

Cortical Functions

REFERENCE

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1 Introduction

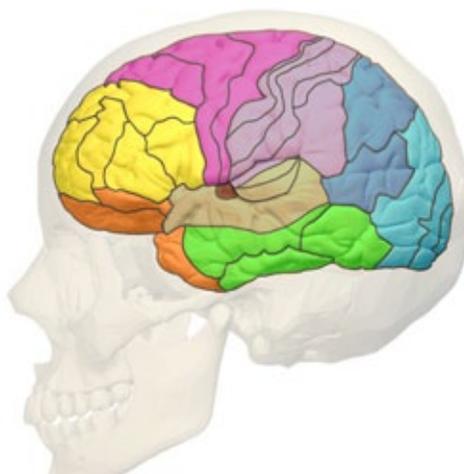
Introduction

Brodmann areas were originally defined and numbered by the German anatomist Korbinian Brodmann based on the cytoarchitectural organization of neurons he observed in the cerebral cortex. Brodmann published his maps of cortical areas in 1909.

From the beginning it was assumed that different structures served different functions, the areas have been discussed, debated, refined, and renamed exhaustively for nearly a century and remain the most widely known and frequently cited cytoarchitectural organization of the human cortex.

Many of the areas Brodmann defined were based solely on their neuronal organization and have since been correlated to diverse cortical functions.

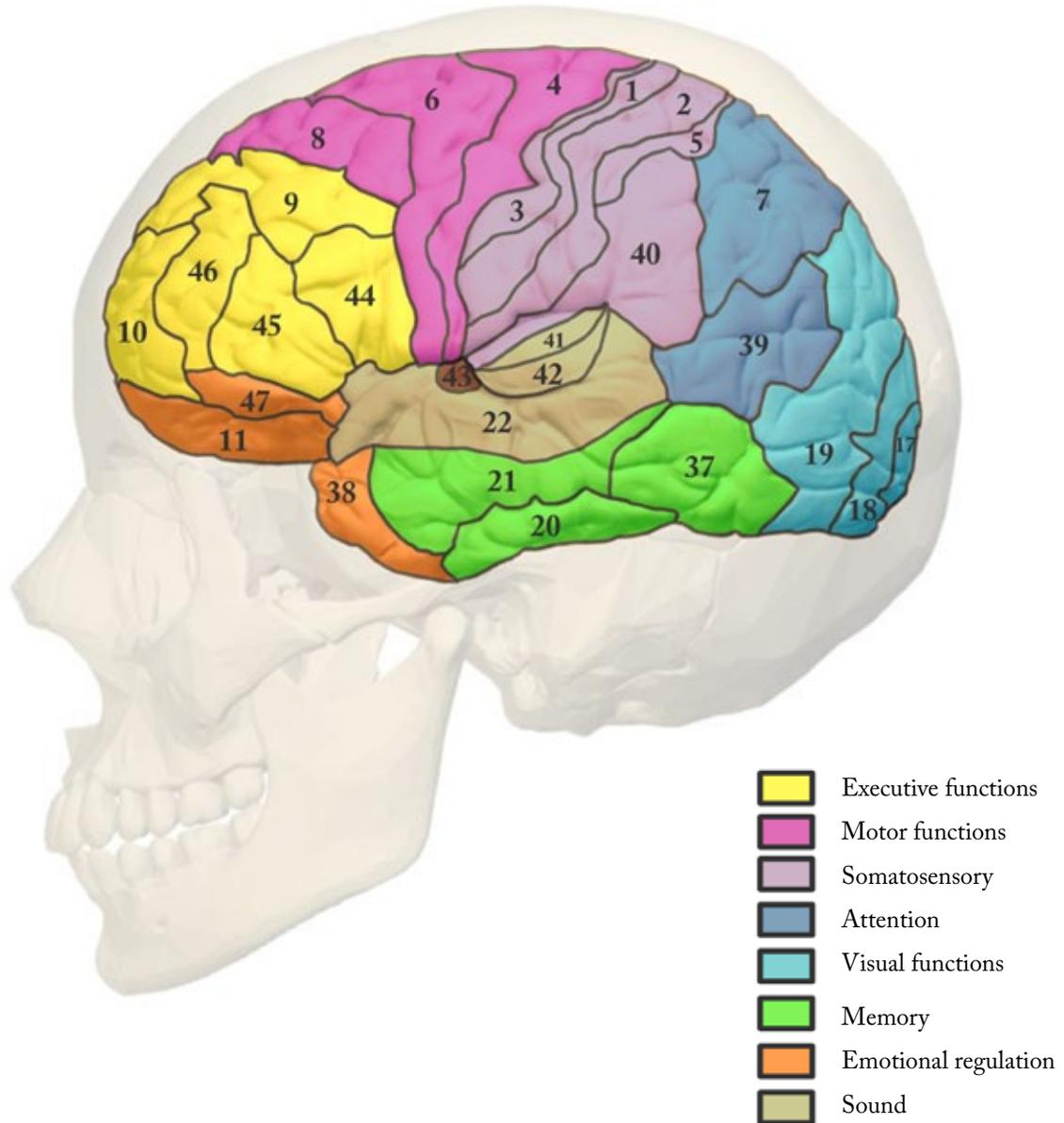
In this document, you will find an overview of the Brodmann area's located on the cortex. A cross reference between the 10/10 and 10/20 electrode positions and their corresponding closest Brodmann area. A review of all cortical Brodmann area's and their function, based on meta analysis of functional research publications.



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2 Brodmann and Electrode Maps

Brodmann Cortical Areas



Brodmann Cortical Area Names

Frontal Lobe

- 4 - gigantopyramidal
- 6 - agranular frontal
- 8 - intermediate frontal
- 9 - granular frontal
- 10 – anterior prefrontal (or frontopolar)
- 11 - prefrontal
- 44 - opercular
- 45 - triangular
- 46 - middle frontal
- 47 - orbital

Temporal Lobe

- 20 - inferior temporal
- 21 - middle temporal
- 22 - superior temporal
- 37 – occipitotemporal
- 38 - temporal pole
- 39 – angular gyrus
- 41 – anterior transverse temporal
- 42 – posterior transverse temporal

Occipital Lobe

- 17 - striate
- 18 – parastriate
- 19 - peristriate

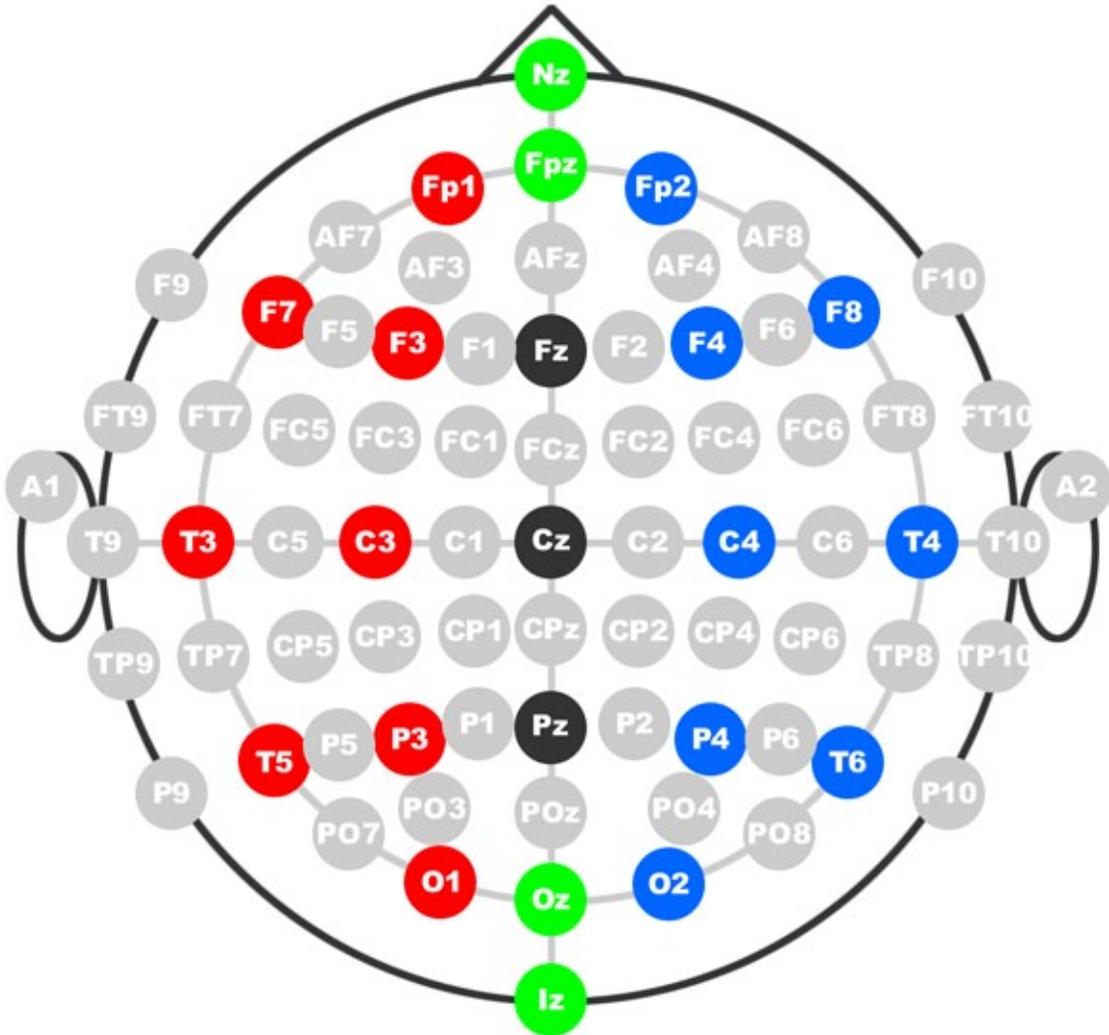
Parietal Lobe

- 1 – intermediate postcentral
- 2 – rostral postcentral
- 3 – caudal postcentral
- 7 - superior parietal
- 40 – supramarginal gyrus

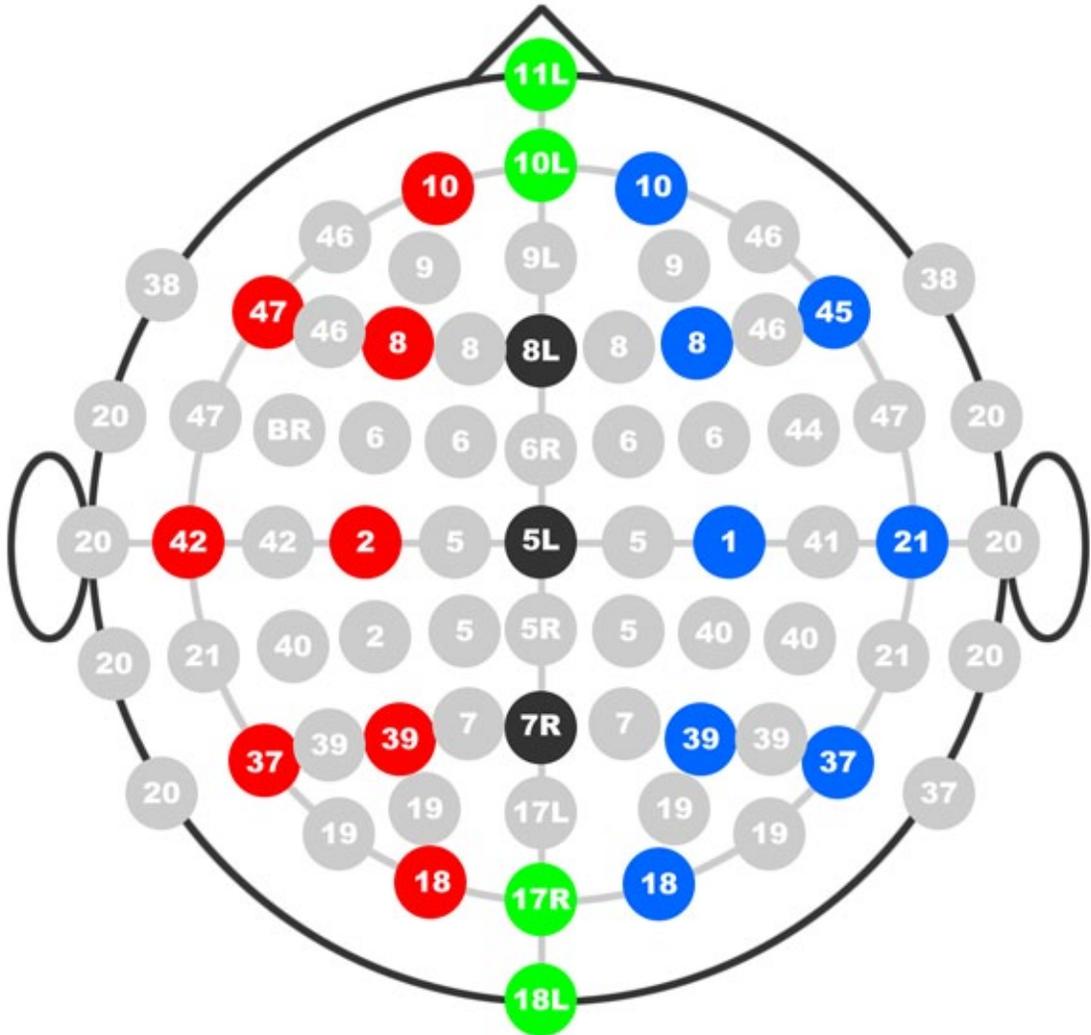
Other designations for Brodmann areas

- 1-3 – Primary Somatosensory Cortex
- 4 – Primary Motor Cortex
- 17 – Primary Visual Cortex
- 41 – Primary Auditory Cortex
- 22 – Wernicke’s area (varies)
- 44,45 - Broca’s area on left hemisphere

10/10 and 10/20 Electrode Positions



Corresponding Brodmann Areas



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Cortical Functions Reference

Area 1, 2, 3 – Postcentral Gyrus

The lateral postcentral gyrus is a prominent structure in the parietal lobe of the human brain and an important landmark. It is the location of primary somatosensory cortex, the main sensory receptive area for the sense of touch.

Clinical significance

Lesions affecting the primary somatosensory cortex produce characteristic symptoms including: agraphesthesia, astereognosia, loss of vibration, proprioception, and fine touch (because the third-order neuron of the medial-lemniscal pathway cannot synapse in the cortex). It can also produce hemineglect, if it affects the non-dominant hemisphere.

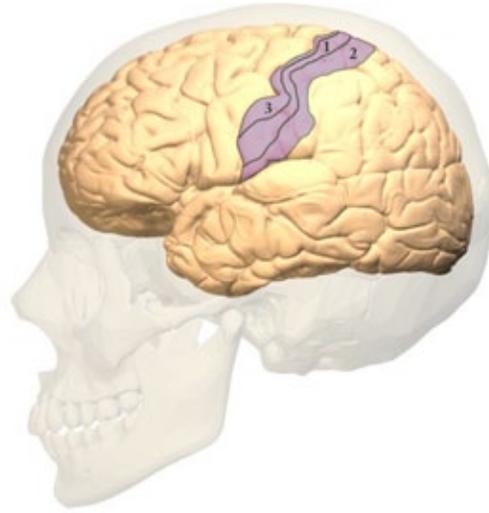
It could also reduce nociception, thermoception, and crude touch, but, since information from the spinothalamic tract is interpreted mainly by other areas of the brain (see insular cortex and cingulate gyrus), it is not as relevant as the other symptoms.

Notes

The primary somatosensory area (SI) traditionally has been related with somatosensory perception (localization of touch, two-point discrimination, proprioception, etc).

Functional studies have demonstrated that SI also participates in movement organization (e.g., voluntary hand and tongue movements), “anticipation”, and “mirror neurons” (i.e., neurons that are active when observing the action of others).

Mirror neurons were initially observed in macaques in the premotor and parietal cortical areas, and only recently, reported in humans. Mirror neurons probably play a crucial role in action understanding, an-



ticipation, imitation, imagery, social behavior, and the like; that is, in the internal representations of actions.

SI activation during movement performance reflects its participation in an extensive movement network that usually includes not only the primary motor cortex, but also the premotor cortex, the basal ganglia and the cerebellum.

Associated Functions

Somatosensory

- Localization of touch
- Localization of temperature
- Localization of vibration
- Localization of pain
- Finger proprioception
- Deep proprioception
- Voluntary hand movement
- Volitional swallowing
- Tongue movement and perception
- Skillful coordinated orofacial movement
(i.e. whistling)

Other

- Somatosensory mirror neuron system
- Pain anticipation
- Touch anticipation (i.e. tickling)
- Mirror neurons for speech perception
- Motor learning

Area 4 – Primary Motor Cortex

The human primary motor cortex is located on the anterior wall of the central sulcus. It also extends anteriorly out of the sulcus partly onto the precentral gyrus. Anteriorly, the primary motor cortex is bordered by a set of areas that lie on the precentral gyrus.

Clinical significance

Lesions of the precentral gyrus result in paralysis of the contralateral side of the body (facial palsy, arm-/leg monoparesis, hemiparesis).

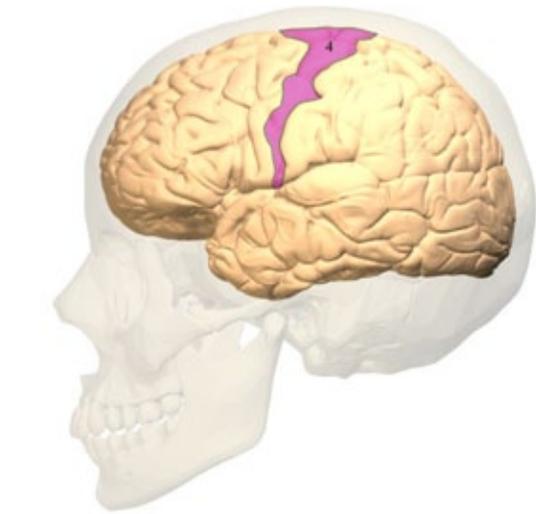
Notes

According to functional neuroimaging techniques area 4 participates in three different groups of functions: Motor, somatosensory, and “others” (“verbal encoding during a non-semantic process”, “attention to action”, and “motor memory for visual landmarks”).

Motor function is the traditional function, and occasionally it has been reported that the primary motor cortex reacts to sensory stimulation. Nonetheless, in these cases the primary motor activation is found in addition to a more extensive pattern of activation, obviously including sensory areas; that is, area 4 may some times be included in a brain circuitry supporting sensory perception; area 4 activation may reflect in those cases the implicit representation of a potential movement.

This implicit representation of movements can also account for “attention to action” and “motor memory”.

The participation in “verbal encoding during a non-semantic process” is probably tangential, considering that it becomes activated (in addition to frontal and



temporal networks) only during “successful encoding”, suggesting a certain role in the attentional process (increased muscle tone).

Associated Functions

Motor

- Contralateral finger, hand, and wrist movements (Dorsal)
- Contralateral lip, tongue, face, and mouth movement (Lateral)
- Swallowing / laryngial movement
- Contralateral lower limb (knee, ankle, foot, toe) movement (Mesial)
- Motor imagery
- Learning motor sequences
- Volitional breathing control
- Control of rhythmic motor tasks (i.e. bicycling)
- Inhibition of blinking / voluntary blinking
- Horizontal saccadic eye movements

Somatosensory

- Kinesthetic perception of limb movements
- Vibrotactile frequency discrimination
- Finger proprioception
- Thermal hyperalgesia (contralateral)
- Response to touch/observed touch (Left)

Other

- Verbal encoding during a non-semantic process (Right)
- Attention to action (posterior)
- Topographic memory (motor memory) for visual landmarks

Area 5 - Somatosensory Association Cortex

Brodmann area 5 is part of the parietal cortex in the human brain. It is situated immediately posterior to the primary somatosensory areas (Brodmann areas 3, 1, and 2), and anterior to Brodmann area 7.

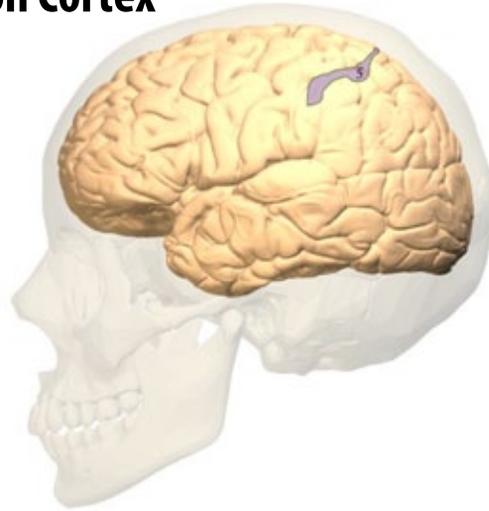
Clinical significance

Lesions in the left superior parietal lobe are associated with ideomotor apraxia (loss of the ability to produce purposeful, skilled movements as the result of brain pathology not caused by weakness, paralysis, lack of coordination, or sensory loss).

It is well established that astereognosis (or tactile agnosia: loss of the ability to recognize objects by handling them) is found in cases of damage in the association sensorimotor cortex.

Notes

The superior parietal lobe includes area 5 and area 7, and is separated from the inferior parietal lobe (area 40 and area 39) by the intraparietal sulcus. The right secondary sensorimotor cortex is clearly involved in visuospatial processing, including the perception of the personal space and spatial imagery. The secondary sensorimotor cortex participates in processing tool-use gestures, motor imagery, bimanual manipulation, and similar praxic abilities. Areas 5/7 may also participate in a circuit underlying imitation of motor learning. Functional studies confirm that the superior parietal lobe participates in tactile localization whereas the inferior parietal lobe may be involved in tactile recognition. The superior parietal lobe also seems to participate in other processes, such as rhyme detection and semantic categorization tasks; and, interestingly, temporal context recognition.



Associated Functions

- Visuospatial processing (mainly right 7)
- Mental rotation
- Stereopsis
- Perception of personal space
- Line bisection judgments
- Processing chaotic patterns
- Using spatial imagery in deductive reasoning

Motor

- Motor imagery
- Processing tool-use gestures (Left)
- Motor execution
- Mirror neurons
- Bimanual manipulation
- Saccadic eye movement

Memory

- Working memory (motor, visual, auditory, emotional, verbal)
- Visuospatial memory (Right)
- Conscious recollection of previously experienced events (7)
- Sensory
- Tactile localization (“where stream”)
- Pain perception

Attention

- Visuomotor attention
- Language
- Language processing
- Literal sentence comprehension (7)
- Word comprehension (imageability)
- Attention to phonological relations (7)

Other

- Processing emotions and self-reflections during decision making (7)
- Goal-intensive processing (7)
- Temporal context recognition (Left 7)

Area 6 – Premotor Cortex

The premotor cortex is an area of motor cortex lying within the frontal lobe of the brain. It extends anterior to the primary motor cortex, near the Sylvian fissure (lateral sulcus), before narrowing near the medial longitudinal fissure, which serves as the posterior border for the prefrontal cortex. Activity within this region is critical to the sensory guidance of movement and control of proximal and trunk muscles of the body.

Clinical significance

Lesions affecting the premotor cortex affect sensory guidance of movement and control of proximal and trunk muscles of the body.

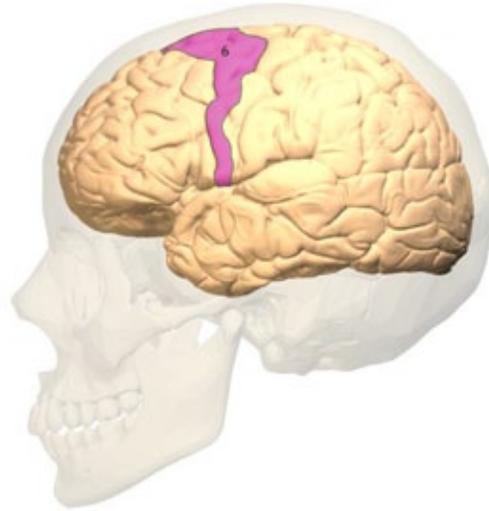
Damage in the lateral premotor area results in kinetic apraxia (loss of the kinetic components of engrams resulting in coarse or unrefined movements with movements that no longer have the appearance of being practiced over time).

Notes

The diversity of functions involving area 6, probably the largest Brodmann's area, is not surprising. However, its basic function seems to be clear enough: motor sequencing and planning movements.

The SMA portion is related with movement initiation.

The left SMA also participates in language initiation and maintenance of voluntary speech production; but, interestingly, it also activates with imagined movements. Linguistic functions of left area 6 are diverse, but a major function evidently is speech motor programming; Broca's area indeed corresponds to a subdivision of the premotor cortex, and some of the



linguistic functions of the lateral premotor area are probable the result of an extended activation of the frontal languages areas.

By the same token, participation of area 6 in memory, attention, and executive functions may be due to the activation of an extended brain network, that sometimes involves area 6. The existence of mirror neurons that activate when observing (and imagining) actions plays an important role in understanding thinking and planning.

Associated Functions

Motor

- Motor sequencing/planning
- Motor learning (SMA)
- Movement preparation/imagined movement (Rostral SMA)
- Movement initiation (Caudal SMA)
- Motor imagery (SMA)
- Volitional control of breathing
- Horizontal saccadic eye movements
- Laughter/smiling (SMA)
- Interlimb coordination

Language

- Speech motor programming (Left)
- Language processing (SMA)
- Language switching
- Reading novel words (aloud and silently) (Left)
- Speech perception
- Updating verbal information (Medial)
- Phonological processing (Left)
- Object naming (Left)
- Lipreading (SMA)
- Word retrieval
- Lexical decision on words and pseudowords
- Syntactical processing

Memory

- Working memory
- Mnemonic rehearsal
- Episodic long-term memory
- Topographic memory

Attention

- Visuospatial attention
- Visuomotor attention
- Response to visual presentation of letters and pseudoletters(Left)
- Updating spatial information (Lateral)
- Visual guided eye movements (frontal eye fields)
- Selective attention to rhythm/processing sequential sounds (Left)
- Attention to human voices

Other

- Observation of actions (Mirror neurons)
- Planning/solving novel problems
- Executive control of behavior
- Response to baroreceptor stimulation
- Generating melodic phrases
- Deductive reasoning (Left)
- Response to strong odorant (Right)
- Formation of qualitative representations
- Processing emotions and self-reflections in decision making (Left)
- Same-different discrimination (Right)
- Calculation
- Temporal context recognition
- Frequency deviant detection

Area 7 - Somatosensory Association Cortex

The somatosensory association cortex is part of the parietal cortex in the human brain. This region is believed to play a role in visuo-motor coordination (e.g., in reaching to grasp an object).

Clinical significance

Lesions in the left superior parietal lobe are associated with ideomotor apraxia (loss of the ability to produce purposeful, skilled movements as the result of brain pathology not caused by weakness, paralysis, lack of coordination, or sensory loss).

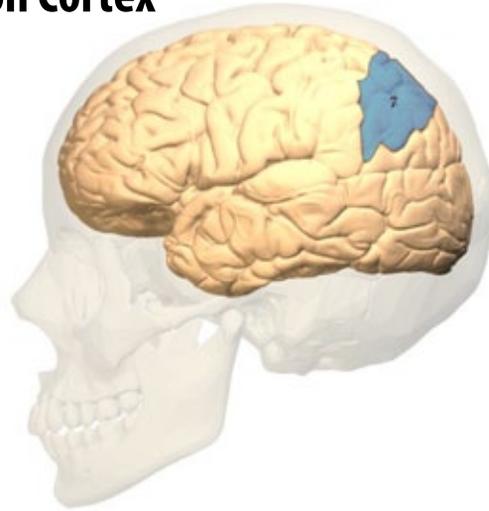
Notes

The superior parietal lobe includes area 5 and area 7, and is separated from the inferior parietal lobe (area 40 and area 39) by the intraparietal sulcus.

The right secondary sensorimotor cortex is clearly involved in visuospatial processing, including the perception of the personal space and spatial imagery. It is understandable that the secondary sensorimotor cortex participates in processing tool-use gestures, motor imagery, bimanual manipulation, and similar praxic abilities. Areas 5/7 may also participate in a circuit underlying imitation of motor learning.

It is well established that astereognosis (or tactile agnosia: loss of the ability to recognize objects by handling them) is found in cases of damage in the association sensorimotor cortex.

Functional studies confirm that the superior parietal lobe participates in tactile localization whereas the inferior parietal lobe may be involved in tactile recognition.



The superior parietal lobe also seems to participate in other processes, such as rhyme detection and semantic categorization tasks; and, interestingly, temporal context recognition.

Associated Functions

- Visuospatial processing (mainly right 7)
- Mental rotation
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- Processing chaotic patterns
- Using spatial imagery in deductive reasoning

Motor

- Motor imagery
- Processing tool-use gestures (Left)
- Motor execution
- Mirror neurons
- Bimanual manipulation
- Saccadic eye movement

Memory

- Working memory (motor, visual, auditory, emotional, verbal)
- Visuospatial memory (Right)
- Conscious recollection of previously experienced events (7)
- Sensory
- Tactile localization (“where stream”)
- Pain perception

Attention

- Visuomotor attention
- Language
- Language processing
- Literal sentence comprehension (7)
- Word comprehension (imageability)
- Attention to phonological relations (7)

Other

- Processing emotions and self-reflections during decision making (7)
- Goal-intensive processing (7)
- Temporal context recognition (Left 7)

Area 8 - Includes Frontal Eye Fields

Situated just anterior to the premotor cortex (area 6), it includes the frontal eye fields (so-named because they are believed to play an important role in the control of eye movements).

Clinical significance

Lesions causes tonic deviation of the eyes towards the side of the injury. The area is also involved in the management of uncertainty.

Notes

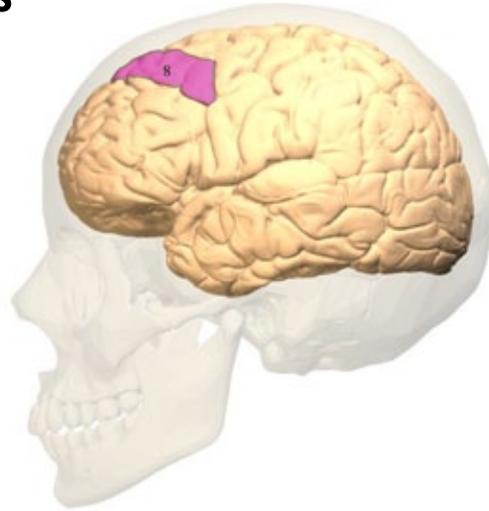
Traditionally area 8 has been regarded as the “frontal eye field”. However, functional studies report the participation of area 8 in a wide diversity of functions, including: motor, language, executive functions, memory, and attention.

Only two studies refer to its participation in eye movements (horizontal saccadic eye movements).

It is very interesting to note the participation of SMA in motor learning, supported by several studies.

Usually it is accepted that SMA participates in initiating, maintaining, coordinating and planning complex sequences of movements performed in a particular order.

Stimulation of the left SMA has been related to arrest of speech, and its damage to a particular type of language disorder referred as the “aphasia of the SMA” (initial mutism lasting about 2-10 days; virtually total inability to initiate speech; nearly normal speech repetition; normal language understanding; and absence of echolalia).



The participation of area 8 in different executive functions (e.g., executive control of behavior, inductive reasoning, and planning) seems evident.

Area 8 also participates in memory processes, particularly in working memory. Its participation in sequence learning seems evident, but its involvement in response to proprioceptive stimulation, pain anticipation and auditory imagery does not seem so obvious; however, in auditory imagery, the activation of SMA may include rehearsal that involves motor programs.

Associated Functions

Motor

- Motor learning (SMA)
- Motor imagery (SMA)
- Motor control
- Horizontal saccadic eye movements
- Laughter/smiling (SMA)

Executive functions

- Executive control of behavior
- Planning

Language

- Speech motor programming (Left)
- Language processing (SMA)
- Language translation
- Generating sentences
- Lipreading (SMA)

Memory

- Working memory
- Perceptual priming
- Memory retrieval (Right)
- Topographic memory

Attention

- Visuospatial and visuomotor attention

Other

- Sequence learning
- Response to proprioceptive stimulation
- Pain anticipation
- Processing related to uncertainty
- Inductive reasoning (Left)
- Calculation
- Auditory imagery (SMA)

Area 9,10 - Dorsolateral / Anterior Prefrontal Cortex (DL-PFC or DLPFC)

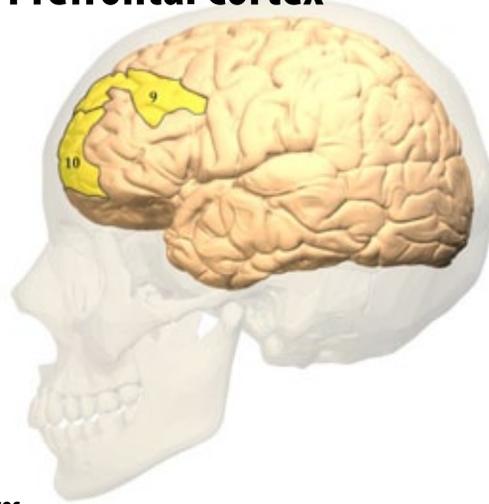
The dorsolateral prefrontal cortex, according to a more restricted definition, is roughly equivalent to Brodmann areas 9 and 46. According to a broader definition DL-PFC consists of the lateral portions of Brodmann areas 9 – 12, of areas 45, 46, and the superior part of area 47. The anterior dorsolateral prefrontal cortex is located in the frontal region of cerebral cortex. It occupies the most rostral portions of the superior frontal gyrus and the middle frontal gyrus.

DL-PFC serves as the highest cortical area responsible for motor planning, organization, and regulation. It plays an important role in the integration of sensory and mnemonic information and the regulation of intellectual function and action. It is also involved in working memory. However, DL-PFC is not exclusively responsible for the executive functions. All complex mental activity requires the additional cortical and subcortical circuits with which the DL-PFC is connected.

The DL-PFC may also be involved in the act of deception and lying, which is thought to inhibit normal propensity to truth telling.

Clinical significance

Damage to the DL-PFC can result in the dysexecutive syndrome, which leads to problems with affect, social judgement, executive memory, abstract thinking and intentionality.



Notes

Areas 9/10 have a significant participation in memory, particularly memory encoding, memory retrieval, and working memory. Those studies relating area 10 with “event- and time-based prospective memory” and “intentional forgetting”, suggest the involvement of area 10 in controlling, and manipulating memory (metamemory). It could be argued that the middle frontal gyrus participates in an extensive memory circuit, and it has a fundamental role in organizing memory strategies and controlling memory. Areas 9/10 have also other evident executive functions, such as “executive control of behavior”, “inferential reasoning”, and “decision making”. Its participation in complex language processes may suggest the use of verbal strategies in executive processing (e.g., syntactic processing, metaphor comprehension, generating sentences, etc), an extensive network is activated, involving diverse language related areas. Area 10 seems to be involved in attending to sensory stimulation (e.g., response to baroreceptor stimulation, response to painful thermal stimuli, and joint attention). The middle frontal gyrus is involved in processing emotions. This involvement may be related to making decisions about emotional stimuli.

Associated Functions

Memory

- Working memory
- Spatial memory
- Short-term memory (9)
- Memory encoding and recognition
- Memory retrieval
- Recency judgments (9)
- Event-and time-based prospective memory (10)
- Prospective memory (Lateral 10)
- Intentional forgetting (10)

Motor

- Executive control of behavior (9)

Language

- Syntactic processing (Left)
- Metaphor comprehension (Left)
- Verbal fluency (Left) (9)
- Semantic categorization (Left 9)
- Word-stem completion (Left)
- Generating sentences (Left 9)
- Verb generation (Left 10)

Auditory

- Nonspeech processing (monaural stimulus) (10)

Other

- Error processing/detection (9)
- Attention to human voices (9)
- Processing emotional stimuli
- Processing emotions and self-reflections in decision making (Left)
- Inferential reasoning (9)
- Decision making (involving conflict and reward) (Right 10)
- Planning (Right 9)
- Calculation / numerical processes
- Attribution of intention to others (9)
- Intention/sensory feedback conflict detection
- Smelling familiar odors (Right)
- Pleasant and unpleasant emotions
- Response to painful thermal stimuli (10)
- Joint attention (10)

Area 11 - Orbitofrontal Area

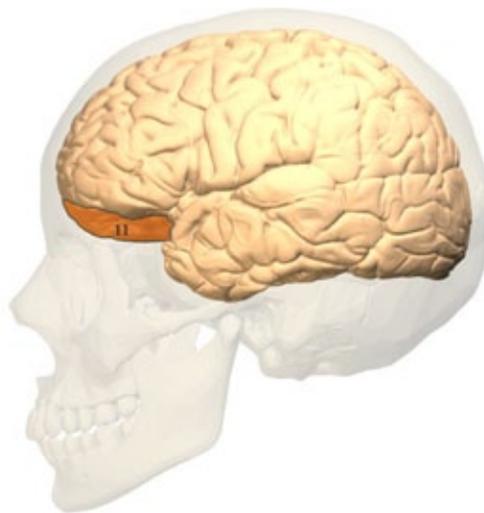
This area is part of the frontal cortex in the human brain. It covers the medial part of the ventral surface of the frontal lobe.

Clinical significance

Lesions in this region cause personality changes. Destruction of the OFC through acquired brain injury typically leads to a pattern of disinhibited behaviour. Examples include swearing excessively, hypersexuality, poor social interaction, compulsive gambling, drug use (including alcohol and tobacco), and poor empathising ability.

Notes

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Associated Functions

Olfaction

- General Olfaction

Auditory

- Nonspeech processing (monaural stimulus)

Other

- Decision making involving reward
- Face-name association (Left)

Area 17 - Primary Visual Cortex (V1)

The visual cortex of the brain is the part of the cerebral cortex responsible for processing visual information. It is located in the occipital lobe, in the back of the brain.

V1 has a very well-defined map of the spatial information in vision. For example, in humans the upper bank of the calcarine sulcus responds strongly to the lower half of visual field (below the center), and the lower bank of the calcarine to the upper half of visual field. Conceptually, this retinotopic mapping is a transformation of the visual image from retina to V1. The correspondence between a given location in V1 and in the subjective visual field is very precise: even the blind spots are mapped into V1.

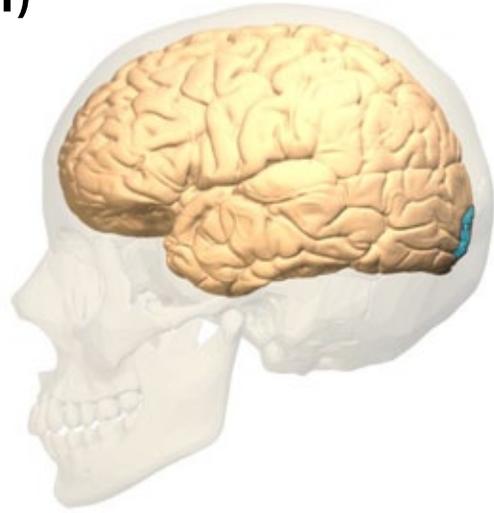
Clinical significance

Complete bilateral lesions of the occipital lobes produce cortical blindness, which is some times associated with unawareness or denial of blindness (Anton's syndrome).

Notes

According to functional studies area17 clearly participates in the detection of light intensity, color recognition, and the detection of visual patterns. It also participates in visuo-spatial information processing, tracking motion and visual attention.

fMRI studies have disclosed its involvement in some unexpected functions, such as visual priming, and word and face encoding; however in the latter case it is just one of the steps in a widespread network, including the bilateral frontal (area 44/45), occipital (area 17/18/19) and fusiform gyri (area 37) as well as the right hippocampal formation.



Interestingly, area 17 is activated not only with the physical presentation of visual information, but also in mental imagery tasks.

Associated Functions

Visual- Early visual processing

- Detection of light intensity
- Detection of patterns
- Contour perception
- Color discrimination
- Visual attention
- Visuo-spatial information processing (Right)
- Processing spatial orientation
- Tracking visual motion patterns (optokinetic stimulation)

Memory

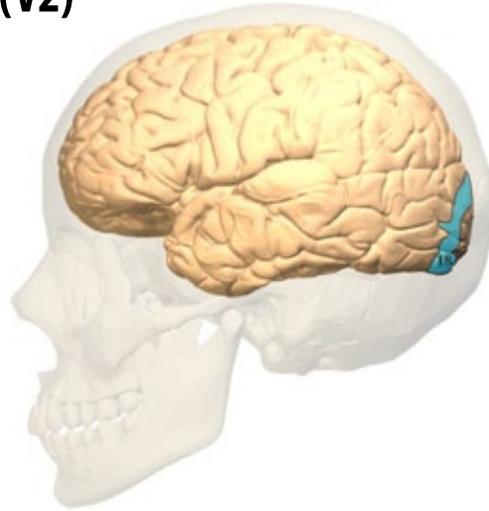
- Visual priming
- Word and face encoding

Other

- Horizontal saccadic eye movements

Area 18 - Secondary Visual Cortex (V2)

Visual area V2, also called prestriate cortex, is the second major area in the visual cortex, and the first region within the visual association area. Most of the neurons of this area are tuned to simple visual characteristics such as orientation, spatial frequency, size, color, and shape. V2 cells also respond to various complex shape characteristics, such as the orientation of illusory contours and whether the stimulus is part of the figure or the ground. Layer 6 cells of the V2 cortex were found to play a very important role in the storage of Object Recognition Memory as well as the conversion of short-term object memories into long-term memories.



Clinical significance

Lesions in area 18/19 are associated with visual agnosia, which can have different manifestations (e.g., object agnosia, face agnosia, color agnosia, topographical agnosia, etc.).

Damage in the left may be associated with pure alexia. It is not surprising either its participation in “response to visual word form”.

Notes

Functions observed in neuroimaging studies include not only the detection of basic visual parameters (e.g., detection of light intensity, feature attention, detection of patterns, etc.), but also the area’s participation in the “confrontation naming circuitry” (confrontation naming activates area 18/19/37 plus the inferior frontal gyrus).

According to functional studies it also participates in other visual related functions such as visual priming and visual attention.

Associated Functions

Visual

- Detection of light intensity
- Detection of patterns
- Tracking visual motion patterns (optokinetic stimulation)
- Discrimination of finger gestures
- Sustained attention to color and shape
- Visuo-spatial information processing (Right)
- Feature-based attention
- Orientation-selective attention

Memory

- Visual priming
- Word and face encoding

Language

- Reponse to visual word form (Left)
- Confrontation naming

Other

- Face-name association (Left)
- Horizontal saccadic eye movements
- Response to emotion/attention in visual processing (Right)
- Visual mental imagery (Left)

Area 19 - Associative Visual Cortex (V3)

The term third visual complex refers to the region of cortex located immediately in front of V2, which includes the region named visual area V3 in humans. Like other visual areas it may contain a complete visual representation.

Clinical significance

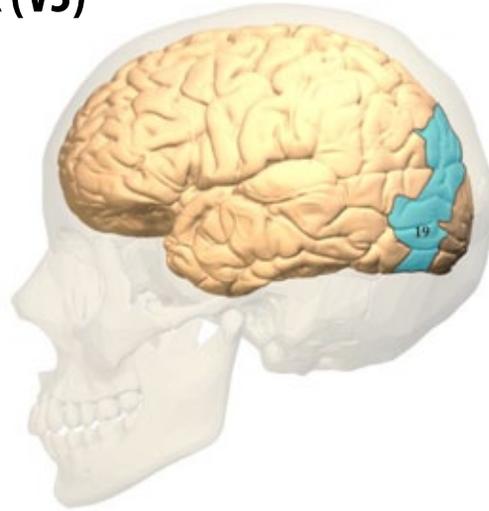
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Notes

Several visual functions found in area 18 are also observed in area 19; or, more exactly, in several visual functions (e.g., detection of light intensity, feature attention, detection of patterns, etc.) area 18 and area 19 are simultaneously activated, suggesting that they participate in a common brain network.

In some other visual functions (e.g., spatial working memory; “where is it?”, that is, stimulus localization) only area 19 is active.

It is interesting to emphasize that, area 19 participates in some language related functions, in particular processing phonological properties of written words (fusiform gyrus), confrontation naming (area 18/19/37 plus the inferior frontal gyrus) and sign language (area 37/19).



Associated Functions

Visual

- Detection of light intensity
- Visuo-spatial information processing (Right)
- Detection of patterns
- Tracking visual motion patterns
- Discrimination of finger gestures
- Sustained attention to color and shape
- Feature-based attention
- Orientation-selective attention

Memory

- Visual priming
- Visual memory recognition
- Word and face encoding
- Spatial working memory

Language

- Processing phonological properties of words
- Confrontation naming
- Sign language

Other

- Face-name association (Right)
- Horizontal saccadic eye movements
- Visual mental imagery
- Inferential reasoning (Left)
- Visual mental imagery (Left)

Area 20 - Inferior Temporal Gyrus

This area is part of the temporal cortex. The region encompasses most of the ventral temporal cortex, a region believed to play a part in high-level visual processing and recognition memory.

Clinical significance

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Notes

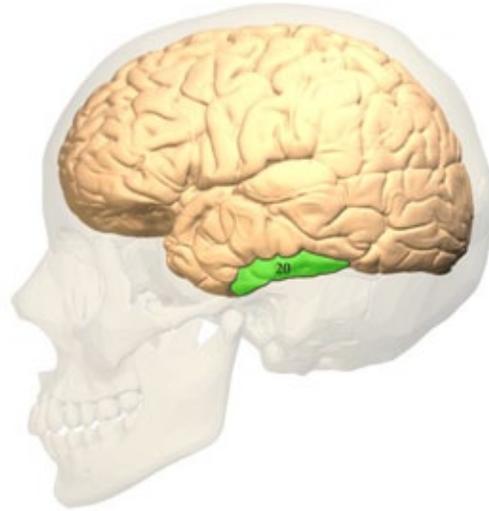
Usually, area 20 is not included as part of Wernicke's area. Different authors describe Wernicke's area in a not completely coincidental way: some authors only include the posterior part of the superior temporal gyrus (area 22); some authors include the superior and middle temporal gyri; and there are authors that even include the angular gyrus of the parietal lobe as part of Wernicke's area.

Functional neuroimaging studies suggest, without question, that area 20 should also be considered as part of Wernicke's area.

Left area 20 participation in language understanding and processing is evident: lexico-semantic processing, metaphor comprehension, language comprehension and production, and selective attention to speech.

Additionally, area 20, as part of the fusiform gyrus, also participates in some types of visual processing: in the integration of visual elements into perceptual wholes (single objects).

Area 20 involvement in the "attribution of intentions" seems to be marginal.



Associated Functions

Language

- Lexico-semantic processing (Left)
- Metaphor comprehension (Left)
- Semantic ambiguity comprehension (Right)
- Language comprehension and production(Left)
- Selective attention to speech (Left)

Visual

- Visual fixation
- Integration of visual elements into perceptual wholes (Right)

Memory

- Dual working memory task processing (Right)

Other

- Attribution of intentions to others

Area 21 - Middle Temporal Gyrus

It is located between the superior temporal gyrus and inferior temporal gyrus. Its exact function is unclear, but it has been connected with processes as different as contemplating distance, recognition of known faces, and accessing word meaning while reading.

Clinical significance

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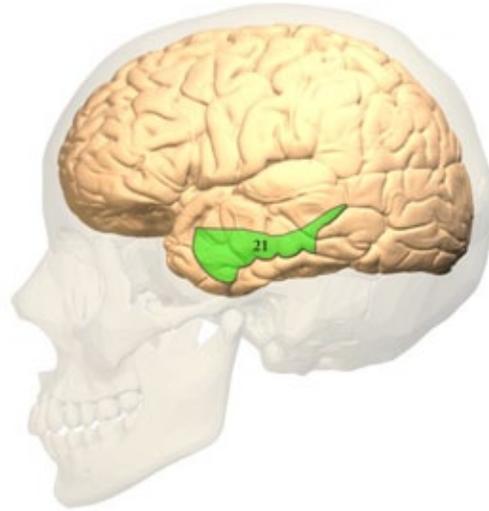
Notes

A rather complex level of language processing is found in area 21 (e.g., selective processing of text and speech and semantic processing).

It also participates together with area 22 in processing complex sounds.

Its activation along with area 45 when observing motion (perhaps mirror neurons) seems intriguing.

In the “attribution of intentions to others” paradigm, a rather extensive activation is observed: areas 9/17/18/19/20/21/22/37/38/47; activation of language areas may suggest a verbal mediation.



Associated Functions

Language

- Selective processing of text and speech (Left)
- Semantic processing (Left)
- Prosodic integration (Right)
- Sentence generation (Left)
- Word generation (Left)

Visual

- Observation of motion

Auditory

- Processing complex sounds (Both hemispheres)

Other

- Attribution of intentions to others
- Deductive reasoning (Left)

Area 22 - Superior Temporal Gyrus (part of Wernicke's area)

The superior temporal gyrus is one of three (sometimes two) gyri in the temporal lobe of the human brain, which is located laterally to the head, situated somewhat above the external ear. The superior temporal gyrus has been involved in the perception of emotions in facial stimuli.

Clinical significance

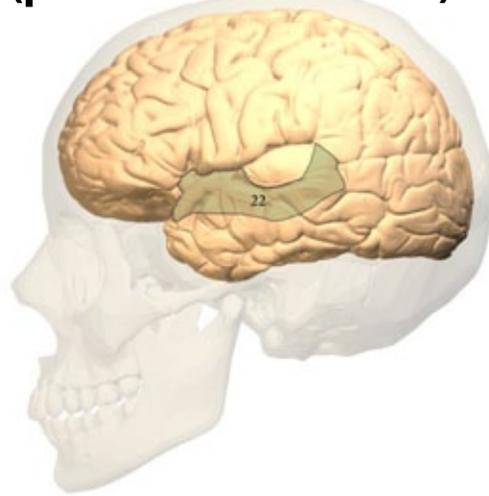
Lesions in area 22 in the left hemisphere result in Wernicke's aphasia (language disorder characterized by fluent speech, paraphasias -wrongly produced words-, and language understanding defects). Wernicke's aphasia however, is quite variable, depending on the exact location and extent of the brain damage.

Notes

The diversity of linguistic functions observed in functional studies reinforces its crucial role in language reception and processing.

Sounds with complex spectral intensity and temporal structures (words, speech, music) activates spatially extensive associative auditory areas in both hemispheres (area 21/22), but right area 22 plays the fundamental role in nonverbal sound processing.

As it is an auditory association area, its activation during non-auditory related tasks seems intriguing, e.g., "remembered saccades"; however, it should be noted that "remembered saccades" activates an extensive network including the striate and extra-striate cortex, posterior parietal cortex, frontal eye fields, supplementary motor area, insula, cingulate, thalamus, midbrain, cerebellum and area 22; area 22 participation is thus quite tangential.



"Deductive reasoning" activates a complex brain network including in the left area 21/22/32/37/45/46/47 (kind of "executive function circuitry"), emphasizing that reasoning is partially mediated by language.

Associated Functions

Language

- Receptive language
- Auditory language processing (Left)
- Semantic processing (Left)
- Sentence generation
- Frequency deviant detection
- Internally-specified word generation (Left)

Language-related

- Selective attention to speech
- Affective prosody comprehension (Right)
- Learning a tone-based second language (Left)
- Repeating words

Auditory

- Nonverbal sounds processing (Right)
- Processing complex sounds
- Lexico-semantic access to melodic representations (Anterior)

Visual

- Remembered saccades (Right)

Other

- Attribution of intentions to others
- Deductive reasoning

Area 37 - Fusiform Gyrus

The fusiform gyrus is part of the temporal lobe in Brodmann area 37. It is also known as the (discontinuous) occipitotemporal gyrus. There is still some dispute over the functionalities of this area, but there is relative consensus on the following:

- processing of color information
- face and body recognition
- word recognition
- number recognition
- within-category identification

Clinical significance

Lesions in the left of area 37 usually results in word-finding difficulties and semantic paraphasias.

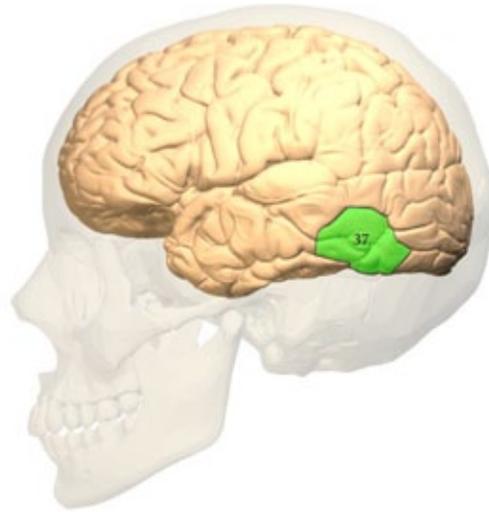
It is known that prosopagnosia (acquired inability to recognize faces) is the result of brain pathology involving the right fusiform gyrus (temporal-occipital) or both fusiform gyri.

Disturbances in drawing (constructional apraxia, or simply visuoconstructive disorder) are observed in cases of right hemisphere pathology

Notes

It is well known that area 37 is involved in lexico-semantic associations (i.e., associated words with visual percepts).

Functional studies have found that left area 37 participates in semantic categorization, word retrieval, word generation, face-name association, and attention to semantic relations. Its participation in sign language is not unexpected either, as well as area 37 participation in some aspects of reading (e.g., single letter processing and orthography-phonology link),



because visual-language associations are involved.

The basal aspect of area 37 corresponds to the fusiform gyrus, which is indeed an extension of the visual association areas, and has visual functions. Hence, area 37 involvement in complex visual functions, such as face recognition, and structural judgment of familiar objects is not surprising.

Area 37 seems to be also participating in some memory circuitries, particularly when visual information is involved.

In the experiments about “attribution of intentions” there is a complex pattern of brain activation, and area 37 involvement may be tangential. Deductive reasoning studies have shown a complex brain network responsible for this particular executive function, including area 21/22/24/32/37/45/46/47; area 37 activation (as well as the activation of other language-related areas) is simply supporting the linguistic underlying nature of the task.

Drawing activates right area 37.

Associated Functions

Language

- Semantic categorization (Left)
- Word retrieval (Left)
- Attention to semantic relations (Left)
- Word generation (Left)
- Sign language
- Single letter processing (Left)
- Metaphor comprehension (Left)
- Orthography-phonology link (Left)

Memory

- True and false memory recognition
- Episodic encoding

Visual

- Face recognition (mostly fusiform gyrus)
- Visual motion processing
- Visual fixation
- Structural judgments of familiar objects
- Sustained attention to color and shape

Other

- Face-name association (Left)
- Attribution of intentions to others
- Deductive reasoning (Left)
- Drawing
- Motion aftereffect

Area 38 - Temporopolar Area

This area is part of the temporal cortex in the human brain. Area 38 is at the anterior end of the temporal lobe, known as the temporal pole. The functional significance of this area is not well defined, but it may bind complex, highly processed perceptual inputs to visceral emotional responses.

Clinical significance

This area is among the earliest affected by Alzheimer's disease and the earliest involved at the start of temporal lobe seizures.

Traumatic head injury usually impacts the temporal pole, and it has been suggested that the difficulties to separate auditory "figure" (e.g., language) from background "noise" found in patients with head injury, is a result of area 38 lesions.

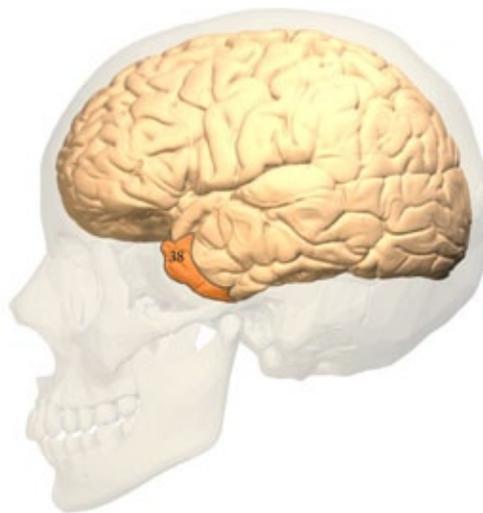
Notes

Functional studies have disclosed the unexpected complexity of area 38 functions. Because of its location in the brain, it is understandable that area 38 participates in language processes, emotion, executive functions, and memory.

Left area 38 is involved in diverse "high level" verbal functions (e.g., semantic processing, naming of items learned in early life, lexico-semantic ambiguity processing, etc.).

Departing from the reported functional studies area 38 involvement in emotion seems evident (e.g., visual processing of emotional images, emotional attachment, response to threat/fearful stimulus, etc.).

In some executive functions (e.g., moral judgment, inferential reasoning, etc) area 38 is also active.



Diverse studies support area 38 contribution to multimodal memory retrieval.

Additionally, it seems to contribute to some complex auditory processing; for instance, recognition of familiar voices (phonognosis), and response to aversive auditory stimulation.

Associated Functions

Cognition

- Attribution of intentions/mental states to others
- Self/other distinction (Left)
- Moral judgments

Emotion

- Experiencing emotional states
- Visual processing of emotional images
- Response to threat/fearful stimulus
- Emotional attachment

Memory

- Multimodal memory retrieval

Language

- Semantic processing (Left)
- Speech comprehension (Left)
- Naming of items learned in early life (Left)
- Word retrieval for specific entities (Left)
- Lexico-semantic ambiguity processing (Left)
- Narrative comprehension (Left)

Auditory

- Selective attention to speech (Left)
- Response to tone stimulus
- Response to aversive auditory stimulation
- Identification of familiar voices (Right)

Visual

- Color and structural judgments of familiar objects

Other

- Humor comprehension
- Irony processing (Right)
- Inferential reasoning (Left)
- Pleasant response to music

Area 39 - Angular Gyrus (sometimes part of Wernickes area)

The angular gyrus is a region of the brain in the parietal lobe, that lies near the superior edge of the temporal lobe, and immediately posterior to the supramarginal gyrus; it is involved in a number of processes related to language, mathematics and cognition.

Clinical significance

The deficit associated to left angular lesion (or Gerstmann's syndrome) includes acalculia (arithmetic deficits), agraphia (deficiency in the ability to write), right-left disorientation, and finger agnosia (inability to distinguish fingers on the hand, left-right disorientation). Spatial knowledge mediated by the language has been proposed as a basic underlying deficit observed in cases of left angular gyrus damage, responsible for observed acalculia and so-called semantic aphasia.

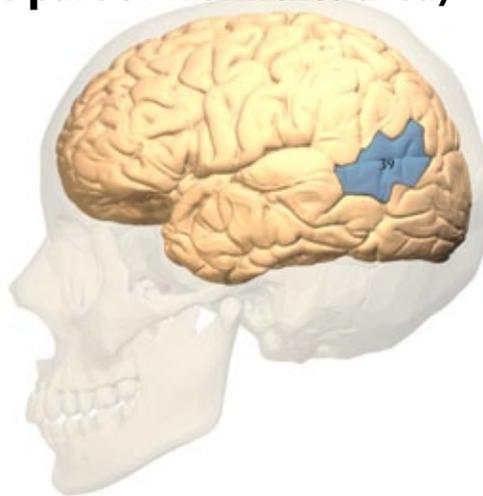
Notes

The angular gyrus is a cortical area involved in cross-modal association among somatosensory (body-knowledge) information, auditory information, and visual information.

Developmentally, the angular gyrus is one of the last to functionally and anatomically mature.

Classically, it has been assumed that the left angular gyrus participate in calculation abilities, reading/writing, naming, and some type of body-knowledge (somatognosis).

fMRI studies support the role of the angular gyrus in arithmetic abilities, but seemingly, the really most crucial area in number processing is the intraparietal sulcus. Interestingly, area 39 activation is observed in



some reading-related tasks (e.g., understanding of the relationship among different characters), but no reports are readily available about its participation in writing, probably because writing may be more exactly associated with the superior parietal lobe and area 40 (apraxic agraphia in cases of parietal lobe damage).

The right angular gyrus clearly participates in visuo-spatial processing, and damage to it results in severe hemi-spatial neglect.

In addition, area 39 seems to also participate in an executive function brain circuitry, and it activates in tasks such as verbal creativity, inferential reasoning and processing sequences.

Associated Functions

Language

- Sentence generation (Left)
- Reading

Calculation

- Calculation (Left)
- Arithmetic learning (Left)
- Abstract coding of numerical magnitude (Left)

Visual

- Spatial focusing of attention
- Visuospatial processing (Right)

Other

- Performing verbal creative tasks (Left)
- Theory of mind
- Executive control of behavior
- Processing a sequence of actions (Left)
- Sight reading (music) (Right)

Area 40 - Supramarginal Gyrus (sometimes part of Wernicke's area)

The supramarginal gyrus is a portion of the parietal lobe. It is probably involved with language perception and processing, and lesions in it may cause Wernicke's aphasia or transcortical sensory aphasia.

Clinical significance

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Notes

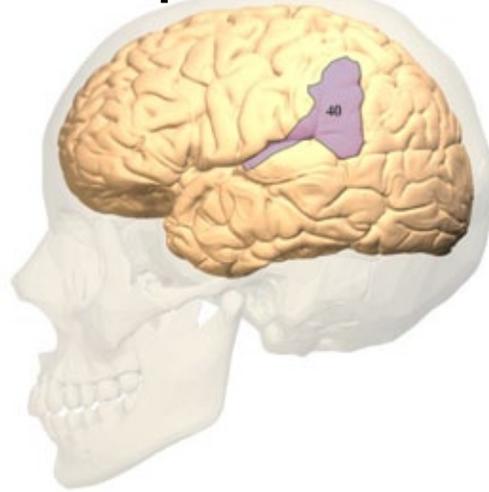
The left supramarginal gyrus of the left hemisphere appears to support some complex linguistic processes, such as semantic processing and verbal creativity.

Its role in spatial knowledge, and particularly, controlling movements guided by visuospatial information seems evident.

Its role in calculation is probably related with its adjacency to the angular gyrus and intraparietal sulcus.

The left supramarginal gyrus seems to be involved in some complex motor activity, such as motor planning; this function is continued in the superior parietal lobe.

Area 40 also participates in an executive function network, involved in tasks such as deductive reasoning and performing creative tasks



Associated Functions

Language

- Attention to phonological relations
- Semantic processing (more elaborate and more complete)
- Verbal creativity
- Writing of single letters

Memory

- Retrieval of unpleasant experiences
- Working memory (emotional/auditory related)
- Conscious recollection of previously experienced events

Motor

- Executive control of behavior
- Response to aversive stimuli
- Visually guided grasping
- Gesture imitation
- Visuomotor transformation/motor planning
- Repetitive passive movements
- Intention/sensory feedback conflict detection

Somatosensory

- Somatosensory spatial discrimination
- Integration of tactile and proprioceptive information

Visual

- Response to visual motion

Other

- Deductive reasoning
- Social perception and empathy
- Emotions vs. self-reflections in decision-making (Right)
- Music performance processing
- Goal-intensive processing
- Same-different discrimination (Right)
- Calculation (integer computation) (Left)
- Motion after-effect
- Performing creative tasks (Left)

Areas 41 & 42 - Primary and Auditory Association Cortex

The primary auditory cortex is a region of the brain that processes sound and thereby contributes to our ability to hear. It is the first cortical region of the auditory pathway. Corresponding roughly with Brodmann areas 41 and 42 of the cerebral cortex, it is located on the temporal lobe, and performs the basics of hearing—pitch and volume. Besides receiving input from the ear and lower centers of the brain, the primary auditory cortex also transmits signals back to these areas.

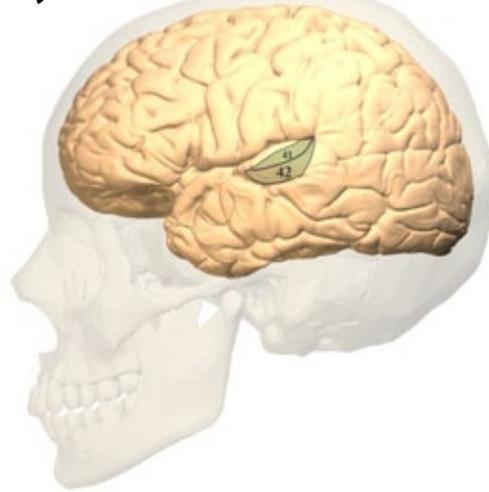
Clinical significance

Lesions to the Primary Auditory Cortex in humans leads to a loss of any awareness of sound, but an ability to react reflexively to sounds remains as there is a great deal of subcortical processing in the auditory brainstem and midbrain.

Notes

The primary auditory area contains a frequency map: different neurons respond best to particular frequencies. This frequency distinction is also found in the cochlea and the auditory pathway to the brain. It means, that the primary auditory cortex possesses a tonotopic organization.

Bilateral lesions of Heschl's gyri may result in central deafness. Heschl's gyrus involvement in basic processing of auditory stimuli, processing discontinued acoustic patterns, rapid sound detection, and similar auditory processes seems quite obvious. Its activation during visual word recognition and auditory short-term memory also seems understandable. Nonetheless, it may be unexpected and intriguing that it activates when reading speech from faces (watching articulatory gestures).



This may suggest an internal representation of the speech sounds (possibly mirror neurons).

Associated Functions

Language

- Basic processing of auditory stimuli (speech and non-speech)
- Processing discontinued acoustic patterns (42)
- Frequency deviant detection
- Perception of harmonic tones (right > left)
- Processing sound intensity
- Sensitivity to pitch
- Rapid sound detection (Bilateral)
- Sound (vowel) segregation
- Auditory priming

Memory

- Repetition priming effect
- Auditory working memory

Other

- Visual speech perception (mirror neurons?)

Area 43 - Primary Gustatory Cortex

This area occupies the postcentral gyrus and the precentral gyrus between the ventrolateral extreme of the central sulcus and the depth of the lateral sulcus at the insula.

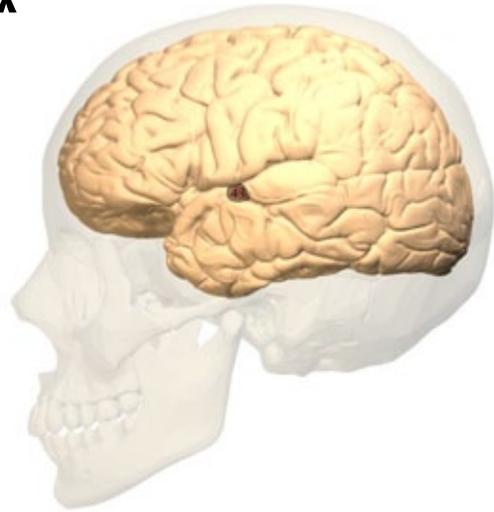
Little is known about its exact function.

Clinical significance

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Notes

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Associated Functions

Motor

- Response to vibrotactile digit stimulation

Language

- Spoken language (Bilateral)

Area 44 - Pars Opercularis (part of Broca's area)

The Orbital part of inferior frontal gyrus (literally “the part that covers”) is the part of the inferior frontal gyrus named opercularis because it covers part of the insula. The pars opercularis together with the pars triangularis form Broca's area, a neuroanatomic region important in speech-language production.

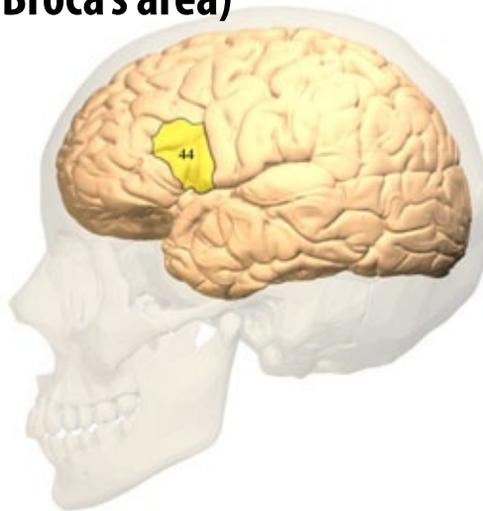
Clinical significance

It has been found that a significant gray matter volume reduction of both the pars opercularis and triangularis was found bilaterally in the subjects with Aspergers/Autism.

Notes

From the traditional point of view, Broca's area corresponds to area 44, but several contemporary authors also include area 45. It can be conjectured that in the future, the most anterior part of the insula could also be included in the Broca's area, given its participation in the praxis of speech (motor speech programming). Different proposals have been presented to explain language disturbances in so-called Broca's aphasia; different hypotheses have attempted to postulate a core area 44 function, including: binding the elements of the language, selecting information among competing sources, generating/extracting action meanings; sequencing motor/expressive elements; cognitive control mechanism for the syntactic processing of sentences; construction of higher parts of the syntactic tree in speech production; and verbal working memory.

Functional studies have further improved our understanding of area 44. Although the core area 44 function remain elusive, fluency and sequencing may



potentially account for many of the functions in which area 44 participates. The suggestion that area 44 includes mirror neurons for expressive movements is particularly provocative and may enlighten the question of inner speech (e.g., internally generated language). Functional studies have also contributed to further understand right area 44, which seemingly participates in perception and expression of prosodic and emotional information. From the perspective of the lesional model, unfortunately just few studies have analyzed the clinical disturbances associated with right area 44. Functional studies have also disclosed the participation of area 44 in a diversity of tasks that are difficult to interpret with our current understanding of the brain, such as pain anticipation, perception of tactile stimulation, motion after-effect, object manipulation, smelling familiar odors, and music enjoyment; in those cases, area 44 activation is just an additional element in a complex brain network; it may be suggested that some internal verbalization can account for area 44 involvement in these unexpected activities. Its participation in working memory may also reflect the internal rehearsal of the information.

Associated Functions

Language

Language (left hemisphere in majority of people)
 Semantic and phonological fluency
 Phonological or syntactic processing
 Grapheme-to-phoneme conversion
 Grammatical processing
 Processing of sequential sounds
 Lexical inflection (Left)
 Response to unintelligible speech
 Expression of emotional information (Right)
 Perception of prosodic information (intonation) in speech (Right)
 Attention in speech processing
 Sentence comprehension
 Internally-specified word generation

Other

Generation of melodies (Right)
 Tactile imagery
 Goal-intensive processing
 Word and face encoding
 Solving arithmetical tasks
 Motion after-effect
 Object manipulation (bilateral)
 Smelling familiar odors (Left)
 Music enjoyment

Memory

Syntactic working memory
 Working memory
 Episodic long-term memory
 Declarative memory encoding

Motor

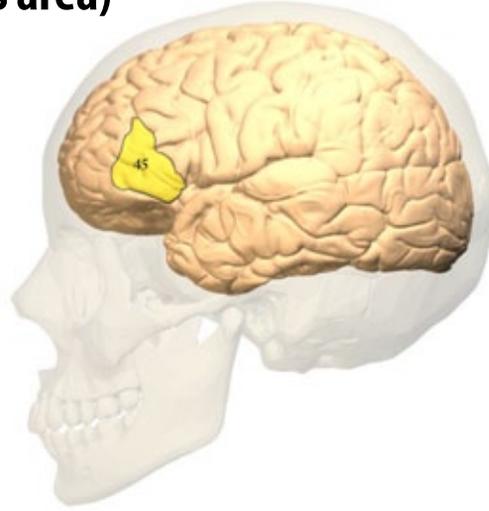
Mirror neurons for expressive movements
 Motor speech programming
 Motor response inhibition (Right)

Area 45 - Pars Triangularis (Broca's area)

Pars triangularis is a region of the human cortex, located in the inferior frontal gyrus of the frontal lobe.

A strong correlation has been found between speech-language and the anatomical asymmetry. Language function can be localized to one region of the brain, as Broca had done before them, but also supported one side of the brain is more involved with language than the other.

Pars triangularis has been shown to have a role in cognitive control of memory. When reading aloud, people must decode written language to decipher its pronunciation. This processing takes place in Broca's area.



Clinical significance

-

Notes

The functions of area 45 are significantly coincidental with the functions of area 44, supporting the proposal that they both, at least partially, correspond to a single system. Nonetheless, area 45 seems to be involved in relatively more complex verbal functions, for instance, processing of metaphors and reasoning processes.

As observed with area 44, area 45 participates in a diversity of functions difficult to interpret with our current understanding of the brain (e.g., smelling of familiar odors) and probably reflecting some inner speech during the performance of those tasks.

Area 45's participation in working memory may also reflect the internal rehearsal of information.

Associated Functions

Language

- Semantic phonological processing
- Internally specified word generation
- Verbal fluency
- Lexical search
- Phonological processing
- Grammatical processing
- Semantic memory retrieval
- Selective attention to speech (Left)
- Sign language
- Affective prosody comprehension (Right)
- Lexical inflection (Left)
- Reasoning processes
- Processing of metaphors

- Modulating emotional response
- Smelling familiar odors (Left)

Memory

- Working memory
- Non-verbal working memory (bilaterally)
- Episodic long-term memory
- Declarative memory encoding
- Recall of digit series

Motor

- Mirror neurons for expressive movements
- Mirror neurons for grasping movements
- Response inhibition

Other

- Mental rotation (mostly in females)
- Word and face encoding
- Aesthetic appreciation
- Music enjoyment
- Generation of melodic phrases (Left)

Area 46 - Dorsolateral Prefrontal Cortex

The dorsolateral prefrontal cortex (DL-PFC or DLPFC), according to a more restricted definition, is roughly equivalent to Brodmann areas 9 and 46.

According to a broader definition DL-PFC consists of the lateral portions of Brodmann areas 9 – 12, of areas 45, 46, and the superior part of area 47.

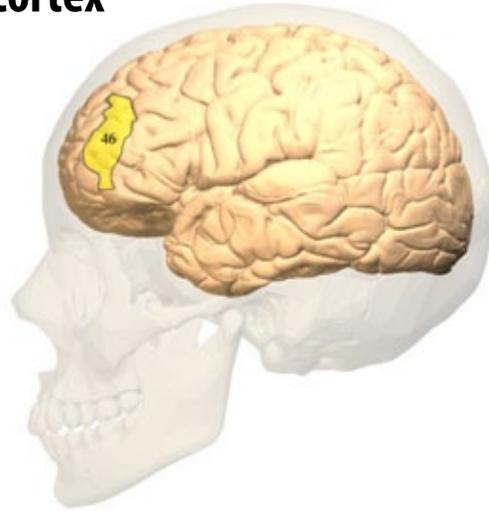
DL-PFC serves as the highest cortical area responsible for motor planning, organization, and regulation. It plays an important role in the integration of sensory and mnemonic information and the regulation of intellectual function and action. It is also involved in working memory. However, DL-PFC is not exclusively responsible for the executive functions. All complex mental activity requires the additional cortical and subcortical circuits with which the DL-PFC is connected.

Clinical significance

Damage to the DL-PFC can result in the dysexecutive syndrome, which leads to problems with affect, social judgement, executive memory, abstract thinking and intentionality.

Notes

It is evident that area 46, as well as area 9/10, are involved in memory, particularly working memory and memory control and organization. Because of the association of working memory with prefrontal activity, some clarification about working memory is important. It has been assumed that working memory is involved in a diversity of cognitive processes, including language comprehension, planning, reasoning, problem solving and even consciousness.



It is important to emphasize that span tests (e.g., digit span) (working memory storage process) exhibit greater dependence on the posterior cortex, whereas delayed recognition performance (working memory rehearsal process) exhibits greater dependence on the prefrontal cortex.

When information has to be manipulated, increased prefrontal activity is found. Whereas they play a fundamental role in the exercise of executive control of working memory, they do not govern the storage per se of the information held in working memory.

The participation of the left anterior middle frontal gyrus in language is also shared by other left prefrontal convexital areas.

During pause, the middle frontal gyrus (area 46) plus those structures involved in motor preparation (dorsal premotor cortex, superior parietal lobule, rostral mesial areas) also become active.

Associated Functions

Memory

- Memory encoding and recognition
- Working memory

Language

- Semantic processing (Left)
- Verbal fluency (Left)
- Phonological processing (Left)

Motor

- Executive control of behavior
- Chewing
- Drawing
- Mirror neurons
- Horizontal saccadic eye movement

Other

- Internal mental calculation
- Processing emotions and self-reflections in decision making (Left)
- Intention/sensory feedback conflict detection
- Music enjoyment
- Willed action
- Strategy change response

Area 47 - Inferior Prefrontal Gyrus

The inferior frontal gyrus is a gyrus of the frontal lobe. It is involved in many functions related to language and emotion.

Clinical significance

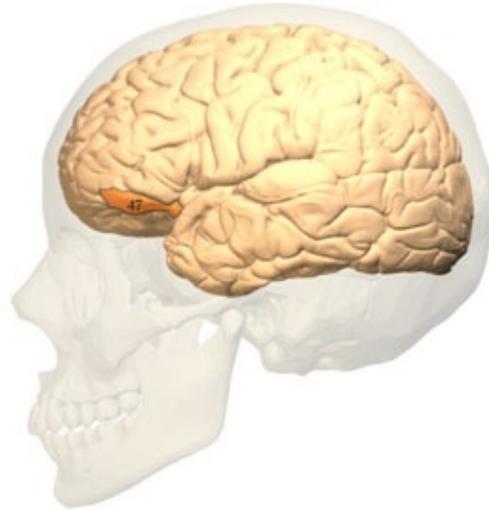
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Notes

The significant amount of language-related functions that have been associated with area 47, such as semantic processing, phonological processing, semantic encoding, and others, is surprising. In these cases, area 47 is simply one of the multiple steps in the brain language processing network.

It could be further speculated that in these verbal related functions, the inferior frontal gyrus may play a more emotional/motivational function.

Moreover, anatomically area 47 is adjacent to area 45, a clearly language brain area. Area 47 participates in some clearly emotional related activities (e.g., adverse emotional inhibition) and also in executive functions (e.g., deductive reasoning).



Associated Functions

Language

- Semantic processing (Left)
- Semantic encoding
- Active semantic retrieval
- Phonological processing
- Single word reading
- Lexical inflection
- Affective prosody (Right)
- Selective attention to speech

Memory

- Working memory
- Episodic long-term memory

Other

- Behavioral and motor inhibition (Right)
- Adverse emotional inhibition
- Nonspatial auditory processing
- Processing of fine-structured stimuli
(i.e. music) (Left)
- Temporal coherence (language and music)
- Lexico-semantic access to melodic
representations
- Smelling familiar odors (Left)
- Attribution of intention to others
- Decision making (involving conflict and
reward) (Right)
- Deductive reasoning

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4

Functional Breakdown

Functional Breakdown

Motor

Function	Brodman Area
Primary motor	4, 1, 2, 3
Secondary motor	6, 8
Motor planning	6, 13-16; 24, 32-33; 40
Motor Imagery	5, 7, 4, 6, 8; 24, 32-33
Motor Learning	4, 1-3, 6, 8; 23, 26, 29-31
Saccadic movements	4, 5, 7, 6, 8, 17, 18, 19, 46
Inhibition of blinking	4

Sensory

Function	Brodman Area
Proprioception	1-3, 4, 8
Touch, temperature, vibration	1-3, 4, 5, 7, 13-16
Somatosensory integration	40

Auditory

Function	Brodman Area
Basic processing	41,42
Complex sounds processing	21, 22
Auditory Imagery	8, 9, 10
Familiar voices	38

Visual

Function	Brodman Area
Light intensity / patterns	17, 18, 19
Color discrimination	17
Visual integration	20
Visual motion processing	37

Olfaction

Function	Brodman Area
General olfaction	11
Familiar odors	9, 10; 24, 32-33; 44, 45, 47

Language

Function	Brodman Area
Comprehension	22,20,21,37,39, 40,5,7,6,9,10,23, 26,29-31,38,43, 44,45,47
Expression	44, 45, 46, 6, 8, 9, 10, 13-16, 21; 24, 32-33; 47
Prosody comprehension	22
Reading	6,39
Writing	40

Memory

Function	Brodman Area
Working Memory	5, 7, 6, 8, 9, 10, 20; 24, 32-33; 40, 41, 44, 45, 46, 47; (27-28, 34-36, 48)
Episodic memory	6, 44, 45, 47
Retrieval	8, 9, 10,; 26, 29, 29-31; 24, 32-33; 38, 40
Encoding	(27-28, 34-36, 48); 9, 10; 24, 32-33; 37, 46
Topokinetic	23, 26, 29-31

Attention

Function	Brodman Area
Visual	17, 18, 37
Visuomotor	5, 7, 6, 8
Visuospatial	6, 8; 39, 24, 32-33; 45
Selective to sounds	6, 9, 10,; 24, 32-33
To speech	20, 22,; 23, 26, 29-31; 38, 47

Pain

Function	Brodman Area
Pain processing	13-16; 24, 32-33, 5, 7

Executive

Function	Brodman Area
Planning	6, 8, 9, 10
Behavioral inhibition	6, 8, 9, 10, 13-16; 24, 32-33; 39, 40, 44, 46, 47
Motor inhibition	24, 32-33, 44, 45, 47

Emotion

Function	Brodman Area
Experiencing / processing emotion	38, 46; (27-28, 34-36, 48)
Related to language	23, 26, 29-31; 25
Emotional stimuli	9, 10; 24, 32-33
Fear response	13-16

Other

Function	Brodman Area
Calculation	39, 40, 6, 8, 9, 10, 13-16, 46
Theory of mind	38, 9, 10, 20, 21, 22, 37, 47
Face recognition	37
Mental time-keeping	24, 32-33
Humor comprehension	38
Music performance	40
Music enjoyment	44, 45, 46
Novelty discrimination	(27-28, 34-36, 48)

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