Neural correlates underlying musical semantic memory

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Abstract:

Numerous functional imaging studies have examined the neural basis of semantic memory mainly using verbal and visuo-spatial materials. Yet, musical material allows an original way to explore semantic memory processes. We used PET imaging to determine the neural substrates that underlie musical semantic memory using different tasks and stimuli. The results of 3 PET studies revealed a greater involvement of the anterior part of the temporal lobe. Concerning clinical observations and our neuroimaging data, the musical lexicon (and most widely musical semantic memory) appears to be sustained by a temporo-prefrontal cerebral network involving right and left cerebral regions.

Keywords: semantic memory, music, PET, temporal lobe.

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INTRODUCTION

Starting from the neuropsychological dissociations observed in clinical cases, Peretz proposed a cognitive model of the access to musical lexicon[1]. In this model, melodic and temporal dimensions contribute to the recognition of a musical tune. This model postulates an independence between a verbal lexicon and a pure musical lexicon (although privileged relations exist). The musical lexicon has different levels of representations and can be largely assimilated as a musical semantic memory. In 2003, using functional neuroimaging (see Method), we have compared semantic and episodic memory processes for music[2]. Using the distinction between Semantic and Episodic memory proposed by Tulving[3], we defined musical semantic memory as corresponding to "well-known" melodies without retrieving the spatial or temporal circumstances of learning. Semantic memory enables us to identify or to have a strong feeling of knowing for familiar songs or melodies. We may name the tune (composer or performer) or just have the capacity to hum or whistle the subsequent notes of a melody. Episodic memory for musical information could refer (in an experimental situation) to the ability to recognize a musical excerpt (whether familiar or not) for which the spatio-temporal context surrounding its former encounter (i.e., when, where, and how) can be recalled. Overall, our results show two distinct networks of activation: in the left hemisphere for musical semantic memory retrieval, and mainly in the right one for episodic retrieval. Our left-lateralized activations in the semantic musical memory task replicated what we previously obtained using a judgment of musical familiarity task[5] (see Method). Although, the musical stimuli were selected to avoid easy association with words, we cannot exclude possible interference with musical semantic memory processes (e.g., searching the melody's title or composer's name). Thus, we constructed another protocol with a semantic musical congruent task to limit verbalization processes.

METHOD

In these 3 PET studies, we used PET H_2O^{15} to analyze healthy young non-musical men. All were right-handed and had normal hearing. Because musicians may develop specific cognitive strategies due to their musical expertise, we purposely studied non-musical subjects (without academic knowledge and ability to read music, common listeners with a homogenous musical culture), so that our findings could be generalized to most people. Throughout the studies, all participants were never informed that the musical component of

semantic memory were being specifically studied, in order to avoid that participants try to memorize many melodies before the experiment and thought that was a musical culture test.

In our first study[4], we construct a Familiarity task where the participants (N= 9) had to judge if short (2.5s) monophonic melodic sequences were familiar or not. Melodic sequences were the same for this task and for perceptive Pitch, Rhythm and Timbre, which serve as reference tasks.

In our second study[2], a Semantic task was proposed where the participants (N=12) had to decide if monophonic sequences (5s) were familiar or not. In the Reference tasks, participants had to judge if the last two notes of familiar or non familiar melodies were the same or not.

In the present study[5], a Semantic congruence memory task was proposed. The participants (N=12) heard the first part of familiar melodies and had to decide if the second part matched the first (5s). In the reference task, subjects must decide if two short unknown melodies are the same or not. Some familiar sequences are the same than in the second study[2].

All familiar stimuli of these studies were selected on the basis of pilot studies. Familiar melodies selected were judged to be very familiar by a least 70% of subjects, and non familiar melodies were judged to be unwknown by more than 80% of participants. These melodies were taken from both the classical and modern repertoires, but we excluded popular songs and songs with lyrics to limit verbal associations. All the melodies were recorded with a flute timbre sound (exept for the first study, where two-sound spectrum of a oboe were used).

All perceptive reference tasks were designed to entail decisional and motor processes similar to the cognitive processes already activated in the semantic memory tasks.

Data were analyzed using SPM. An analysis of covariance was performed on a voxel-by-voxel basis. The significant cut-off was set at $p< 0.001$, uncorrected for multiple comparisons.

RESULTS & DISCUSSION

Our data revealed, with different musical semantic memory tasks and different stimuli, a similar pattern of brain activity, left-lateralized, including mainly the inferior frontal and the anterior part of the superior temporal gyri (Fig 1).

Do these cerebral areas specifically support the musical lexicon? In light of neuroimaging studies, these areas appear to be implicated in cognitive tasks different from music. Notably, left-lateralized activations are usually detected for semantic memory tasks using mainly verbal stimuli[6]. However, concerning the left inferior frontal area, similar findings were obtained for music[7,8]. Plailly et al.[8] also showed activation of this area during feeling of

familiarity for musical, but also for odors items. Concerning the superior temporal pole, the activation of this region was previously shown in the retrieval of specific or unique semantic information[9,10], abstract concepts[11], personal semantic information[12], person identity information[13], famous faces or buildings[14] and emotional material[15]. The role of the anterior part of the left temporal region in the processing of specific or unique semantic information has been reported in several studies[9,13]. On the basis of these findings, we suggest that each familiar melody could refer to a unique semantic representation, comparable to face identity[14]. In other words, a particular melody is not shared by other items of the same category and, as postulated by Sacks[16], memories for music are particularly related to earlier personal events, encounters or states of mind evoked by the familiar melody, which is rarely the case for verbal semantic information, like familiar proverbs. Thus, the anterior part of the temporal lobe would be much more activated for the access to concepts having a personal semantic weight, whereas the access to general linguistic concepts (semantic memory) would more largely imply the posterior part of the temporal lobe, as observed here.

Besides clinical deficits sometimes observed for music memory, we could meet patients with selective preservation of musical abilities. In an Alzheimer' disease (AD) unit, we have succeeded to teach new songs to AD patients with moderate to severe dementia. Moreover, we observe that this learning resists particularly well after a long time period of non exposure (4 or 5 months). A potential explanation of these preserved musical abilities in AD is the relative preservation of the temporal poles from structural and functional damages produced by the pathology, areas that we show as critical for the musical mnesic process. More behavioral and neuroimaging studies are needed to highlight this issue.

To conclude, clinical and neuroimaging data suggest that the musical lexicon (and most widely musical semantic memory) is sustained by a bilateral temporo-prefrontal cerebral network. We hypothesized that these right regions refer mainly to the perceptive melodic traces of familiar tunes, whereas left areas would be linked to the access of semantic attributes and associative memories (knowledge of style or personal information related to a particular melody), involved in the feeling of familiarity. In the left hemisphere, this network is largely common with the neural basis classically shown for verbal semantic memory. Moreover, the neuroimaging literature about syntactic dimension of music shows that this temporo-prefrontal network is equally engaged[17]. This spread neural organization could possibly explain the good preservation of musical memory abilities in some brain damaged patients.

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REFERENCES

[1]Peretz, I. & M. Coltheart. 2003. Modularity of music processing. Nat Neurosci 6: 688-691.
[2]Platel, H. et al. 2003. Semantic and episodic memory of music are subserved by distinct neural networks. Neuroimage 20: 244-256.
[3] Tulving, E. 1972. Episodic and semantic memory. In Organization of memory. E.Tulving et al., Eds.: 381-403. Academic Press. New York.
[4]Platel, H. et al. 1997. The structural components of music perception. A functional anatomical study. Brain 120: 229-243.
[5]Groussard, M. et al. 2008. Neural correlates underlying musical and verbal semantic memory. Presented at the Neurosciences and music III, Montreal, QC, June 28.
[6]Cabeza, R. & L. Nyberg. 2000. Imaging cognition II: an empirical review of 275 PET and fMRI studies. J Cogn Neurosci 12: 1-47.
[7]Satoh, M. et al. 2006. Positron-emission tomography of brain regions activated by recognition of familiar music. AJNR Am J Neuroradiol 27: 1101-1106.
[8]Plailly, J. B. Tillmann. & J.P. Royet. 2007. The feeling of familiarity of music and odors: the same neural signature? Cereb Cortex 17: 2650-2658.
[9]Rogers, T.T. et al. 2006. Anterior temporal cortex and semantic memory: reconciling findings from neuropsychology and functional imaging. Brain. 129: 2528-2532.
[10]Patterson, K. P.J. Nestor. & T.T. Rogers. 2007. Where do you know what you know? The representation of semantic knowledge in the human brain. Nat Rev Neurosci 8: 976-987.
[11]Fliessbach, K. et al. 2006. The effect of word concreteness on recognition memory. Neuroimage 32: 1413-1421.
[12]Svoboda, E. M.C. McKinnon. & B. Levine. 2006. The functional neuroanatomy of autobiographical memory: a meta-analysis. Neuropsychologia 44: 2189-2208.
[13]Tsukiura, T. et al. 2008. Differential contributions of the anterior temporal and medial temporal lobe to the retrieval of memory for person identity information. Hum Brain Mapp 29: 1343-54.
[14]Gorno-Tempini, M.L. & C.J. Price. 2001. Identification of famous faces and buildings: a functional neuroimaging study of semantically unique items. Brain 124: 2087-2097.
[15]Olson, I.R. A. Plotzker. & Y. Ezzyat. 2007. The enigmatic temporal pole: a review of findings on social and emotional processing. Brain 130: 1718-1731.
[16]Sacks, O. 2006. The power of music. Brain. 129: 2528-2532.
[17]Koelsch, S. 2006. Significance of Broca's area and ventral premotor cortex for music-syntactic processing. Cortex. 42: 518-520.

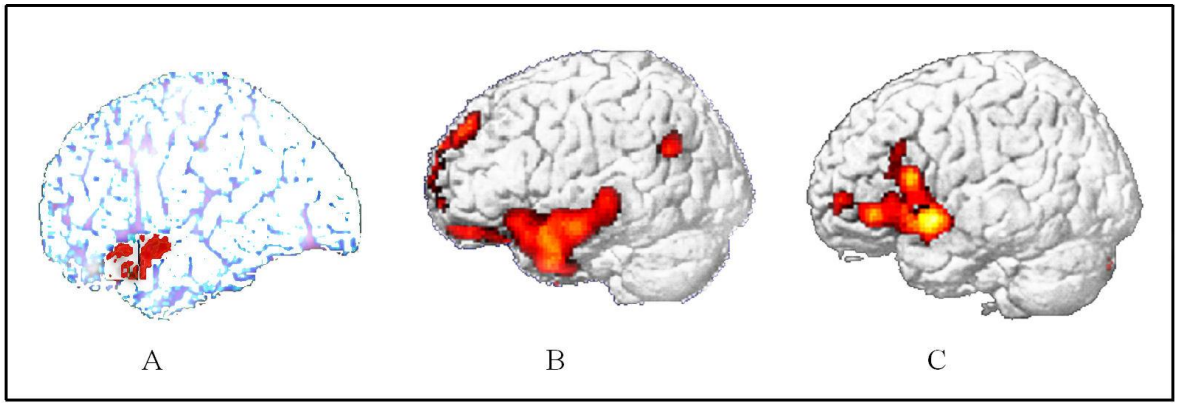

Figure 1: Musical semantic activations from 3 different neuroimaging PET paradigms.

A. Familiarity *vs* Pitch, Rhythm and Timbre tasks contrast from Platel et al. (1997).
B. Semantic *vs* Reference tasks contrast from Platel et al. (2003).
C. Semantic congruence memory *vs* reference tasks contrast of the present study (Groussard et al., 2008, and this paper).