Marx E, Deutschländer A, Stephan T, Dieterich M, Wiesmann M, Brandt T.
Source

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Abstract
The patterns of associated brain activations during eyes-open and eyes-closed states in complete darkness considerably differ in fMRI. An "interoceptive" state with the eyes closed is characterized by visual cortex activation, while an "exteroceptive" state with the eyes open is characterized by ocular motor system activity. The impact of the chosen rest condition (eyes open or eyes closed in complete darkness) on the pattern of brain activations during visual stimulation was evaluated in 14 healthy volunteers. During fixation or dim light room illumination, the activation of the visual cortex was larger with the eyes-open rest condition than with the eyes-closed rest condition; however, activation of the lateral geniculate nucleus was smaller. Activations that can be attributed to ocular motor structures, such as the prefrontal cortex, parietal and frontal eye fields, cerebellar vermis, the thalamus, and basal ganglia were larger with the eyes-closed rest condition than with the eyes-open rest condition. BOLD signal decreases of cortical areas that represent visual, somatosensory, auditory, and vestibular functions were seen in the comparison fixation of light emitting diode (LED) minus eyes closed. Thus, the choice of rest condition (either eyes closed or eyes open) is critical for stimulus-induced brain activation patterns. Activity of the ocular motor system as well as deactivation of sensory cortical areas may go undetected with eyes open as rest condition.

PMID: 15050602 [PubMed - indexed for MEDLINE]

Differential effects of eyes open or closed in darkness on brain activation patterns in blind subjects.

Hüfner K, Stephan T, Flanagin VL, Deutschländer A, Stein A, Kalla R, Dera T, Fesl G, Jahn K, Strupp M, Brandt T.
Source

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Abstract
In functional brain imaging, specific task conditions can be compared to a reference condition which is often eyes-open or eyes-closed in darkness without the execution of a specific task. Previous fMRI studies in sighted subjects have shown that eyes-open in darkness, without visual stimulation, increases the relative activity in cortical ocular motor and attentional areas ("exteroceptive" state; contrast OPEN>CLOSED). By contrast, eyes-closed causes a relative signal increase in sensory systems ("interoceptive" state; contrast CLOSED>OPEN). In the present study we used fMRI to determine whether these differential brain activity states can also be found in congenitally blind subjects: there were intragroup differences between the OPEN and CLOSED conditions. These differences were, however, less pronounced and occurred in other areas than in sighted controls. The contrast OPEN>CLOSED revealed a relative signal increase in the left frontal eye field, the middle occipital gyrus bilaterally and in the anterior cingulum. Relative signal increases in occipital cortex areas and the anterior cingulum were also apparent for this contrast in the intergroup comparison (congenitally totally blind subjects vs. sighted controls). They reflect the increased attentional load or arousal during the eyes-open condition and could be indicative of a functional reorganization of the occipital cortex in the blind. The contrast CLOSED>OPEN in the congenitally totally blind subjects lead to relative activations in the somatosensory cortex bilaterally, the middle temporal gyrus on the left and the

frontal gyri on the right. These activations are residues of the "interoceptive" state found in sighted controls.

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Differences in saccade-evoked brain activation patterns with eyes open or eyes closed in complete darkness.

Hüfner K, Stephan T, Glasauer S, Kalla R, Riedel E, Deutschländer A, Dera T, Wiesmann M, Strupp M, Brandt T.

Source

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Abstract

In this study we attempted to differentiate distinct components of the saccade network, namely cortical ocular motor centers and parieto-occipital brain regions, by means of a "minimal design" approach. Using a blocked design fMRI paradigm we evaluated the BOLD changes in a 2 x 2 factorial design experiment which was performed in complete darkness: while looking straight ahead with eyes open (OPEN) or closed (CLOSED) as well as during the execution of self-initiated horizontal to-and-fro saccades with the eyes open (SACCopen) or closed (SACCclosed). Eye movements were monitored outside the scanner via electro-oculography and during scanning using video-oculography. Unintentional eye-drifts did not differ during OPEN and CLOSED and saccade frequencies, and amplitudes did not vary significantly between the two saccade conditions. The main findings of the functional imaging study were as follows: (1) Saccades with eyes open or closed in complete darkness lead to distinct differences in brain activation patterns. (2) A parieto-occipital brain region including the precuneus, superior parietal lobule, posterior part of the intraparietal sulcus (IPS), and cuneus was relatively deactivated during saccades performed with eyes closed but not during saccades with eyes open or when looking straight ahead. This could indicate a preparatory state for updating spatial information, which is active during saccades with eyes open even without actual visual input. The preparatory state is suppressed when the eyes are closed during the saccades. (3) Selected ocular motor areas, not including the parietal eye field (PEF), show a stronger activation during SACCclosed than during SACCopen. The increased effort involved in performing saccades with eyes closed, perhaps due to the unusualness of the task, may be the cause of this increased activation.

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Abstract

Background

Recent functional MRI (fMRI) studies have demonstrated that there is an intrinsically organized default mode network (DMN) in the resting brain, primarily made up of the posterior cingulate cortex (PCC) and the medial prefrontal cortex (MPFC). Several previous studies have found that the DMN is minimally disturbed during different resting-state conditions with limited cognitive demand. However, this conclusion was drawn from the visual inspection of the functional connectivity patterns within the DMN and no statistical comparison was performed.

Methodology/Principal Findings

Four resting-state fMRI sessions were acquired: 1) eyes-closed (EC) (used to generate the DMN mask); 2) EC; 3) eyes-open with no fixation (EO); and 4) eyes-open with a fixation (EO-F). The 2–4 sessions were counterbalanced across participants (n = 20, 10 males). We examined the statistical differences in both functional connectivity and regional amplitude of low frequency fluctuation (ALFF) within the DMN among the 2–4 resting-state conditions (i.e., EC, EO, and EO-F). Although the connectivity patterns of the DMN were visually similar across these three different conditions, we observed significantly higher functional connectivity and ALFF in both the EO and the EO-F conditions as compared to the EC condition. In addition, the first and second resting EC conditions showed significant differences within the DMN, suggesting an order effect on the DMN activity.

Conclusions/Significance

Our findings of the higher DMN connectivity and regional spontaneous activities in the resting state with the eyes open suggest that the participants might have more non-specific or non-goal-directed visual information gathering and evaluation, and mind wandering or daydreaming during the resting state with the eyes open as compared to that with the eyes closed, thus providing insights into the understanding of unconstrained mental activity within the DMN. Our results also suggest that it should be cautious when choosing the type of a resting condition and designating the order of the resting condition in multiple scanning sessions in experimental design.

Citation: Yan C, Liu D, He Y, Zou Q, Zhu C, et al. (2009) Spontaneous Brain Activity in the Default Mode Network Is Sensitive to Different Resting-State Conditions with Limited Cognitive Load. PLoS ONE 4(5): e5743. doi:10.1371/journal.pone.0005743

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THE SCIENCE OF BRAINWAVES

The language of the brain

Definitions

The EEG (electroencephalograph) measures brainwaves of different frequencies within the brain. Electrodes are placed on specific sites on the scalp to detect and record the electrical impulses within the brain. A frequency is the number of times a wave repeats itself within a second. It can be compared to the frequencies that you tune into on your radio. If any of these frequencies are deficient, excessive, or difficult to access, our mental performance can suffer. The raw EEG has usually been described in terms of frequency bands: Gamma greater than 30(Hz) BETA (13-30Hz), ALPHA (8-12 Hz), THETA (4-8 Hz), and DELTA(less than 4 Hz). For example: Our brain uses 13Hz (high alpha or low beta) for "active" intelligence. Often we find individuals who exhibit learning disabilities and attention problems having a deficiency of

13Hz activity in certain brain regions that affects the ability to easily perform sequencing tasks and math calculations.
Brain Wave Frequencies:

DELTA (0.1 to 3.5 Hz)

The lowest frequencies are delta. These are less than 4 Hz and occur in deep sleep and in some abnormal processes. It is the dominant rhythm in infants up to one year of age and it is present in stages 3 and 4 of sleep. It tends to be the highest in amplitude and the slowest waves. We increase Delta waves in order to decrease our awareness of the physical world. We also access information in our unconscious mind through Delta. Peak performers decrease Delta waves when high focus and peak performance are required. However, most individuals diagnosed with Attention Deficit Disorder, naturally increase rather than decrease Delta activity when trying to focus. The inappropriate Delta response often severely restricts the ability to focus and maintain attention. It is as if the brain is locked into a perpetual drowsy state.Another way to look at Delta is to imagine you are driving in a car and you shift into 1st gear....you're not going to get anywhere very fast. So Delta would represent 1st gear.
DELTA (0.1-3 Hz): Distribution: generally broad or diffuse; may be bilateral, widespread
Subjective feeling states: deep, dreamless sleep, non-REM sleep, trance, unconscious
Associated tasks & behaviors: lethargic, not moving, not attentive
Physiological correlates: not moving, low-level of arousal
Effects of training: can induce drowsiness, trance, deeply relaxed states
THETA (4-8 Hz)

The next brainwave is theta. Theta activity has a frequency of 3.5 to 7.5 Hz and is classed as "slow" activity. It is seen in connection with creativity, intuition, daydreaming, and fantasizing and is a repository for memories, emotions, sensations. Theta waves are strong during internal focus, meditation, prayer, and spiritual awareness. It reflects the state between wakefulness and sleep and relates to the subconscious mind. It is abnormal in awake adults but is perfectly normal in children up to 13 years old. It is also normal during sleep. Theta is believed to reflect activity from the limbic system and hippocampal regions. Theta is observed in anxiety, behavioral activation and behavioral inhibition. When the theta rhythm appears to function normally it mediates and/or promotes adaptive, complex behaviors such as learning and memory. Under unusual emotional circumstances, such as stress or disease states, there may be an imbalance of three major transmitter systems, which results in aberrant behavior. Back to our car example, Theta would be considered 2nd gear. Not as slow as 1st gear (Delta) but still not very fast.
THETA (3.5-7.5 Hz): Distribution: usually regional, may involve many lobes, can be lateralized or diffuse;
Subjective feeling states: intuitive, creative, recall, fantasy, imagery, creative, dreamlike, switching thoughts, drowsy; "oneness", "knowing"
Associated tasks & behaviors: creative, intuitive; but may also be distracted, unfocused
Physiological correlates: healing, integration of mind/body
Effects of Training: if enhanced, can induce drifting, trance-like state. If suppressed, can improve concentration, ability to focus attention
ALPHA (8-12 Hz)

Alpha waves are those between 8 and 12(Hz). Alpha waves will peak around 10Hz. Good healthy alpha production promotes mental resourcefulness, aids in the ability to mentally coordinate, enhances overall sense of relaxation and fatigue. In this state you can move quickly and efficiently to accomplish whatever task is at hand. When Alpha predominates most people feel at ease and calm. Alpha appears to bridge the conscious to the subconscious. It is the

major rhythm seen in normal relaxed adults - it is present during most of life especially beyond the thirteenth year when it dominates the resting tracing. Alpha rhythms are reported to be derived from the white matter of the brain. The white matter can be considered the part of the brain that connects all parts with each other. Alpha is a common state for the brain and occurs whenever a person is alert (it is a marker for alertness and sleep), but not actively processing information. They are strongest over the occipital (back of the head) cortex and also over frontal cortex. Alpha has been linked to extroversion (introverts show less), creativity (creative subjects show alpha when listening and coming to a solution for creative problems), and mental work. When your alpha is within normal ranges we tend to also experience good moods, see the world truthfully, and have a sense of calmness. Alpha is one of the brain's most important frequency to learn and use information taught in the classroom and on the job. You can increase alpha by closing your eyes or deep breathing or decrease alpha by thinking or calculating. Alpha-Theta training can create an increase in sensation, abstract thinking and self-control. In our car scenario, Alpha would represent neutral or idle. Alpha allows us to shift easily from one task to another.
ALPHA(8-12 Hz): Distribution: regional, usually involves entire lobe; strong occipital w/eyes closed
Subjective feeling states: relaxed, not agitated, but not drowsy; tranquil, conscious
Associated tasks & behaviors: meditation, no action
Physiological correlates: relaxed, healing
Effects of Training: can produce relaxation
Sub band low alpha: 8-10: inner-awareness of self, mind/body integration, balance
Sub band high alpha: 10-12: centering, healing, mind/body connection
BETA (above 12 Hz)

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Sub band high alpha: 10-12: centering, healing, mind/body connection
BETA (above 12 Hz) Beta activity is 'fast' activity. It has a frequency of 14 and greater Hz. It reflects desynchronized active brain tissue. It is usually seen on both sides in symmetrical distribution and is most evident frontally. It may be absent or reduced in areas of cortical damage.
It is generally regarded as a normal rhythm and is the dominant rhythm in those who are alert or anxious or who have their eyes open.
It is the state that most of brain is in when we have our eyes open and are listening and thinking during analytical problem solving, judgment, decision making, processing information about the world around us.
Beta would represent overdrive or hyperdrive in our car scenario.
The beta band has a relatively large range, and has been divided into low, midrange and high.

LOW BETA (12-15HZ): Distribution: localized by side and by lobe (frontal, occipital, etc)
Subjective feeling states: relaxed yet focused, integrated
Associated tasks & behaviors: low SMR can reflect "ADD", lack of focused attention
Physiological correlates: is inhibited by motion; restraining body may increase SMR
Effects of Training: increasing SMR can produce relaxed focus, improved attentive abilities,

MID BETA (15-18hz): Distribution: localized, over various areas. May be focused on one electrode.
Subjective feeling states: thinking, aware of self & surroundings
Associated tasks & behaviors: mental activity
Physiological correlates: alert, active, but not agitated
Effects of Training: can increase mental ability, focus, alertness

HIGH BETA (above 18hz): Distribution: localized, may be very focused.
Subjective feeling states: alertness, agitation
Associated tasks & behaviors: mental activity, e.g. math, planning
Physiological correlates: general activation of mind & body functions.
Effects of Training: can induce alertness, but may also produce agitation
GAMMA (above 30 Hz)

GAMMA (above 30hz Hz): Distribution: very localized
Subjective feeling states: thinking; integrated thoughts
Associated tasks & behaviors: high-level information processing, "binding"
Physiological correlates: associated with information-rich task processing
Effects of Training: not known
Gamma is measured between 30 and 44 (Hz) and is the only frequency group found in every part of the brain. When the brain needs to simultaneously process information from different

areas, its hypothesized that the 40Hz activity consolidates the required areas for simultaneous processing. A good memory is associated with well-regulated and efficient 40Hz activity, whereas a 40Hz deficiency creates learning disabilities.

The Measurement of Brain Waves

Part A

The cerebral cortex is composed of neurons that are interconnected to each other in networks and also receive inputs from other areas of the brain. Electrical activity in the form of nerve impulses being sent and received to and from cortical neurons is always present, even during sleep. Biologically, medically and legally, the absence of cortical activity signifies death.

The electrical activity you are measuring reflects both the intrinsic activity of neurons in the cerebral cortex and the information sent to it by subcortical structures and the sense receptors. This composite activity is called an electroencephalogram or EEG.

An EEG electrode will mainly detect the activity in the brain region just under it. Nevertheless, the electrodes receive the activity from thousands of neurons. In fact, one square millimeter of cortex has more than 100,000 neurons. It is only when the input to a region is synchronized with electrical activity occurring at the same time that you begin to distinguish simple periodic waveforms in the EEG.

Four simple periodic rhythms recorded in the EEG are *alpha, beta, delta, and theta.* These rhythms are identified by frequency (Hz or cycles/sec) and amplitude. The amplitudes recorded by scalp electrodes are in the range of microvolts (μV or 1/1,000,000 of a volt).

rhythm	Freq (Hz)	Amp(μV)
alpha	8-13	20-200
beta	13-30	5-10
delta	1-5	20-200
theta	4-8	10

Alpha: The four basic rhythms have been associated with various states. In general, the alpha rhythm is the prominent EEG wave pattern of an adult who is awake but relaxed with eyes closed. Each region of the brain had a characteristic alpha rhythm but alpha waves of the greatest amplitude are recorded from the occipital and parietal regions of the cerebral cortex. In general, amplitudes of alpha waves diminish when subjects open their eyes and are attentive to external stimuli although some subjects trained in relaxation techniques can maintain high alpha amplitudes even with their eyes open.

Beta: Beta rhythms occur in individuals who are alert and attentive to external stimuli or exert specific mental effort, or paradoxically, beta rhythms also occur during deep sleep, REM (Rapid Eye Movement) sleep when the eyes switch back and forth. This does not mean that there is less electrical activity, rather that the “positive” and “negative” activities are starting to counterbalance so that the sum of the electrical activity is less. Thus, instead of getting the wave-like synchronized pattern of alpha waves, desynchronization or alpha block occurs. So, the beta wave represents arousal of the cortex to a higher state of alertness or tension. It may also be associated with “remembering” or retrieving memories.

Delta and Theta: Delta and theta rhythms are low-frequency EEG patterns that increase during sleep in the normal adult. As people move from lighter to deeper stages of sleep (prior to REM sleep), the occurrence of alpha waves diminish and is gradually replaced by the lower frequency theta and then delta frequency rhythms.

Although delta and theta rhythms are generally prominent during sleep, there are cases when delta and theta rhythms are recorded from individuals who are awake. For example, theta waves will occur for brief intervals during emotional responses to frustrating events or situations. Delta waves may increase during difficult mental activities requiring concentration. In general, the occurrence and amplitudes of delta and theta rhythms are highly variable within and between individuals.
Scientists had 15 volunteers listen with their eyes open or closed to music clips with scary “Hitchcock-like, frightening themes,” Hendler said, as well as comparatively emotionally neutral melody-less musical tones.

As expected, the researchers found that closing one’s eyes enhanced the responses the volunteers felt toward the more emotionally charged scary music. Brain scans revealed that activity ramped up in the amygdala, a primary center for emotion in the brain. In turn, the amygdala fired up brain regions linked with vigilance to the environment and regulation of emotion. [From MSNBC.com - Scary music? Better keep your eyes open by Charles Q. Choi.]