD) signal changes were measured during a Mystical condition, a Control condition, and a Baseline condition. In the Mystical condition, subjects were asked to remember and relive the most intense mystical experience ever felt in their lives. The mystical experiences were characterized by a sense of union with God, the experience of timelessness and spacelessness, the sense of union with humankind and the universe, as well as feelings of positive affect, peace, joy and unconditional love. In the Control condition, subjects were instructed to remember and relive the most intense state of union with another human ever felt and the Baseline condition was a normal restful state, to measure brain activity during a normal state of consciousness. In all conditions eyes were closed. The results showed a broad activation of brain activity. In particular, *significant loci of activation* were found in the right medial orbitofrontal cortex, right middle temporal cortex, right inferior and superior parietal lobules, right caudate, left medial prefrontal cortex, left anterior cingulate cortex, left inferior parietal lobule, left insula, left caudate and left brainstem. Other loci of activation were seen in the extrastriate visual cortex. Beauregard & Paquette suggest that each of these loci was supposedly involved in different aspects of the religious experience, such as representation of the somatovisceral reactions associated with the feelings of joy and unconditional love, subjective pleasantness, internal somatic state, positive emotions and emotional awareness. Thus they conclude that mystical experiences are mediated by several brain regions and systems. (3)

A recent fMRI study by Davanger et al. (2010) showed that some areas within the prefrontal cortex were significantly more activated during meditation with 'a relaxed focus of attention' than during concentrative meditation-like cognitive tasks. Four experienced Acem meditation practitioners were studied. Each subject had 23 years of experience in practicing Acem meditation, which is a form of "mantra meditation" where they focus their attention on the mental repetition of a mantra (meditation sound) without effort, while thoughts and impressions are allowed to come and go freely. fMRI recordings during meditation were compared to three control tasks consisting of: (1) concentrative repetition of a pseudoword without any semantic meaning, (2) generation of continuous word sequence, (3) audio-based instructions for physical relaxation. The results showed that bilateral areas of the inferior frontal gyrus (BA 47) were significantly *more activated* during repetition of a meditation sound than during similar, but more concentrative cognitive control tasks. Absence of significant activation during control tasks indicates that activation may be specific to the relaxed focus of attention during meditation. It was also observed that activation did not habituate over time, but was strongest in the continuous meditation task. Accordingly, Davanger and colleagues suggest that meditation practiced with a relaxed focus of attention, in which thoughts and sensations may emerge and pass freely, activates distinctive areas of the prefrontal cortex. (Other language specific brain areas like left superior temporal gyrus and left precentral gyrus were also activated during meditation, which indicate that mental repetition of the meditation sound during Acem meditation also activates cortical areas related to language, processing of verbal stimuli and motor control). (6)

While all of the studies mentioned above revealed increased activity in the prefrontal cortex, however one study of guided type of meditation did not demonstrate such increase in prefrontal activity. Lou et al. (1999) studied relaxation meditation (Yoga Nidra) using PET (^{15}O-H$_2$O) technique in nine yoga teachers. Yoga Nidra is a meditative state in the Yoga tradition 'where the mind withdraws from wishing to act and the meditator becomes a neutral observer'. Cerebral blood flow distribution was investigated during auditory-guided relaxation meditation and during the resting state of normal consciousness. Their subjects listened (eyes closed) to a tape recording that guided them through experiences of attention to regions of the body (1), abstract joy (2), visualization of a summer landscape (3), and visualization of an abstract symbol of the self (4), which were then compared to four control conditions in the resting state. A common experience of emotional and volitional detachment was reported throughout the meditation session but not during the control session. Each of the guided meditation phases was correlated with different regional *activations* relative to the control condition: bodily sensations were supported mainly by parietal lobe and supplementary motor area activity; abstract sensation of joy by left parietal and superior temporal (Wernicke area) activity; visual imagery by occipital lobe with exception of V1 region (primary visual cortex) and symbolic representation of self by bilateral parietal lobes. Additionally, activation in bilateral hippocampi was observed in all conditions. However, the apparent lack of prefrontal and cingulate activity during meditation were interpreted as reflecting the limited volitional control during this type of "passive" auditory guided meditation. Thus, prefrontal and cingulate activation may be associated with the volitional aspects of meditation. (20)

Decreased activity in the parietal lobe

These studies indicate a potentially important role of the prefrontal cortex and other frontal lobe regions in RSEs. However, frontal lobe activity alone does not seem to provide a complete understanding for those experiences. Some studies also suggest that the parietal lobe, particularly

decreased activation of the superior parietal lobe, may play an important role in mediating the sense of unity with the universe or a divine being, and a "feeling of oneness", which are common features in the RSEs. Decreased activation in this area may result in a decreased sense of awareness or loss of ability to distinguish between the self and the external world. This is hypothesized as the neurophysiological substrate of "oneness" feeling experienced in RSEs (Newberg et al., 2010).

A SPECT study by Newberg et al. (2001) was conducted on eight Tibetan Buddhist meditators who used a type of "visualization" technique meditation involving active concentration. In this form of meditation, practitioners initially focus their attention on a visualized image and maintain that focus with increasing intensity. The 'peak' experience of their meditation is described as a sense of absorption into the visualized image associated with clarity of thought and a loss of the usual sense of space and time. Each subject had more than 15 years of experience in practicing Tibetan meditation. The meditators were scanned at baseline condition (resting state) and after approximately 1 hour of meditation, when they had indicated entering into the deepest part of their meditation session. Meditation compared with baseline was related to *increased* activity in the cingulate gyrus, inferior and orbital frontal cortex, dorsolateral prefrontal cortex, sensorimotor cortex, midbrain and thalamus. *Decreased* activity in the left superior parietal lobe was negatively correlated with the activity increase observed in left dorsolateral prefrontal cortex. Newberg et al. suggest that meditation is associated with increased activity in the frontal lobes and that such activity is correlated with decreased activity in the posterior parietal lobes. These two findings, respectively, may reflect active focused concentration and the experience of alterations of the sense of space during meditation. The fact that changes in activity are also observed in the thalamus, sensorimotor cortex, and midbrain may indicate that there is an intricate level of central nervous system interactions during this type of meditative practice. (23)

A SPECT study by Newberg et al. (2003) has measured changes in cerebral blood flow in three Franciscan nuns during a practice called "centering prayer" involving the internal repetition of a particular phrase. Centering prayer requires focused attention on a phrase from the Bible and involves "opening themselves to being in the presence of God" and "loss of the usual sense of space". All three nuns had performed more than 15 years of daily practice of this prayer. Subjects were scanned also in a baseline condition, which was a normal restful state. Compared with baseline, scans during prayer demonstrated *increased* blood flow in the prefrontal cortex, inferior parietal lobes, and inferior frontal lobes. Furthermore, there was a strong inverse correlation between blood flow changes in the left prefrontal cortex and the ipsilateral superior parietal lobe. Increased blood flow in the frontal cortex was interpreted as reflecting attention focusing tasks (nuns were focusing on a particular phrase) and activation of inferior parietal region reflects its function related to language (this was a "verbal" based prayer). Further, *decreased* activity in the superior parietal lobe was interpreted as reflecting an altered sense of the body schema experienced during the prayer state (recall that this region usually helps to generate the normal sense of spatial awareness). (24)

In contrast, Lou et al. (1999), Lazar et al. (2000) and Beauregard & Paquette (2006) found (superior) parietal lobe activation, as we have seen before. The implication was that different meditative practices affect brain function in different ways.

Baseline differences and structural changes in long-term meditation practitioners

According to Lazar et al. (2005), regular meditation is thought to promote structural changes in a subset of cortical regions. MRI was used to assess cortical thickness in 20 experienced Buddhist Insight meditation practitioners (mean practice 9,1 years; 6,2 h per week) and 15 control participants with no meditation or yoga experience. This form of meditation focus mainly on a mental capacity termed 'mindfulness', which is a specific nonjudgmental observation of constantly changing internal and external stimuli without cognitive elaboration. The meditators were typical Western practitioners who incorporated their meditation practices with their careers and family life. The study showed that brain regions associated with attention, interoception and sensory processing, like right anterior insula and right parts of the prefrontal cortex (Brodmann areas 9 and 10) were thicker in meditation practitioners than matched controls. In one focal region of BA 9/10 the average cortical thickness of the 40-50-year-old meditation participants was similar to the average thickness of the 20-30-year-old meditators and controls, accordingly Lazar et al. suggest that regular practice of meditation may slow the rate of normal age changes at this specific locus. It was also noted that thickness of the inferior occipitotemporal visual cortex and right anterior insula were correlated with meditation experience. The data provides structural evidence for experience-dependent cortical plasticity associated with meditation practice – implying that regular meditation practices may promote neuroplasticity. (19)

A recent study revealed that higher activity in the prefrontal areas are not only involved during the peak state of meditation or religious practices, but also in the long-term effects of such practices. To evaluate whether there were baseline differences in specific brain regions in long-term meditators compared to non-meditators, Newberg et al. (2010) examined 12 experienced meditators and 14 non-meditators (a group of healthy controls) with cerebral blood flow SPECT imaging at rest. Each meditator described himself or herself as practicing meditation or prayer for more than fifteen years and all individuals practiced a focus based meditation which involved either imagery or various words or mantras. Comparing long-term meditators with the control group showed a significant *increase* in activity in the prefrontal cortex, parietal cortex, thalamus, putamen, and midbrain. In addition, a greater asymmetry in the thalamic laterality in long-term meditators was also observed. The higher baseline activities in the parietal regions in long-term meditators were speculated to have some correlation with stronger decrease during the actual practice, which in turn amplifies the experience of losing the sense of space. The results indicate that there are differences in baseline brain function in long-term meditators compared to non-meditators, particularly in structures that are related to attention (prefrontal areas), emotion and emotional regulation (putamen & caudate nucleus – basal ganglia), and autonomic function (thalamus, midbrain). (25)
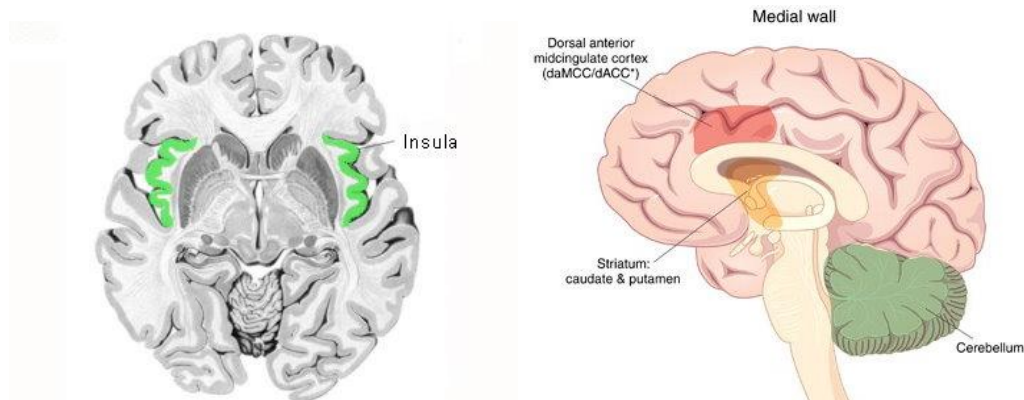
Table 1. Summary of neuroimaging studies of spiritual and religious practices

Study	Subject population	N	Religious or meditative task	Control task	Method	Findings
Herzog et al., 1990	Yoga meditation group – no control group	8	Yoga meditative relaxation	Resting state – thinking about daily affairs	PET	**Increased activation**: frontal cerebral glucose metabolism **Decreased activation**: occipital and temporo-occipital cerebral glucose metabolism
Lou et al., 1999	Experienced yoga teachers – no control group	9	Yoga Nidra meditation	Resting state	PET (^{15}O-H$_2$O)	**Increased activation**: bilateral hippocampi, supplementary motor area, bilateral parietal lobes, left superior temporal and occipital cortex **Decreased activation**: Prefrontal and anterior cingulate cortex, caudate, thalamus, pons and cerebellum
Lazar et al., 2000	Kundalini meditation practitioners – no control group	5	Observing their breath and silently repeating "sat nam" during inhalations and "wahe guru" during exhalations	Silently generating a random list of animals and not observing their breath	fMRI	**Increased activation**: dorsolateral prefrontal and parietal cortices, hippocampus/parahippocampus, temporal lobe, pregenual anterior cingulate cortex, striatum, and pre- and post- central gyri 20% decrease in global blood oxygen level
Azari et al., 2001	6 religious teachers and 6 nonreligious college students	12	Recitation of first verse of biblical Psalm 23	Happy (German children's nursery rhyme) and Neutral (instructions to use a German phone card)	PET	**Increased activation**: right dorsolateral prefrontal, dorsomedial frontal and medial parietal cortex.
Newberg et al., 2001	Tibetan Buddhist meditators (and healthy controls were only scanned at baseline condition)	8	"Visualization" technique meditation	Resting state	SPECT	**Increased activation**: cingulate gyrus, inferior and orbital frontal cortex, dorsolateral prefrontal cortex, and thalamus **Decreased activation**: left superior parietal lobe
Newberg et al., 2003	Franciscan nuns – no control group	3	Centering prayer – internal repetition of a phrase from the Bible	Resting state	SPECT	**Increased activation**: prefrontal cortex, inferior parietal lobes and inferior frontal lobes.

					Decreased activation: left superior parietal lobe.
Ritskes et al., 2003	Zen meditation practitioners – no control group	11	Zen meditative state	Resting state – engaging in random thoughts	fMRI	**Increased activation**: right medial prefrontal cortex (BA 10) and basal ganglia **Decreased activation**: superior occipital gyrus and anterior cingulate cortex
Lazar et al., 2005	20 experienced Buddhist Insight (Vipassana) meditators and 15 control subjects	35	None	None	MRI	Thicker right anterior insula and parts of the right prefrontal cortex (BA 9 & 10) Decreased age-related cortical thinning in BA 9/10.
Beauregard & Paquette, 2006	Carmelite nuns – no control group	15	Remember and relive (eyes closed) most intense mystical experience being a nun	Remember and relive (eyes closed) most intense "state of union" with another person	fMRI	**Increased activation**: right medial orbitofrontal cortex, right middle temporal cortex, right inferior and superior parietal lobules, right caudate, left medial prefrontal cortex, left anterior cingulate cortex, left inferior parietal lobule, left insula, left caudate, and left brainstem.
Davanger et al., 2010	Experienced Acem meditators – no control group	4	"Mantra meditation" technique	Pseudoword repetition, word sequence generation and relaxation	fMRI	**Increased activation**: bilateral areas of the inferior frontal gyrus (BA 47), left superior temporal gyrus and left precentral gyrus
Newberg et al., 2010	12 long-term meditators and 14 non-meditators (healthy controls)	26	None	None	SPECT	**Increased activation**: prefrontal cortex, parietal cortex, thalamus, putamen, and midbrain. In addition, a greater asymmetry in the thalamic laterality.

Table 2. Summary of findings

	Increased activation	Decreased activation
Frontal lobe	• **Frontal lobes** (Herzog et al., 1990) • **Supplementary motor area** (Lou et al., 1999) • **Dorsolateral prefrontal, pregenual anterior cingulate cortex and precentral gyrus** (Lazar et al., 2000) • **Right dorsolateral prefrontal and dorsomedial frontal cortex** (Azari et al., 2001) • **Dorsolateral prefrontal cortex, cingulate gyrus, inferior and orbital frontal cortex** (Newberg et al., 2001) • **Prefrontal cortex and inferior frontal lobes** (Newberg et al., 2003) • **Right medial prefrontal cortex - BA 10** (Ritskes et al., 2003) • **Thicker right prefrontal cortex - BA 9 & 10** (Lazar et al., 2005) • **Left medial prefrontal cortex, right medial orbitofrontal cortex and left anterior cingulate cortex** (Beauregard & Paquette., 2006) • **Bilateral areas of the inferior frontal gyrus - BA 47 and left precentral gyrus** (Davanger et al., 2010) • **Right and left prefrontal cortex** (Newberg et al., 2010)	• **Prefrontal and anterior cingulate cortex** (Lou et al., 1999) • **Anterior cingulate cortex** (Ritskes et al., 2003)
Parietal lobe	• **Bilateral parietal lobes** (Lou et al., 1999) • **Parietal cortex and postcentral gyrus** (Lazar et al., 2000) • **Right medial parietal cortex** (Azari et al., 2001) • **Inferior parietal lobes** (Newberg et al., 2003) • **Right inferior and superior parietal lobules, left inferior parietal lobule** (Beauregard & Paquette., 2006) • **Right and left parietal cortex** (Newberg et al., 2010)	• **Left superior parietal lobe** (Newberg et al., 2001) • **Left superior parietal lobe** (Newberg et al., 2003)
Temporal lobe	• **Left superior temporal cortex** (Lou et al., 1999) • **Temporal cortex** (Lazar et al., 2000) • **Right middle temporal cortex** (Beauregard & Paquette., 2006) • **Left superior temporal gyrus** (Davanger et al., 2010)	
Occipital lobe	• **Occipital cortex except V1 region** (Lou et al., 1999)	• **Occipital lobes** (Herzog et al., 1990) • **Superior occipital gyrus** (Ritskes et al., 2003)
Subcortical structures	• **Bilateral hippocampi** (Lou et al., 1999) • **Hippocampus/parahippocampus and striatum** (Lazar et al., 2000) • **Thalamus** (Newberg et al., 2001) • **Basal ganglia** (Ritskes et al., 2003) • **Thicker right anterior insula** (Lazar et al., 2005) • **Right and left caudate, left insula and left brainstem** (Beauregard & Paquette., 2006) • **Thalamus, putamen, and midbrain. A greater asymmetry in the thalamic laterality** (Newberg et al., 2010)	• **Caudate, thalamus, pons and cerebellum** (Lou et al., 1999)

DISCUSSION

The results of the included studies suggest that several brain regions and systems mediate the various aspects of RSEs, implying that RSEs are complex and multidimensional experiences which involve changes in perception (e.g., visual mental imagery), cognition (e.g., representations about the self) and emotion (e.g., peace, joy, bliss) (Beauregard et al., 2006). Like many other higher cortical functions these experiences also involve many parts of the brain, thus no single specific neural correlate of RSEs do exist. In other words "no single God spot exists" in the brain.

A methodological bias in studying meditative practices utilizing neuroimaging techniques may lie in the fact that meditators and nuns were proposed to perform practices in an unusual supine position during the neuroimaging sessions. Meditation practices are usually done in a seated position (lotus or half lotus position), while keeping spine straight and erect, which have got an immense importance in eastern spiritual teachings. Altering this essential position may affect the meditative state subjects were supposed to achieve and thereby the imaging results. Moreover, loud noises generated by the imaging machines could also have distracted the individuals and hindered them in attaining the expected meditative state.

Potential confounding bias with these type of studies include the fact that the subjective sense during the RSEs are difficult to measure. Hence, it is important to ascertain as much as possible what the subject thinks he or she is experiencing. Some studies used standard measures such as 'Hood's mysticism scale' (Beauregard et al. 2006) and 'PANAS' (Azari et al. 2001) to analyze and quantify the subjective experiences in a systematic manner. However, most of the studies only used brief questionnaires to evaluate the subjective experiences after termination of neuroimaging measurements. Such reports could be very limited in evaluating the actual experiences and to ensure whether subjects managed to maintain the meditative state throughout the scanning procedures. For instance, researchers could have applied concomitant physiological measurements including heart rate, respiratory rate, blood pressure or hormone levels as an objective measurement of RSEs which might give additional information about the depth of the experiences. Only two studies (Lazar et al. 2000 & 2005) used such objective measurements to determine whether changes in these measures could influence the imaging results.

The included studies report activation patterns corresponding to brain regions known to be involved in their respective functions, for instance, prefrontal activation during attention focusing tasks, parietal lobe in generation of spatial awareness, occipital lobe in visual imagery etc. Although there are some discrepancies in the findings between studies, we have to remember that the spiritual task included in each study varied substantially. Many different types of meditation and prayer practices were evaluated and they also varied in sample size and imaging methods. The variety of practices with respect to procedures and processes, makes it likely that they also differ with respect to the patterns of brain activity reported. Therefore, integration of the results in an attempt to identify *common neural correlates of RSEs* are likely to be unsuccessful. Despite this, increased activity in particular brain regions was observed in several studies, indicating a potential important role of those regions in RSEs, like the prefrontal cortex, parietal lobes, basal ganglia and limbic system. Indeed, these findings are only correlative in nature, nothing is revealed about the causal relationships. Although RSEs are associated with changes in regional brain activity, it is not clear whether these changes "caused that experience or responded to that experience" (Newberg et al., 2005).

CONCLUSION

Perhaps the most striking finding observed in the included studies is that there exists no single specific neural correlate of RSEs. Furthermore, the findings of the included studies have revealed some discrepancies, which are predominantly attributed to the diversity of meditative practices included in the studies. Nevertheless, there appears to be some coherence of their findings with the frontal lobes, parietal lobes, basal ganglia and limbic system frequently related in a network associated with RSEs. However, the methodological limitations, small sample size and the multitude of spiritual and religious practices (or techniques) examined in the included studies make generalization difficult. Hence, future studies with larger samples are needed to replicate and extend findings from previous studies, in order to identify common neural correlates of RSEs. Ultimately such studies should also attempt to integrate neuroimaging results with other objective physiological measures such as heart rate, respiratory rate and blood pressure.

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