SHORT REPORT

Modularity of music: evidence from a case of pure amusia

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Abstract
A case of pure amusia in a 20 year old left handed non-professional musician is reported. The patient showed an impairment of music abilities in the presence of normal processing of speech and environmental sounds. Furthermore, whereas recognition and production of melodic sequences were grossly disturbed, both the recognition and production of rhythm patterns were preserved. This selective breakdown pattern was produced by a focal lesion in the left superior temporal gyrus. This case thus suggests that not only linguistic and musical skills, but also melodic and rhythmic processing are independent of each other. This functional dissociation in the musical domain supports the hypothesis that music components have a modular organisation. Furthermore, there is the suggestion that amusia may be produced by a lesion located strictly in one hemisphere and that the superior temporal gyrus plays a crucial part in melodic processing.
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Keywords: amusia; melodic processing; superior temporal gyrus

Music is a complex ability with characteristics that are unique with respect to other cognitive abilities[1]: therefore, several issues are still open to debate—for example, if music is a faculty that is independent of the rest of the cognitive system, and if musical skills are mediated by a single mechanism or by a combination of processes that are independent from each other. Moreover, the anatomical correlations of music have yet to be clarified.[2–6]

We report a case of pure amusia without aphasia, and with selective impairment of melodic processing and precise lesion localisation. The clinical picture described here can be considered further evidence supporting the modular interpretation of musical skills, their hemispheric lateralisation, and the part played by the superior temporal gyrus.

Case report

A 20 year old left handed man who was enrolled in his first year of law school, was referred to us in December 1997 for the onset of a sudden and violent left frontotemporal headache, which was followed by nausea and vomiting and was associated with a language disorder. The neurological examination performed at admission showed only aphasia characterised by rare literal paraphasia corrected by the patient himself, with impaired verbal comprehension. Medical history did not indicate any noteworthy diseases, with the exception of surgery performed when the patient was 3 years old to remove an angioma from the pulp of the second finger on his left hand.

An emergency cerebral CT showed a left temporal haematoma with a maximum diameter of 4.5 cm, surrounded by perilesional oedema.

Angiography of the cerebral circle, performed immediately after the CT, disclosed a medium sized arteriovenous malformation in the left temporal region, with an ovoid shaped nest with a maximum diameter of 4.5 cm. The arteriovenous malformation seemed to be supplied mainly by three vessels rising from the temporal branch of the left middle cerebral artery and it was also supported by the anterior choroid artery. Drainage of the angioma occurred exclusively in the surface venous system through a single ectasic venous collector that discharged in the left transverse sinus.

In January 1998, the patient underwent blocked flow embolisation with NBCA and particles that completely occluded the arteriovenous malformation, leaving all the branches of the sylvian artery intact.

Three months after the acute event, a neurological examination and an otological examination with audiometry were normal.

A cranial MRI showed an area with altered signals at the left temporal site with a cortical-subcortical extension. The area was uneven as both the embolising material and haemoglobin catabolism byproducts were present.

NEUROPSYCHOLOGICAL EVALUATION

To investigate the aphasic disorder seen at the onset of the patient's symptoms, a preliminary language evaluation was conducted during the first week after the acute event.[6] This examination showed fluent oral production characterised by dysprosody, anomia, and frequent

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literal paraphasia. Comprehension was well maintained for interactive communication, but proved to be partially impaired in specific tests (token test=23). In the written naming tests, the patient had letter paragraphia which he often corrected himself; oral reading, and repetition were characterised by the same types of errors seen in oral production.

Over the next several days, language impairment improved rapidly and spontaneously. One month later, a detailed examination was performed using the BADA battery[7] and this disclosed extremely infrequent literal errors that mainly involved inflectional morphemes (for example, mamma=mammo). The same battery repeated 3 months after onset was performed very well.

A few days after admission, the patient began to complain that his music perception had changed: "I can't hear any musicality: all the notes sound the same". Listening to music gave him an unpleasant feeling and he found this very worrisome because he was an avid music lover and devoted most of his free time to this hobby. The patient's father had taught him to play the guitar when he was 14 years old. He did not know how to read music, but he could listen to a musical excerpt and reproduce it. Despite the fact that he was left handed, his right handed father had taught him to play the instrument and as a result, he would strum with his right hand and use his left hand on the frets. He and his friends had formed a band in which he sang and played the guitar, although he himself stated that he had no special talent as a singer.

A detailed neuropsychological evaluation was performed 90 days after the acute event. The patient reported that he no longer had any speech problems, but he continued to complain that he had difficulty in perceiving and producing music: "Sounds are empty and cold. Singing sounds like shouting to me. When I hear a song, it sounds familiar at first but I can't recognise it. I think I've heard it correctly, but then I lose its musicality. I can recognise the guitar but not the melody."

In tests designed to explore other cognitive functions,[8 9] the patient's performance was consistently within the normal range. In particular, he was administered tests to examine the following: verbal and non-verbal memory and learning (WMS digit forward, Corsi block tapping test, Rey complex A figure, Benton visual retention test, Spinnler prose memory test, Buschke-Fuld verbal learning test, Rey 15 word auditory-verbal learning test, Spinnler spatial supraspan learning test, Barbizet-Cany 7/24 test), attention and executive functions (Wisconsin card sorting test, Stroop test, trail making test, Hanoi towers, FAS literal fluency, sentence generation, barrage of letters, and geometric figures), perceptual recognition (Poppelreuter test, colour recognition, and naming), praxis (ideational, ideomotor, buccofacial and constructional tests suggested by De Renzi), visuospatial analysis (Benton line orientation test, behavioural inattention test), psychomotor integration (Luria test, WAIS digit symbol, grooved pegboard test), and intellectual processes (Raven 47 coloured progressive matrices, Weigl sorting test, Spinnler's verbal judgement). Performance was normal also in semantic fluency, calculation, and somatognosia tests. Furthermore, the patient did not make any errors in the interhemispheric transfer of tactile stimuli, which was performed to examine callosal function.[10]

Evaluation of musical ability

a) Preliminary tasks:	
Grison scale (6)	4
Verbal dichotic listening test (40)	Left 90%
Recognition of non-musical sounds:	
Human noises (10)	100%
Animal sounds (10)	100%
Ambient noises (10)	90%
Prosodic emotional tone interpretation:	
Meaningful sentences (10)	90%
Meaningless sentences (10)	80%
b) Musical perception tasks:	
Recognition of familiar melody (20)	5%
Bentley's test:	
Pitch discrimination (20)	60%
Tonal memory (10)	30%
Chord analysis (20)	75%
Rhythmic memory (10)	90%
Recognition of musical characteristics:	
Musical instruments (10)	90%
Intensity (10)	90%
Ascending and descending scales (10)	100%
Familiar rhythms (10)	100%
c) Musical production tasks:	
Reproduction of a rhythm with a reflex hummer (10)	80%
Stambak test (38)	87%
Spontaneous singing (10)	0%
Reproduction of familiar melody (20)	0%
Spontaneous guitar performance (10)	0%
Instrumental reproduction of a familiar melody (10)	0%
Instrumental reproduction of a unknown melody (10)	0%

Results are percentage of correct responses (number of trials in parentheses).

The Oldfield questionnaire showed that the patient was fully left handed (100%), as did the eye and foot dominance tests. There was no family history of left handedness.

To study the difficulties in music skills, a musical ability examination was also performed.[11–13]

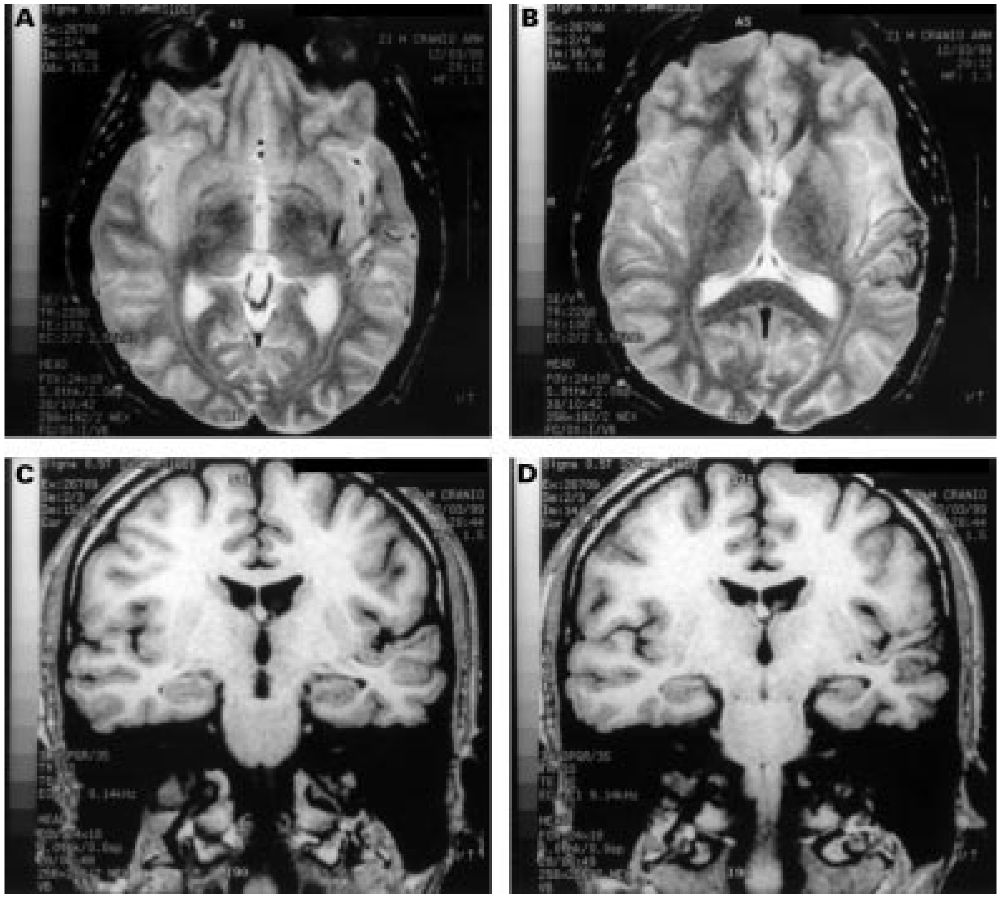
EVALUATION OF MUSICAL ABILITY (table)

Preliminary tasks

Grison scale of musical ability before illness[14]—The patient could play an instrument but was not familiar with music theory and was thus unable to read or write music. Consequently, he was placed at the fourth level of this six level scale (musicians are considered level six).

Verbal dichotic listening tests—Dichotic listening to word pairs showed a marked preference for the left ear (only four answers out of 40 were for the right ear). These results can be interpreted as suggestive of right hemispheric dominance for language functions.

Recognition of non-musical sounds—The task was proposed as both direct and multiple choice recognition. In any case, the patient appropriately recognised environmental sounds regardless of type—human noises, such as coughing and laughing, and animal sounds—as well as ambient noises such as a brook or a typewriter, and vehicle noises such as trains and motorcycles.



Axial (A, B) and coronal (C, D) brain MRI performed 15 months after the event showing a moderate atrophy of the left temporal lobe and focal damage involving the middle and posterior third of the left superior temporal gyrus, including Brodman's areas 22 (auditory association cortex), 41, and 42 (transverse gyri of Heschl, primary auditory cortex).

Prosodic emotional tone interpretation—During this test of recall and recognition of emotional tone, the patient could easily identify the mood that matched the tone of a sentence. This test was performed using a meaningful sentence (recall) and a meaningless one composed of neologisms (recognition). He also had no trouble distinguishing between the characteristics of men's, women's, and children's voices; likewise, he found it easy to distinguish foreign accents (French, English, German, Spanish).

MUSICAL PERCEPTION TASKS

Recognition of familiar melodies—Serious difficulties were found even with extremely commonplace hummed songs such as the national anthem and "O sole mio" as well as with musical pieces chosen from the ones that were previously the patient's favourites.

Musical ability examination—Bentley's test[15] was used. This test involves four subtests: pitch discrimination (comparison between two notes), tonal memory (comparison between two five note motifs that differ by just one note, without any contour changes), chord analysis (two, three, and four note chords), and rhythmic memory (comparison between two rhythmic figures with four beats and no change in pitch). The subtests in this battery were set up so that melodic structure and rhythmic structure could be analyzed separately, according to the indications of Peretz *et al*.[12] Analysis of the scores of subtests disclosed a selective decline in the tonal memory test.

Perception test of musical characteristics—This investigates the patient's ability to recognise intensity, timbre (musical instruments), familiar rhythms (waltz, tango, etc), and ascending and descending scales. This examination did not present any particular difficulties for the patient.

MUSICAL PRODUCTION TASKS

The patient made mistakes only on the longer sequences in the rhythm reproduction tasks[11 16]; on all the other tests, listed in the table, he experienced such serious difficulty that he refused to do the tests at all. Moreover, he could no longer play the guitar even when he was given the chords. Lastly, as far as his singing was concerned, because of his undeniably poor performance he stopped performing with his band.

FOLLOW UP

The neuropsychological evaluation of musical abilities was repeated after 1 year and did not show any change.

Brain MRI, performed in March 1999 (figure), showed focal damage involving the middle and posterior third of the left superior temporal gyrus including Brodman's areas 22 (auditory association cortex), 41 and 42 (transverse gyri of Heschl, primary auditory cortex); the images also show moderate atrophy of the left temporal lobe, a feature often reported in subjects with bleeding arteriovenous malformations.[17]

Discussion

Recently, data raising the question of the specificity for music renewed interest about amusia.[1] Comparing our case report with other cases in the literature[3 5] suggests several considerations on musical abilities and their neuroanatomical substrate.

Our patient manifested a specific disorder involving musical ability, without any deficits in other verbal and non-verbal cognitive domains. His ability to recognise musical sounds seems to show selective impairment compared with his ability to recognise both linguistic and ambient sounds. This dissociation between speech and non-speech sounds on the one hand, and between music and environmental sounds on the other, supports the hypothesis that music requires a specialised processing channel which is separable from the neural systems subserving the analysis of the other classes of auditory stimuli.[1–3]

Musical impairment was limited to processing melodic structures; on the contrary**,** rhythmic structure and timbre seemed to be processed correctly.[1 12 13] This neuropsychological pattern can be interpreted as a confirmation of the modular hypothesis proposed by Peretz *et al*,[3 12] in which two separate subsystems mediate the processing of information on melodic structure (defined by the sequential pitch variations) and of information related to temporal structure (defined by variations in length), respectively. Although the indications are only suggestive as, to give a direct comparison of performance, melodic, and temporal components should be assessed using similar tasks,[12] the functional dissociation manifested by our patient supports recent claims for fractionation of musical abilities.[4]

It may be interesting to note perception and expression are equally impaired; it is likely that the production disorder is attributable to a perception disorder. In any event**,** our report confirms other literature cases showing a dissociation between melodic and rhythmic aspects of singing.[18]

It is also noteworthy that affective prosody, at least as assessed by conventional tasks, was not impaired. To date, the question regarding the relation between the processing of prosodic and musical patterns has not yet been resolved[19]; furthermore the neural systems responsible for prosody remain largely unspecified.[20] Our findings suggest that affective aprosodia and amusia can be independently and selectively impaired.

From an anatomical standpoint, the brain lesion of our patient seems to be very well defined within the superior temporal gyrus. Recent research has pointed out that separate musical processes can correspond to different intrahemispheric and interhemispheric anatomofunctional patterns suggesting a correlation between the type of amusia and the site of the lesion.[4 12 21 22] Howeve**r,** it is agreed that the superior temporal gyrus plays a crucial part in the perception of pitch organisation[4 12 21 23]: Results with our patient seem to confirm this hypothesis.

For the interhemispheric pattern, unilateral localisation of cerebral damage strongly supports, according to previous report of Griffiths *et al*,[24] but not of Peretz *et al*,[2 3] the hypothesis that strictly unilateral lesions may be able to produce an impairment of musical abilities. In our patient amusia appeared as a result of a lesion in the left hemisphere. As the patient is left handed, the pattern of functional lateralisation is unclear. However, the very rapid and complete remission of aphasic symptoms together with the results of the dichotic listening tests and the 100% left dominance not only for handedness, but also for foot and eye preference suggest that language is likely to be lateralised to right hemisphere. On the basis of this interpretation, our report seems to support the classic suggestion that the anatomofunctional representation of melodic aspects of music is carried out by the hemisphere opposite to the one subserving language.[5 6 18 21 25]

To summarise, our case report, consistently with the few previous reports in the literature,[2 3 24] seems to provide further evidence for the modularity of music as well as for the existence of a specific neural architecture devoted to music. The exact site of lesion confirms the crucial role of the superior temporal gyrus in this music processing system. Moreover, unilateral localisation of cerebral damage strongly supports the hypothesis that pure amusia may be produced by a strictly unihemispheric lesion that may very well involve the cerebral structures contralateral to the ones subserving linguistic skills.

1 Peretz I, Morais J. Specificity for music. In: Boller F, Grafman J, eds. *Handbook of neuropsychology.* Amsterdam: Elsevier 1993;**8**:59–89.
2 Peretz I, Kolinsky R, Tramo M, *et al*. Functional dissociations following bilateral lesions of auditory cortex. *Brain* 1994;**117**:1283–301.
3 Peretz I, Belleville S, Fontaine S. Dissociations entre musique et language après atteinte cerebrale: un nouveau cas d'amusie sans aphasie. *Can J Exp Psychol* 1997;**51**:354–68.
4 Liegeois-Chauvel C, Peretz I, Babai M, *et al*. Contribution of different cortical areas in the temporal lobes to music processing. *Brain* 1998;**121**:1853–67.
5 Basso A. Amusia. In: Boller F, Grafman J, eds. *Handbook of neuropsychology.* Amsterdam: Elsevier 1993;**8**:391–410.
6 Basso A, Capitani E. Spared musical abilities in a conductor with global aphasia and ideomotor apraxia. *J Neurol Neurosurg Psychiatry* 1985;**48**:407–12.
7 Miceli G, Laudanna A, Burani C, *et al*. *Batteria per l'analisi dei deficit afasici (BADA)*. Rome: CEPSAG, 1991
8 Lezak MD. *Neuropsychological assessment.* New York: Oxford University Press, 1995.
9 Spinnler H, Tognoni G. Standardizzazione e taratura italiana di test neuropsicologici. *Ital J Neurol Sci* 1987;(suppl):8.
10 Piccirilli M, Finali G, Sciarma T. Negative evidence of difference between right- and left-handers in interhemispheric transfer of information. *Neuropsychologia* 1989;**27**:1023–6.
11 Botez MI, Wertheim N. Expressive aphasia and amusia following right frontal lesion in a right-handed man. *Brain* 1959;**82**:186–203.
12 Peretz I. Processing of local and global musical information by unilateral brain-damaged patients. *Brain* 1990;**113**:1185–205.
13 Mazzucchi A, Marchini C, Budai R, *et al*. A case of receptive amusia with prominent timbre perception deficit. *J Neurol Neurosurg Psychiatry* 1982;**45**:644–7.
14 Grison B. Une étude sur les alterations musicales au cours des lesions hemispheriques [thesis]. Paris: 1972. (Cited in: Critchley McD, Henson RA, eds. *Music and the brain*. London: Heinemann, 1977).

15 Bentley A. *Measures of musical abilities*. Windsor: NFER-NELSON, 1985.
16 Stambak M. *Tre prove di ritmo*. Florence: Organizzazioni Speciali, 1980.
17 Le Blanc R. Ethier R, Little JR. Computerized tomography findings in arteriovenous malformation of the brain. *J Neurosurg* 1979;**51**:765–72.
18 Peretz I. Asymétrie hémispherique dans les amusies. *Rev Neurol (Paris)* 1985;**141**:169–83.
19 Patel AD, Peretz I, Tramo M, *et al*. Processing prosodic and musical patterns: a neuropsychological investigation. *Brain Lang* 1998;**61**:123–44.
20 Baum SR, Pell MD. The neural bases of prosody: insights from lesion studies and neuroimaging. *Aphasiology* 1999; **13**:581–608.
21 Zatorre RJ. Discrimination and recognition of tonal melodies after unilateral cerebral excisions. *Neuropsychologia* 1985;**23**:31–41.
22 Samson S, Zatorre RJ. Contribution of the right temporal lobe to musical timbre discrimination. *Neuropsychologia* 1994;**32**:231–40.
23 Zatorre RJ, Evans AC, Meyer E. Neural mechanisms underlying melodic perception and memory for pitch. *J Neurosci* 1994;**14**:1908–19.
24 Griffiths TD, Rees A, Witton C, *et al*. Spatial and temporal auditory processing deficits following right hemisphere infarction. *Brain* 1997;**120**:785–94.
25 Signoret JL, Van Eeckhout P, Poncet M, *et al*. Aphasie sans amusie chez un organiste aveugle. *Rev Neurol (Paris)* 1987; **143**:172–81.