

Analysis of Traditional Scalp Acupuncture Point Locations as Local Cortical Region and Functional Network Node Targets in Non-Invasive Brain Network Neuromodulation

Section 4 - The Insula and Opercular Cortex

Douglas S. Wingate

Abstract

Background/Objective: Non-invasive neuromodulation techniques have increasingly been utilized and investigated as potential treatment approaches for neurological and psychiatric disorders. Increasing evidence supports the possibility of non-invasive neuromodulation affecting larger scale brain networks rather than just local stimulation targets. In this article, this concept and implications thereof are explored within the context of traditional acupuncture points located on the scalp and their cortical region correlates.

Method: This article addresses the conceptual framework of traditional acupuncture point locations on the scalp as potential local cortical region and/or neural network nodes of non-invasive neuromodulation modalities and may expand existing understanding of the influence of scalp acupuncture points based on these network connections. Studies that support this hypothesis are provided followed by an exploration of functionally and structurally connected brain parcellations elucidated by connectomic mapping and correlations with traditional acupuncture points. In this installment cortical regions of the insula and opercular cortex are explored.

Main Results/Conclusion: Studies stimulating brain regions by various non-invasive methods including manual and laser scalp acupuncture, repetitive Transcranial Magnetic Stimulation (rTMS), and transcranial Direct Current Stimulation (tDCS) offer evidence of underlying neuromodulatory mechanisms and clinical therapeutic effect in cases of various neuropathologies. These effects have evidence to support that in addition to local cortical region responses; structural and functional brain network modulatory influence including influence upon deeper brain structures, have been demonstrated. In light of this evidence, it is proposed that applying a network perspective to non-invasive transcranial stimulation may lend a broader understanding of therapeutic potential in using these techniques.

Keywords: scalp acupuncture, connectome, neuromodulation, brain networks, brain hubs, insula, interoception, opercular cortex

Anterior Apex Regions

Area Pir (piriform cortex)

Location:

In the pyriform cortex, which itself is located just anterior to the anterior perforated substance, at the point where the limen insula folds onto the orbitofrontal surface.

Functions:

The piriform cortex is a region of the anterior apex that has been studied previously.

-Contains axons that distribute widely and extensively branch throughout other cortical regions with functional roles attributed to cognition, behavior, emotion, and memory.³

-The largest area of the brain to receive olfactory signals.

-Activation with all olfactory tasks and pivotal role in the memory of olfaction, discrimination of odors, and distribution of this information to other brain regions

Functional Connectivity:

Insula: areas AAIC, Pol1, and Pol2

White Matter Connections:

Structurally connected to local parcellations and posterior insular regions. The white matter tracts of this parcellation are difficult to delineate due to the proximity of the area to underlying white matter tracts.

Connections to posterior insular regions project from Pir to Pol2, Ig, and OP2-3.

Local short association bundles connect with AAIC and TGd.

Traditional Acupoint Correlates:

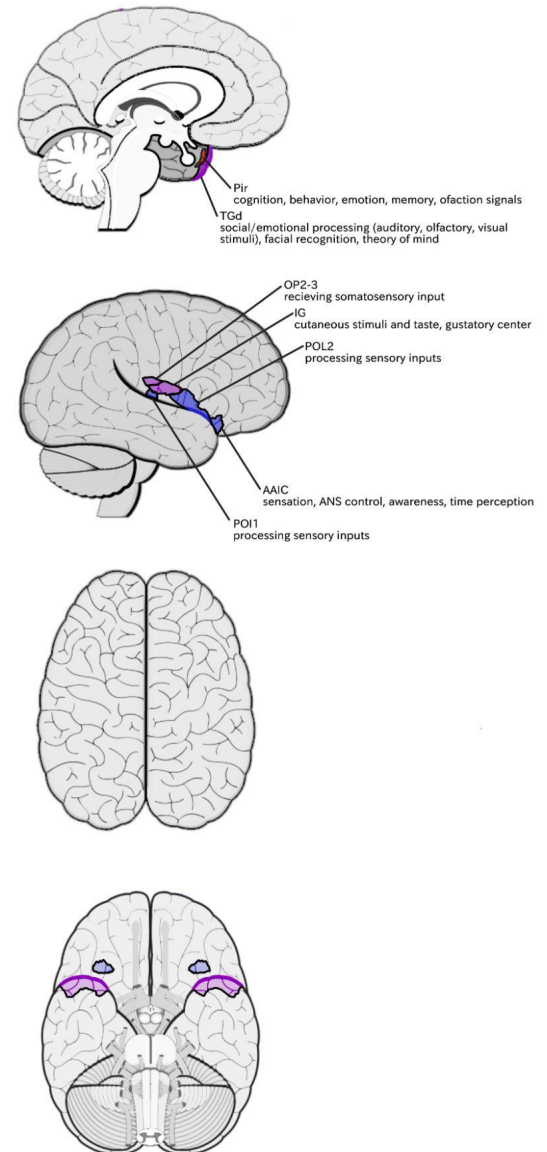
N/A

Functionally Connected Acupoints:

GB5 (Pol2)

Structurally Connected Acupoints:

N/A



Area AAIC (anterior agranular insular cortex)

Location:

In the anteroinferior insula near the limen insula and in the transverse insular gyrus.

Functions:

-The anterior insula is suggested to have a role in sensation and control of autonomic nervous system processes as well as playing a role in human awareness, self-recognition, time perception, and perceptual decision making

-parcellated from areas MI and AVI based on functional activity differences related to motor, arithmetic, auditory language, and semantic tasks

Functional Connectivity:

Insula: areas AVI, MI, Pir, 47s, and Pol2

White Matter Connections

Structurally connected to local parcellations. Local short association bundles connect with Pir, 47s, AVI, Pol2, and MI.

Traditional Acupoint Correlates:

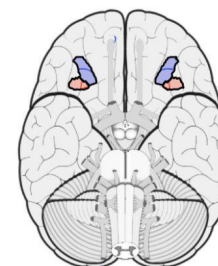
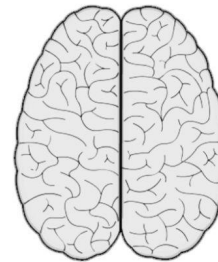
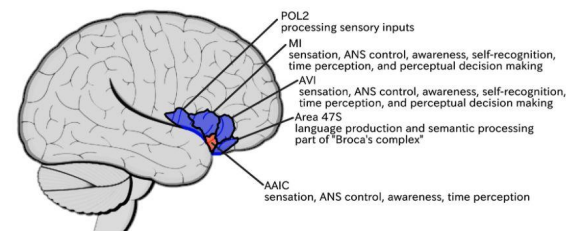
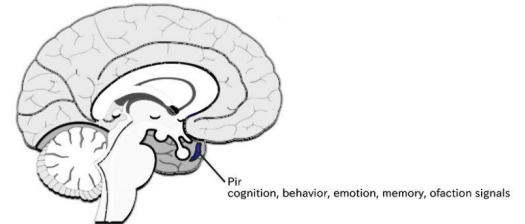
N/A (½ the distance from GB1->GB5)

Functionally Connected Acupoints:

GB5 (Pol2)

Structurally Connected Acupoints:

GB5 (Pol2)



Area AVI (anterior ventral insula)

Location: In the anterior superior apex of the insula.

Functions:

-The anterior insula is suggested to have a role in sensation and control of autonomic nervous system processes as well as playing a role in human awareness, self-recognition, time perception, and perceptual decision making
 -Area AVI was parcellated from areas MI and AAIC based on functional activity differences related to motor, arithmetic, auditory language, and semantic tasks

Functional Connectivity:

Premotor regions: 6ma, 6r
 Lateral frontal lobe: 44, p47r, 8C, a9-46v, p9-46v, 9-46d
 Medial frontal lobe: 8BM d32, a32pr
 Superior insula opercular regions: FOP4, FOP5
 Lower opercula and Heschl's gyrus regions: AAIC, MI
 Temporal lobe: TE2p, PHA3, PHT
 Lateral parietal lobe: LIPd, PF, PFm, IP2
 Medial occipital lobe: V1

White Matter Connections:

Structurally connected to local parcellations. Local short association bundles connect to insular parcellations 47s, 47l, AAIC, FOP4, FOP5, and MI, and temporal pole parcellations TGd.

Traditional Acupoint Correlates:

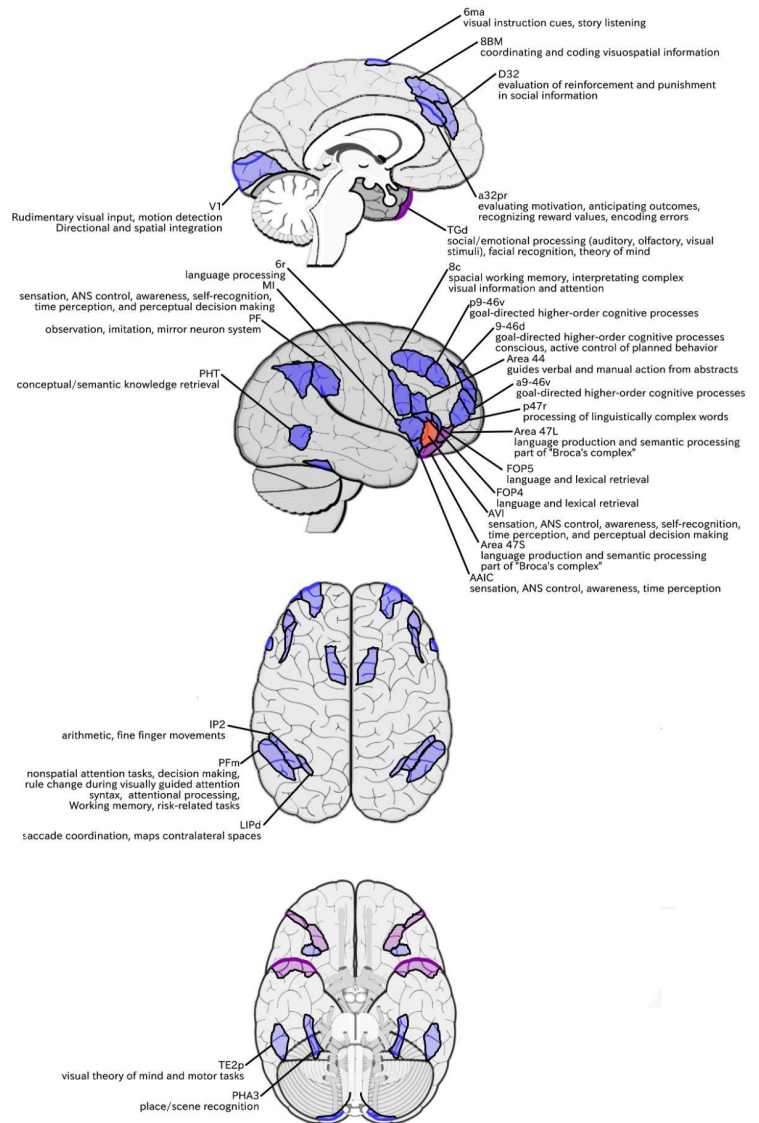
N/A (1/2 distance between GB1-> GB4)

Functionally Connected Acupoints:

- | | |
|---------------|------------------|
| BL4 (9-46d) | GB4 (Area 6r) |
| GB8 (PHT) | GB9 (PHT) |
| GB13 (p9-46v) | GB15 (8C/p9-46v) |
| GB18 (PFm) | TW20 (TE2p) |
| ST8 (6r) | GV18 (V1) |

Structurally Connected Acupoints:

N/A



Area MI (middle insula)

Location:

In the posterior superior portion of the short insular gyrus.

Functions:

-The anterior insula is suggested to have a role in sensation and control of autonomic nervous system processes as well as playing a role in human awareness, self-recognition, time perception, and perceptual decision making.

-Area MI was parcellated from areas AAIC and AVI based on functional activity differences related to motor, arithmetic, auditory language, and semantic tasks.

Functional Connectivity:

Premotor regions: SCEF, FEF, PEF, 6ma, 6r

Lateral frontal lobe: IFSa, 46, 9-46d

Medial frontal lobe: 5mv, 23c, a24pr, p24pr, a32pr, p32pr

Superior insula opercular regions: OP4, 43, PFcm, FOP1, FOP3, FOP4, FOP5

Lower opercula and Heschl's gyrus: 52, PI, AVI, AAIC, Pol1, Pol2

Temporal lobe: PHT

Lateral parietal lobe: LIPd, PF, PFm, PFop, PFt

Medial parietal lobe: 7am

Dorsal visual stream: V6

White Matter Connections:

Structurally connected with the arcuate/SLF, frontal aslant tract, and local parcellations. Some individuals have connections to the parietal and occipital lobe though these tracts are inconsistent. Connections to the superior frontal gyrus through the FAT project superior to 8BL, 6ma, and SFL. Superior temporal gyrus connections are portions of the arcuate/SLF and course from MI, medial and superior to the insula to end laterally at A4 and A5. Local short association bundles connect with Pol1, 47s, Pir, AAIC, AVI, FOP3, FOP4, and FOP5.

Traditional Acupoint Correlates:

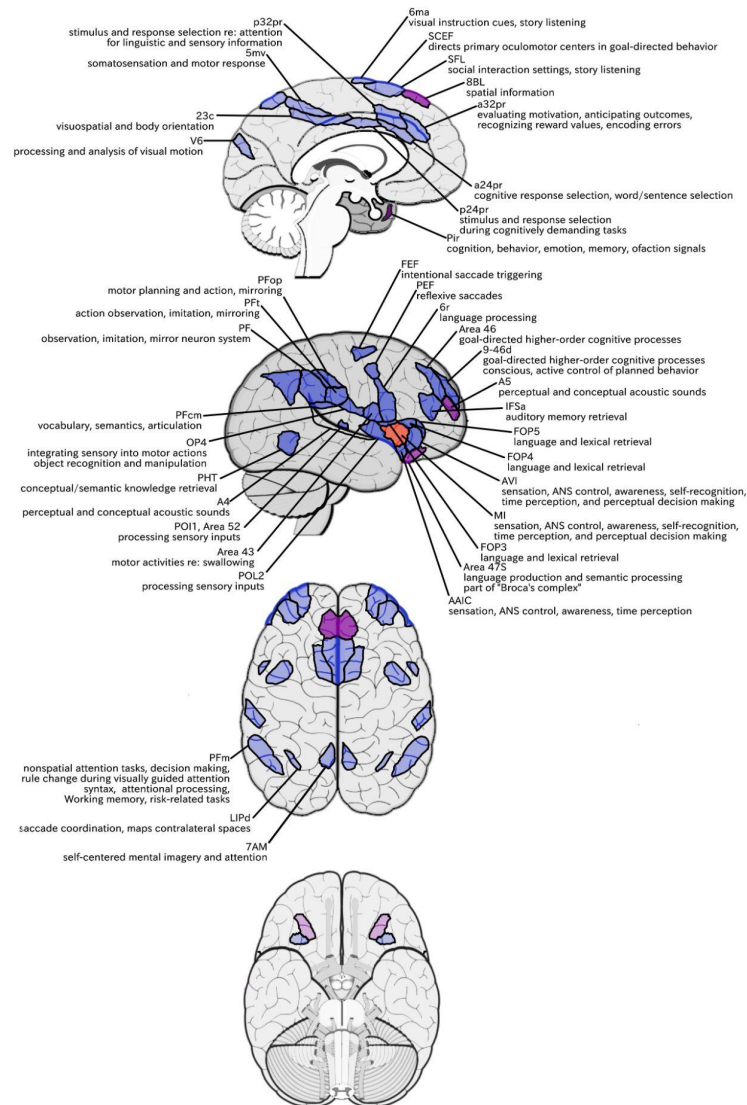
N/A (~1/3 distance from GB4->GB1)

Functionally Connected Acupoints:

BL4 (Area 46/9-46d)	GB4 (Area 43/6r)
GB5 (POL2)	GB8 (PHT)
GB9 (PHT)	GB15 (Area 46)
GB16 (FEF)	GB18 (PFm)
ST8 (6r)	GV21 (SCEF)

Structurally Connected Acupoints:

BL3 (8BL)	GB5 (A4)
GB14 (A5)	GV22 (8BL)



Area FOP5 (frontal operculum 5)

Location:

In the undersurface of the opercular portions of pars triangularis of the IFG.

Functions:

-The frontal operculum plays a key role in the initiation of language and lexical retrieval required for language Learning

-Compared to FOP4: greater activity in motor tasks during which individuals squeezed their left and right toes, tapped their left and right fingers, and moved their tongue
 Compared to Area 44: differences in motor cue and semantic tasks.

Functional Connectivity:

- Premotor regions: SCEF, FEF, PEF, 6ma, 6r
- Lateral frontal lobe: 44, 45, IFSa, IFja, 46, 9-46d
- Medial frontal lobe: 23c, a24pr, p24pr, a32pr, p32pr
- Superior insula opercular regions: 43, PFcm, FOP3, FOP4
- Lower opercula and Heschl's gyrus: AVI, MI Pol1, Pol2
- Temporal lobe: PHT
- Lateral parietal lobe: LIPd, PF, PFop
- Medial parietal lobe: 7am
- Occipital lobe: V1

White Matter Connections:

Structurally connected to the IFOF and arcuate/SLF. The IFOF courses from occipital lobe parcellations V1, V2 V3, and parietal area MIP, through the extreme/external capsule to turn laterally to FOP5. FOP5 has arcuate/SLF fibers projecting posteriorly above the insula and turning laterally to end at the posterior insula and planum temporale parcellations RI and LBelt. Local short association fibers connect with 45, FOP4, and AVI. White matter tracts from FOP5 in the right hemisphere have less consistent connections with the arcuate/SLF.

Traditional Acupoint Correlates:

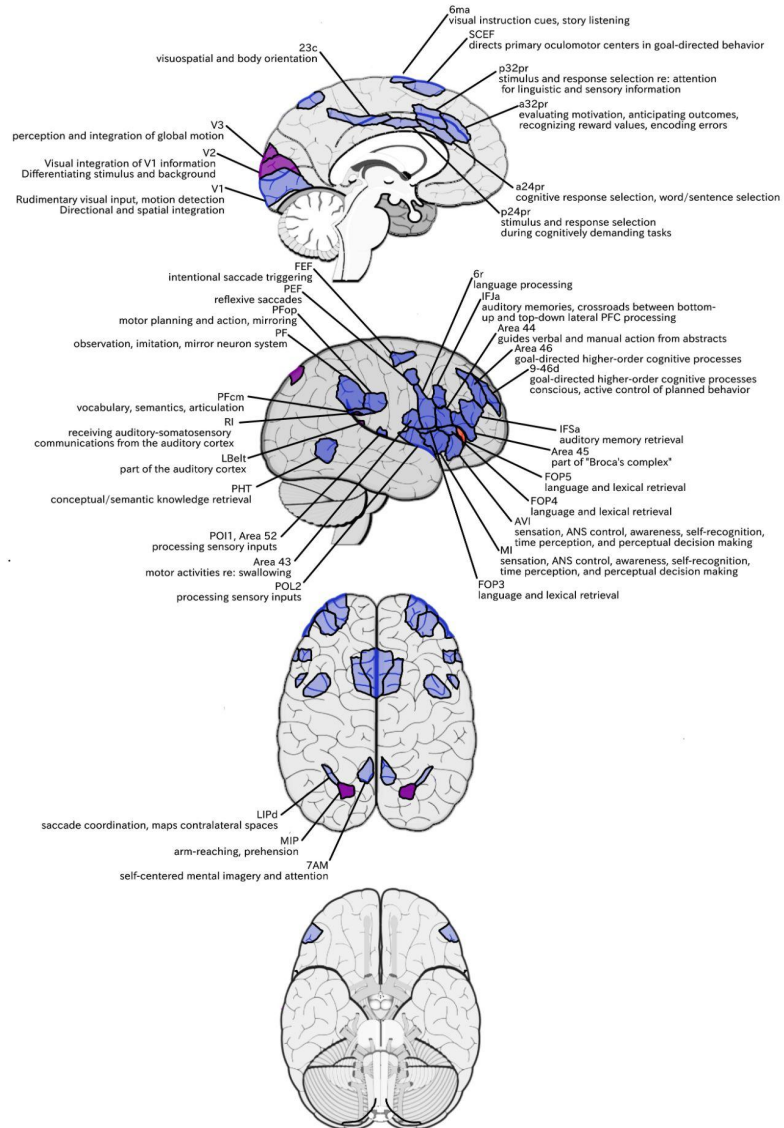
N/A (center of triangle formed by GB1, GB4, and GB14)

Functionally Connected Acupoints:

- | | |
|---------------------|------------------|
| BL4 (Area 46/9-46d) | GB4 (Area 43/6r) |
| GB5 (POL2) | GB8 (PHT) |
| GB9 (PHT) | GB15 (Area 46) |
| GB16 (FEF) | ST8 (6r) |
| GV18 (V1) | |

Structurally Connected Acupoints:

GV18 (V1/V2)



Area FOP4 (frontal operculum 4)

Location:

On the inner surface of the pars opercularis of the IFG.

Functions:

- The frontal operculum plays a key role in the initiation of language and lexical retrieval required for language learning.
- Parcellated from areas AVI and FOP1 based on differences in functional activity in motor-based tasks.

Functional Connectivity:

Premotor regions: SCEF, FEF, PEF, 6v, 6a, 6ma, 6r

Lateral frontal lobe: IFSa, 46, 9-46d

Medial frontal lobe: 5mv, 23c, 24dv, a24pr, p24pr, a32pr, p32pr

Superior insula opercular regions: 43, PFcm, OP4, FOP3, FOP5

Lower opercula and Heschl's gyrus: AVI, MI, PI, 52, Pol1, Pol2

Temporal lobe: area PHT

Lateral parietal lobe: 7AL, 7PL, AIP, LIPv, LIPd, PF, PFT, PGp, PFop

Dorsal visual stream: V6

Medial parietal lobe: 7am, DVT

Occipital lobe: V1, V2, V3

White Matter Connections:

Structurally connected to the frontal aslant tract and the arcuate/SLF.

Connections from FOP4 with the frontal aslant tract project superior to the superior frontal gyrus to end at parcellations 6ma and SFL.

Arcuate/SLF fibers project posteriorly above the insula, curving around the termination of the sylvain fissure to end at TGd and TE1a. From the arcuate/SLF there are also projections to the superior temporal gyrus that end at A4 and A5.

Local short association fibers connect with AVI, FOP3, FOP5, and MI.

White matter connections from FOP4 in the right hemisphere have less consistent connections with the arcuate/SLF.

Traditional Acupoint Correlates:

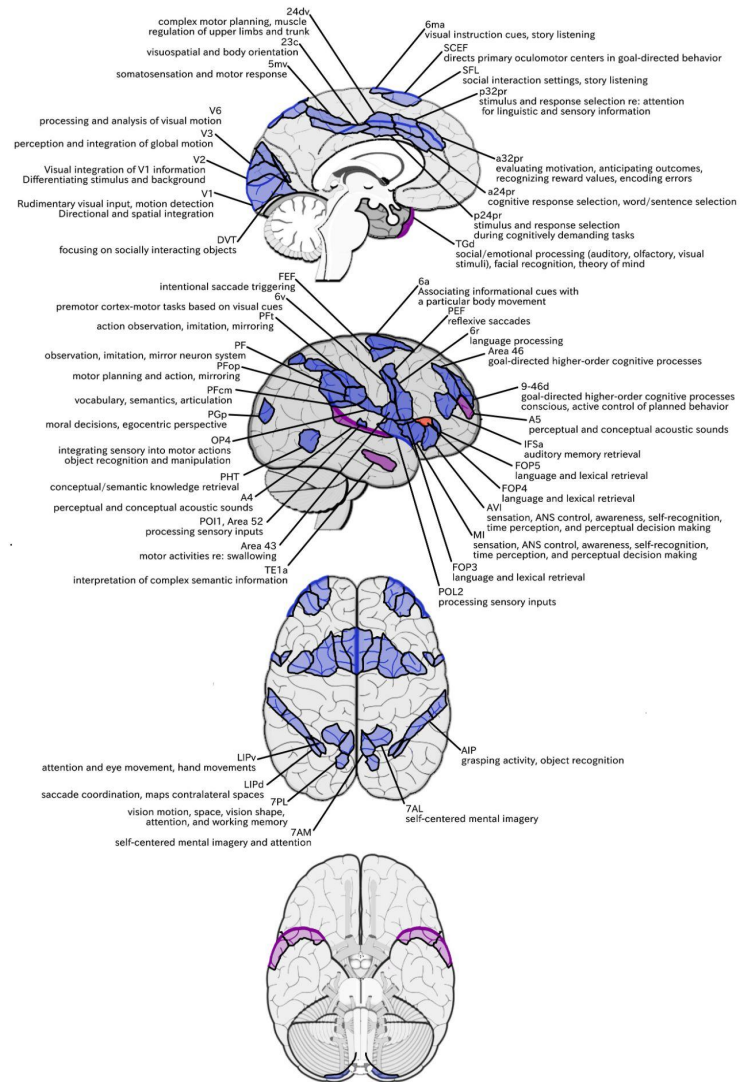
N/A (posterior to GB4, superior to GB6)

Functionally Connected Acupoints:

- | | |
|---------------------|------------------|
| BL4 (Area 46/9-46d) | BL6 (6a) |
| BL7 (7AL) | GB4 (Area 43/6r) |
| GB5 (POL2) | GB8 (PHT) |
| GB9 (PHT) | GB15 (Area 46) |
| GB16 (FEF) | GB18 (LIPv) |
| ST8 (6r/6v) | GV18 (V1/V2) |
| GV21 (SCEF) | |

Structurally Connected Acupoints:

- | | |
|----------|------------|
| GB5 (A4) | GB6 (TE1a) |
| GB14(A5) | |



Area FOP3 (frontal operculum 3)

Location:

In the superior circular sulcus of the insula, just anterior to the junction of this sulcus with the superior aspects of the long and short gyri. FOP3 sits just between these 2 junctions, slightly deviated toward the short gyri.

Functions:

- The frontal operculum plays a key role in the initiation of language and lexical retrieval required for language learning
- Area FOP3 was separated from FOP4 based on functional activity differences during motor cue and arithmetic tasks

Functional Connectivity:

Premotor regions: SCEF, 6v, 6ma, 6r

Lateral frontal lobe: area 46, 9-46d

Medial frontal lobe: 5mv, 23c, 24dv, a24pr, p32pr

Superior insula opercular regions: area 43, PFcm, OP4, FOP1, FOP2, FOP5

Lower opercula and Heschl's gyrus: MI, 52, Pol1, Pol2

Temporal lobe: PHT

lateral parietal lobe: 7AL, PF, PFop

Dorsal visual stream: V3a, V6

Medial occipital lobe: V2

White Matter Connections:

Structurally connected to the frontal aslant tract and local parcellations. Portions of the frontal aslant connect with FOP3, the fibers project superiorly to the superior frontal gyrus to end at parcellations 6ma and SFL.

Local short association bundles connect with FOP2, FOP4, FOP5, MI, Pol2, and Ig

Traditional Acupoint Correlates:

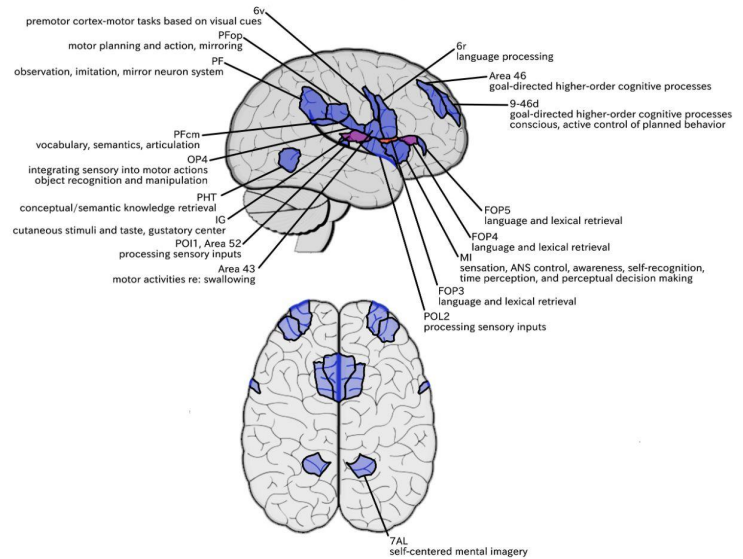
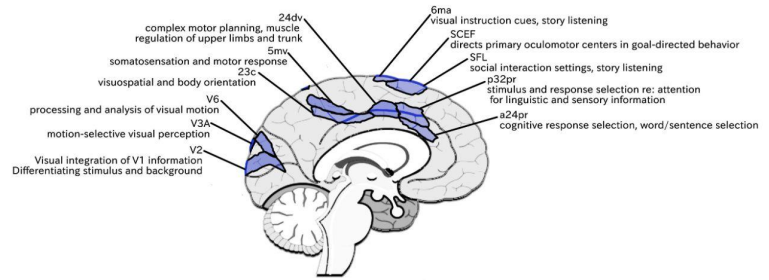
N/A (inferior to GB4)

Functionally Connected Acupoints:

BL4 (Area 46/9-46d)	BL7 (7AL)
BL8 (V7)	GB4 (Area 43/6r)
GB5 (POL2)	GB8 (PHT)
GB9 (PHT)	GB15 (Area 46)
ST8 (6r/6v)	GV18 (V2)
GV21 (SCEF)	

Structurally Connected Acupoints:

GB5 (Pol2)



Area FOP2 (frontal operculum 2)

Location: Lies in the superior circular sulcus of the insula. It is a small area which sits just anterior to the junction of the long insular gyri and the circular sulcus.

Functions:

- The frontal operculum plays a key role in the initiation of language and lexical retrieval required for language learning.
- Parcellated from FOP3 based on functional activity differences during arithmetic and auditory language tasks
- Parcellated from FOP1 based on object interaction tasks.

Functional Connectivity:

Sensory strip: areas 1, 2, 3a, 3b

Motor strip: area 4

Premotor regions: SCEF, 6v, 6d, 6a, 6mp, 6r

Superior insula opercular regions: 43, PFcm, IG, OP4, OP1, FOP1, FOP3

Lower opercula and Heschl's gyrus: PO11, PO12

Lateral parietal lobe: 7AL, 7PC, AIP, PFT, PFop

Lateral occipital lobe: FST

White Matter Connections:

Structurally connected to local parcellations. Local short association bundles are connected to FOP3, FOP4, FOP1, OP1, and OP2-3.

Traditional Acupoint Correlates:

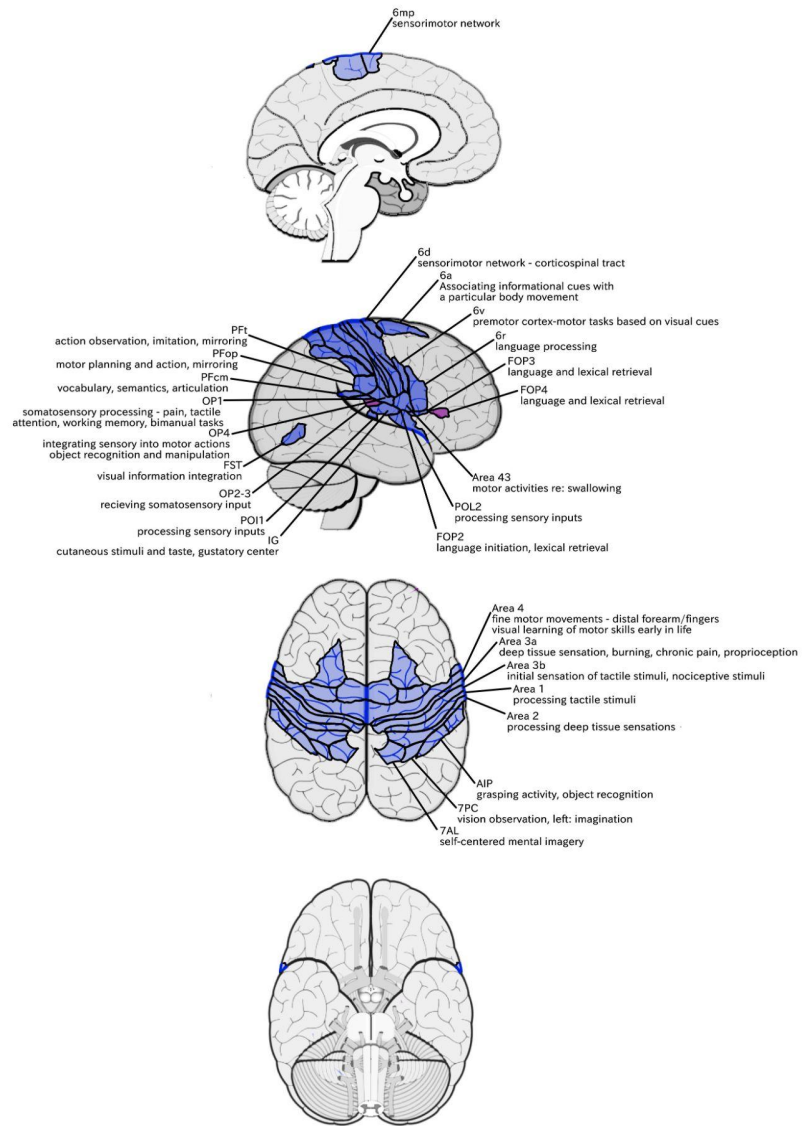
N/A (inferior to GB4)

Functionally Connected Acupoints:

BL6 (6a/6d)	BL7 (Area 2/7AL/7PC)
GB4 (Area 43/6r)	GB5 (POL2)
GB9 (FST)	GB17 (1/2/3a/3b/4)
GB18 (AIP)	ST8 (6r/6v)
GV20 (1/3a/3b/4)	

Structurally Connected Acupoints:

N/A



Area FOP1 (frontal operculum 1)

Location: A small area on the undersurface of the posterior portions of the pars opercularis of the inferior frontal gyrus

Functions:

- The posterior operculum demonstrates activity during imagined abstract movement from a third person perspective
- The posterior operculum is an important area for perception of pain, and may act as a messenger for transmitting somatosensory information to the limbic system.

Functional Connectivity:

- Sensory strip: area 2
- Premotor regions: SCEF, FEF, 6v, 6ma, 6mp, 6r
- Lateral frontal lobe: 46, 9-46d
- Medial frontal lobe: 5mv, 23c, 24dv, a24pr, p32pr
- Superior insula opercular region: 43, PFcm, OP4, FOP2, FOP3, FOP4
- Lower opercula and Heschl's gyrus: MI, 52, Pol1, Pol2
- Temporal lobe: PHT
- Lateral parietal lobe: 7AL, PF, PFop
- Dorsal visual stream area: V3a, V6

White Matter Connections:

Structurally connected to portions of the frontal aslant tract and arcuate/SLF. While the majority has connections to these white matter tracts, they are not consistent across all individuals. Frontal aslant fibers project superiorly from FOP1 to the superior frontal gyrus to end at SFL. Connections with the arcuate/SLF course in the lateral frontal lobe, areas 5mv, 23c, 24dv, a24pr above the insula, wrapping around the termination of Sylvian fissure to end at inferior temporal gyrus area TE1a. From the arcuate/SLF there are also connections to the inferior parietal lobule to PF. Local short association bundles connect with FOP2, FOP3, FOP4, and FOP5. Majority of connections from FOP1 in the right hemisphere are local.

Traditional Acupoint Correlates:

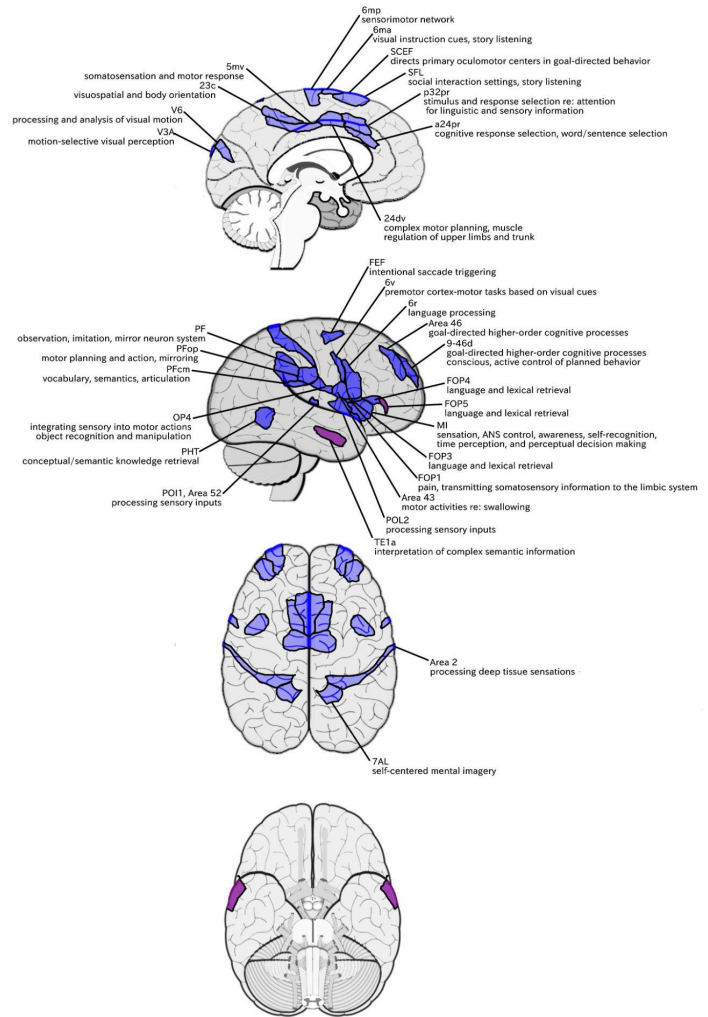
N/A (inferior to GB4)

Functionally Connected Acupoints:

- BL4 (Area 46/9-46d)
- BL7 (Area 2/7AL)
- GB4 (Area 43/6r)
- GB5 (POL2)
- GB8 (PHT)
- GB9 (PHT)
- GB15 (Area 46)
- GB16 (FEF)
- GB17 (Area 2)
- ST8 (6r/6v)
- GV21 (SCEF)

Structurally Connected Acupoints:

GB6 (TE1a)



Area 43

Location: On the anterior portions of the subcentral gyrus (where the precentral and postcentral gyri meet just below the central sulcus). It involves the lateral surface of that operculum as well as the inferior surface which faces the Sylvian fissure.

Functions:

-Functionally correlated with area 41 which has been implicated in motor activities related to swallowing.

Functional Connectivity:

- Sensory strip: area 1, 2, 3a, 3b
- Motor strip: area 4
- Premotor regions: SCEF, FEF, PEF, 6ma, 6mp, 6r, 6v
- Middle cingulate regions: a24pr, p24pr, p32pr, 24dd, 24dv, 5mv, 23c
- Lateral frontal lobe: area 46, 9-46d
- Superior insula and opercular regions: IG, OP4, OP2-3, OP1, PFcm, FOP1, FOP3, FOP4, FOP5
- Lower opercula and Heschl's gyrus: STV, LBelt, PBelt, MBelt, A1, TA2, PI, A4, MI, 52, RI, Pol1, Pol2
- Temporal lobe: PHT
- Lateral parietal lobe: PF, 7AL
- Medial parietal lobe: DVT
- Medial occipital lobe: V1, V2, V3, V4
- Dorsal visual stream: V3a, V3b, V6, V6a, V7
- Ventral visual stream: V8, FFC
- Lateral occipital lobe: LO3, TPOJ2, MST, FST

White Matter Connections:

Structurally connected to the superior parietal lobe and local parcellations. Parietal lobe connections project posterior from 43 to end at PFT, PFm, and PFcm. Local short association bundles connect with 6v, 6r, OP4, 3a, 4, FOP1, FOP2, and MI.

Traditional Acupoint Correlates:

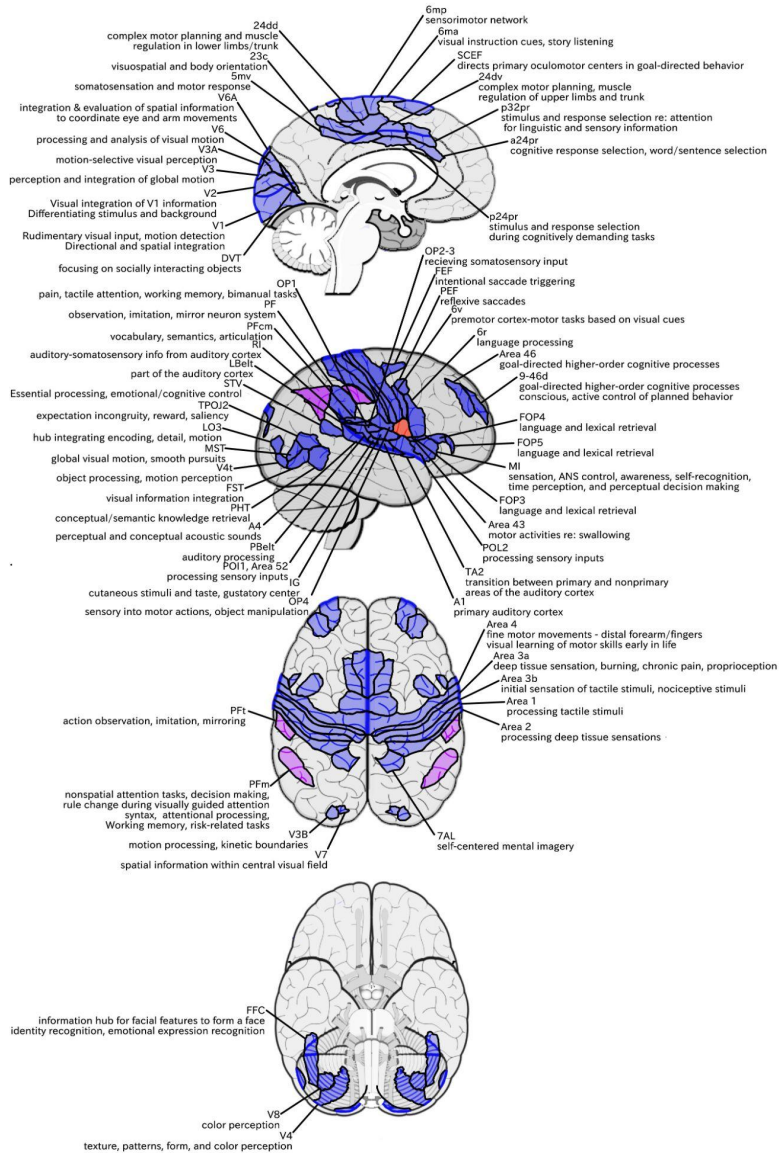
GB4

Functionally Connected Acupoints:

- BL4 (Area 46/9-46d)
- BL7 (Area 2/7AL)
- BL8 (V3b/V7)
- GB4 (6r)
- GB5 (A1/A4/POL2/TA2)
- GB8 (PHT)
- GB9 (PHT/FST)
- GB15 (Area 46)
- GB16 (FEF)
- GB17 (1/2/3a/3b/4)
- ST8 (6r/6v/PEF)
- GV18 (V1/V2)
- GV19 (V6a)
- GV20 (1/3a/3b/4)
- GV21 (SCEF)

Structurally Connected Acupoints:

- GB4 (6r)
- GB17 (3a/4)
- GB18 (PFm)
- ST8 (6r/6v)



Parietal Apex Regions

Area Ig (Insula Granular Cortex)

Location:

At the superior portion of the long insular gyri. It is the posterior superior most part of the insula proper.

Functions:

Has been shown to be activated in response to cutaneous stimuli.¹⁴ This area has also been shown to respond to different stimuli related to taste and is thought to be the gustatory center of the brain.¹⁵

Functional Connectivity:

Sensory strip: areas 1, 3a, and 3b

Motor strip: area 4

Insula opercular region: areas FOP2, OP2-3, OP4, 43, 52, and Pol2

White matter connections:

Structurally connected to local parcellations and MI. From Ig there are anterior fibers that project to MI.

Local short association bundles are connected with A1, MBelt, FOP2, OP1, OP2-3, OP4, Pol2, and Pol1.

Traditional Acupoint Correlates:

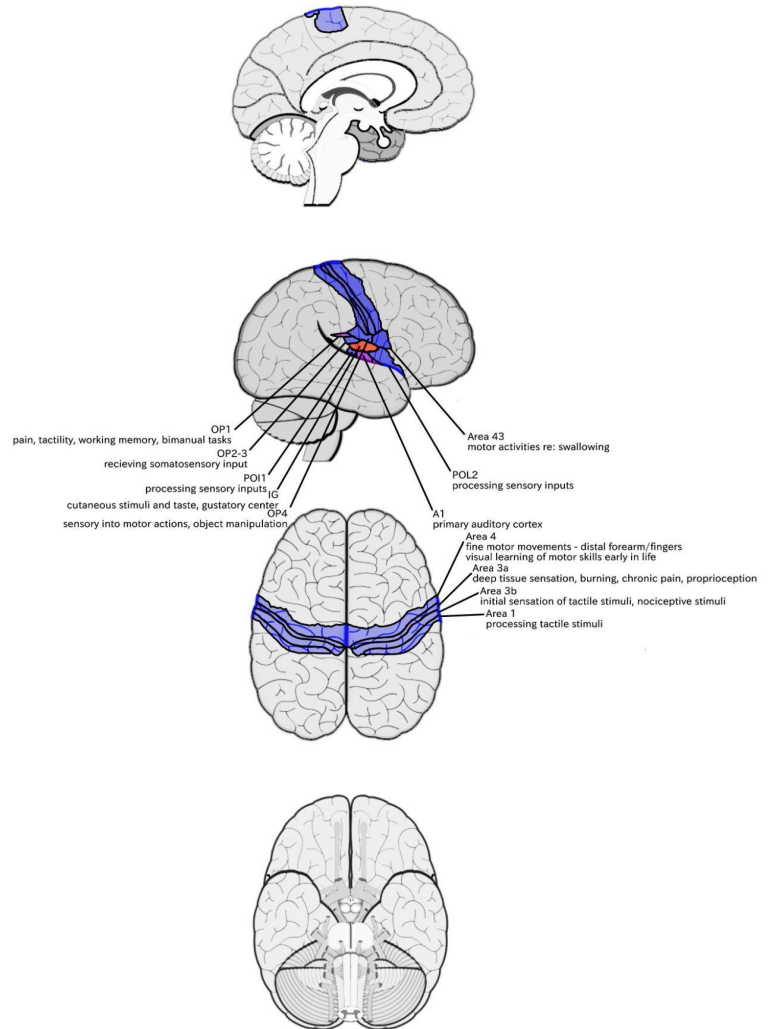
N/A (superior posterior to GB5)

Functionally Connected Acupoints:

GB4 (Area 43)	GB5 (POL2)
GB17 (1/3a/3b/4)	GV20 (1/3a/3b/4)

Structurally Connected Acupoints:

GB5 (A1)



Area OP4 (Operculum 4)

Location:

In the posterior portion of the subcentral gyrus, which is the opercular portion of the sensory and motor cortices. It folds onto the inferior surface to face the Sylvian fissure

Functions:

-The posterior opercular cortex is involved in processes required for sensory motor functions, such as integrating sensory responses into motor actions, and is crucial in tangible object recognition and manipulation

-Differentiated from areas OP1 and OP2-3 based on differences in activity on fMRI during motor and arithmetic tasks.

Functional Connectivity:

Sensory strip: areas 1, 2, 3a, 3b

Motor strip: area 4

Premotor regions: SCEF, FEF, 6mp, 6r, 6d, 6v

Middle cingulate: a24pr, p32pr, 24dd, 24dv, 5mv, 23c

Lateral frontal lobe: area 46

Superior insula and opercular region: IG, 43, OP2-3, OP1, PFcm, FOP1, FOP2, FOP3, FOP4

Lower opercula and Heshl's gyrus: STV, LBelt, PBelt, MBelt, A1, TA2, PI, A4, A5, MI, 52, RI, Pol1, Pol2

Lateral parietal lobe: PF, PFop, PFt, AIP, 7PC, 7AL

Medial occipital lobe: V3

Dorsal visual stream: V6, V6a, V7

Ventral visual stream: FFC

Lateral occipital lobe: LO3, TPOJ2, TPOJ3, MT, MST, FST

White Matter Connections:

Structurally connected to local parcellations. Local short association bundles connect with 43, PFcm, PFop, Ig, LBelt, OP1, OP2-3, OP4, 1, 3a, 3b, RI, Pol1, and Pol2

Traditional Acupoint Correlates:

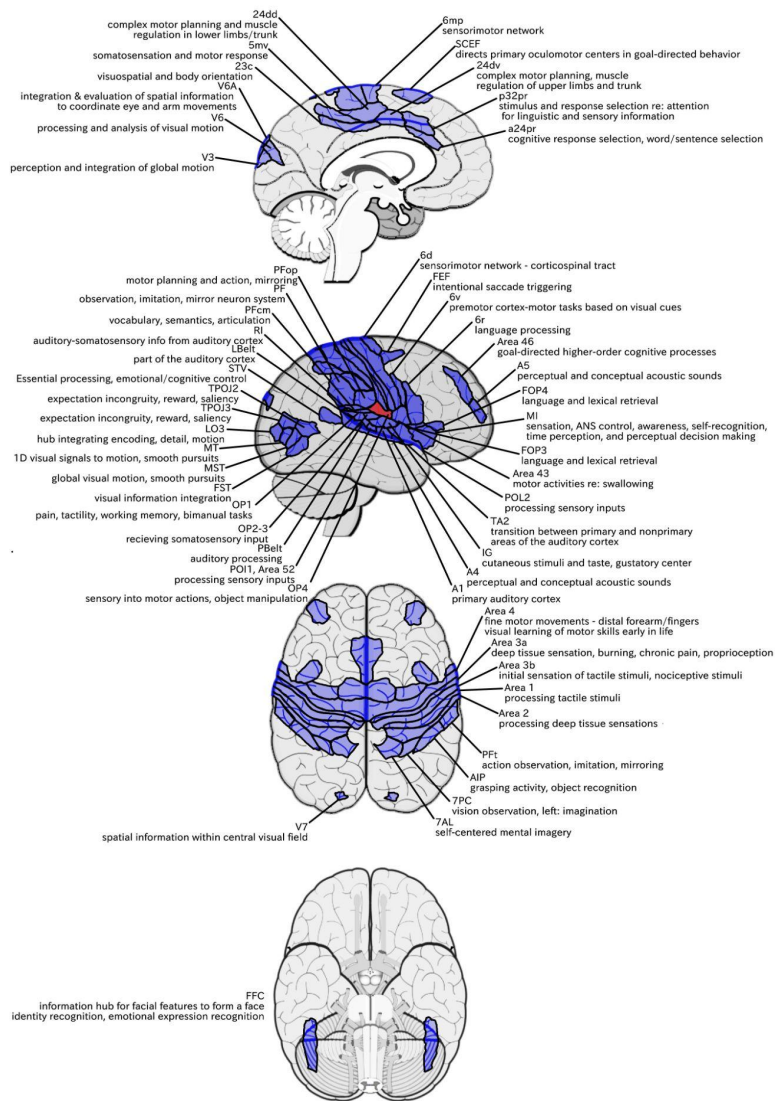
N/A (posterior to GB4, superior to GB6)

Functionally Connected Acupoints:

- | | |
|----------------------|----------------------|
| BL4 (Area 46) | BL6 (6d) |
| BL7 (Area 2/7AL/7PC) | BL8 (V7) |
| GB4 (Area 43/6r) | GB5 (A1/A4/POL2/TA2) |
| GB9 (FST) | GB15 (Area 46) |
| GB16 (FEF) | GB17 (1/2/3a/3b/4) |
| ST8 (6r/6v) | GV20 (1/3a/3b/4) |
| GV21 (SCEF) | |

Structurally Connected Acupoints:

- | | |
|----------------|----------------|
| GB5 (Pol2) | GB17 (1/3a/3b) |
| GV20 (1/3a/3b) | |



Area OP2-3 (Operculum 2-3)

Location:

A small area located in the posterior superior most part of the circular sulcus of the insula.

Functions

These 2 areas are located within the Sylvian fissure and are so closely intertwined that it is difficult to distinguish between them

-The posterior operculum plays a role in receiving input from somatosensory stimuli.

Differentiated from areas Ig and OP1 based on differences in activity on fMRI during motor and arithmetic tasks.

Functional Connectivity:

Sensory strip: area 1, 2, 3a, 3b

Motor strip: area 4

Superior insula opercular regions: IG, 43, OP4, OP1, PFCm

Lower opercula and Heschl's gyrus: PBelt, A4, RI

Lateral parietal lobe: PFop

Medial occipital lobe: V2, V3

Dorsal visual stream: V6, V3a

White Matter Connections:

Structurally connected to anterior insula areas and local parcellations.

Anterior projections from OP2-3 end at anterior insula parcellations MI, AAIC, and PoI2.

Local short association bundles connect with A1, Ig, LBelt, MBelt, and OP4.

Traditional Acupoint Correlates:

N/A (posterior to GB4, superior to GB6)

Functionally Connected Acupoints:

BL7 (Area 2)

GB4 (Area 43)

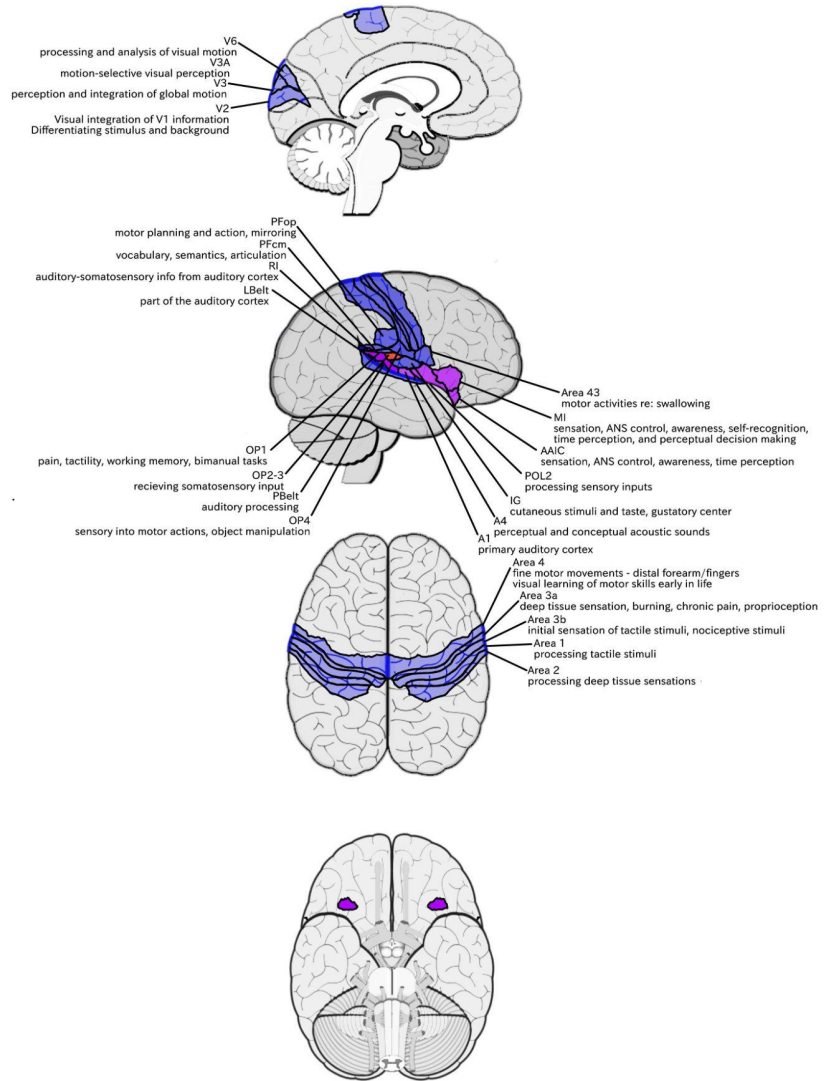
GB5 (A4)

GB17 (1/2/3a/3b/4)

GV20 (1/3a/3b/4)

Structurally Connected Acupoints:

GB5 (A1/PoI2)



Area OP1 (Operculum 1)

Location:

On the undersurface of the anterior portion of the superior supramarginal gyrus.

Functions:

- Somatosensory processing tasks such as recognition of pain, tactile attention, and working memory
- Important role in bimanual task activities.16
- Differentiated from OP2-3 based on decreased levels of fMRI activity during working memory tasks.

Functional Connectivity:

Sensory strip: area 1, 2, 3a, 3b

Motor strip: area 4

Premotor areas: areas 6d, 6v, 6mp

Medial cingulate areas: 5L, 24dd, 24dv, SCEF

Superior insula opercular regions: 43, OP4, OP2-3, FOP2, PFcm

Lower opercula and Heshl's gyrus: PBelt, A4, 52, RI

Lateral parietal lobe: areas 7AL, PFop

Lateral occipital lobe: areas MST, FST

White Matter Connections:

Structurally connected to local parcellations, the anterior insula and the temporal pole. Fibers from OP1 project anteriorly to the anterior insula ending at parcellation MI and continue to the temporal pole at parcellation TGd. Local short association bundles connect with PFcm, RI, OP2-3, OP4, and 43 (Figure 32). There are less consistent connections from OP1 to the temporal pole.

Traditional Acupoint Correlates:

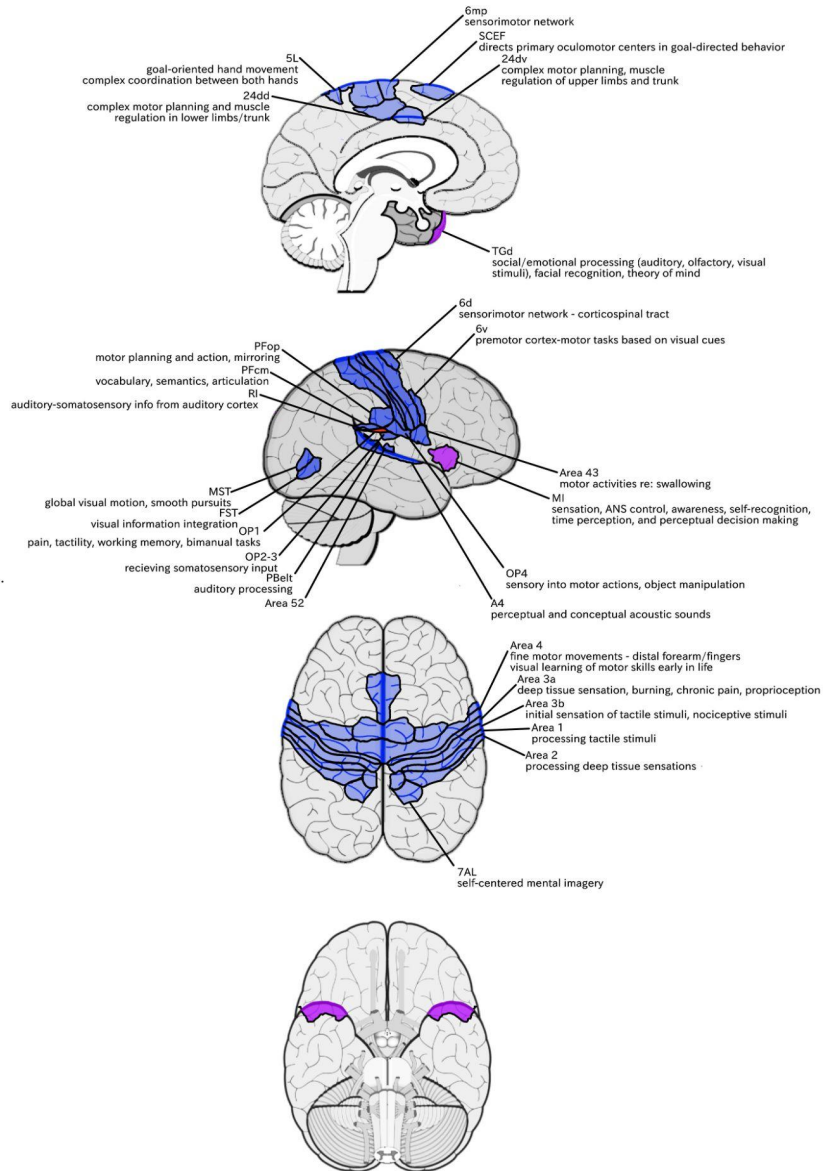
N/A (posterior to GB4, superior to GB6)

Functionally Connected Acupoints:

- | | |
|---------------|--------------------|
| BL6 (6d) | BL7 (Area 2/7AL) |
| GB4 (Area 43) | GB5 (A4) |
| GB9 (FST) | GB17 (1/2/3a/3b/4) |
| ST8 (6v) | GV20 (1/3a/3b/4) |
| GV21 (SCEF) | |

Structurally Connected Acupoints:

N/A



Area PFcm (Parietal F, region cm)

Location:

In the superior portion of the supramarginal gyrus. It is primarily located on the opercular cleft of this part of the gyrus.

Functions:

- The inferior parietal cortex is believed to be important in processing language with regard to language vocabulary, semantics, articulation, and working memory
- Differentiated from area PSL based on lower levels of activity on fMRI during arithmetic and auditory story tasks
- Differentiated from area RI based on higher levels of activity on fMRI during motor cue tasks

Functional Connectivity:

- Sensory strip: area 1, 2, 3a, 3b
- Premotor regions: SCEF, FEF, PEF, 6mp, 6r, 6a, 6v
- Middle cingulate: a24pr, p24pr, p32pr, 24dd, 24dv, 5mv, 23c
- Lateral frontal lobe: areas 9-46d, 46
- Superior insula opercular regions: areas 43, OP4 OP2-3, OP1, FOP1, FOP2, FOP3, FOP4, FOP5
- Lower opercula and Heschl's gyrus: LBelt, PBelt, MBelt, A1, Pl, A4, TA2, MI, STV, 52, RI, Pol1, Pol2
- Temporal lobe: PHT
- Lateral parietal lobe: PF, PFop, PFt, PGp, AIP, 7PC, 7AL
- Medial parietal lobe: 7am, DVT
- Medial occipital lobe: V2, V3
- Dorsal visual stream: V3a
- Ventral visual stream: FFC
- Lateral occipital lobe: LO3, TPOJ1, TPOJ2, TPOJ3, MST, FST

White Matter Connections:

- Structurally connected to portions of the arcuate/SLF.
- Arcuate/SLF connection wraps around the termination of the Sylvian fissure with inferior projections through the temporal lobe to end at TE1a, STSva and TE2a.
- Local short association bundles are connected with OP1, OP4, PFop, PBelt, PF, and RI.
- There are less consistent inferior connections from PFcm in the right hemisphere through the temporal lobe.

Traditional Acupoint Correlates:

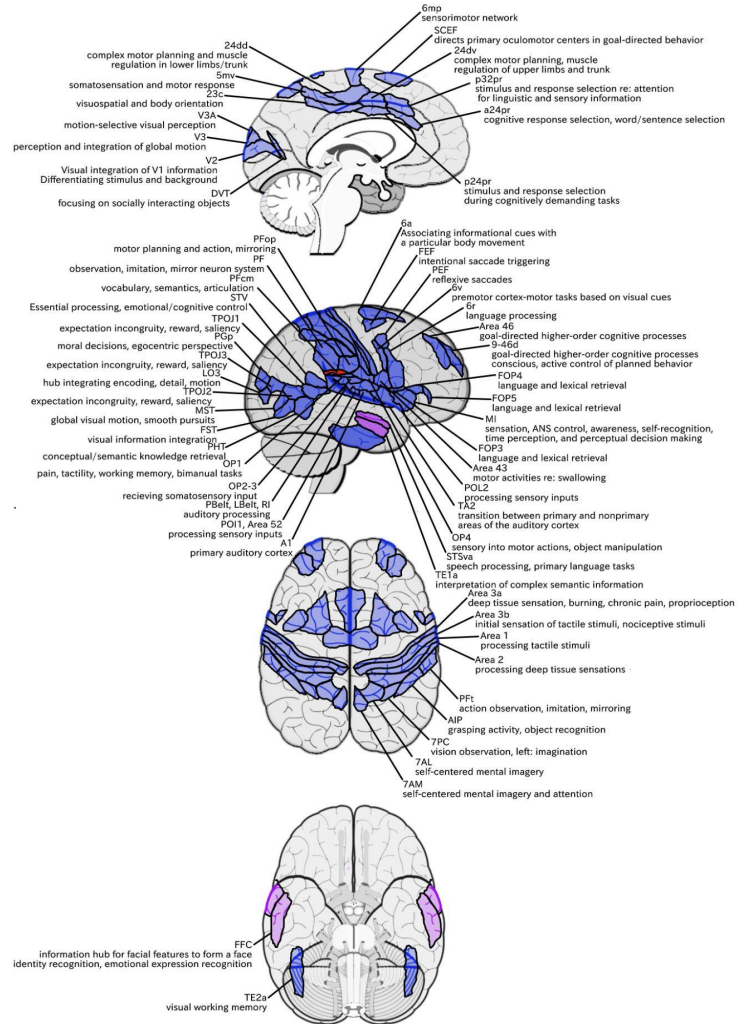
GB5

Functionally Connected Acupoints:

- | | |
|----------------------|------------------|
| BL4 (9-46d/Area 46) | BL6 (6a) |
| BL7 (Area 2/7AL/7PC) | GB4 (Area 43/6r) |
| GB5 (A1/A4/Pol2/TA2) | GB7 (TE2a) |
| GB8 (PHT) | GB9 (PHT/FST) |
| GB15 (Area 46) | GB16 (FEF) |
| GB17 (1/2/3a/3b) | GB18 (AIP) |
| TW22 (TE2a) | ST8 (6r/6v) |
| GV18 (V2) | GV20 (1/3a/3b) |
| GV21 (SCEF) | |

Structurally Connected Acupoints:

GB6 (STSva/TE1a)



Area RI (Retrosomular cortex)

Location:

In the anterior superior to the long gyri of the insula. It is located at the deep termination of Heschl's gyrus at its superomedial termination

Functions:

- Part of the early auditory cortex
- Connected to various somatosensory areas and receives somatosensory input: believed to play a role in receiving auditory-somatosensory communications from the auditory cortex in conjunction with the granular insula

Functional Connectivity:

- Sensory strip: area 1, 2, 3a, 3b
- Motor strip: Area 4
- Premotor regions: FEF, 6mp, 6v
- Superior insula opercular regions: areas 43, OP4 OP2-3, OP1, PFcm
- Lower opercula and Heschl's gyrus: LBelt, PBelt, MBelt, A1, TA2, PI, A4, A5, STV, 52
- Lateral parietal lobe: PFop
- Medial occipital lobe: V2, V3, V4
- Dorsal visual stream: V3a, V3b, V6, V7
- Ventral visual stream: FFC
- Lateral occipital lobe: LO3, TPOJ1, TPOJ2, TPOJ3, MT, MST, V4t, FST

White Matter Connections:

Structurally connected to portions of the arcuate/SLF, anterior insula, and local parcellations. Arcuate/SLF fibers project anterior from RI to inferior frontal gyrus parcellations 44 and 6r. Insular fibers course anterior to insular parcellations POI2 and POI1. Local short association bundles are connected with A1, OP1, OP4, PBelt, and A4

Traditional Acupoint Correlates:

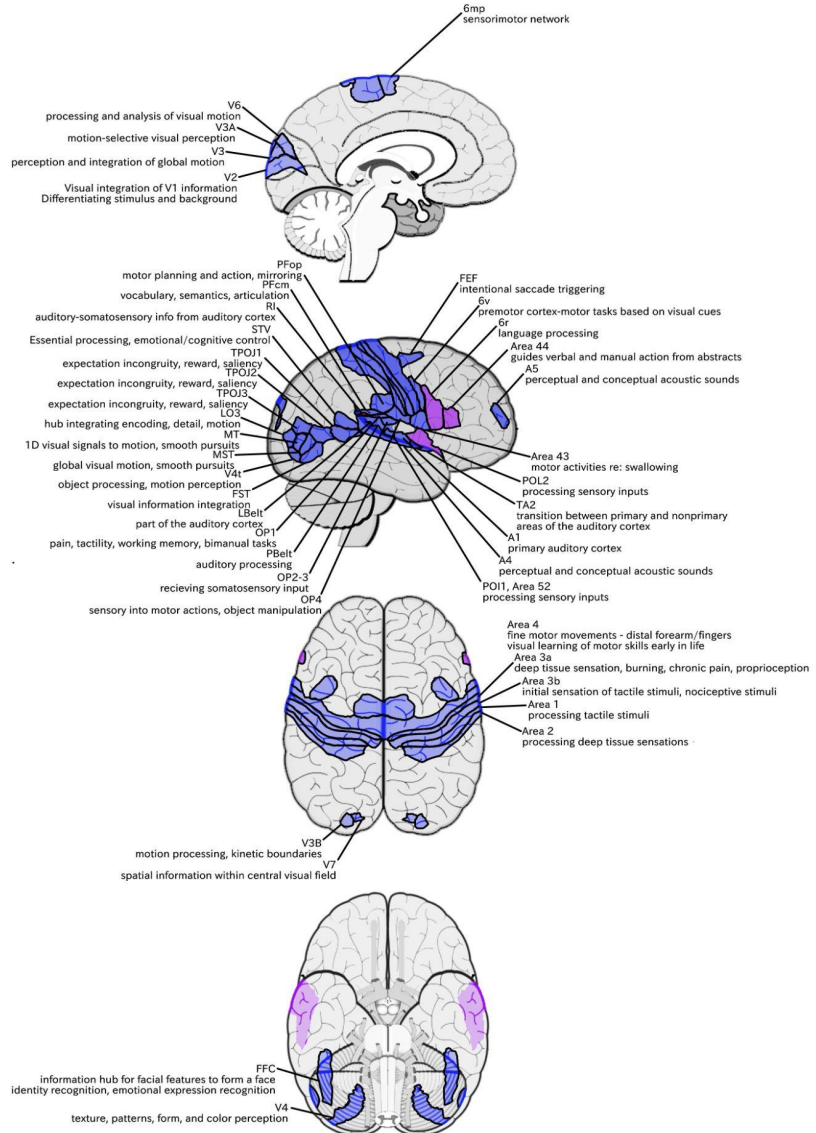
N/A (Superior to GB7)

Functionally Connected Acupoints:

- | | |
|---------------------|--------------------|
| BL7 (Area 2) | BL8 (V3b/V7) |
| GB4 (Area 43) | GB5 (A1/A4/TA2) |
| GB9 (FST) | GB14 (A5) |
| GB16 (FEF) | GB17 (1/2/3a/3b/4) |
| ST8 (6v) | GV18 (V2) |
| GV20 (1, 3a, 3b, 4) | |

Structurally Connected Acupoints:

- | | |
|----------|------------|
| GB4 (6r) | GB5 (POI2) |
| ST8 (6r) | |



Area 52

Location:

In the posterior edge of the lower limb of the circular sulcus of the insula. It lies between Heschl's gyrus and the long gyri of the insula.

Functions:

-An understudied region on the insular-opercular cortex. No specific functional capabilities have been discussed in the literature for this region.

-Parcellated from MBelt based on differences in activity on fMRI during arithmetic and auditory story tasks

Functional Connectivity:

- Sensory strip: area 1, 2, 3a, 3b
- Middle cingulate: 24dv, p32pr, a24pr, 23c, 5mv
- Premotor regions: SCEF, FEF
- Lateral frontal lobe: Area 46
- Superior insula opercular region: 43, IG, FOP1, FOP3, FOP4, OP4, OP1, PFcm
- Lower opercula and Heschl's gyrus: MI, Pol1, Pol2, LBelt, PBelt, MBelt, A1, TA2, PI, A4, STV
- Temporal lobe: PHT
- Parietal lobe: DVT, PF, PFop
- Medial occipital lobe: V2, V3, V4
- Dorsal visual stream: V6, V3a
- Lateral Occipital lobe: TPOJ2

White Matter Connections:

Structurally connected to local parcellations. In some individuals fibers connect to parietal and occipital lobes, however, these tracts are inconsistent.

Local short association bundles connect anteriorly to Pol1 and Pol2, and to surrounding parcellations A1, Ig, MBelt, OP1, OP2-3, Pol1, Pol2, and TA2

Traditional Acupoint Correlates:

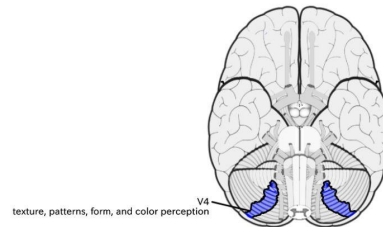
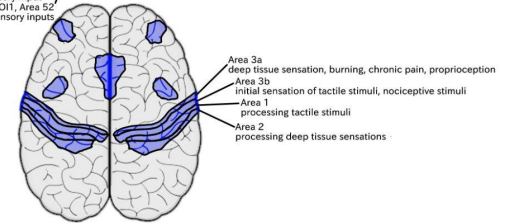
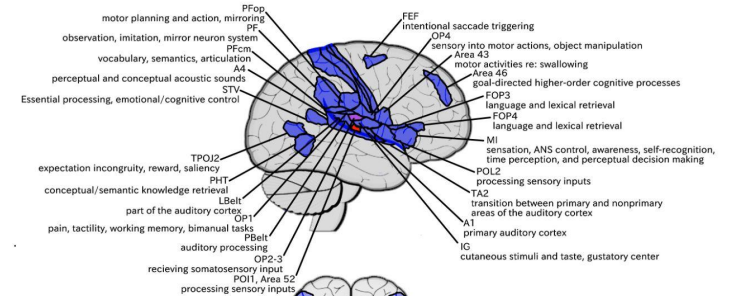
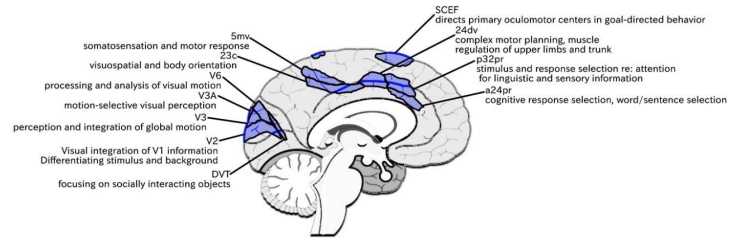
N/A (superior to GB6)

Functionally Connected Acupoints:

- | | |
|------------------|----------------------|
| BL4 (Area 46) | BL7 (Area 2) |
| GB4 (Area 43) | GB5 (A1/A4/POL2/TA2) |
| GB8 (PHT) | GB9 (PHT) |
| GB15 (Area 46) | GB16 (FEF) |
| GB17 (1/2/3a/3b) | GV18 (V2) |
| GV20 (1/3a/3b) | GV21 (SCEF) |

Structurally Connected Acupoints:

GB5 (A1/Pol2/TA2)



Area A1 (Primary Auditory Cortex)

Location:

In superior central portion of Heschl's gyrus

Functions:

- Receives input from the ventral division of the medial geniculate complex
- Contains a tonotopic map which then interprets input received from the cochlea

Functional Connectivity:

Sensory strip: area 2, 3a, 3b
 Superior insula opercular region: 43, PFcm, OP4
 Lower opercula and Heschl's gyrus: A4, MBelt, PBelt, LBelt, RI, 52
 Medial occipital lobe: V1, V2, V3, V4

White Matter Connections:

Structurally connected to the parietal lobe, occipital lobe, inferior frontal gyrus, and local parcellations. Parietal connections are likely portions of the middle longitudinal fasciculus. Fibers from A1 project posterior to parietal parcellations LIPv and 7PC, and to occipital parcellations V3B, V3CD, and V4. Fibers that project anteriorly to the inferior frontal gyrus connect to 44.

Local short association bundles connect with 52, LBelt, MBelt, PBelt, and MI

Traditional Acupoint Correlates:

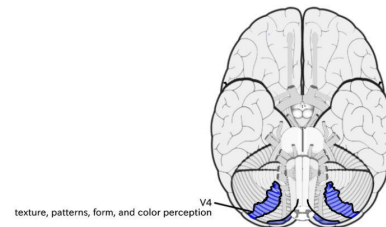
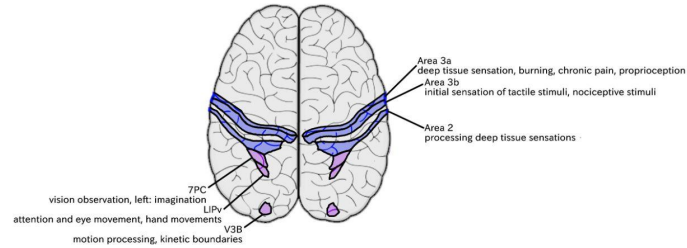
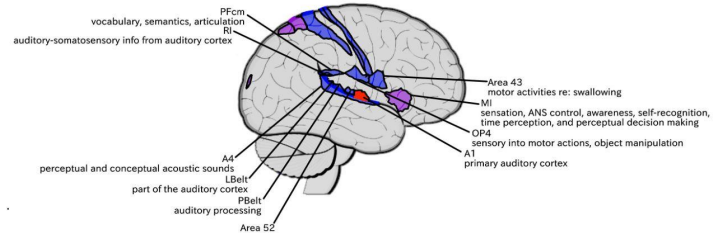
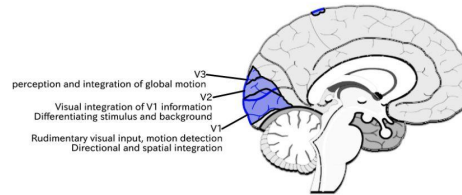
GB5

Functionally Connected Acupoints:

- | | |
|--------------|----------------|
| BL7 (Area 2) | GB4 (Area 43) |
| GB5 (A4) | GB17 (2/3a/3b) |
| GV18 (V1/V2) | GV20 (3a/3b) |

Structurally Connected Acupoints:

- | | |
|-------------|-----------|
| BL7 (7PC) | BL8 (V3b) |
| GB18 (LIPv) | |



Area MBelt (Medial Belt)

Location:

Runs on the medial surfaces of Heschl's gyrus

Functions:

- Newly described area of the brain parcellated from the auditory cortex
- Differentiated from area 52 based on differences in activity on fMRI during arithmetic and auditory story tasks
- Differentiated from PBelt based on differences in activity on fMRI during arithmetic, auditory story, and object recognition tasks

Functional Connectivity:

Sensory strip: area 1, 2, 3a, 3b
 Superior insula opercular region: 43, PFcm, OP4
 Lower opercula and Heschl's gyrus: Pol1, A1, A4, PBelt, LBelt, RI, 52
 Medial occipital lobe: V1, V2, V3, V4

White Matter Connections:

structurally connected with the middle longitudinal fasciculus. Fibers from the middle longitudinal fasciculus project posterior just lateral to the lateral ventricle to occipital and parietal lobes to end at parcellations V3, V3A, V6, V6A, IPS1, and DVT. The majority of short association bundles connect anterior to A4, TA2, STGa, and locally to PBelt and LBelt

Traditional Acupoint Correlates:

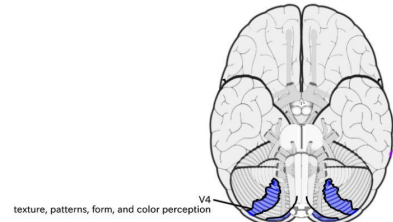
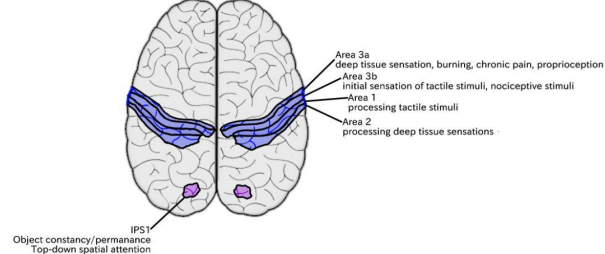
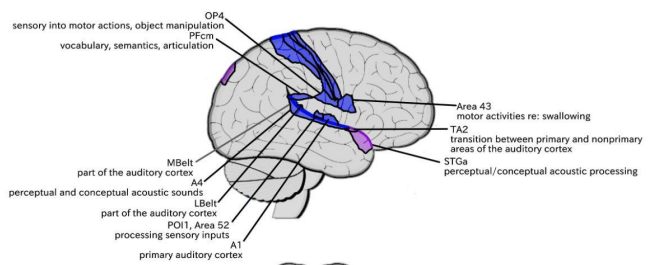
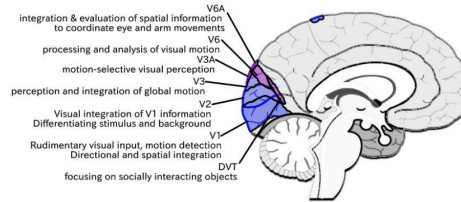
N/A (posterior to GB4, superior to GB7)

Functionally Connected Acupoints:

- BL7 (Area 2)
- GB4 (Area 43)
- GB5 (A1/A4)
- GB17 (1/2/3a/3b)
- GV20 (1/3a/3b)

Structurally Connected Acupoints:

- BL8 (IPS1)
- GB5 (TA2)
- GV19 (V6a)



Area LBelt (Lateral Belt)

Location:

Runs on the lateral surface of Heschl's gyrus

Functions:

- Newly described area of the brain parcellated from the auditory cortex
- Differentiated from area PBelt and RI based on differences in activity on fMRI during arithmetic, auditory story, and social interaction tasks

Functional Connectivity:

- Sensory strip: area 1, 2, 3a, 3b
- Superior insula opercular region: 43, PFCm, OP1, OP4
- Lower opercula and Heschl's gyrus: Pol1, Pol2, A1, A4, A5, MBelt, STV, Ta2, PI, RI, 52
- Medial occipital lobe: V1, V2, V3, V4

White Matter Connections:

Structurally connected to the arcuate/SLF. Arcuate/SLF fibers wrap around the termination of the sylvain fissure ending at inferior frontal gyrus and insula parcellations 44 and MI. Local short association bundles include the temporal terminations of the arcuate/SLF to parcellations MBelt, PBelt, A4, and A5. White matter tracts from LBelt in the right hemisphere have more insula projections from the arcuate/SLF.

Traditional Acupoint Correlates:

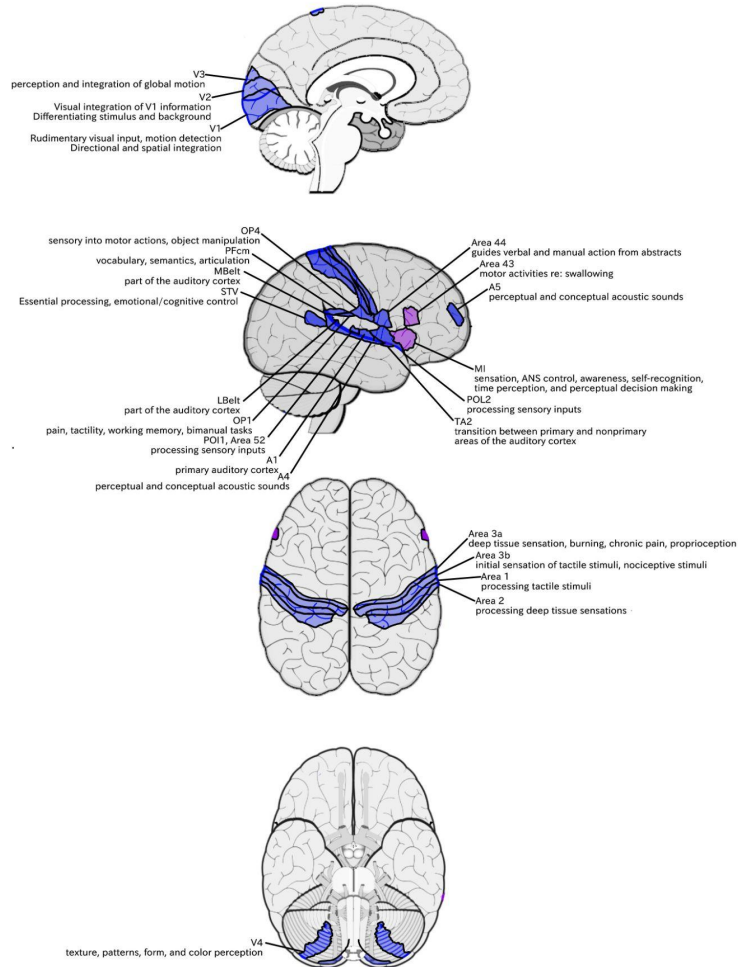
N/A (superior to GB7)

Functionally Connected Acupoints:

- BL7 (Area 2)
- GB4 (Area 43)
- GB5 (A1/A4/POL2/TA2)
- GB14 (A5)
- GB17 (1/2/3a/3b/)
- GV20 (1/3a/3b/)

Structurally Connected Acupoints:

- GB5 (A4)
- GB14 (A5)



Area PBelt (Parabelt Complex)

Location:

on the superior surface of the inferior portion of the supramarginal gyrus. It lies in the small region between the lateral edge of Heschl's gyrus and the opercular cleft of the inferior SMG

Functions:

- Newly described area of the brain parcellated from the auditory cortex
- Differentiated from areas A4 and LBelt based on differences in activity on fMRI during arithmetic, auditory story, and motor cue tasks

Functional Connectivity:

- Sensory strip: area 1, 2, 3a, 3b
- Motor strip: area 4
- Paracingulate areas: 24dd
- Premotor areas: FEF, 6d, 6v, 6mp
- Superior insula opercular region: 43, PFcm, OP1, OP2-3, OP4
- Lower opercula and Heschl's gyrus: Pol1, Pol2, A1, A4, A5, LBelt, MBelt, STV, Ta2, PI, RI, 52
- Parietal Lobe: PFop, 7PC
- Medial occipital lobe: V1, V2, V3, V4
- Dorsal visual stream: V6, V6a, V7, V3a, V3b
- Ventral visual stream: V8, FFC, Pit, VVC
- Lateral occipital lobe: LO2, LO3, V3cd, FST, MT, MST, V4t, TOPJ1, TPOJ2

White Matter Connections:

Structurally connected to the middle longitudinal fasciculus and arcuate/SLF. Arcuate/SLF fibers wrap around the termination of the Sylvian fissure to end at the inferior frontal gyrus at parcellation 45 and FOP5. Fibers from the middle longitudinal fasciculus project posterior to occipital and parietal lobes to end at parcellations MIP, LIPv, and IP1. Local short association bundles connect with A1, LBelt, MBelt, PFcm, PSL, A4, A5, and TPOJ1

Traditional Acupoint Correlates:

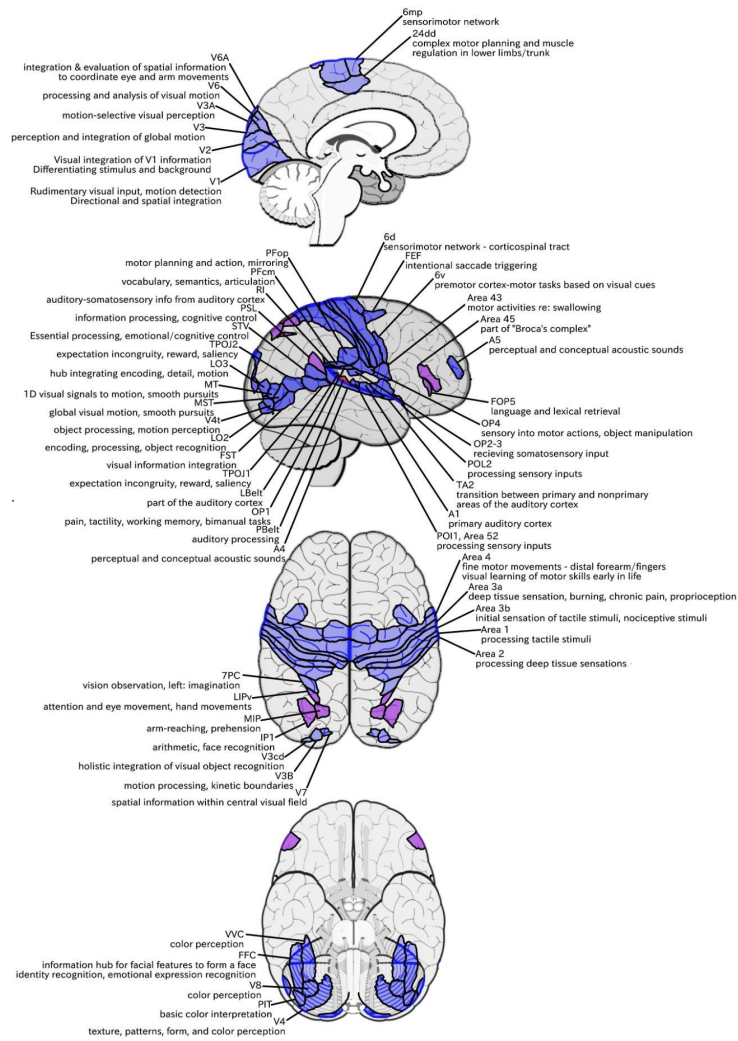
N/A (superior to GB7)

Functionally Connected Acupoints:

- BL6 (6d)
- BL8 (V3b/V7)
- GB5 (A1/A4/Pol2/TA2)
- GB9 (FST)
- GB16 (FEF)
- ST8 (6v)
- GV20 (1/3a/3b/4)
- BL7 (Area 2/7PC)
- GB4 (Area 43)
- GB7 (TE2p)
- GB14 (A5)
- GB17 (1/2/3a/3b/4)
- GV18 (V1/V2)

Structurally Connected Acupoints:

- BL8 (IP1)
- GB14 (A5)
- GB5 (A1/A4)
- GB18 (IP1/LIPv)



Area PSL (Perisylvian Language Area)

Location:

In the supramarginal gyrus at the apex of the posterior Sylvian fissure, in the lower portion of this posterior part of the SMG

Functions:

-Thought to play a role in higher cognitive functions such as essential information processing, motional control, and control of cognitive functions.

-The temporo-parieto-occipital junction (TPOJ) is also believed to be associated with special cognitive functions such as generation of language, visuospatial attention, and assimilation of audiovisual information

-Differentiated from areas PFcm and RI based on differences in fMRI activity during arithmetic and auditory story tasks.

Functional Connectivity:

Paracingulate areas: SCEF

Premotor areas: 55b

Lateral frontal lobe: IFJa, 9-46d, 44, 45

Lower opercula and Heschl's gyrus: A5, STV

Temporal lobe: STSda, STSdp, STSvp

Medial occipital lobe: V2, V3, V4

Dorsal visual stream: V6, V6a, V7, V3a, V3b

Ventral visual stream: V8, FFC, Pit, VVC

Lateral occipital lobe: TPOJ1

White Matter Connections:

Structurally connected to the arcuate/SLF. Arcuate/SLF fibers project anteriorly from PSL above the insula to end at 6r, and inferiorly from PSL through the temporal lobe to end at TE1a, STSdp, STSva, and STSvp. Local short association bundles connect with PBelt, STV, RI, A5, and PF

Traditional Acupoint Correlates:

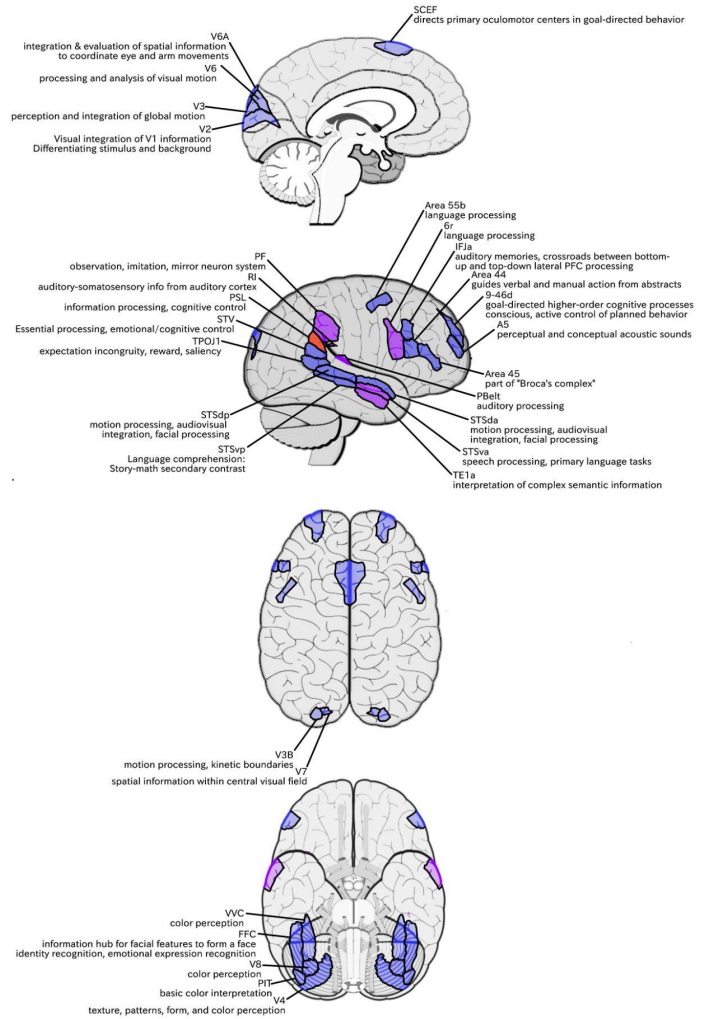
N/A (superior to GB8)

Functionally Connected Acupoints:

BL4 (9-46d)	BL8 (V3b/V7)
GB6 (STSda/STSdp/STSvp)	GB14 (A5)
GB16 (55b)	GV18 (V2)
GV21 (SCEF)	

Structurally Connected Acupoints:

GB4 (6r)	GB6 (STSva/TE1a)
ST8 (6r)	



Area STV (Superior Temporal Visual Area)

Location:

On the inferior posterior, and straddles across the posterior part of the superior temporal sulcus to have its posterior aspect on the anterior angular gyrus.

Functions:

- TPOJ plays a role in higher cognitive functions such as essential information processing, emotional control, and control of cognitive functions
- TPOJ associated with special human cognitive functions such as generation of language, visuospatial attention, and assimilation of audiovisual information.
- Differentiated from area STV based on differences in fMRI activity during arithmetic and auditory story tasks

Functional Connectivity:

- Sensory strip: area 1, 2, 3a, 3b
- Motor strip: area 4
- Premotor area: FEF, 55b
- Superior opercular region: area 43, PFCm, OP4
- Lower opercula and Heschl's gyrus: PSL, A4, A5, PBelt, LBelt, Pol1, PI, RI, 52
- Temporal lobe: STSda, STSdp
- Parietal lobe: PCV
- Medial occipital lobe: V2, V3, V4
- Dorsal visual stream: V6
- Ventral visual stream: FFC
- Lateral occipital lobe: TPOJ2, TPOJ3

White Matter Connections:

Structurally connected to the temporal portion of the arcuate/SLF. Fibers from the STV course through the temporal lobe to end at middle temporal gyrus parcellations TE1a, STSdp, STSda, STSva, and STSvp. Local short association fibers connect with PSL, STV, PGI, PFm, and PFCm

Traditional Acupoint Correlates:

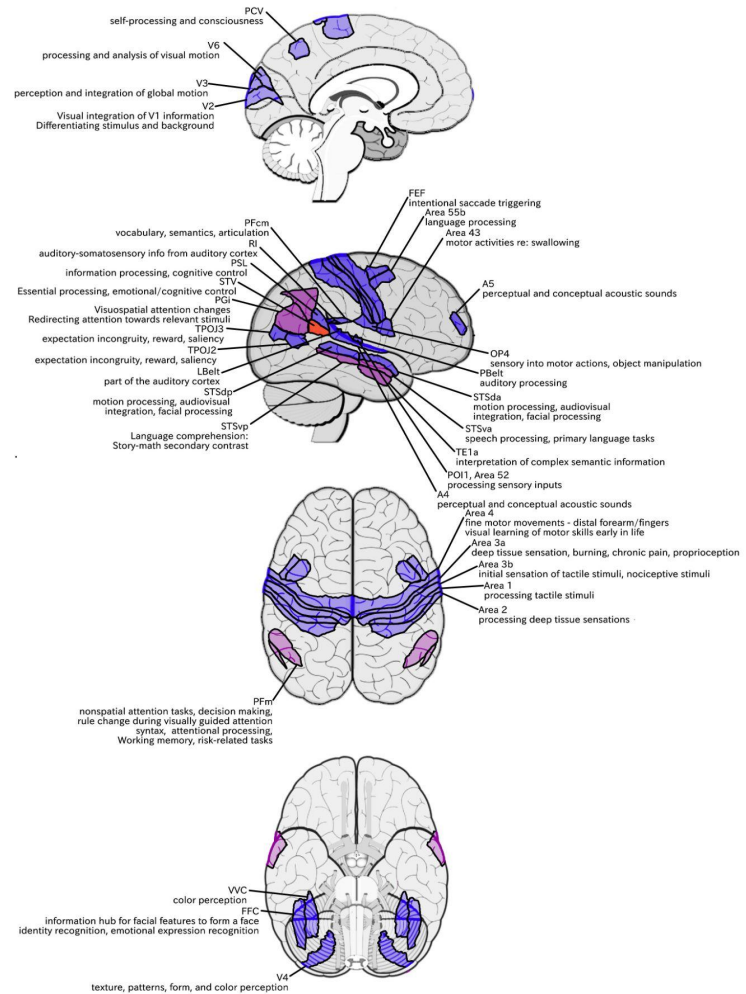
N/A (inferior to GB4, anterior to GB6)

Functionally Connected Acupoints:

GB6 (STSda/STSdp) GB14 (A5)

Structurally Connected Acupoints:

GB5 (TA2) GV18 (V1/V2)



Area Pol1 (Posterior Insula 1)

Location:

On the posterior long gyrus of the insula

Functions:

- The posterior insula is anatomically and functionally connected with primary and secondary somatosensory and motor cortices, and takes part in processing various sensory inputs
- Differentiated from area Pol2 based on differences in fMRI activity during motor-based tasks

Functional Connectivity:

Sensory strip: area 2

Premotor area: SCEF, FEF, 6a, 6ma, 6r

Lateral frontal lobe: IFSa, 46, 9-46d

Medial frontal lobe: 5mv, 23c, 24dv, a24pr, p24pr, p32pr

Superior opercular region: OP4, 43, PFCm, FOP1, FOP2, FOP3, FOP4, FOP5

Lower opercula and Heschl's gyrus: Pir, 52, PI, MI, MBelt, PBelt, A4, STV, Pol2

Lateral parietal lobe: 7AL, PF, PGp, PPop, PFT

Medial parietal lobe: DVT, 7am

Temporal lobe: PHT

Medial occipital lobe: V2, V3, V4

Dorsal visual stream: V3a, V6

Lateral occipital lobe: FST

White Matter Connections:

Structurally connected to the occipital and parietal lobe through the middle longitudinal fasciculus and to local parcellations. Fibers from Pol1 project posterior deep to the supramarginal gyrus ending at parietal and occipital parcellations 7AL, 7PC V3A, V3B, V6, and V6A. The majority of local short association bundles project posteriorly to parcellations Pol1, Ig, MBelt, PBelt, FOP2, OP2-3, OP1, and MI

Traditional Acupoint Correlates:

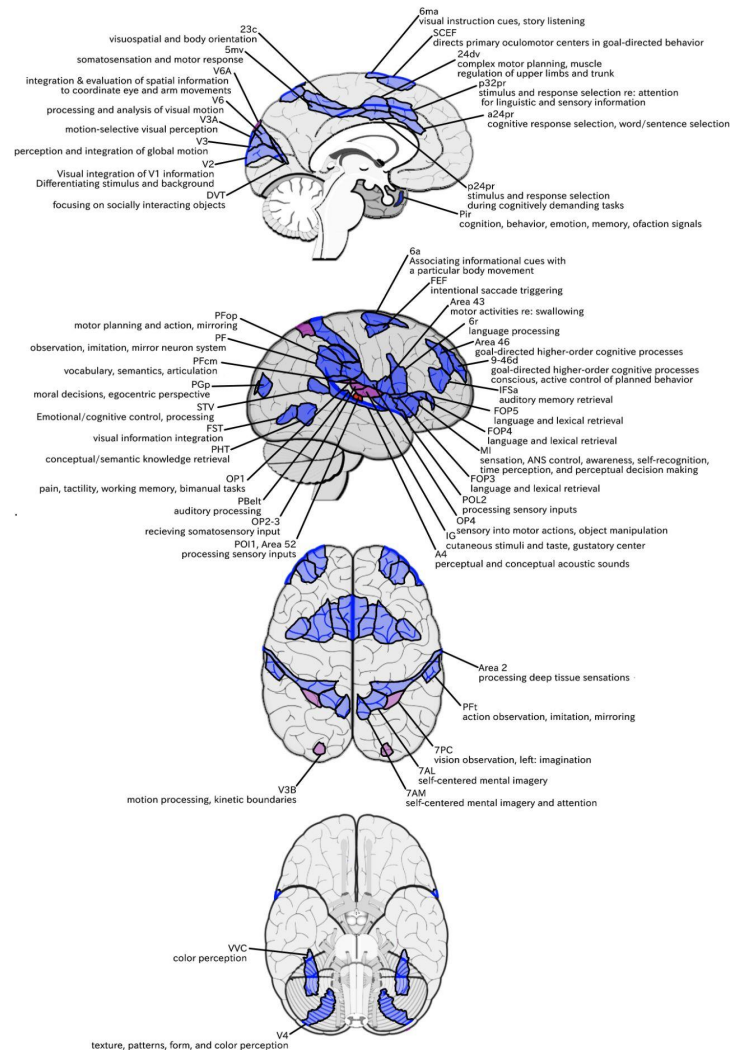
N/A (posterior to GB5)

Functionally Connected Acupoints:

- | | |
|---------------------|-------------------|
| BL4 (Area 46/9-46d) | BL6 (6a) |
| BL7 (Area 2) | GB4 (Area 43, 6r) |
| GB5 (A4/Pol2) | GB8 (PHT) |
| GB9 (PHT/FST) | GB15 (Area 46) |
| GB16 (FEF) | GB17 (Area 2) |
| ST8 (6r) | GV18 (V2) |
| GV21 (SCEF) | |

Structurally Connected Acupoints:

BL8 (V3b)



Area PoI2 (Posterior Insula 2)

Location:

On the anterior of the 2 long insular gyri

Functions:

- The posterior insula is anatomically and functionally connected with primary and secondary somatosensory and motor cortices and takes part in processing various sensory inputs
- Differentiated from area AAIC based on differences in fMRI activity during motor-based tasks

Functional Connectivity:

- Sensory strip: area 2, 3a
- Premotor area: SCEF, FEF, 6a, 6ma, 6v, 6r
- Lateral frontal lobe: IFSa, 46
- Medial frontal lobe: 5mv, 23c, 24dv, a24pr, p24pr, p32pr
- Superior opercular region: OP4, 43, IG, PFcm, FOP1, FOP2, FOP3, FOP4, FOP5
- Lower opercula and Heschl's gyrus: Pir, 52, PI, MI, PBelt, A4, AAIC, Pol1
- Lateral parietal lobe: 7AL, AIP, LIPd, PF, PGp, PFop, PFT
- Medial parietal lobe: 7am
- Temporal lobe: TE2p, PHT
- Medial occipital lobe: V2
- Dorsal visual stream: V6
- Lateral occipital lobe: TPOJ2, PH, FST

White Matter Connections:

Structurally connected to the entorhinal cortex, local parcellations, and to the parietal lobe through the middle longitudinal fasciculus. Fibers from PoI2 project posterior deep to the supramarginal gyrus ending at parietal parcellations 2, 7PC, 7PL, LIPd, LIPv, and VIP. PoI2 has inferior projections to PeEc of the entorhinal cortex and TGd of the temporal pole. The majority of local short association bundles project posteriorly to parcellations Pol1, Ig, MBelt, PBelt, FOP2, OP2-3, OP1, and MI. Fibers from PoI2 in the right hemisphere have less consistent projections to the entorhinal cortex.

Traditional Acupoint Correlates:

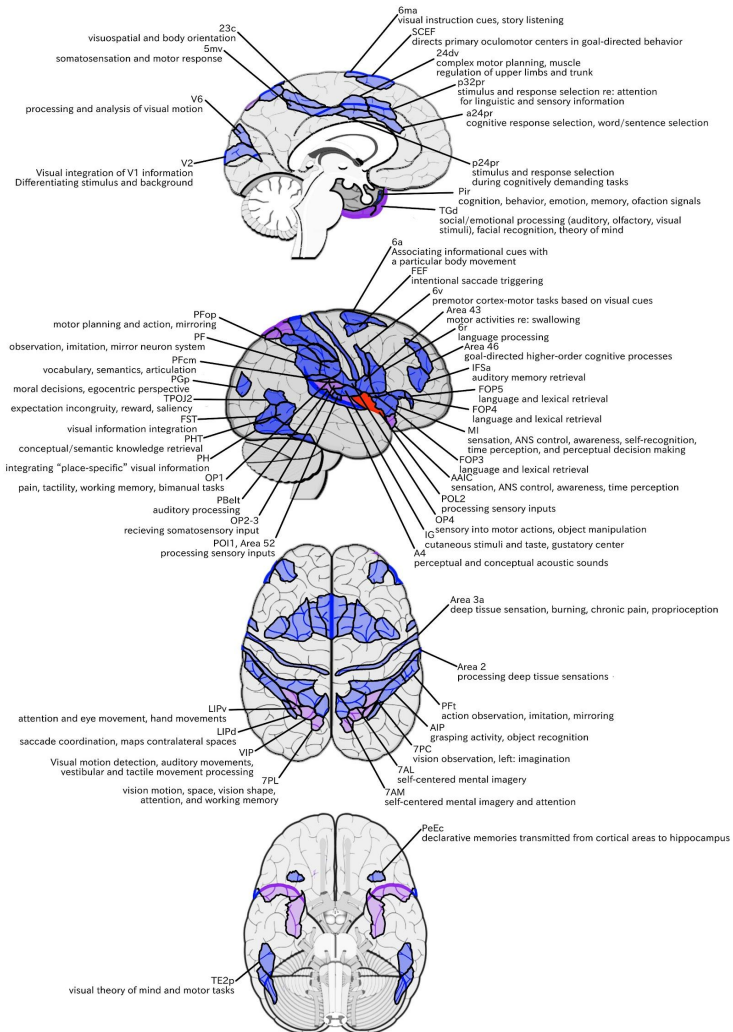
GB5

Functionally Connected Acupoints:

- | | |
|----------------|-------------------|
| BL4 (Area 46) | BL6 (6a) |
| BL7 (Area 2) | GB4 (Area 43, 6r) |
| GB5 (A4) | GB7 (TE2p) |
| GB8 (PHT) | GB9 (PH/PHT/FST) |
| GB15 (Area 46) | GB16 (FEF) |
| GB17 (2/3a) | GB18 (AIP) |
| TW20 (TE2p) | ST8 (6r/6v) |
| GV18 (V2) | GV20 (3a) |
| GV21 (SCEF) | |

Structurally Connected Acupoints:

- | | |
|----------|-------------|
| GB5 (A1) | GB18 (LIPv) |
|----------|-------------|



Area PI (Parainsular Area)

Location:

In the anterior inferior circular sulcus of the insula

Functions:

- Role in internal regulatory processes and in the processing of somatosensory, visual, and motor stimuli
- Activated when the body assesses its physiological condition when individuals are subject to heat

Functional Connectivity:

Insula opercular regions: Pol1, Pol2, MBelt, PBelt, 43, PFm, RI, 52, FOP4, OP4, TA2, STGa
 Lateral parietal lobe: PFop

White Matter Connections:

Structurally connected to the temporal pole, occipital lobe, and local parcellations. This area's structural connectivity is difficult to distinguish due to the proximity of the area to the extreme and external capsule. Occipital connections project through the temporal lobe to end at parcellation V1. Connections to the temporal pole course inferiorly to end at area TGd. Local short association bundles connect with Pol1, Pol2, Ig, and OP2-3

Traditional Acupoint Correlates:

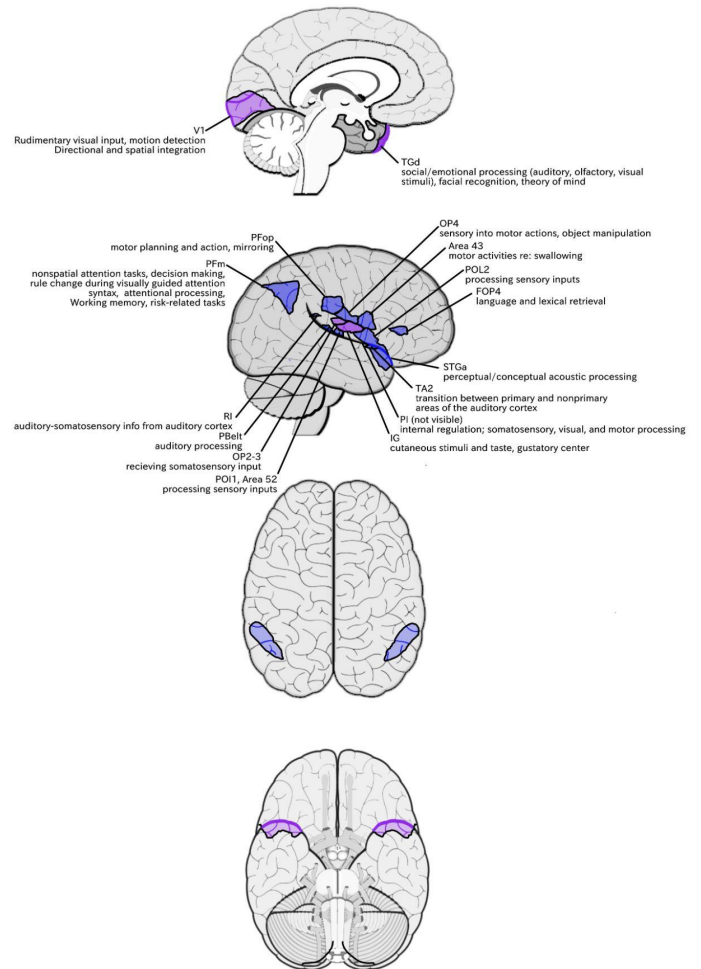
GB5

Functionally Connected Acupoints:

GB4 (Area 43, 6r) GB5 (Pol2/TA2)
 GB18 (PFm)

Structurally Connected Acupoints:

GV18 (V1)



Area A4 (Auditory Area 4)

Location:

On the superior face of the posterior half of the STG. It occupies this portion of the gyrus posterior to its junction with Heschl's gyrus

Functions:

- Processes perceptual and conceptual acoustic sounds.
- Differentiated from area TA2 based on differences in fMRI activity during arithmetic and auditory story tasks

Functional Connectivity:

- Sensory strip: area 1, 2, 3a, 3b
- Motor strip: area 4
- Premotor region: SCEF, FEF, 6mp, 6v
- Medial frontal lobe: 5m, 5l, 24dd
- Superior insula opercular region: area 43, PFcm, OP4, OP2-3, OP1
- Lower opercula and Heschl's gyrus: STV, 52, RI, TA2, PI, MI, PBelt, MBelt, LBelt, A1, A5, Pol1, Pol2
- Lateral parietal lobe: 7PC, PFop
- Medial occipital lobe: V2, V3, V4
- Dorsal visual stream: V6, V6a, V7, V3a
- Ventral visual stream: V8, FFC, VVC, PIT
- Lateral occipital lobe: TPOJ1, TPOJ2, LO1, LO3, MT, MST, PH, FST

White Matter Connections:

Structurally connected to the arcuate/SLF and middle longitudinal fasciculus. Arcuate/SLF fibers wrap around the termination of the Sylvian fissure from A4 to inferior frontal gyrus parcellations 45 and FOP5. The middle longitudinal fasciculus projects posterior from A4 to run just lateral to the lateral ventricle ending at occipital and parietal lobe parcellations V2, V3, V6, V7, MIP, LIPd, LIPv, and IP1. Local short association bundles connect with A5, PFop, RI, STV, LBelt, MBelt, PBelt, and PFcm

Traditional Acupoint Correlates:

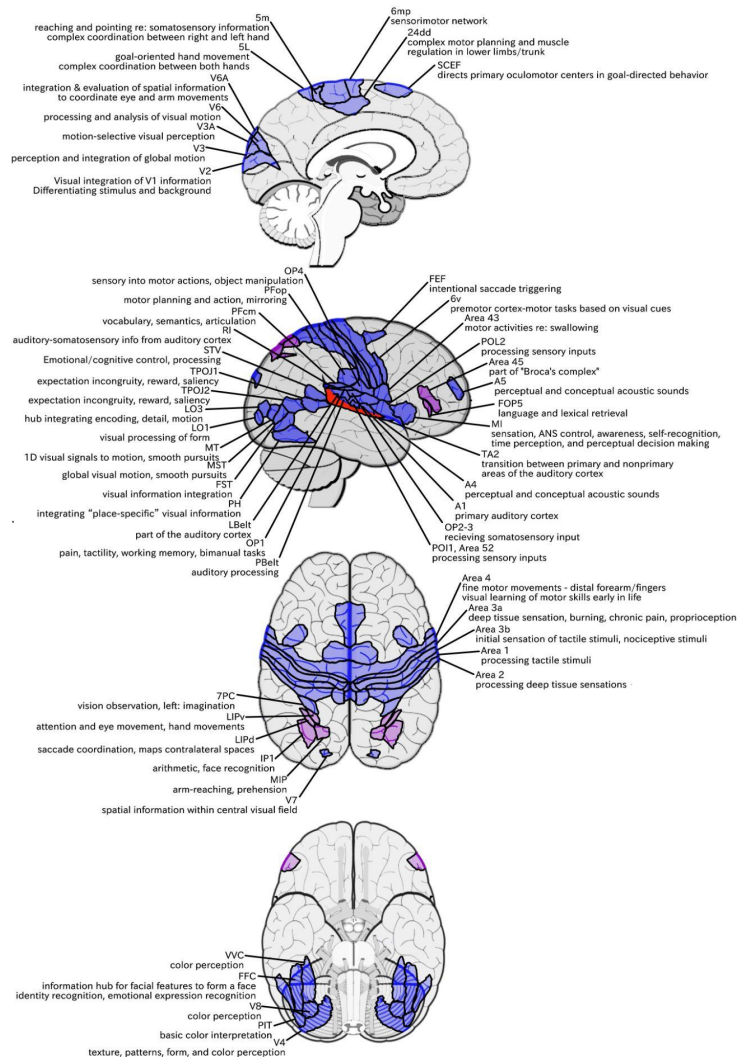
GB5

Functionally Connected Acupoints:

- | | |
|------------------|--------------------|
| BL7 (Area 2/7PC) | BL8 (V7) |
| GB4 (Area 43) | GB5 (A1/POL2/TA2) |
| GB9 (PH/FST) | GB14 (A5) |
| GB16 (FEF) | GB17 (1/2/3a/3b/4) |
| ST8 (6v) | GV18 (V2) |
| GV20 (1/3a/3b/4) | GV21 (SCEF) |

Structurally Connected Acupoints:

- | | |
|-----------------|-----------|
| BL8 (IP1) | GB14 (A5) |
| GB18 (LIPv/IP1) | GV18 (V2) |



Area A5 (Auditory Area 5)

Location:

A thin anterior-posterior running strip on the superior lateral surface of the posterior portions of the STG.

Functions:

- Processes perceptual and conceptual acoustic sounds
- Differentiated from area TA2 based on differences in fMRI activity during arithmetic, auditory story, and social interaction tasks

Functional Connectivity:

Sensory strip: area 1, 2, 3a, 3b

Motor strip: area 4

Superior insula opercular region: OP4

Lower opercula and Heschl's gyrus: STV, RI, STGa, TA2, PBelt, LBelt, A4, PSL

Temporal lobe: STSda, STSdp

Ventral visual stream: FFC

Lateral occipital lobe: TPOJ1, MT

White Matter Connections:

Structurally connected to the arcuate/SLF and middle longitudinal fasciculus. Arcuate/SLF fibers wrap around the termination of the Sylvian fissure from A5 to inferior frontal parcellation 44. The middle longitudinal fasciculus projects posterior from A5 to run just lateral to the lateral ventricle to end at intraparietal sulcus parcellations V6 and V6A. Local short association bundles connect with A4, STSda, and STSdp

Traditional Acupoint Correlates:

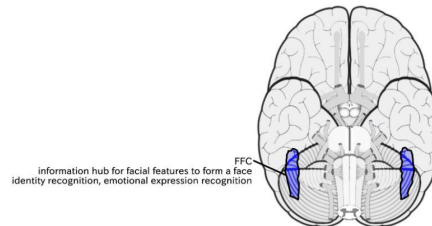
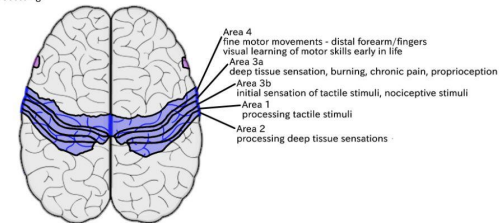
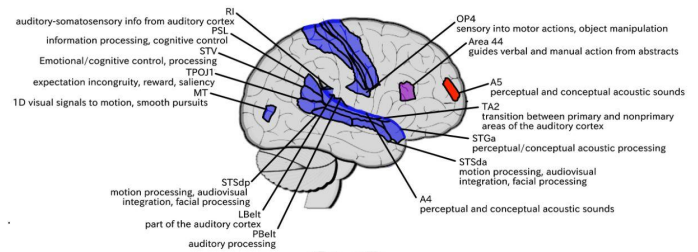
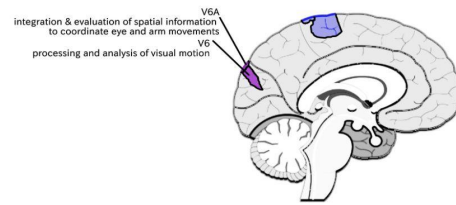
GB14

Functionally Connected Acupoints:

BL7 (Area 2) GB5 (A4/TA2)
 GB6 (STSda/STSdp) GB17 (1/2/3a/3b/4)
 GV20 (1/3a/3b/4)

Structurally Connected Acupoints:

GB5 (A4) GB6 (STSda/STSdp)
 GB14 (A5) GV19 (V6a)



Area STGa (Superior Temporal Gyrus A)

Location:

On the anterior superior surface of the superior temporal gyrus with no extension onto the lateral surface.

Functions:

- Processes perceptual and conceptual acoustic sounds
- Differentiated from areas TGd and PI based on differences in fMRI activity during arithmetic, auditory story, and social interaction tasks

Functional Connectivity:

Insula opercular region: A5, PI

Temporal lobe: TGd, STSda, STSdp

White Matter Connections:

Structurally connected to the inferior longitudinal fasciculus and local parcellations. Inferior longitudinal fasciculus fibers project posterior from STGa coursing through the temporal lobe to end at occipital lobe parcellations V1, V2, V3, V3A, and V3CD. Local short association bundles connect with TA2 and STSda

Traditional Acupoint Correlates:

N/A (~ $\frac{1}{3}$ distance from GB5->GB1)

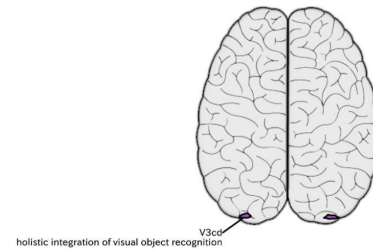
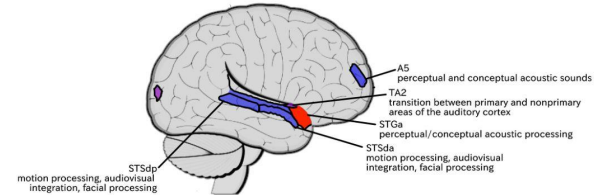
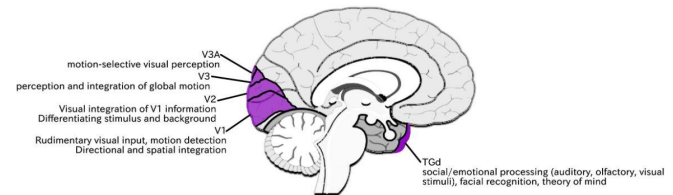
Functionally Connected Acupoints:

GB5 (A4) GB6 (STSda/STSdp)

GB14 (A5)

Structurally Connected Acupoints:

GB5 (TA2) GV18 (V1/V2)



Area TA2 (Temporal Region A, Area 2)

Location:

A region of the medial planum polare anterior to the anterolateral extent of Heschl's gyrus

Functions:

-Believed to be a transition zone between nonprimary and primary auditory areas of the auditory cortex

-Activated when perceiving auditory stimuli, as each hemisphere recognizes different complex acoustic stimulation

Left auditory cortex: processing quick changes in speech

Right auditory cortex: activating more with the tone of

speech

-Shares features with cortical sensory areas, but contains fewer granular cells than the primary auditory cortex

Functional Connectivity:

Sensory strip: area 1, 2, 3a, 3b

Motor strip: area 4

Insula opercular region: OP4, 43, PFcm, A4, A5, MBelt, PBelt, LBelt, RI, PI

Medial occipital lobe: V2, V3, V4

Dorsal visual stream: V6

White Matter Connections:

Structurally connected to the inferior longitudinal fasciculus and local parcellations. Inferior longitudinal fasciculus fibers project posterior from TA2 coursing through the temporal lobe to end at occipital lobe parcellations V1, V2, V3, and V6A. Local short association fibers connect with 52, MBelt, A5, PI, and STGa

Traditional Acupoint Correlates:

GB5

Functionally Connected Acupoints:

BL7 (Area 2)	GB4 (Area 43)
GB5 (A4)	GB14 (A5)
GB17 (1/2/3a/3b/4)	GV18 (V2)
GV20 (1, 3a, 3b, 4)	

Structurally Connected Acupoints:

GV18 (V1)

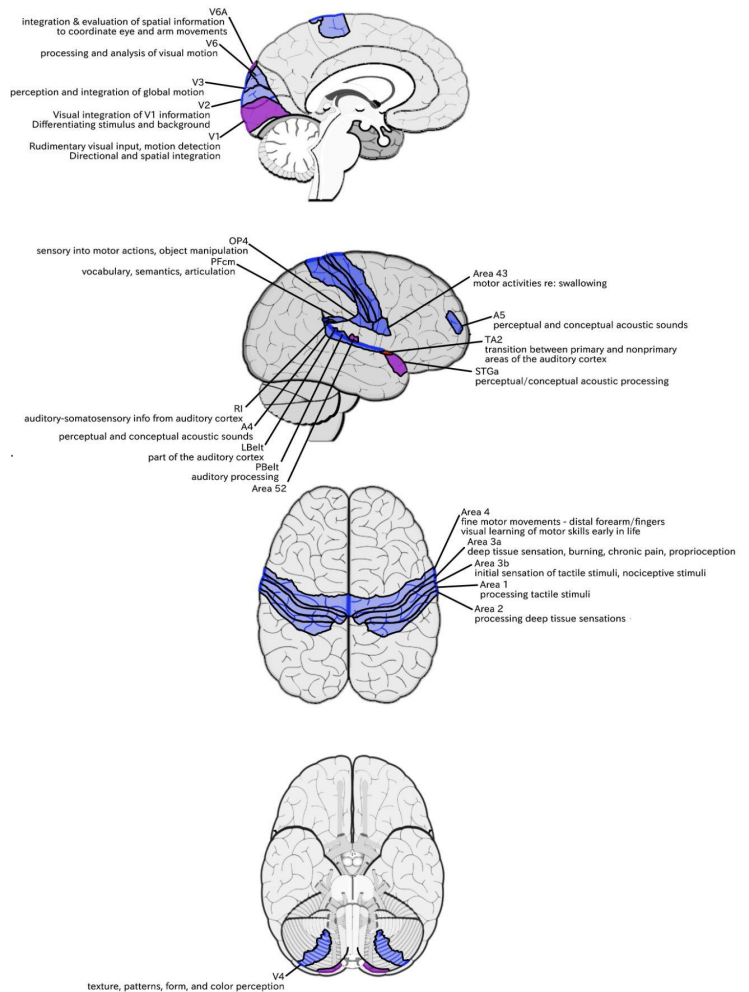


Table 1 Traditional Acupuncture Point Associations With The Insula and Opercular Cortex

Acupoint	Cortical Parcellation Correlation
BL3	8Ad, 8BL, 9P
BL4	8Ad, 8AV, 9-46d, Area 46
BL5	8Ad, 8Av, i6-8
BL6	6a, 6d
BL7	Area 2, 7AL, 7PC
BL8	IP0, IP1, IPS1, V3b, V7
GB4	Area 43, 6r
GB5	A1, A4, POL2, TA2
GB6	STSds, STSdp, STSva, STSvp, TE1a, TE1p
GB7	TE1m, TE1p, TE2a, TE2p
GB8	PHT, TE1p
GB9	PH, PHT, FST
GB13	p9-46v
GB14	a10p, a47r, p10p, A5
GB15	8AD, 8AV, 8C, p9-46v, Area 46
GB16	55b, FEF
GB17	Area 1, 2, 3a, 3b, 4
GB18	AIP, Lipv, PFm, PGs, IP1
ST8	6r, 6v, IFJp, PEF
TW20	TE2p
TW22	TE2a
GV18	V1, V2
GV19	7PM, V6a
GV20	Area 1, 3a, 3b, 4, 5m
GV21	SCEF, SFL
GV22	8BL
GV23	9m, 10d
GV24	10d
Yintang	10v

Conflict of Interest Statement

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.