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Novel Model of Auditory Sensory Processing: is There Fast Gating Stream That Directly Links Primary Auditory Areas To Executive Prefrontal Cortex?

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Abstract

The generally accepted model of sensory processing of visual and auditory stimuli assumes two major parallel processing streams, ventral and dorsal, which comprise functionally and anatomically distinct but probably interacting processes in which a ventral stream supports stimulus identification, and a dorsal stream is involved with recognizing the stimulus spatial location and sensory-motor integration functions. However, recent studies suggest the existence of third, very fast sensory processing pathway, a gating stream that directly links primary auditory cortices to executive prefrontal cortex within the first 50 milliseconds after presentation of a stimulus.Gating stream propagate sensory gating phenomenon, which serves as a basic protective mechanism preventing irrelevant, repeated information from recurrent sensory processing.The goal of the present paper is to emerge the novel ‘three-stream’ model of auditory processing, introducing the fast sensory processing stream, i.e., gating stream, alongside well-affirmed dorsal and ventral sensory processing pathways.

Keywords: Sensory Processing; Dorsal Stream; Ventral Stream; Gating Stream; Auditory Processing.

Abbreviations: STG: Superior Temporal Gyri; MTG: Middle Temporal Gyrus; ITG: Inferior Temporal Gyrus; IFG: Inferior Frontal Gyrus; STS: Superior Temporal Sulcus; IPL: Inferior Parietal Lobule; SFS: Superior Frontal Sulcus; MEG: Magneto Encephalography.

Introduction

Processing of external sensory stimuli is a fundamental feature of any living system. Sensory processing has an integral role in interaction and adaptation, by which individual navigates through a stimulus-loaded environment. Although intensive research of sensory processing accumulated a large body of knowledge over the years, the key-issues such as where, when and how the human neural system process, integrate and influenceenvironmentalinformation’s to produce personal experiences and an image of reality, are still not well understand. The widely accepted two-stream hypothesis reveals dual pathways of processing for visual and auditory stimulus: the ‘where’ and ‘what’ pathways or dorsal and ventral processing streams respectively [1-7]. It has been demonstrated that these two pathways comprise functionally and anatomically distinct but probably interacting processes in which a ventral stream supports stimulus recognition and identification, and a dorsal stream is involved with recognizing the stimulus spatial location relative to the subject along with sensory-motor integration functions [2,8]. It is suggested that dorsal and ventral pathways have hierarchical processing architecture by which feed forward connections conveying sensory information from “the bottom to the top” but also they provide infrastructure for strong feedback connections returning processed information from “the top to the bottom” [9-11].

However, the functional mapping of cortical sensory processing pathways remains an ongoing quest. Recent Neuroimaging studies investigating the patio-temporal characteristic of the early auditory sensory processing provide strong evidences of existence the third, very fast sensory processing stream which directly links execute prefrontal brain centers with primary sensory areas [12-16]. This novel processing stream supports the phenomenon well-known as sensory gating. Sensory gating is the core feature of a neural system to automatically adjust its response to subsequent stimuli: in gating-out mode selectively suppress its responses to irrelevant or repeated information, while in gating-in mode enhance responses on task-relevant or novel sensory information. The goal of the present paper is to introduce the novel ‘triple-stream’ model of auditory processing, Introducing the third sensory processing stream, i.e., gating stream, that directly connects execute prefrontal cortex to primary auditory cortices, alongside well-affirmed dorsal and ventral sensory processing pathways (Figure 1).

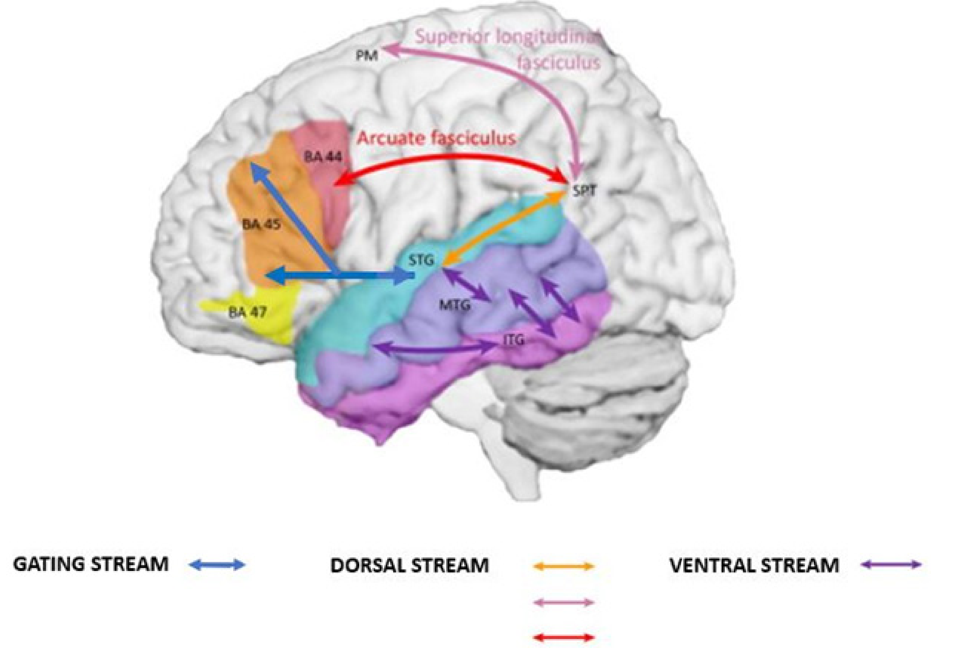

Figure 1: Triple-stream model of auditory sensory processing.Auditory sensory processing system, from primary auditory area (STG), diverges into three processing streams, a gating stream, which is in charge of producing the gating phenomena, ventral stream, which is involved in mapping auditory stimulus onto meaning, and a dorsal stream, which is involved in mapping auditory stimulus onto articulators-based representations.

Discussion

Neurophysiology of auditory processing

Numerous neuron imaging studies conducted in humans have revealed different cortical areas underlying auditory sensory processing, generally dividing these functions along a posterior medial-anterior lateral axis [6,17-19]. the early cortical stages of auditory processing start at the primary auditory-responsive fields in bilateral superior temporal gyri (STG). This auditory sensory processing system, then diverges into three processing streams, a gating stream, which is in charge of producing the gating phenomena, ventral stream, which is involved in mapping auditory stimulus onto meaning, and a dorsal stream, which is involved in mapping auditory stimulus onto articulator-based representations [9,20] as shown on (Figure 1). Gating stream process sensory information very fast, within the first 50 ms after stimulus presentation, while both ventral and dorsal processing are slower, extending through 200 ms post-stimulus, completing perception [9,12].

Ventral auditory processing stream

Studies investigating the structure and organization of the auditory cortex have revealed that the ventral (what) stream projects ventral-laterally through the cortex spreading along an anterior-lateral-temporal to inferior-frontal axis. Ventral stream involves the portions of the middle temporal gyrus (MTG) and the posterior inferior temporal sulcus where the complex sounds are converted into somatic words. Afterwards, inferior temporal gyrus (ITG) process distributed semantic information's into conceptual representation through two-step combinatorial sets ending at inferior frontal gyrus (IFG) [18,21].

Dorsal auditory processing stream

The dorsal (where) stream projects from primary auditory areas across inferior parietal regions to the more posterior regions of the prefrontal compared with ventral stream projections [22]. The dorsal stream projects dorso-posteriorly toward the parietal lobe and finally to frontal regions comprising the posterior STG, posterior superior temporal sulcus (STS) and the inferior parietal lobule (IPL) [21,23-25]. The critical dorsal region is placed within the posterior parts of Sylvian fissure at the boundary between the parietal and temporal lobes [26,27]. The dorsal streamappears to end at the lateral prefrontal cortex (PFC), and the superior frontal sulcus (SFS). Together, these regions comprise a distributed network for spatial auditory processing [28-30].

Gating auditory processing stream

Magneto encephalography (MEG) is non-invasive Neuroimaging technique with high both temporal and spatial resolutions thus enabling direct and real-time investigation of human sensory processing [31-33]. Recent MEG studies suggest the existence of third, very fast sensory processing pathway, a gating stream that directly links primary auditory cortices to executive PFC within the first 50 milliseconds after presentation of an auditory stimulus [12-15]. Contrary to the hierarchical model of sensory processing, Josef Golubic and colleagues demonstrated direct top-down modulator role of PFC on the primary auditory areas as mechanism underlying pre-perceptive auditory sensory gating [12].

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In addition, their novel results provide evidences that fast gating stream as effect of attention diverge at prefrontal cortex intodorso-lateral (dlPFC) and medial prefrontal (mPFC) line, demonstrating the regional specificity of PFC due to differences in which the same information is processed [13,15]. As shown on Fig.1. Passive listening of tone provokes the activation of dlPFC, while both, voluntary directing attention or automatic, stimuli driven, initiation of attention involvement in sensory processing activate mPFCduring sensory gating [12-15]. The fast gating stream enables PFC to apply top-down attention control during the earliest stage of sensory processing but also rapid initiation of bottom-up stimulus driven attention involvement, demonstrating that that the both top–bottom and bottom-up connections are critical for attention and working memory [13,15,16,33].

Conclusion

Novel data challenge actual dual stream model of sensory processing, suggesting the triple stream model, with one fast and two concurrent parallel anatomical pathways for processing of sensory information. Here is introduced the triple sensory loop concept that assumes three major parallel processing streams which connect primary auditory cortices with executive frontal areas: direct, fast and pre-perceptive gating stream and two long streams, directed above (dorsal) or below (ventral) the Sylvian fissure [20]. According to this concept, fast gating stream serve as a basic protective mechanism preventing irrelevant, repeated information from recurrent sensory processing, while at the same time enable recognition of relevant environment inputs that are essential for survival. This fast connection enable executive PFC to apply top-down attention control during the earliest stage of sensory processing but also rapid initiation of bottom-up stimulus driven attention involvement. Slower ventral and dorsal pathways both have ability to process information about the intrinsic properties of stimuli and their spatial characteristic, but the transformations performed upon those features differ across streams [34-36].

References

1. Ungerleider LG, Mishkin M (1982) Analysis of visual behavior. (eds Ingle, DJ, Goodale MA, Mansfield, R JW) MIT Press, Cambridge, Massachusetts 4(3): 549-586.
2. Milner AD, Goodale MA (1995) The visual brain in action. Oxford Univ. Press, Oxford.
3. Rauschecker JP (1998) Cortical processing of complex sounds. Curr Opinm Neurobiol 8(4): 516-521.
4. Bushara KO, Weeks RA, Ishii K, Catalan MJ, Tian B, et al. (1999) Modality-specific frontal and parietal areas for auditory and visual spatial localization in humans. Nat Neurosci 2(8): 759-66.
5. Recanzone GH (2000) Spatial processing in the auditory cortex of the macaque monkey. Proceedings of the National Academy of Sciences of the United States of America 97(22): 11829-11835.
6. Maeder PP, Meuli RA, Adriani M, Bellmann A, Fornari E, et al. (2001) Distinct pathways involved in sound recognition and localization: A human fMRI study. Neuroimage 14(4): 802-816.
7. Recanzone GH (2008) Representation of con-specific vocalizations in the core and belt areas of the auditory cortex in the alert macaque monkey. Journal of Neuroscience 28(49): 13184-13193.
8. Hickok G, Poeppel, D (2004) Dorsal and ventral streams: A framework for understanding aspects of the functional anatomy of language. Cognition 92(1-2): 67-99.
9. Fuster JM (1997) Network memory. Trends Neurosci 20: 451-459.
10. Mesulam MM (1998) From sensation to cognition. Brain 121(6): 1013-1052.
11. Huntenburg JM, Bazin PL, Margulies DS (2017) Large-scale gradients in human cortical organization. Trends Cogn Sci 22(1): 21-31.
12. Josef Golubic S, Aine CJ, Stephen JM, Adair JC, Knoefel JE, et al. (2014) Modulatory role of the prefrontal generator within the auditory M50 network. Neuroimage 92: 120-131.
13. Josef Golubic S, Susac A, Huonker R, Haueisen J, Supek S (2014) Early Attentional Modulation of the Neural Network Evoked with the Auditory Paired-click Paradigm: An MEG Study. Procedia Social and Behavioral Sciences 126: 195-196.
14. Josef Golubic S, Aine CJ, Stephen JM, Adair JC, Knoefel JE, et al. (2017) MEG biomarker of Alzheimer's disease: Absence of a prefrontal generator during auditory sensory gating. Human brain mapping 38(10): 5180-5194.
15. Josef Golubic S, Jurasic MJ, Susac A, Huonker R, Gotz T, et al. (2018) Attention modulates topology and dynamics of auditory sensory gating. Forthcoming; In submission Neuroimage.
16. Josef Golubić S (2018) Topological biomarker of Alzheimers disease in Biomarker (edited by: Ghousia Begum).
17. Ahveninen J, Huang S, Nummenmaa A, Belliveau JW, Hung AY, et al. (2013) Evidence for distinct human auditory cortex regions for sound location versus identity processing. Nat Commun 4: 2585.
18. Alain C, Arnott SR, Hevenor S, Graham S, Grady CL (2001) What and where in the human auditory system. Proc Natl AcadSci USA 98(21): 12301-12306.
19. Hart HC, Palmer AR, Hall DA (2004) Different areas of human non-primary auditory cortex are activated by sounds with spatial and nonspatial properties. Hum Brain Mapp 21(3)178-190.
20. Josef Golubic S (2014) Neurodynamics of normal and pathology-changed sensory processing. Dissertation. Faculty of Science, University of Zagreb, Zagreb, USA, pp. 1-175.
21. Arnott SR, Binns MA, Grady CL, Alain C (2004) Assessing the auditory dual-pathway model in humans. Neuroimage 22(1): 401-408.
22. Skipper JI, Nusbaum HC, Small SL (2006) Lending a helping hand to hearing: Another motor theory of speech perception. Action to Language via the Mirror 250-286.
23. Harrington IA, Stecker GC, Macpherson EA, Middlebrooks JC (2008) Spatial sensitivity of neurons in the anterior, posterior, and primary fields of cat auditory cortex. Hearing Research 240(1-2): 22-41.
24. Rinne T, Ala Salomaki H, Stecker GC, Patynen J, Lokki T (2014) Processing of spatial sounds in human auditory cortex during visual, discrimination and 2-back tasks. Front Neurosci 8: 220.
25. Stecker GC, Harrington IA, Middlebrooks JC (2005) Location Coding by Opponent Neural Populations in the Auditory Cortex. PLoS Biol 3(3): e78.
26. Buchsbaum B, Hickok G, Humphries C. (2001) Role of left posterior superior temporal gyrus in phonological processing for perception and production. Cognitive Science 25: 663-678.

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27. Hickok G, Buchsbaum B, Humphries C, Muftuler T (2003) Auditory-motor interaction revealed by fMRI: speech, music, and working memory in area Spt. J Cogn Neurosci 15(5): 673-682.

28. Ahveninen J, Jaaskelainen IP, Raij T, Bonmassar G, Devore S, et al. (2006) Task-modulated "what" and "where" pathways in human auditory cortex. Proc Natl AcadSci USA 103(39): 14608-14613.

29. Bizley JK, Cohen YE (2013) The what, where and how of auditory-object perception. Nat Rev Neurosci 14(10): 693-707.

30. Krumbholz K, Eickhoff SB, Fink GR (2007) Feature- and object-based attentional modulation in the human auditory "where" pathway. J CognNeurosci 19(10): 1721-1733.

31. Josef Golubic S, Susac A, Grilj V, Ranken D, Huonker R, et al. (2011) Size matters: MEG empirical and simulation study on source localization of the earliest visual activity in the occipital cortex. Med Biol Eng Comput 49(5): 545-554.

32. Supek S, Stingl K, Josef Golubic S, Susac A, Ranken D (2006) Optimal spatio-temporal matrix subdivision for cortical neurodynamics estimation. In: Proceedings of the 15th International conference on biomagnetism (BIOMAG 2006) Vancouver pp.180-181.

33. Supek Selma, Josef Golubić, Sanja Bryant, Jennifer Donahue, Chris Montaño, et al. (2008) Neuromagnetic auditory activity reflects differences between normal aging, MCI and AD subjects: An oddball study. Proceedings of the 16th International Conference on Biomagnetism (BIOMAG 2008) / Kakigi, K ;Yokosawa, K ; Kuriki, S. (ur.).- Sapporo: Hokkaido University Press, pp.171-173.

34. Weiller C, Bormann T, Saur D, Musso M, Rijntjes M (2011) How the ventral pathway got lost: and what its recovery might mean. Brain Lang 118(1-2): 29-39.

35. Rijntjes M, Weiller C, Bormann T, Musso M (2012) The dual loop model: its relation to language and other modalities. Front Evol Neurosci 4:9.

36. Lambon Ralph MA (2014) Neurocognitive insights on conceptual knowledge and its breakdown. Philos Trans R Soc Lond B Biol Sci 369(1634): 20120392.

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