# A neurocognitive analysis of rhythmic memory process as a social space phenomenon

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*Abstract* — **Functional neuroimaging has recently offered the means to map the workings of the human auditory system during music processing. I propose a cognitive theoretical account of rhythmic memory brain processing on the basis of current functional neuroimaging data on music perception in the light of my own work on the brain coding of body perception. This framework allows unifying experimental evidence showing activity in brain areas involved in the appreciation of the emotional cues conveyed by music, and data showing activity in the same areas but during the perception of emotional cues conveyed by body actions. This account postulates that the human brain may code the rhythmic processing space as a social space with communicative value.**

*Key words:* **human brain, functional neuroimaging, sound processing, memory, emotion**

## I. PROLEGOMENA

Neuroanatomical evidence in monkeys (1) have shown that, through a number of hierarchical steps 'en cascade', the auditory inputs, like the visual and haptic ones, are conveyed and integrated into the medial temporal lobe regions (amygdala and anterior temporal poles), brain areas sustaining memory and emotion.

## II. EXPERIMENTAL FRAMEWORK

Functional neuroimaging techniques represent a modern method of investigation into neural structural and functional correlates in human subjects. Recent functional imaging studies demonstrated the use of music-related stimuli as a uniquely powerful tool for the study of the structural and functional organization of the human auditory cortex and its connectivity.

These methods have revealed that the classical definition of the auditory cortex as the brain area containing neurons responding to sound is unsufficient, and that cortical systems involved in memory, mental imagery and emotion, essentially unrelated to sound processing, may nevertheless be activated by an auditory stimulus; conversely, it is possible to demonstrate activity within classical auditory cortical areas in the complete absence of sound (for a recent review, see 2).

More specifically, the distributed nature of the auditory cortical function has been assessed by fMRI experiments (3) performed to identify the neural systems involved in pitch and melody perception. Spectrally matched sounds that produce no pitch, fixed pitch, or melody were all found to activate the Heschl's gyrus and planum temporale. When the pitch was varied to produce a melody, there was activation in regions beyond the anatomically defined auditory cortex, specifically in the superior temporal gyrus and planum polare. In agreement with the anatomical organization of the monkey brain, the results are compatible with a hierarchical model of primate auditory processing in which the center of activity moves anterolaterally away from primary auditory cortex as the processing of melodic sounds proceeds.

Furthermore, functional neuroimaging studies (for example, see 4) measured cerebral blood flow in response to the intensity of subjects' experience of 'shivers-down-the-spine' or 'chills' in response to subject-selected music. Responses are observed in areas located more further medially and ventrally in the brain, i.e midbrain, ventral striatum, amygdala and medial-orbital frontal cortex, brain circuitry known to be involved in pleasure and reward. In the same line, studies (5) using auditory-musical stimuli to evoke emotion have also determined that unpleasant (permanently dissonant) music contrasted with pleasant (consonant) music showed activations in the anterior medial temporal lobe areas (amygdala, hippocampus, parahippocampal gyrus, and temporal poles).

Our previous neuroimaging studies have investigated the role of specific neural subsystems that are involved in the perception of body action (6).

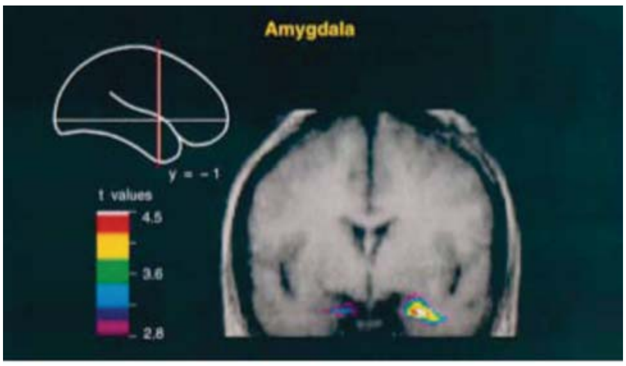


***Fig 1. From Bonda E, Petrides M, Ostry D. and Evans A., Specific Involvement of Human Parietal Systems and the Amygdala in the Perception of Biological Motion, The Journal of Neuroscience, 1996 (11), p. 3741***

We have measured cerebral metabolic activity in human subjects by positron emission tomography during the perception of simulations of biological motion with point-light displays. The experimental design involved comparisons of activity during the perception of goal-directed hand action, whole body motion, object motion, and random motion. The results demonstrated that the perception of scripts of goal-directed hand action implicates the cortex in the intraparietal sulcus and the caudal part of the superior temporal sulcus, both in the left hemisphere. By contrast, the rostrocaudal part of the right superior temporal sulcus and adjacent temporal cortex, and limbic structures such as the amygdala, are involved in the perception of signs conveyed by expressive body movements (see Fig. 1).

## III. An Unified Proposal

The common functional neural network, revealed in both cases, may lie at the root of the whole notion of rhythm. In its primary manifestation as employed in culture, rhythm arises in physical motions of parts of the human body. There are grounds for thinking that these types of rhythm are more memorizable by the brain and may have the effect of assisting memorization of the words and reinforcing the act of their recall.

Rhythm in all its forms, vocal, instrumental, choreographic, involves physical motion regularized in recurrent patterns, and this motion is of organs of the human body. As performed in union with words uttered, the rhythms are likely to tempt the brain to choose for utterance words which themselves describe action and movement. The verbs used in such statements will be such as will signalize action in the form of happenings or events. The subjects of such verbs will therefore have to be agents or actors in the framing of a perpetual drama of representation.

## References


[1] LA de la Mothe, S Blumell, Y Kajikawa & TA Hackett 'Cortical connections of the auditory cortex in marmoset monkeys: core and medial belt regions', *J Comp Neurol.* vol. 496 (1), pp. 27-71, May 2006.

[2] RJ Zatorre 'There's more to auditory cortex than meets the ear', *Hear Res.* (Epub ahead of print), 25 Jan 2007.

[3] RD Patterson, S Uppenkamp, IS Johnstrude & TD Griffiths 'The processing of temporal pitch and melody information in auditory cortex', *Neuron* vol. 36 (4), pp. 767-76, Nov 2002.

[4] AJ Blood & Zatorre RJ 'Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotion', *Proc Natl Acad Sci USA* vol. 98 (20), pp. 11818-23, Sep 2001.

[5] S. Koelsch, T. Fritz, DY. V Cramon, K. Muller & AD. Friederici 'Investigating emotion with music: an fMRI study', *Human Brain Mapp.* vol. 27 (3), pp. 239-250, Mar 2006.

[6] E. Bonda, M. Petrides, D. Ostry & A. Evans 'Involvement of human parietal systems and the amygdala in the perception of biological motion', *J Neurosci.* vol. 16 (11), pp. 3737-44, Jun 1996.


Eva Bonda received MSc degrees in Clinical Psychology (1990) and Developmental Psychology (1990) from the University of René Descartes-Paris V, and a MSc degree in Cognitive Science (1991) from the University of Pierre et Marie Curie-Paris VI, France. For her PhD thesis in Cognitive Neuroscience (1995), she conducted Functional Neuroimaging studies on the neural systems sustaining the body image in the human brain at the Montreal Neurological Institute, McGill University, Montreal, Canada. In her postdoctoral research, she worked, as a EC research fellow at the Department of Psychology, University College London, UK. She subsequently worked, as a Human Frontiers research fellow, on the neuroanatomy of the monkey brain areas involved in memory and emotion, at the Center for Neuroscience, California Primate Center, University of California at Davis and the Department of Anatomy, School of Medicine, Washington University-in-St. Louis, Missouri, USA. She is currently extending her research on sound and emotional memory processing by means of fMRI studies in the human brain.