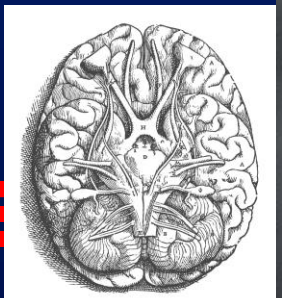
Music of the hemispheres: Melody and Prosody

Presentation at
The Swedish Conference on
Communication, Music, and Language

Stockholm 19 November 2010.

Jan Fagius
Neurologkliniken,
Akademiska sjukhuset
Uppsala University



Olof von Dalin 1745

BERÅTTELSE

Om en DUMBE, *ſom kan ſiunga:*

Af

OLOF DAHLIN.

Jon Perſon, en Bondeſon från Ofvankihl i Juleta ſokn i Sörmanland, född 1703, upfödd på vanligt enfaldigt ſätt, at veta ſin Chriſtendom och läſa i bok, föll åhr 1736, ſen han i 3. åhr varit gift, i en hetſig ſiukdom, hvaruti han blef rörd af ſlag på hela högra ſidan af kroppen, och aldeles *mål-lös*. Efter näſtan et halft åhrs ſång-

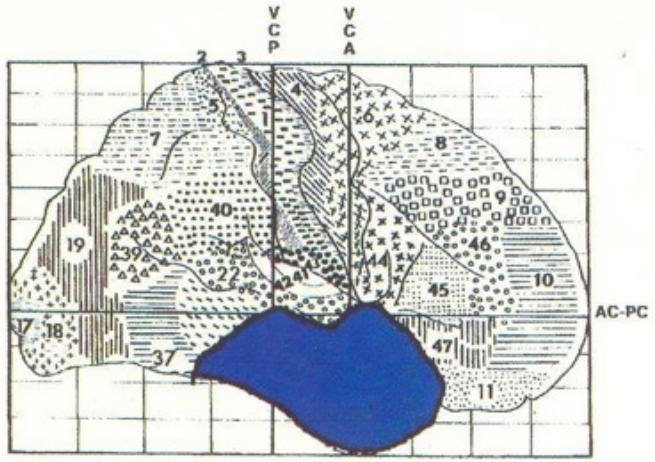
Olof von Dalin 1745
Berättelse Om en DUMBE som kan siunga 1

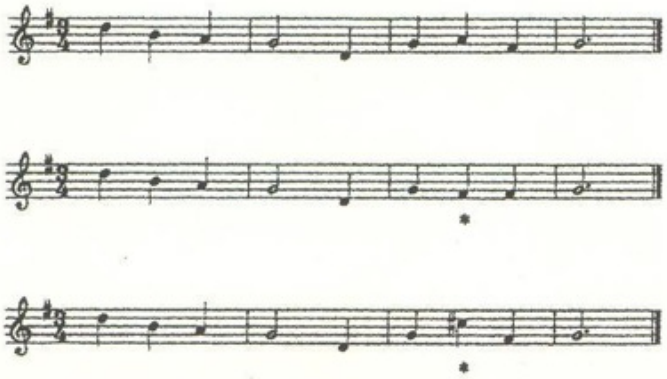
- Jon Persson, en Bondeson i Juleta sokn i Sörmanland, upfödd på vanligt enfaldigt sätt, at veta sin Christendom och läsa i bok, föll i en hetsig siukdom, hvaruti han blev rörd av slag på hela högra sidan af kroppen och aldeles *mål-lös.*
  . . . ingen annan bätring finna, än at redigt utsäja det lilla, men vid många tilfällen viktiga ordet *Ja.*

Olof von Dalin 1745
Berättelse Om en DUMBE som kan siunga 2

- likväl . . . han kan siunga vissa Psalmer, som han lärt innan han blef siuk, så rent och tydeligt som en annan färdig menniska: men det är till märkandes, at han i början av Psalmen måste litet underhiälpas af en annan, som siunger tillika.

BRAIN





”Universal language”

Fritz et al 2009 *Curr Biol, March*

- Western music with different character
  - happy
  - sad
  - fearful
- ”Native African population” – the Mafas
- Identified the emotional character ”above chance”
- Basic emotional traits in music universally perceived!

”Universal language”

Balkwill & Thompson *Music Perception 1999*

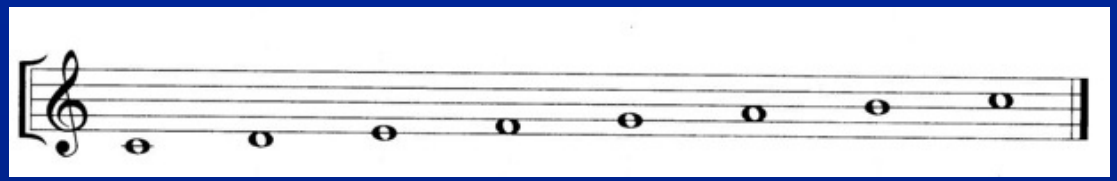
- 12 Hindustani raga excerpts,
  with different mood (”rasa”) character
  - joy /*hasaya*
  - sadness /*karuna*
  - anger / *raudra*
  - peacefulness / *shanta*
- 30 Western listeners
- Listeners sensitive to the intended emotion
- Basic emotional traits in music universally perceived!

Premature infants *Standley 2000*

- 10 premature infants, 35th pregnancy week
- Pacifier with pressure transducer, started a 10 s lullaby sung by a female
- Significantly more sucking when music reinforcement was given
- An average of 2.5 min required to learn to get the music continuously!

”Musical universality”

Essentially all known cultures use music with stable scales and features in common:

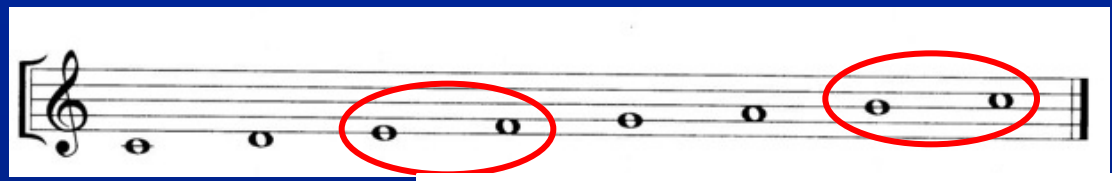


- Discrete pitch levels
- Octave equivalence, perfect fifth
- A moderate number (5-7) pitches within an octave
- Unequal scale steps
- A tonal hierarchy with certain pitches as “stable” and others as “unstable”.
- Small integer frequency ratios (2:1, 3:2, 4:3) preferred

- Special genre of music for infants (lullabies)

”Musical universality”

Essentially all known cultures use music with stable scales and features in common:



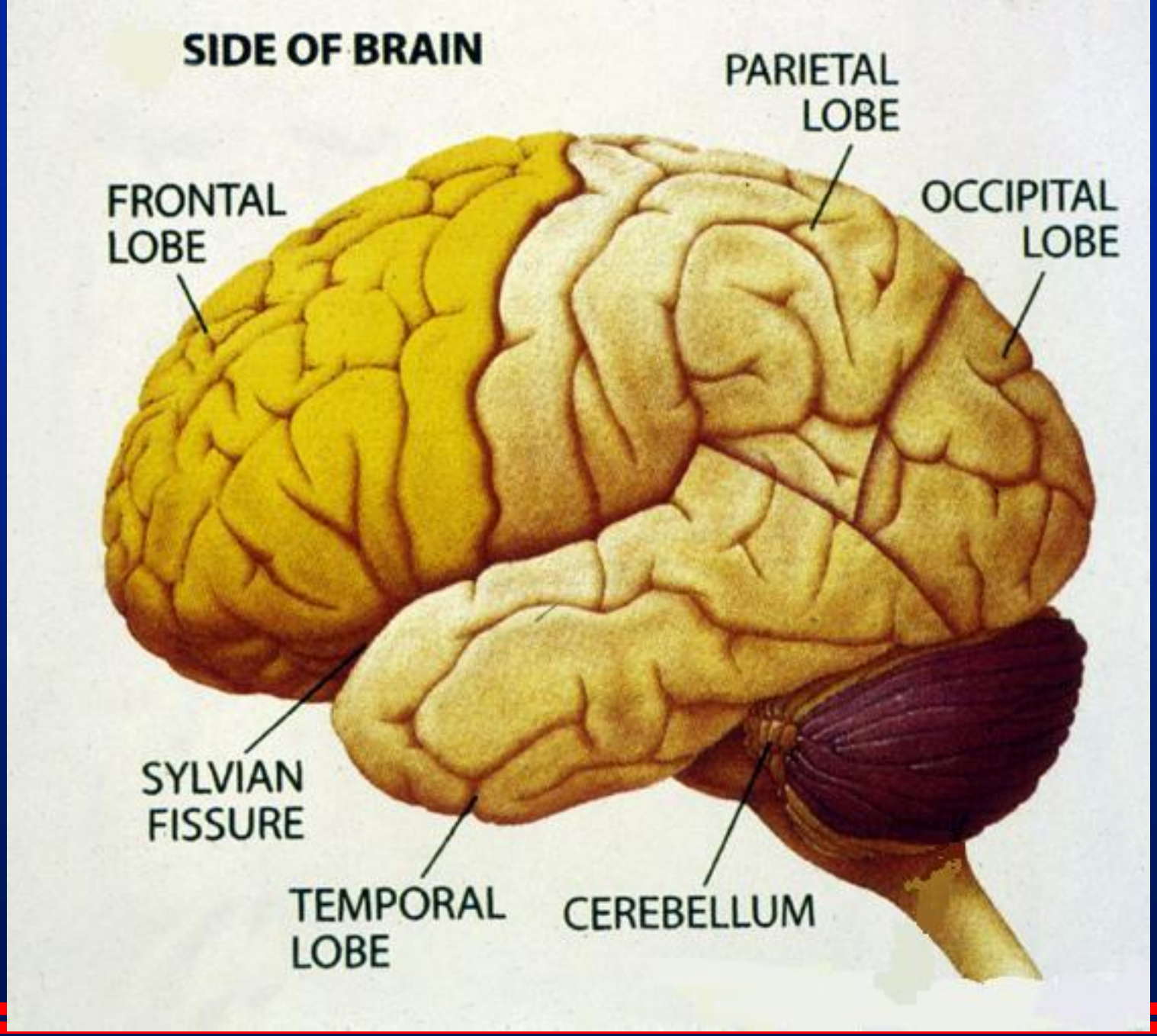
Half steps, semi-tones

- Discrete pitch levels
- Octave equivalence, perfect fifth
- A moderate number (5-7) pitches within an octave
- Unequal scale steps
- A tonal hierarchy with certain pitches as “stable” and others as “unstable”.
- Small integer frequency ratios (2:1, 3:2, 4:3) preferred

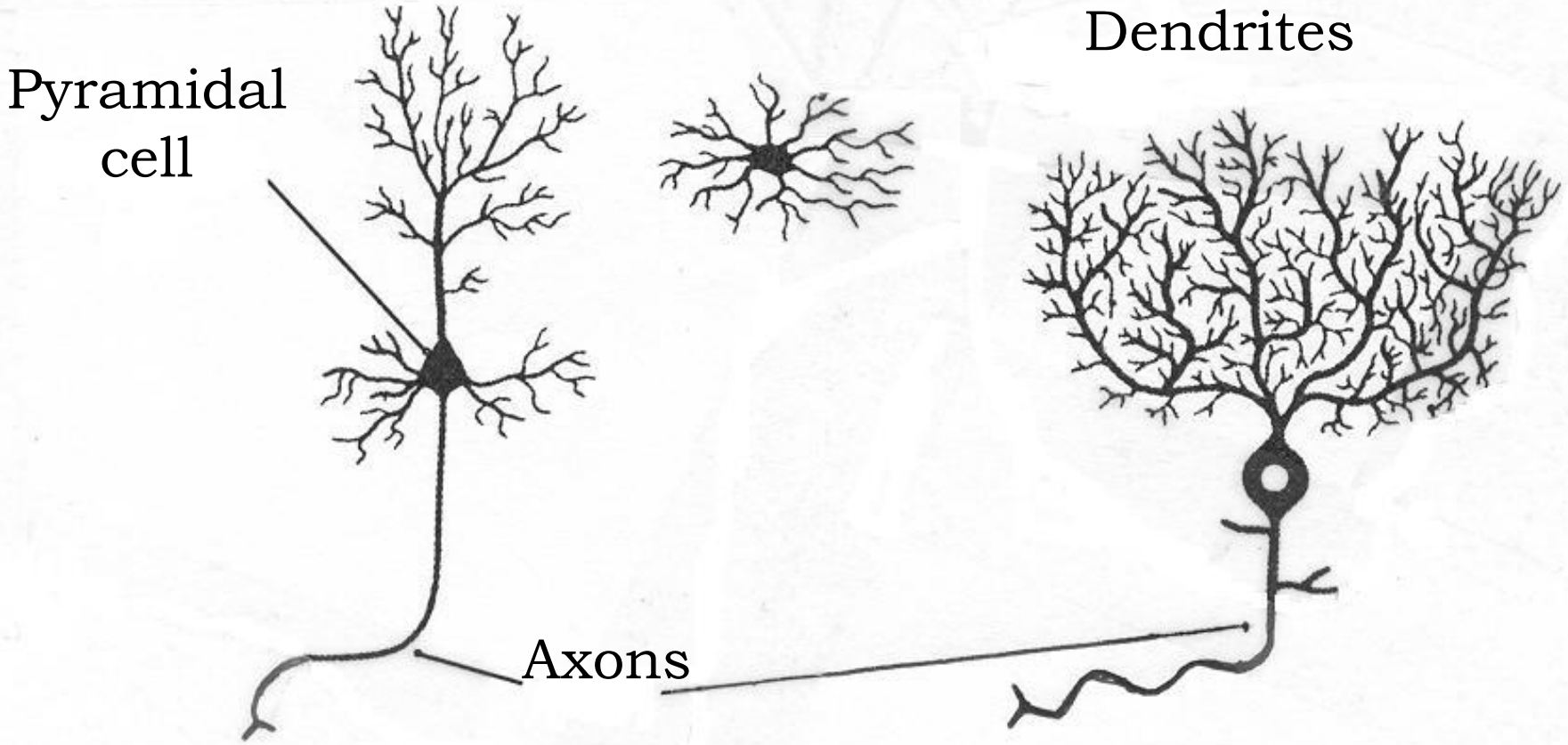
- Special genre of music for infants (lullabies)

Left cerebral hemisphere

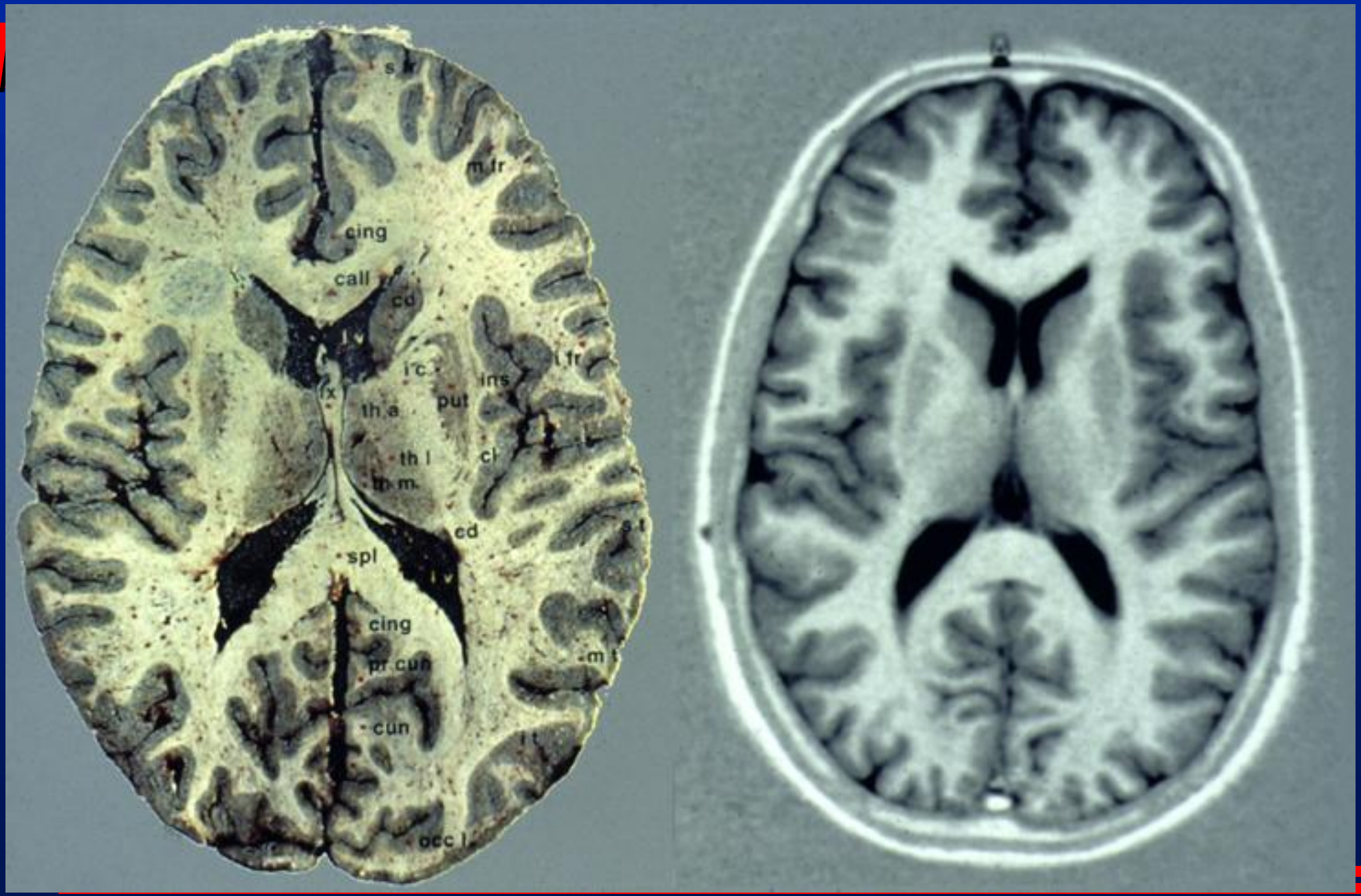
Left half of the brain



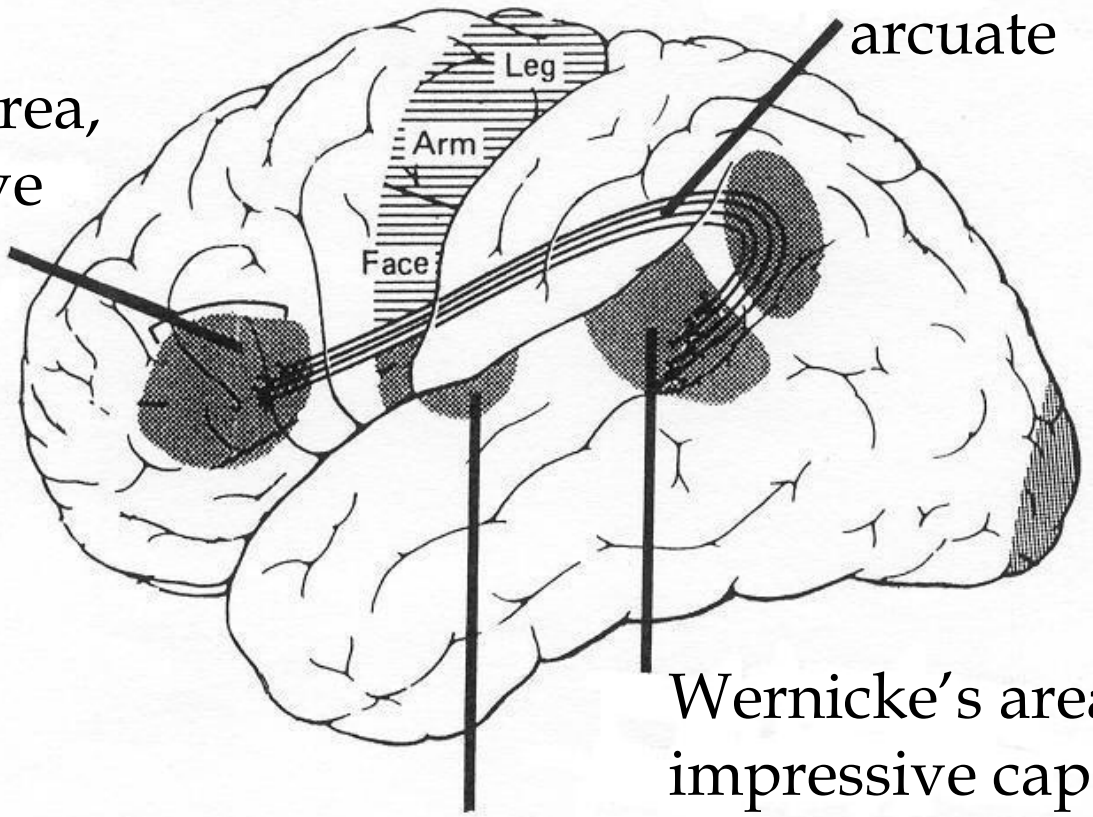
Nerve cells - neurons



> 100 billions of neurons in the human brain


s f
m fr
cing
call
cd
l v
i c
ins
l fr
fx
th a
put
th l
cl
th m
cd
s t
spl
l v
cing
pr cun
m t
cun
occ l

Our linguistic capacity – the ”major” hemisphere



Fasciculus arcuate

Broca’s area, expressive capacity

Wernicke’s area, impressive capacity

Primary auditory centre

Our linguistic capacity

- Left hemisphere [usually] dominant
- Broca's area - expressed language
- Wernicke's area - interpreted language
- Everyone "virtuoso" in mother's tongue !
- Aquired brain damage
  - language disturbance, *aphasia*
- Analogue for reduced musical capacity
  - *amusia*

Svenska Dagbladet 17 nov 2004

Forskare har hittat musiken i hjärnan

Nya studier visar var takt och ton sitter – och varför vi stampar takten

Vi sjunger och stampar takten med olika delar av hjärnan. Nu kan forskarna för första gången visa var i hjärnan det händer. Med dagens kunskap kan man också säga: det är aldrig för sent att börja spela, men börja tidigt om du vill bli ”underbarn”.

Frågan om vi *föds* musikaliska eller *blir* det, har besvarats på olika sätt i olika tider. Den äldre uppfattningen att det enbart är en medfödd gåva, har via sentida ”alla kan lära sig”-filosofier så småningom landat i både och: det verkar finnas genetiska komponenter, men stimulans krävs för att musikaliteten ska förlösas.

Nästa fråga är vad musikalitet är? Att spela ett instrument, sjunga, dansa? Härma dialekter?

Fakta

Färger visar aktivitet

Hjärnbilderna efter bearbetning och analys. Färgområdena visar var och när i hjärnan jobbar ut vid olika musikaliska aktiviteter.

som musikalitet har studerats. Men nu har hjärnforskarna klivit in på

–Hjärnan är oerhört flexibel, spelar man piano varje dag så för-

Pian

handen på en specialbyggd klaviatur, dels efter noter, dels utan.

Förenklat kan man säga att apparaten gör bilder av vilka nervcellspopulationer som aktiveras

även långt upp i åldrarna går det att lära sig att spela. Men det går långsammare och leder inte lika ofta till de högsta höjderna.

Det motoriska systemet har

No ”music center”

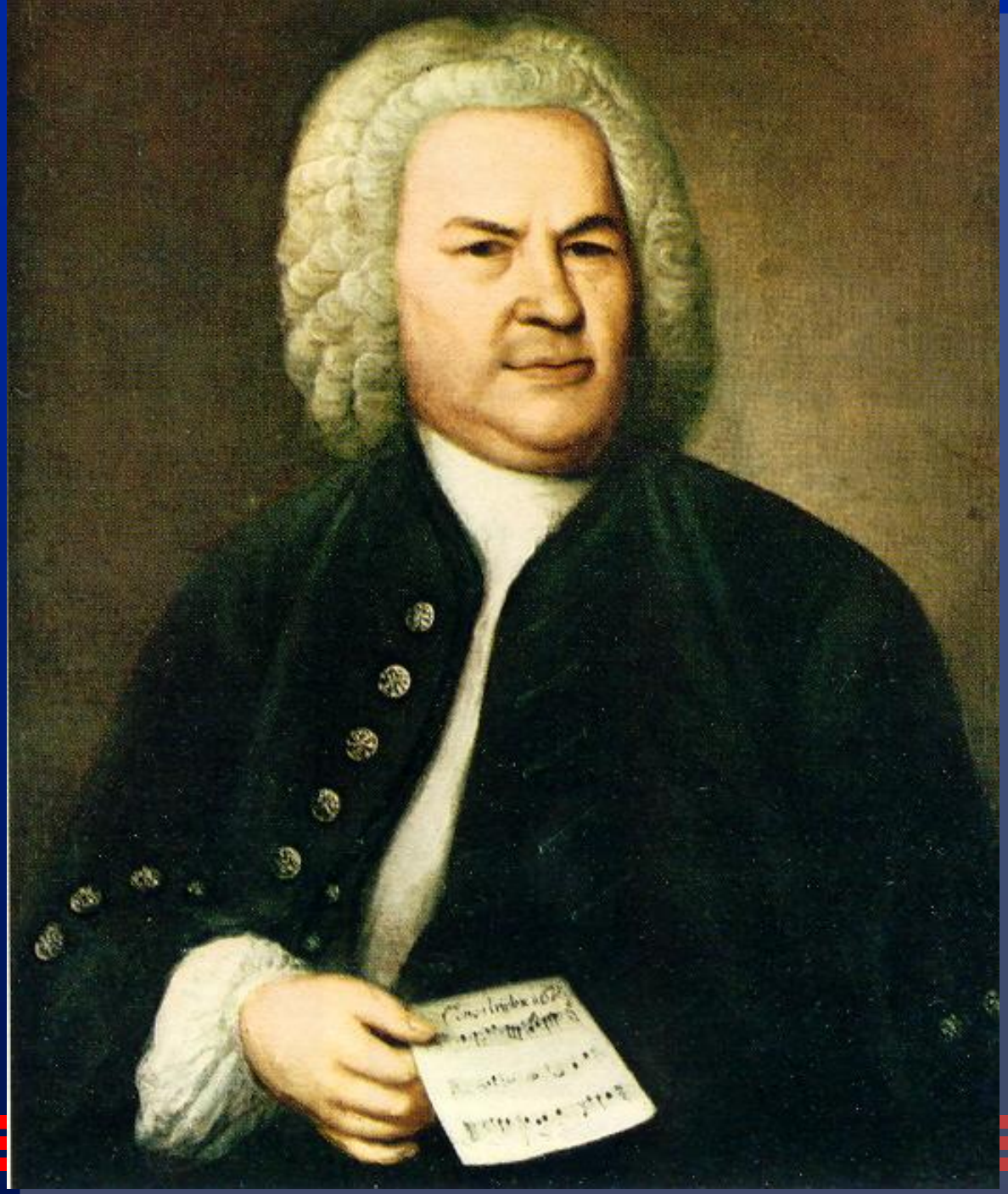
Music processing widely distributed in the brain.

Talent versus training – differences!

- Execute
  - hum a popular melody
  - sing a plain song or hymn
  - execute the quartet from Verdi's Rigoletto
- Listen to Beethoven's 7th symphony
  - unexperienced first time listener
  - devoted Beethoven lover
  - experienced Beethoven conductor
- Different activities in these brains!

Johann Sebastian Bach 1685-1750

An enormous talent!



Music - what is going on?

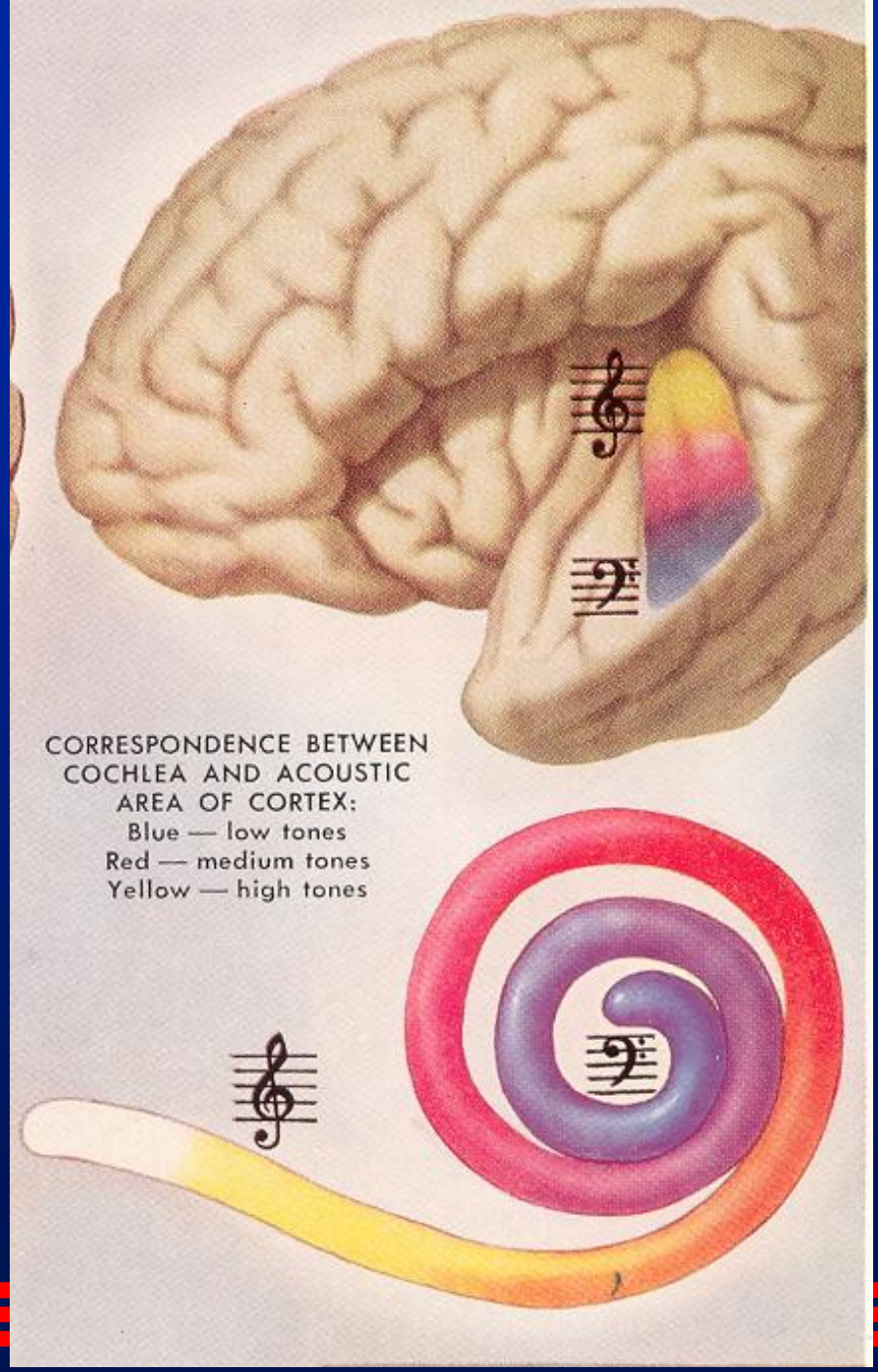
- listening - hear, recognize, “understand”, analyze
- emotional responses
- (reading music - see, interpret symbols)
- executing
  - singing - sound, **words**
  - playing - motor activity: hands, (feet), mouth

Deutsch 1970

	Per cent error	
	Pitch	Figures
Pitch! Ignore if tones	32%	---
Pitch! Ignore if figures	2,4%	---
Pitch! Report if figures	5,6%	25%
(Pitch.) Report if figures	---	27%

Mechanical analysis of pitch in the cochlea, [snäckan]

Both ears connected to both hemispheres but ***stronger*** to the opposite half of the brain

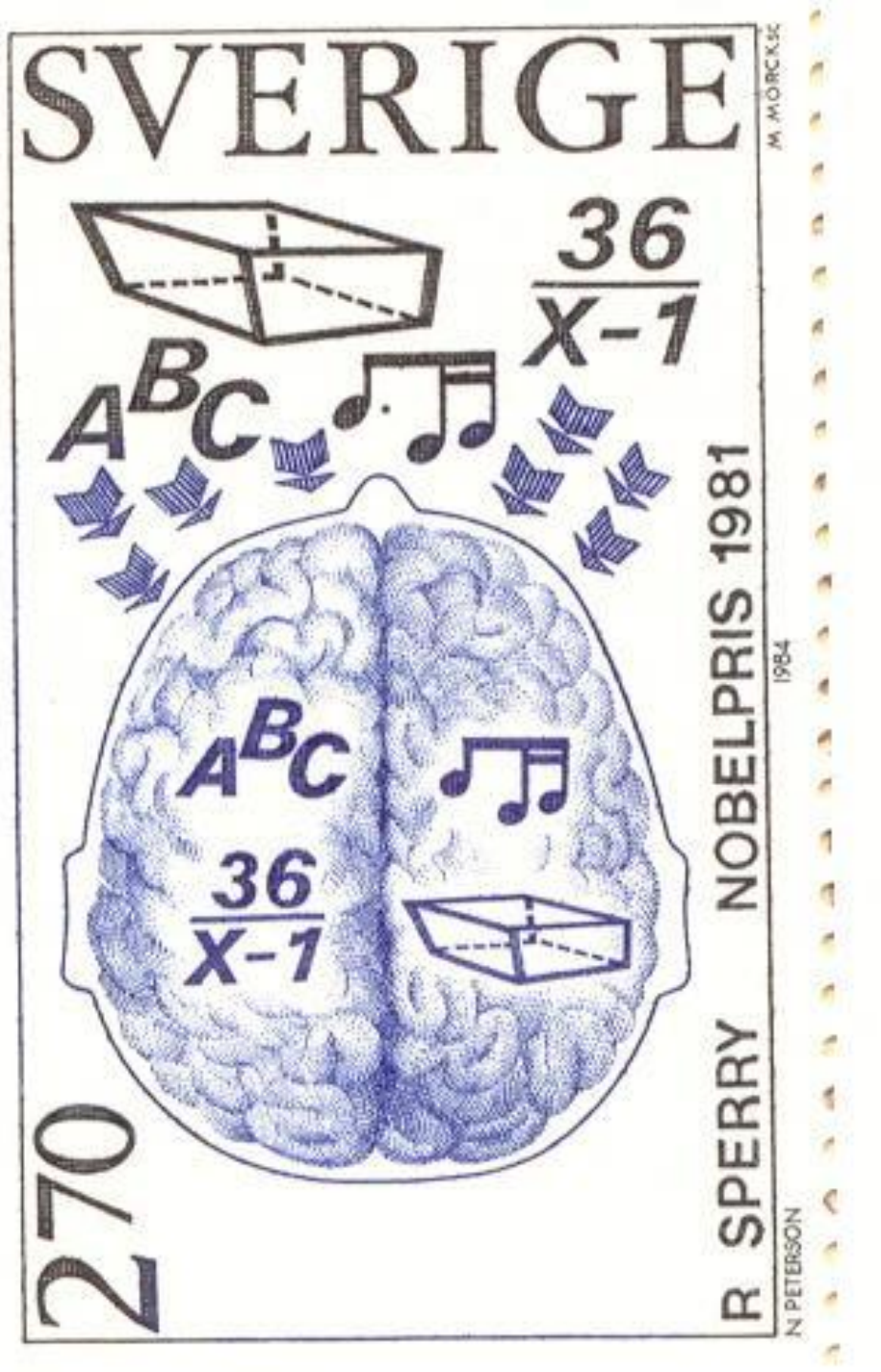


Music - what do we hear?

- Contour - a melody, “an entity”, *versus*
- Interval - distance between single notes
- Chords, harmonies, instrumental timbre
- Rhythm, note length, counterpoint
- Different ways of listening
- Pitch level - usually disregarded
  - absolute/perfect pitch - 1/10.000

Cerebral localization

Where in the brain is processing of music localized?



Are there music centra in the brain? Cf specialized language areas.

- Amusia - often related to aphasia
  - left hemisphere ! ?
- Aphasia - often without amusia - ???
- Amusia is observed in musicians
- Brenda Milner 1962
  - non-musicians with temporal lobe lesion
    - right hemisphere most important

Kimura 1960s

- Dichotic listening - “split listening ”
- Linguistic, simple test
- Two digits simultaneously, one in each ear
- Three such pairs in rapid succession
- The right ear perceived better,

  i.e. left hemisphere grasps word better

Kimura 1964

- 20 healthy non-musicians
- Brief 18th century melodies,
  solo instrument
- Mozart, Telemann, Vivaldi, Bach
- Dichotic playback,
  two melodies simultaneously
- Left ear = right hemisphere
  perceived the melody better

Bever & Chiarello 1974

- WHOLE/GESTALT versus ELEMENT, i.e. total impression vs detail analysis
- Right and left hemisphere respectively
- Musical training will increase detail analysis
- The left hemisphere will take over more and more of the music processing!

Bever & Chiarello 1974

- Musically “naive” person; perception of melodic ”whole” -> right hemisphere dominates
- Musically “competent” person; increased perception of details -> left hemisphere will take over

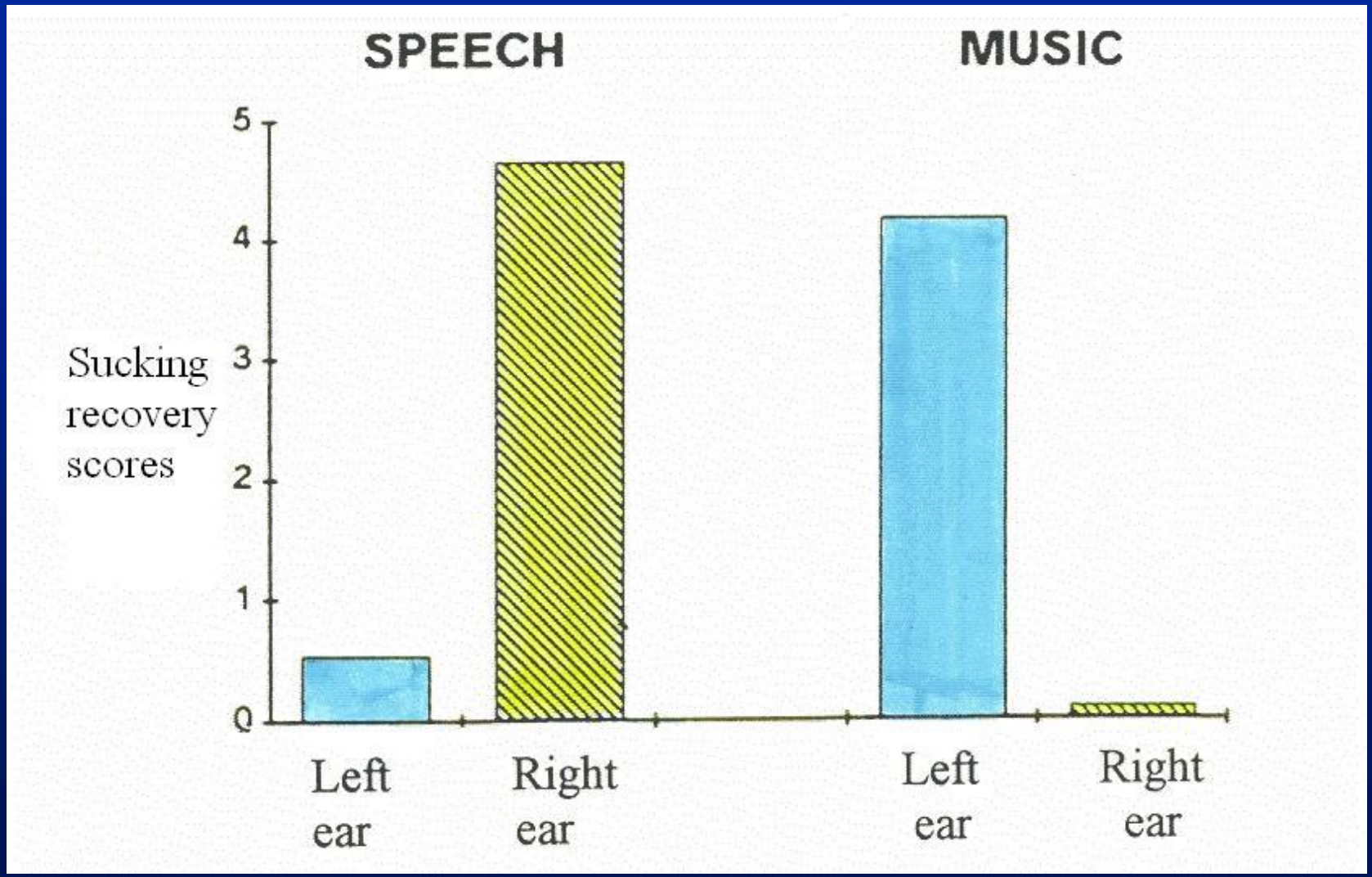
Summary thus far

- The right hemisphere basically more ”musically talented” - melody, chords
- Amusia and aphasia often parallelled, patients struck by amusia have by definition had a musical competence, damaged by the disease;
- hence a left hemisphere lesion -> amusia

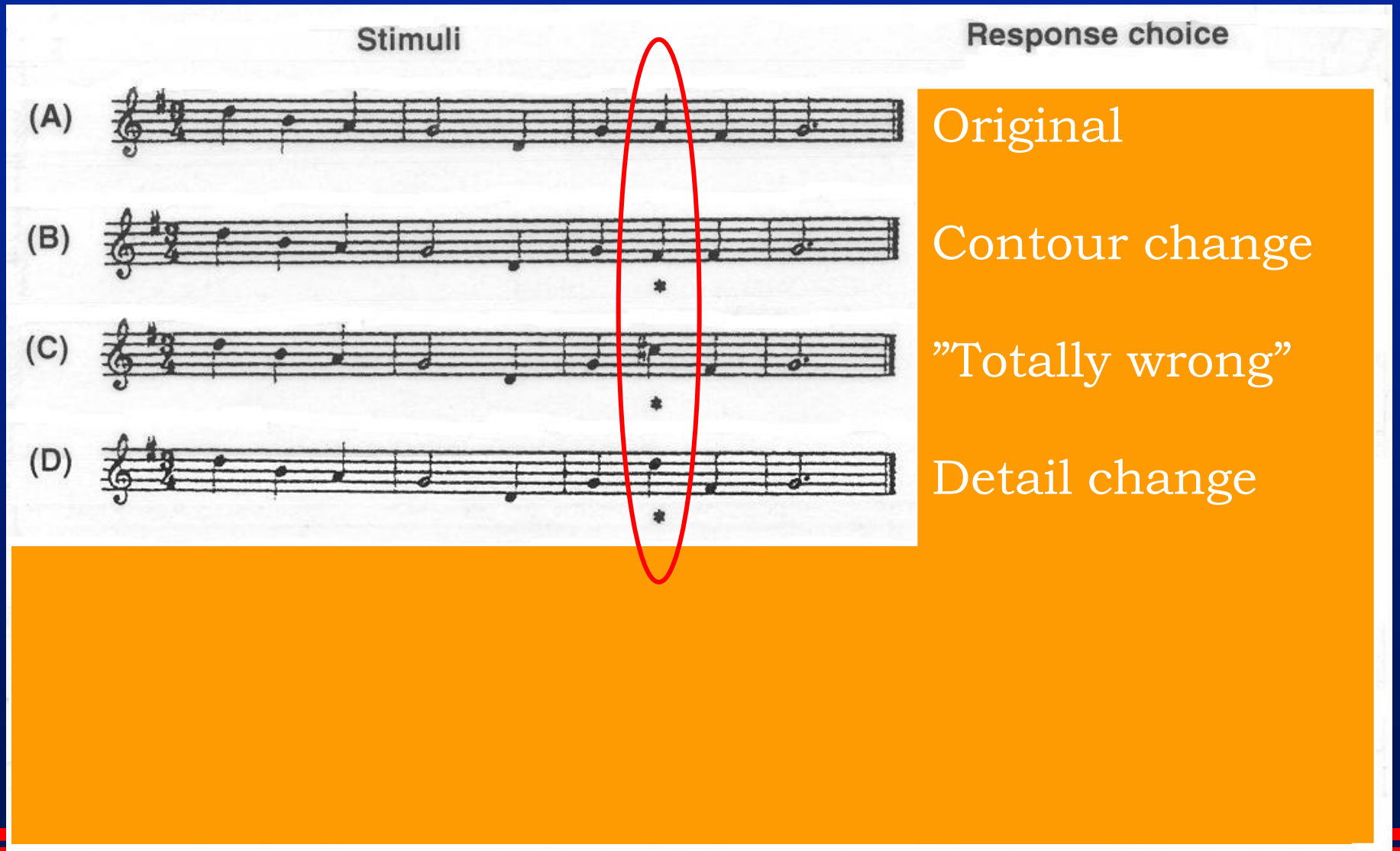
4 days old infants

Bertoncini et al 1989

Dichotic presentation of language or music

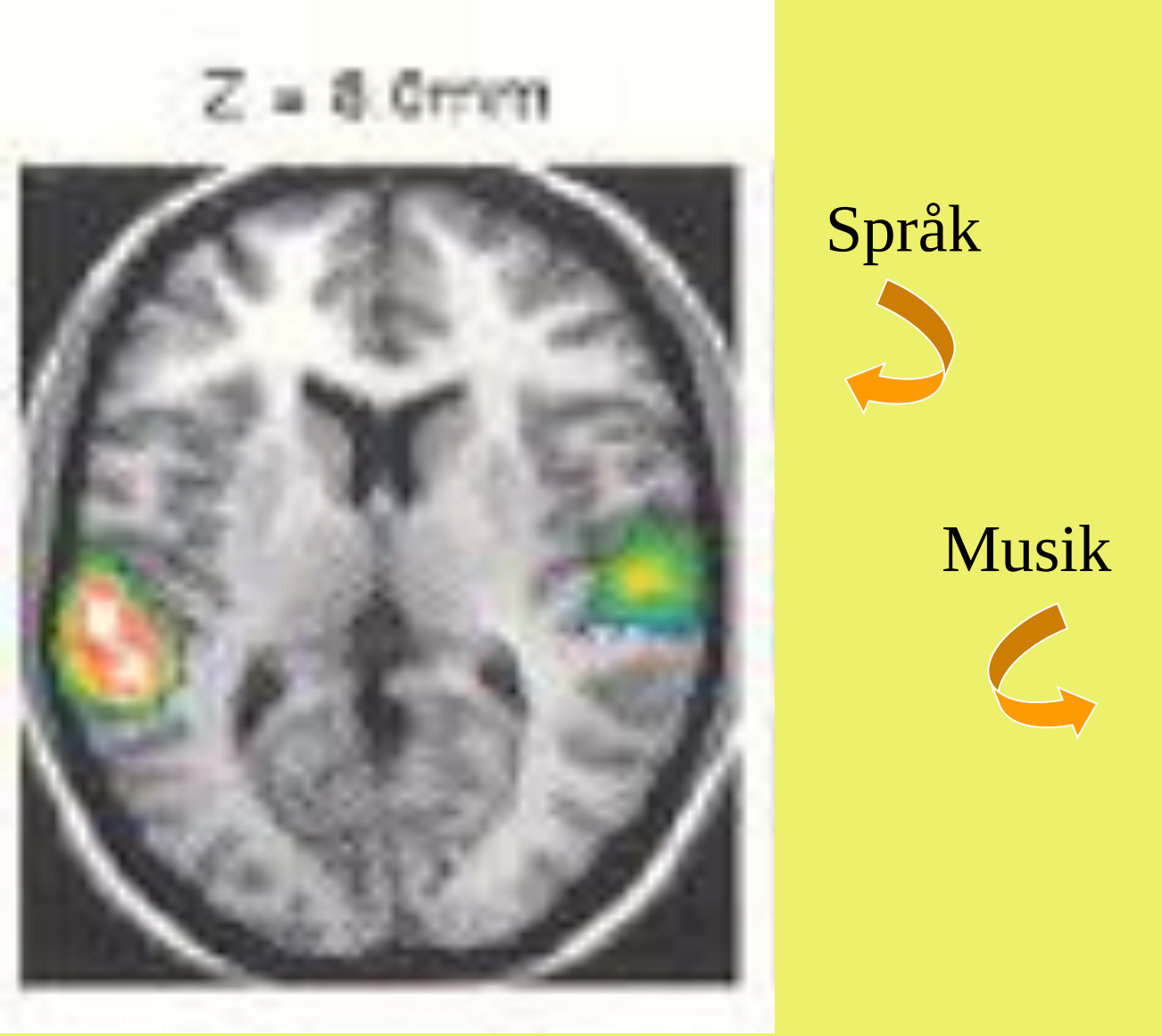


Liégeois-Chauvel et al 1998



Liégeois-Chauvel et al 1998

- The right temporal lobe analyzes the melody contour
- The left half goes on with the relationship between individual notes - i.e. interval
- Cooperation between the hemispheres already in the musically non-trained individual
- The capacity of the left hemisphere will come more into use with musical training



Språk

Musik

^{15}O-PET i MRT-bild av hjärna vid aktivering av språkljud respektive musikinstrument.
Detalj, samma snitt vid båda situationerna.

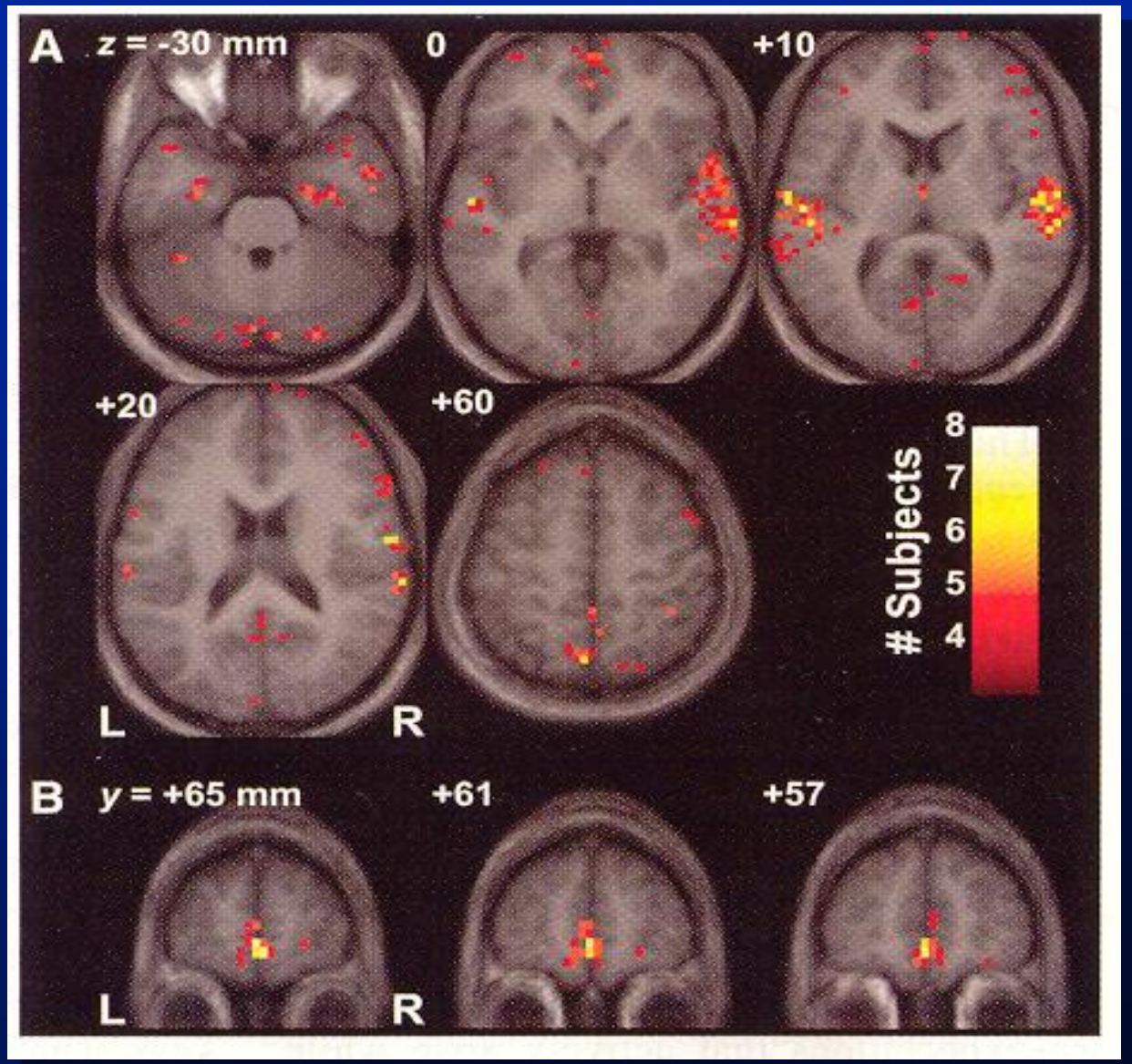
Hugdahl 2003

Identifying of tones out of key.

Control task:
Change in timbre
(clarinet vs flute)
8 experienced listeners.
Functional MRI-technique.

A: Activated areas
at both listening
tasks

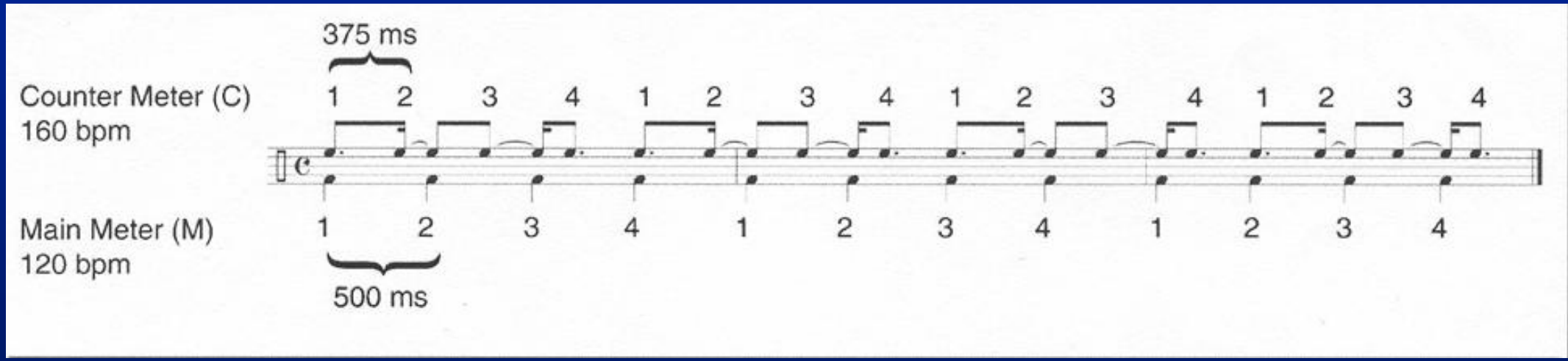
B: Specifically activated areas when tones out of key were presented;
”rostromedial prefrontal cortex”



Janata et al, Science dec 2002

Vuust et al, Neuroimage 2006

- Polyrhythmic structures. Expert jazz musicians.
- Keeping the main meter against a heard counter meter.

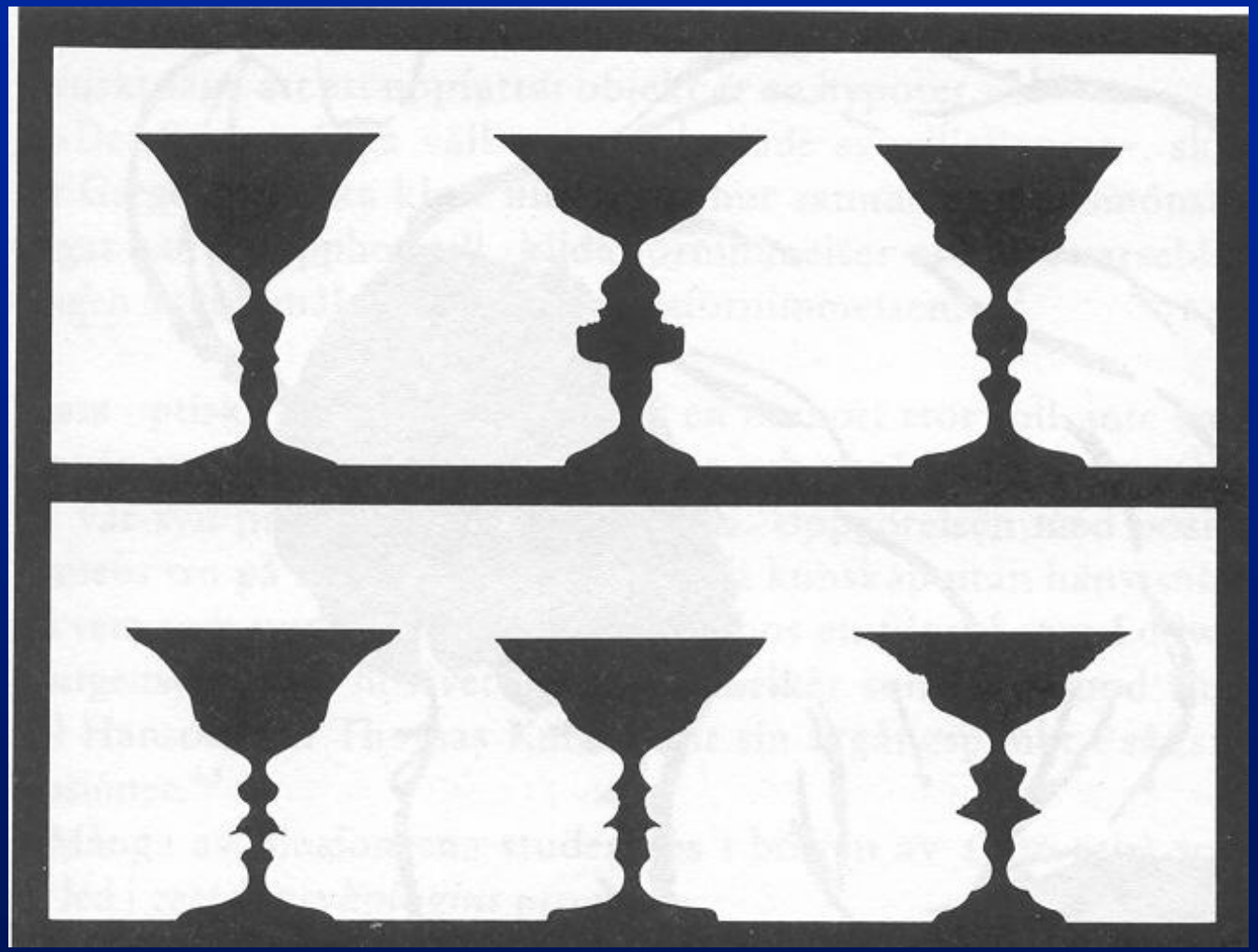


A ”bistable” state
- two simultaneous observations perceived alternatively
- c.f. Rubin’s vase

Vuust et al, Neuroimage 2006??

Rubin's vase 1918

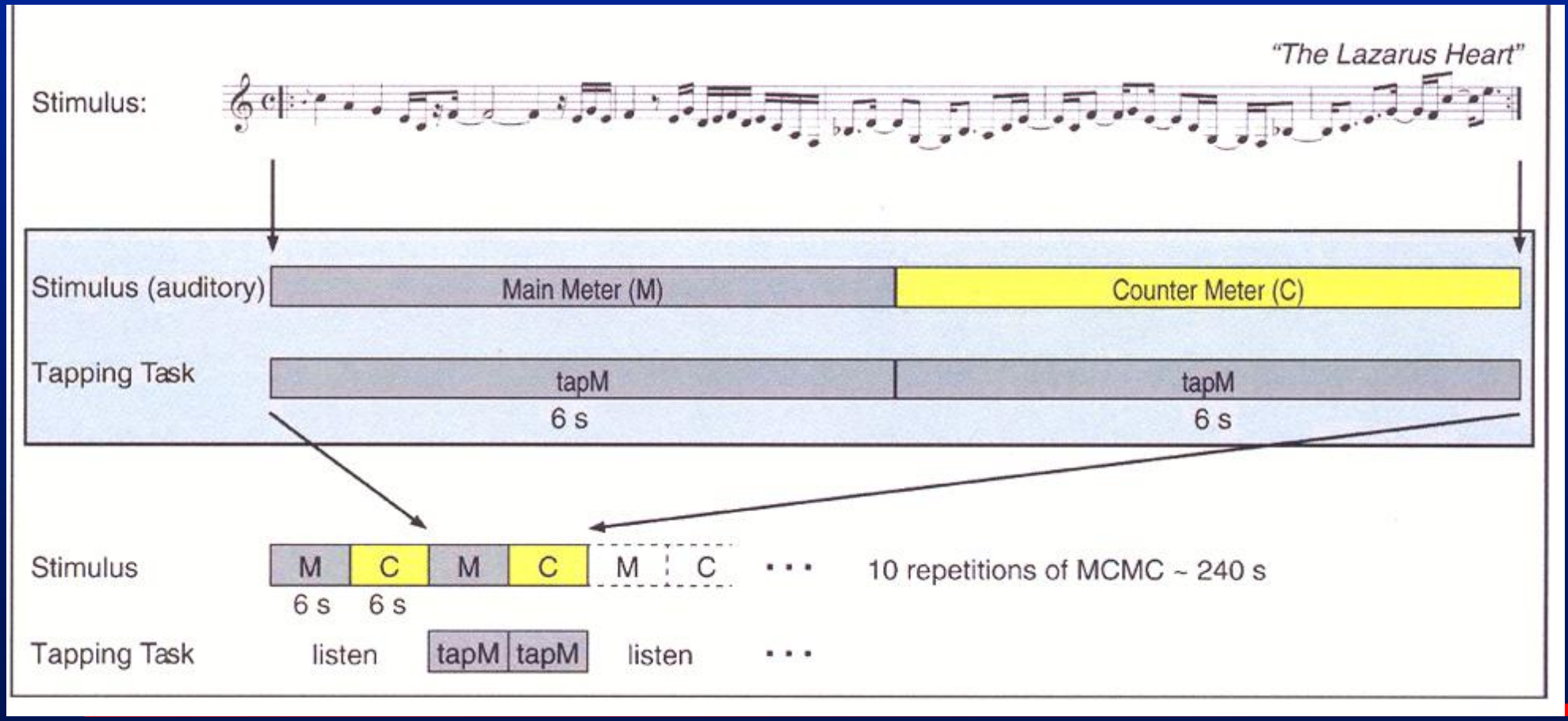
architype of a bistable state



Variants of Rubin's vase, based on photos; Berman

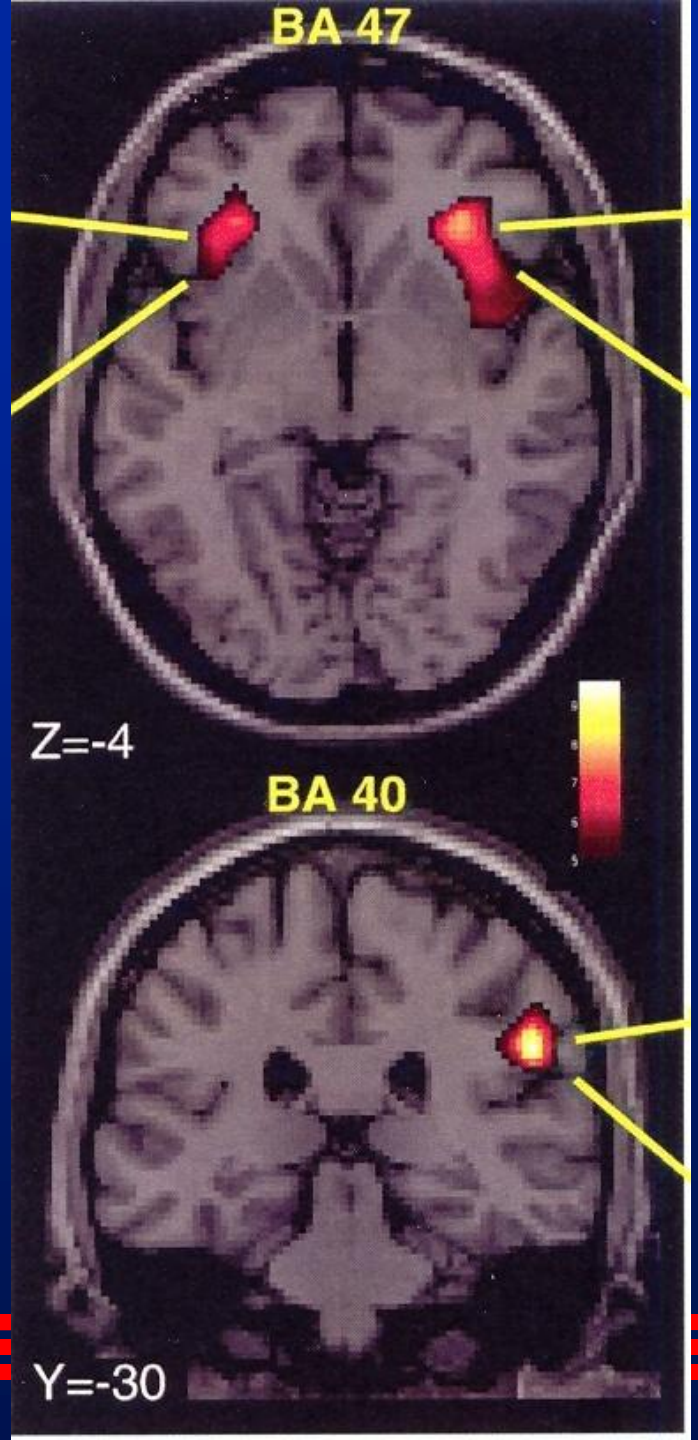
Vuust et al, Neuroimage 2006

- Keeping the main meter against a heard counter meter
- The real test situation: Difficult!



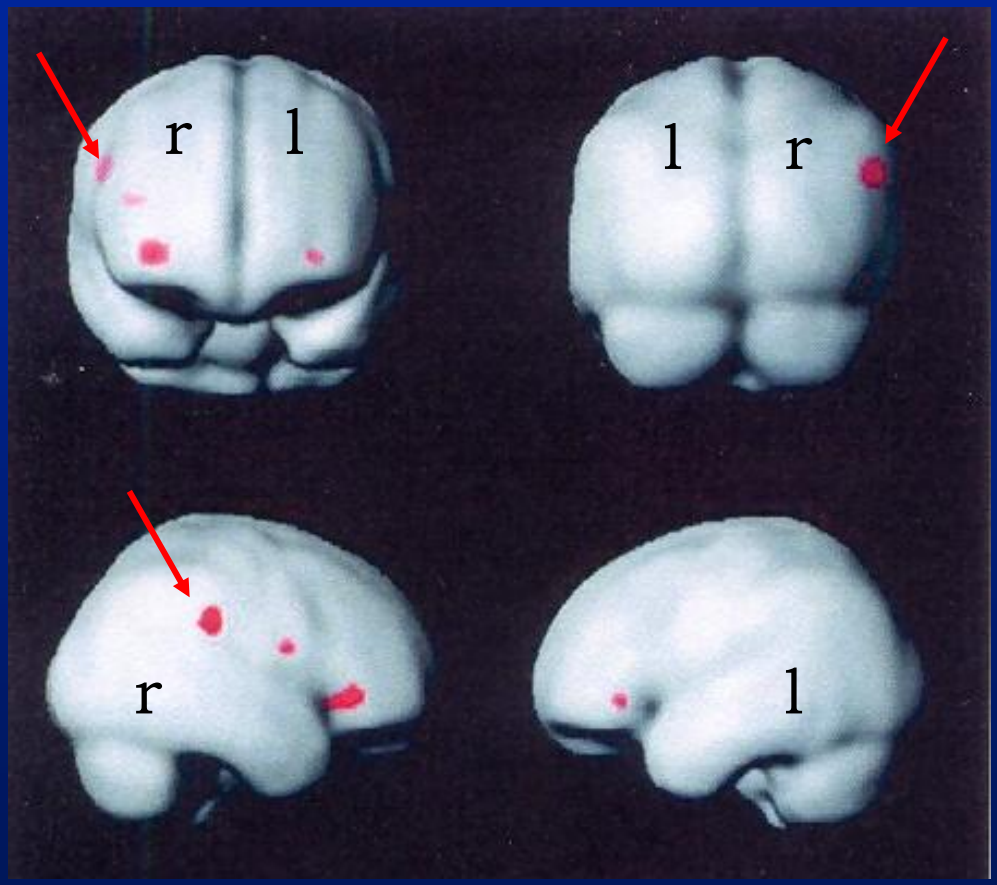
Vuust et al 2006

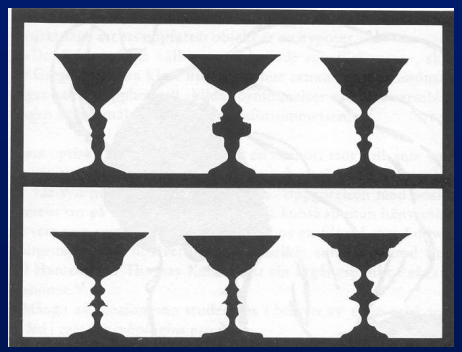
- fMRI during tapping the main meter against the violating, ”disturbing” counter meter.
- Activation of
  inferior frontal gyrus
  both sides,
  but predominantly
  left hemisphere



Vuust et al, Neuroimage 2006

The second most activated region during tapping was the right supramarginal gyrus, shown to be activated when regarding bistable states like Rubin's vase.



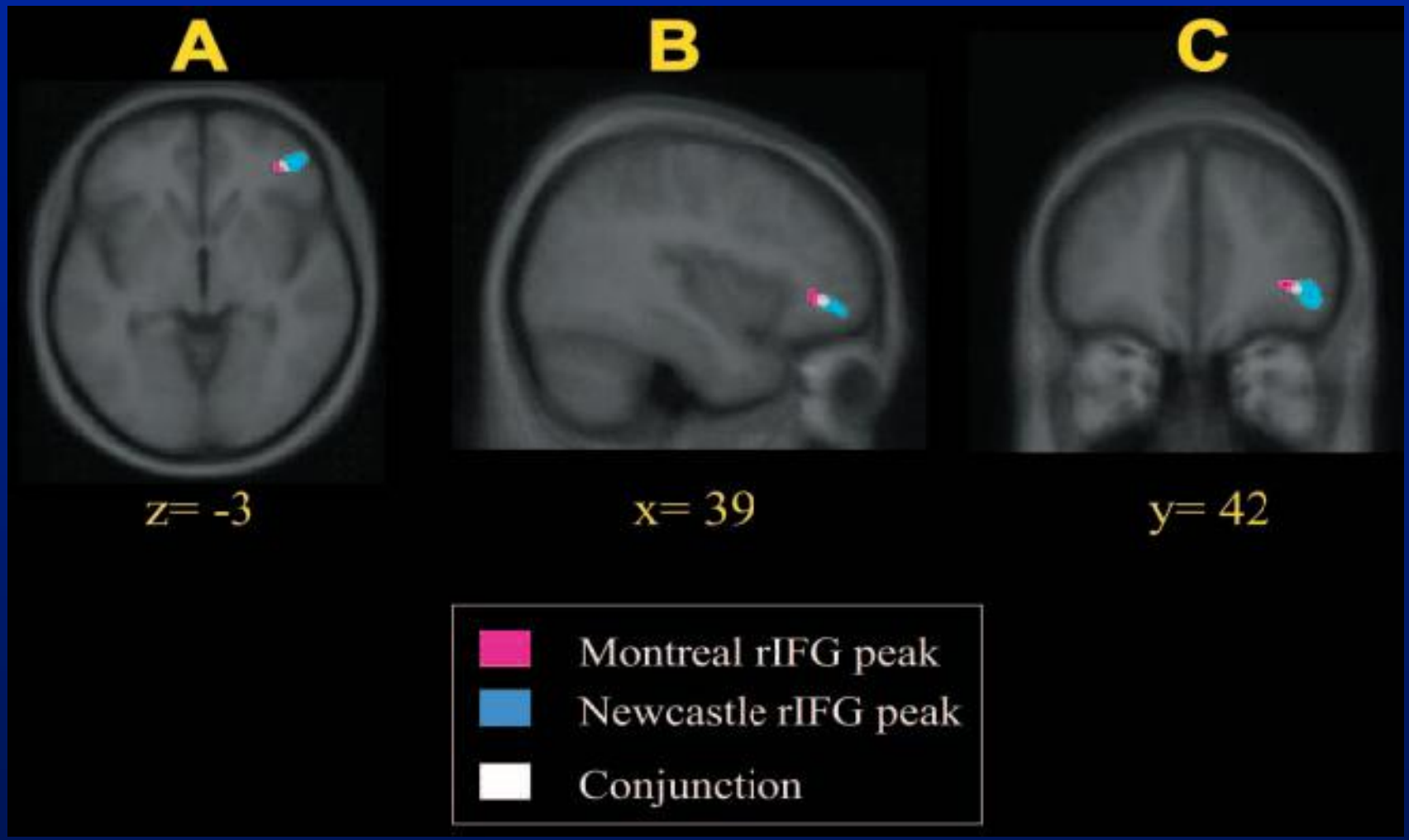


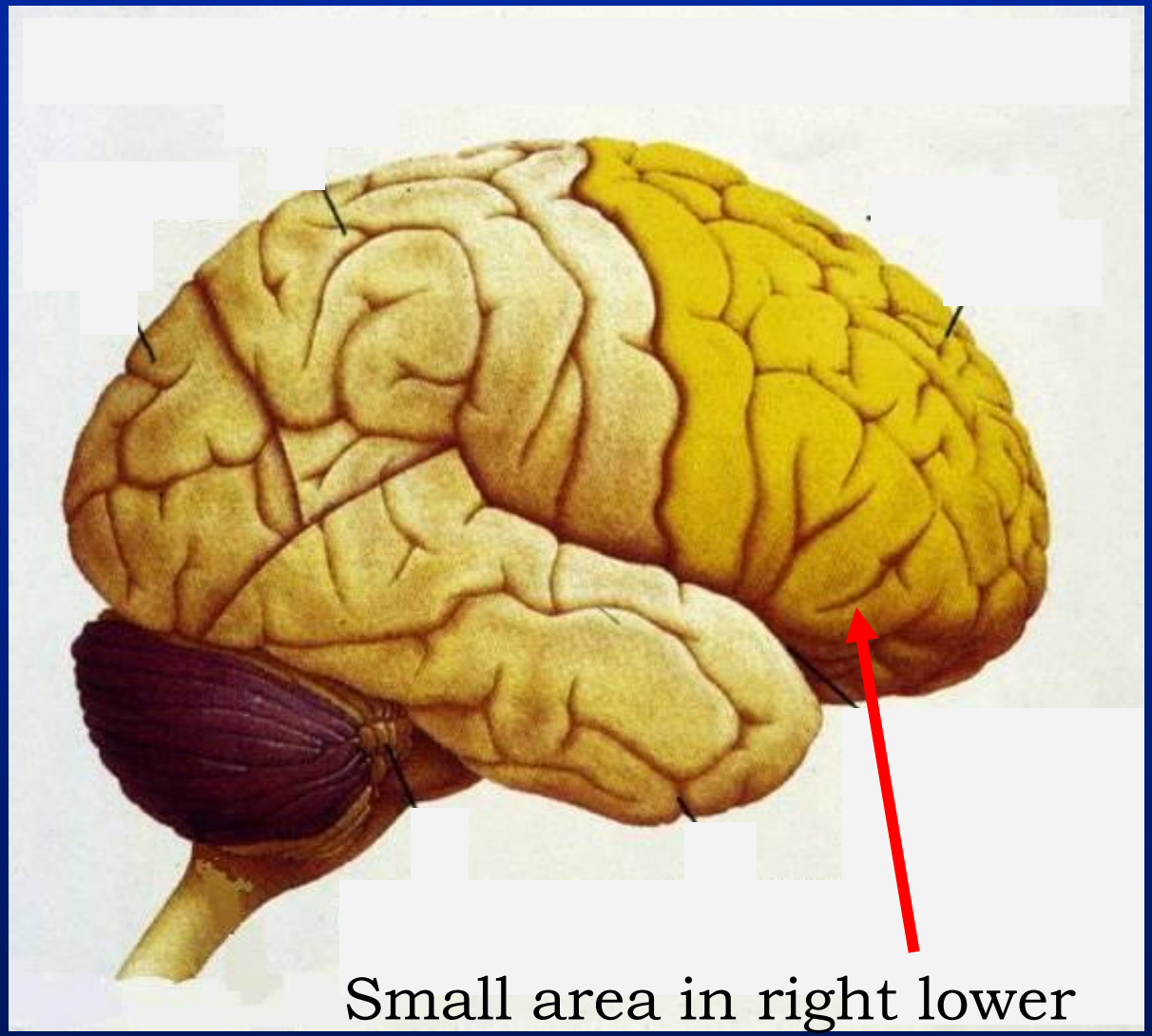
Hyde et al (Zatorre, Peretz) Brain okt 2006

- ”Morphometry of the amusic brain”
  - ”Congenital amusia”; inborn tone-deafness; newspaper anouncing
  - MRI-technique, voxelbased morphometry
- Small area in right lower frontal lobe gyrus, ” orbital aspect of gyrus frontalis inferior”
- Less volume white substance in the ”amusic” group
- No difference for hearing centers;

  no detectable image defect on individual level

Hyde et al Brain 2006, fig 5





Small area in right lower frontal lobe gyrus,
” orbital aspect of gyrus frontalis inferior”

Hyde et al (Zatorre, Peretz) Brain okt 2006

- ”Morphometry of the amusic brain”
  - ”Congenital amusia, inborn tone-deafness”; newspaper anouncing
  - MRI-technique, voxelbased morphometry
- Small area in right lower frontal lobe gyrus, ”orbital aspect of gyrus frontalis inferior”
- Is thereby a ”music center” discovered??
- Or should it be regarded as a more isolated ability to discriminate pitch, (”tone height”), that makes human sound play – i.e MUSIC – possible? If so, an analogue to the pitch analysis in the cochlea??

MUSIC
vs
LANGUAGE

MELODY and PROSODY (speech melody)

Melody Greek *meloidia,* to sing; *melos* song, *oide* lyrics

- "Organized one-part tone sequence that constitutes a musical unit" and "pitch course in speech"

  Swedish NE minor 2009

- "A succession of musical tones /with/ different pitches . . . ; by its very nature melody cannot be separated from rhythm"

  Apel: Harvard Dictionary of Music 1965

- "An organized sequence of pitches that conveys a rich variety of information to a listener"

  – in order to get rid of the music part of the definition.

  Patel: Music, language and the brain 2008

MELODY and PROSODY (speech melody)

Different functional domains

- Musical melody - an aesthetic object, an end in itself -

  Swedish självändamål

- Linguistic intonation - a service to the message
- Musical melody is “a group of tones in love with each other” (Simon Shaheen, interview - Arabic composer/violinist)
- Speech melody is “a group of tones that work together to get a job done” (Patel 2008)

PROSODY - SPEECH MELODY

Two different types of prosody

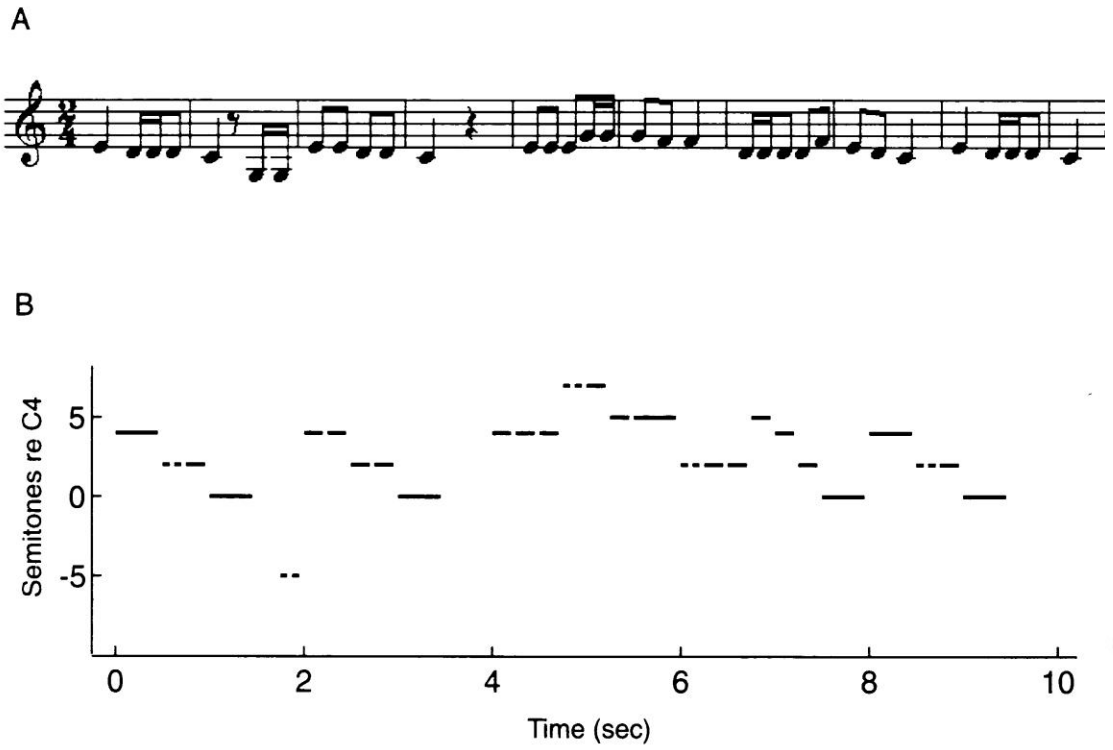
- Semantic prosody -
  - I want to STRESS PARTICULARLY what I am saying to you NOW!
- Emotional prosody -
  - I cannot control my voice pitch since I am so angry!
  - I cannot control my voice pitch since I am so sad . . .
- Regulated from different parts, different hemispheres of the brain
  - Semantic the left, “major” hemisphere
  - Emotional the right, “minor” hemisphere

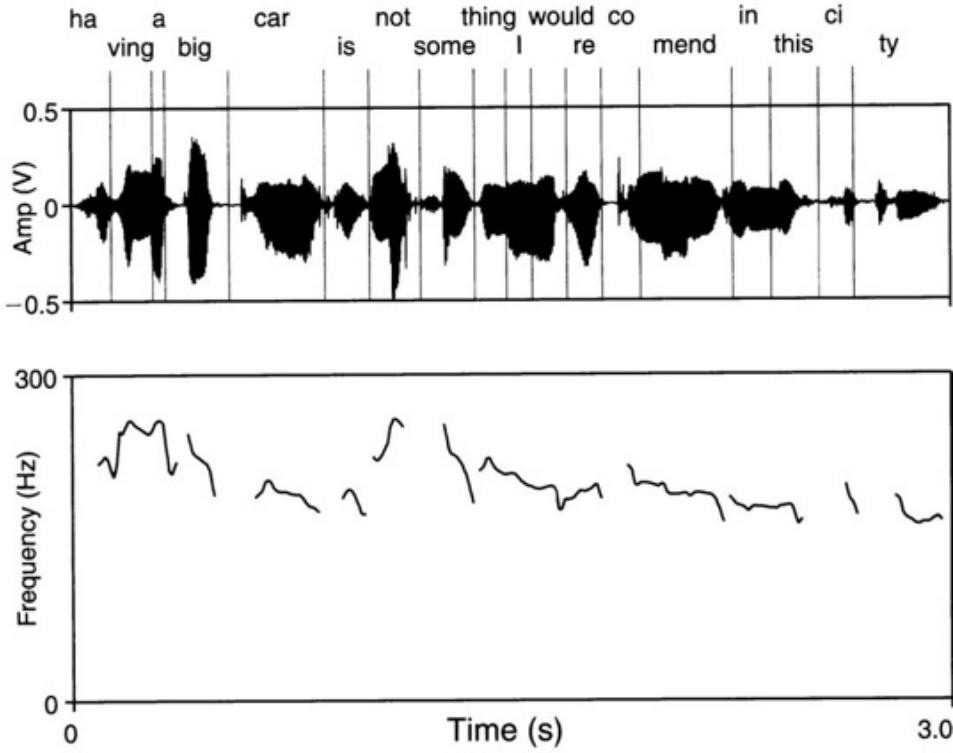
PROSODY - SPEECH MELODY *Patel, Peretz et al 1998*

- Bilateral hemisphere lesions Amusia, IR > CN
- Prosodic variation – sentence pairs
  - *statement-question*: He wants to *leave* now vs He wants to leave *now?*
  - *focus shift*: Take the *train* to Paris vs Take the train to *Paris.*
  - *timing shift*: Henry, the child eats a lot vs Henry, the child, eats a lot.
- Melodic variation – sentence pairs "translated" to musical sequences
  - CN performed normally in both tasks
  - IR performed badly in both tasks
- Prosody and melody seem to share neural network

Pitch and rhythm of a melody and a sentence

From Patel 2008





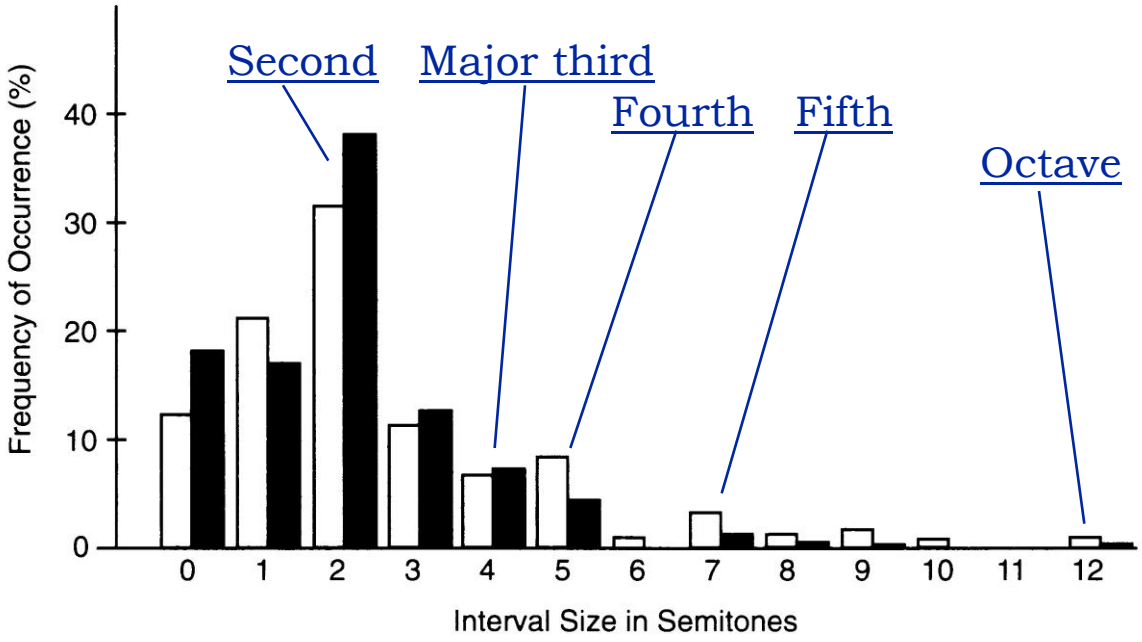
”Having a big car is not something
I would recommend in this city”

Interval distribution in melodies and speech

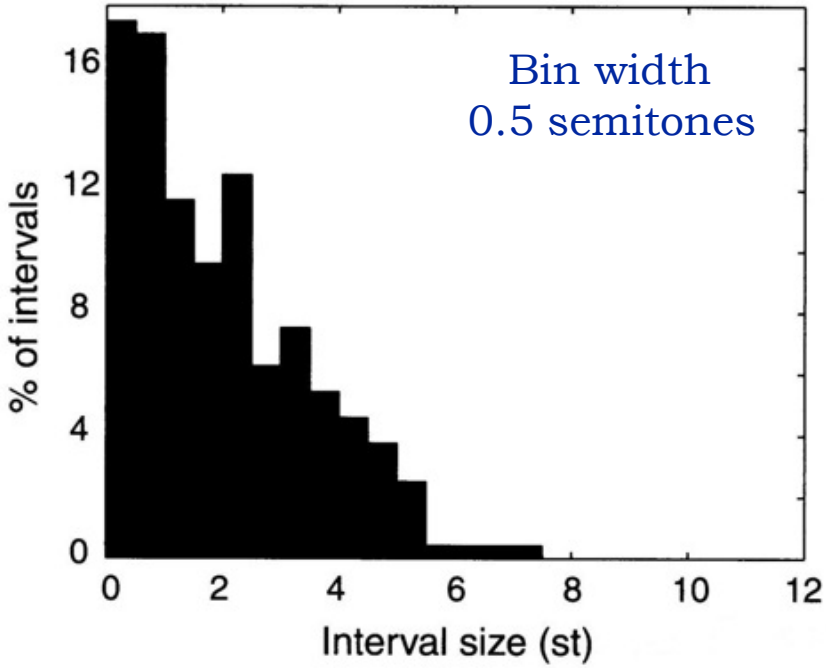
From Patel 2008

A sample of Western music

white bars classical/rock; black bars folkmusic



English & French speech

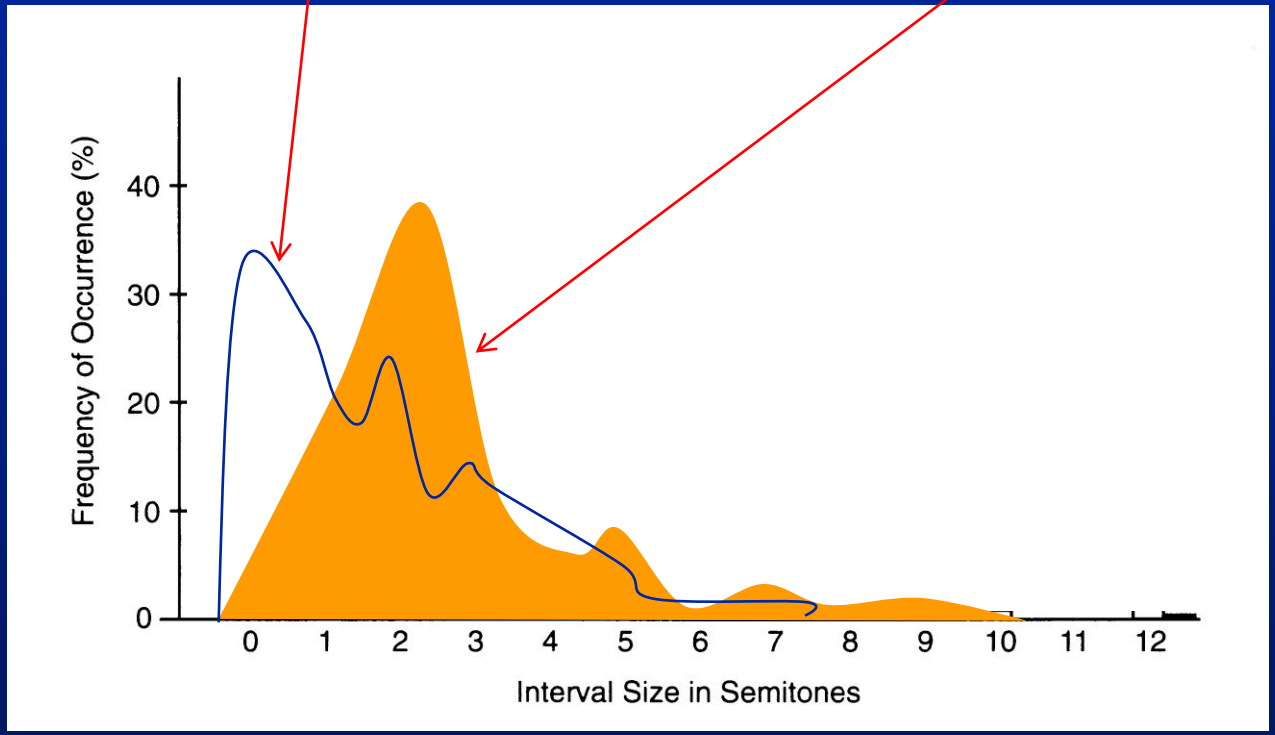


Interval distribution in melodies and speech

Modified from Patel 2008

The speech sample

The music sample



Not very similar distributions!

Syntax in language and music

Related/overlapping functional domains ? ?

- Linguistic syntax – principles governing the combination of semantic structural elements into sequences. Swedish ***satslära!***
- Musical syntax – principles governing the combination of discrete musical structural elements into sequences;

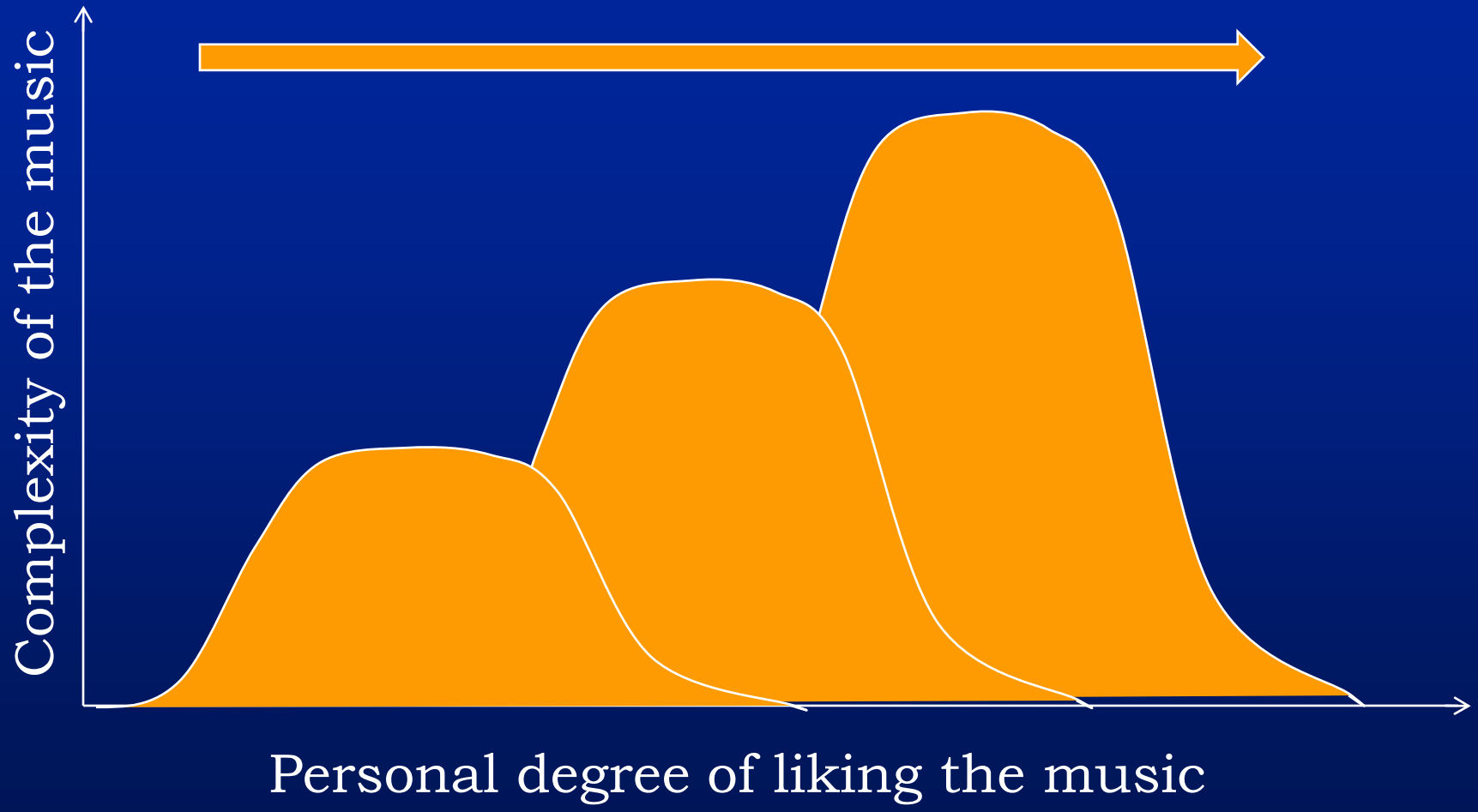
  or "principles of harmonic distance and relatedness" Swedish ***satslära!!***

- Musical syntax – "repose" on the tonic – "tension" with movement from the tonic – repose again when returning to the tonic
- Violations from the musical syntax – modulation, dissonance, (timbre?)
- Violations from linguistic syntax:

  The concert that was given on Monday. . . . vs

  The concert that had given on Monday. . . .

With practise/experience, you learn to appreciate ”difficult music”, including dissonance – ”syntax errors”



Language and music

Related/overlapping functional domains ? ?

- Musical skills facilitate the aquisition of a second language, especially the phonological part, i.e. *sound quality*.

  Sleeve & Miyake Psychol Sci 2006

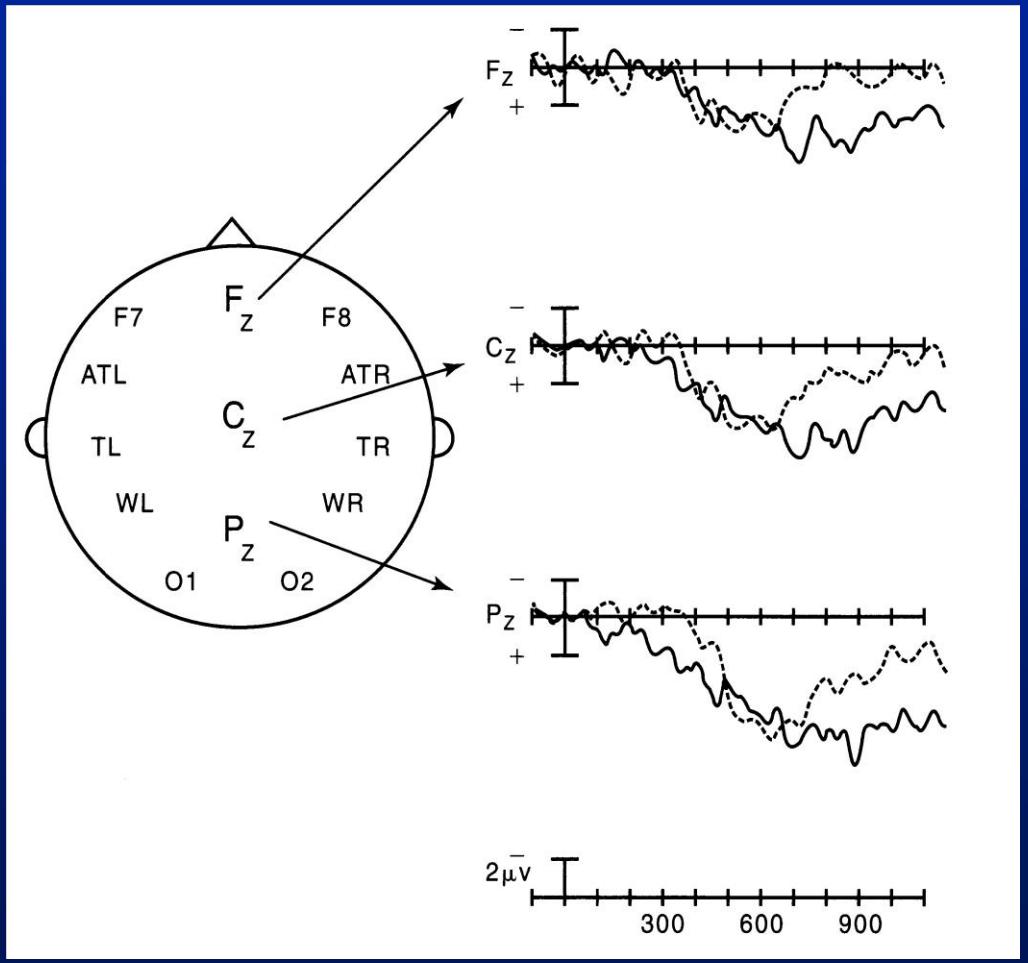
- But strong individuals exceptions are documented

  Novoa et al 1988 : Native English; started 2nd language at 15 yrs;
  talked French, German, Spanish, Italian, Morrocan Arabic like a native;
  "lower part of average" in simple musical tests.
  An atypical savant??

- Musical skills correlate sign with phonological awareness and reading development in children. ***Anvari, Trainor et al J Exp Child Psychol 2002***
- But impact from general talent cannot be ruled out.

ERP 600 following linguistic and musical "syntactic incongruity"

Patel et al 1998



Brief speech sequences

Chord sequences:
(Not simple tone sequence

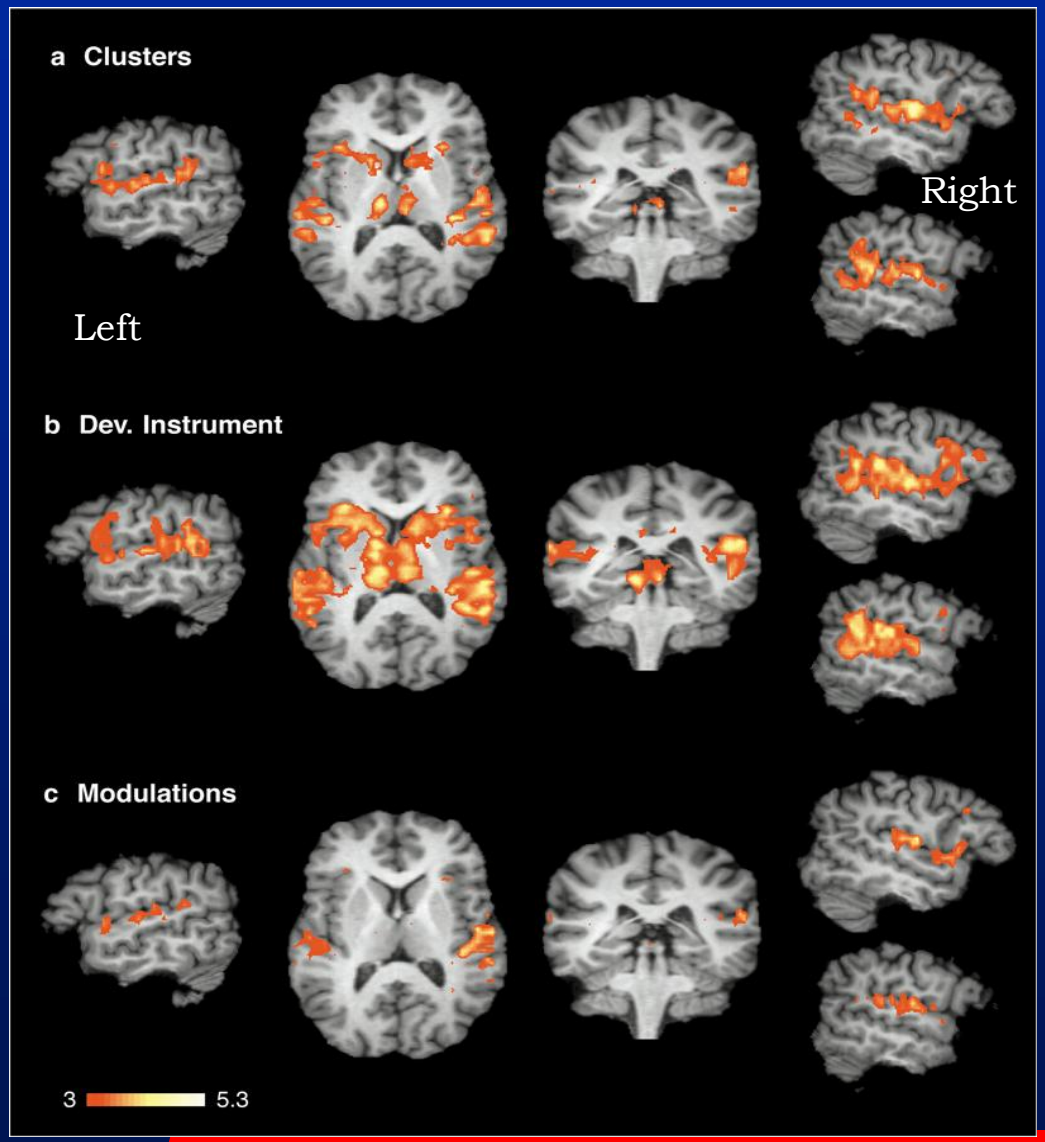
Solid line – speech
Dashed line – music

Similar ERPs

Reaction rather symmetrical

Syntax in language and music

Koelsch et al 2002
Bach speaks . . .



Subjects w/o musical training

Chord sequences:
(Not simple tone sequences)

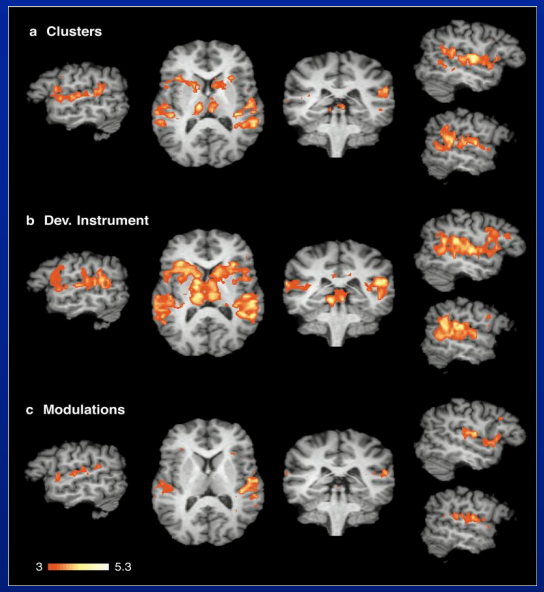
In key vs
- terminating i dissonance
- in key; different timbre
- modulating to another key

Markedly similar, symmetrical activation,
incl ”language areas”
(but different strength of activity)

Left is left in the transaxial and frontal images

Syntax in language and music

Koelsch et al 2002
Bach speaks . . .



Right hemisphere predominance for

- change in timbre
- dissonance

especially rear parts of gyrus temporalis superior;

”Areas involved in phoneme identification”!

(Pöppel 1996)

A possible conclusion:

- Auditory areas in the right hemisphere identifies individual sounds, musical or linguistical
- Corresponding left areas put them together to be meaningful (= syntax)

At variance with other observations

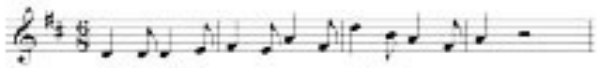
”Music and language side by side in the brain”

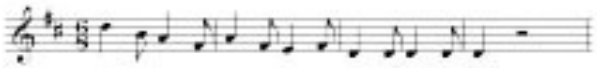
Brown et al
Eur J Neurosci 2006

Amateur musicians PET $^{15}O_2$
Task: spontaneous, ”fanciful” generation of a completion to a simple unfinished melody or sentence

”Representative examples”:

Melody Completion





Sentence Completion

"August was the *best* month for them to take the Spanish course in Peru because..."

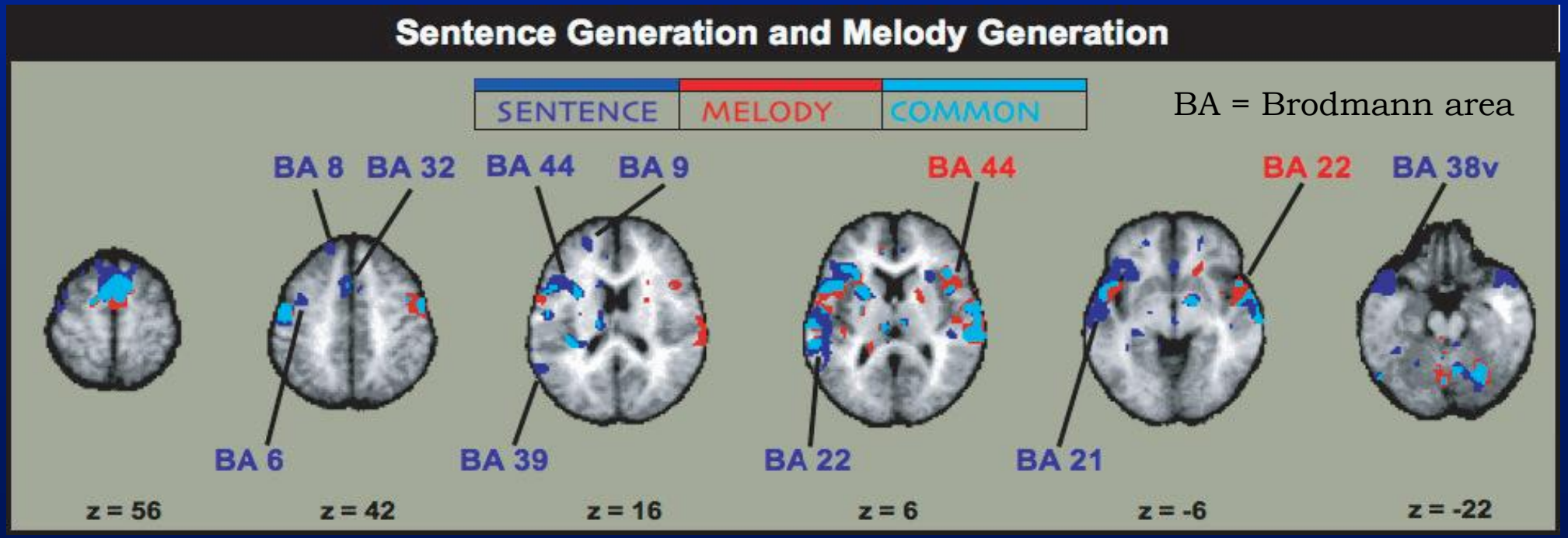
"...Peru was a great place to be that time of year, and the weather was just fine."

Music and language side by side

Brown et al
Eur J Neurosci 2006

Left hemispere dominance for speech – ”unique” spots dark blue
Right hemisphere dominans for melody – ”unique” spots red

CONSIDERABLE OVERLAPPING – light blue

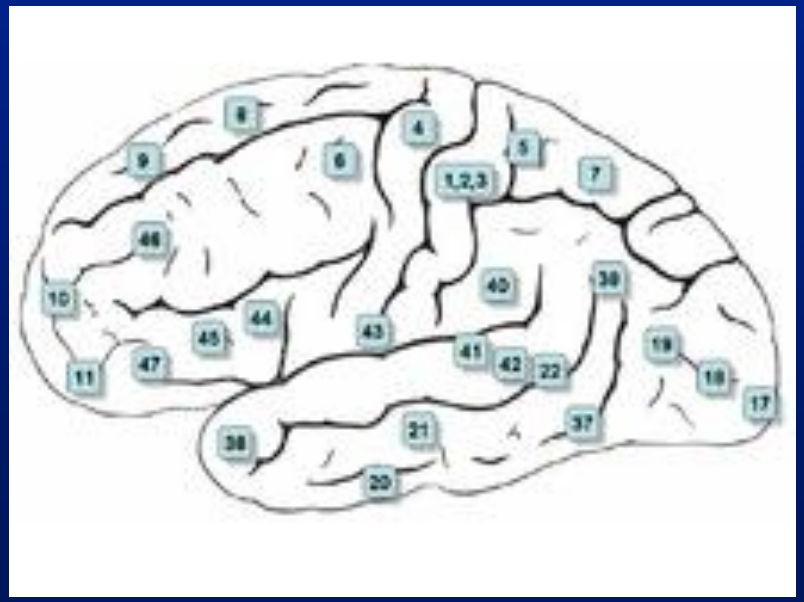


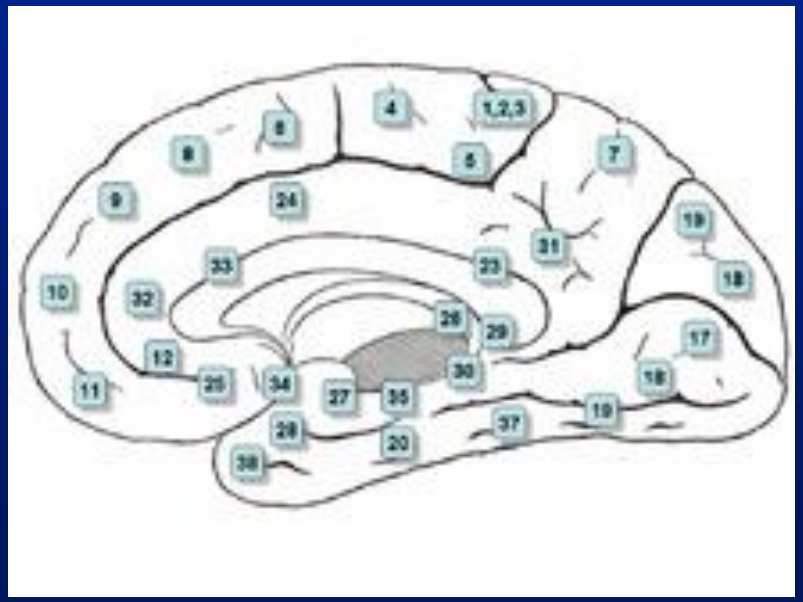
Left hemispere to the left in the image

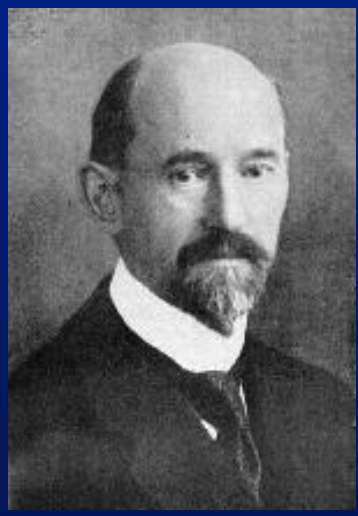
Brodmann areas

A detailed ”geographical” mapping of the cerebral cortex

Korbinian Brodmann, 1868 – 1918), German neurologist,
52 distinct cerebral cortex regions corresponding to their
cytoarchitectonic (cell appearance) characteristics







No language impairment in congenital amusia!!

Ayotte, Peretz, Hyde Brain 2002; 125;238-51

- 4% of the general population might suffer from tone-deafness
- Pitch variation, musical memory and recognition, singing and tapping the rhythm!!
- Normal speech processing, including prosody and recognition of environmental sounds and human voices!

- Does this make sense? Musical ability widespread!
- A paradoxical proudness of being an individual with the unique feature of tone deafness?? Exaggerating difficulties????

- Boasting of bad talent – common with music and athletics?!

The FOXP2-gene, "the KE family"

- A "grammar gene" ??
- Aphasia-like difficulties
  - distinguish real words from non-words;
  - phoneme-handling
- Orofacial dyspraxia

- Singing ability affected
  - rhythm more than pitch recognition

Music and language side by side ?

Despite a number of documented overlappings between language and music domains:

from a practical ”clinical” point of view the dominance for language to the left is very strong.

Aphasia!

Olof von Dalin 1745

BERÅTTELSE

Om en DUMBE, *ſom kan ſiunga:*

Af

OLOF DAHLIN.

Jon Perſon, en Bondeſon från Ofvankihl i Juleta ſokn i Sörmanland, född 1703, upfödd på vanligt enfaldigt ſätt, at veta ſin Chriſtendom och läſa i bok, föll åhr 1736, ſen han i 3. åhr varit gift, i en hetſig ſiukdom, hvaruti han blef rörd af ſlag på hela högra ſidan af kroppen, och aldeles *mål-lös*. Efter näſtan et halft åhrs ſång-

Luria et al 1965

- Vissarion Shebalin 1902-1963
- Accomplished composer
- Stroke 1959, severe aphasia
- Composed thereafter
  cello sonata, piano sonata , choral works, string quartets, a symphony
- “Corresponded to his previous high level”

Amusia – a comparison to aphasia

- Amusia – not as strictly localized and ”predicitive” as aphasia
- General principles:
  - right-sided lesion in laymen of importance
  - left-sided lesion in musicians of importance
  - motor amusia – frontal lobe lesion
  - sensory amusia – temporal lobe lesion

CHILDREN

Mozart in Vienna 1762

Fetal learning infant recognition

James et al 2002

- 10 + 10 fetuses, 2-3 days before delivery (elective Cesarian sectio) - normal pregnancy
- Headphone on mother's abdomen: "Little Brown Jug" with Glenn Miller Band or silence, 4 hours
- More heart rate variation and fetal movements
- Same music to all infants 3-5 days after birth:

  those who "knew the music" more alert and active

The child's sound, language, song

- Babbling – 3-4 months (descent of larynx 6 mo)
- Language
  - 1 yr – single words;
  - 2 yrs – two-three-word sentences (+ jingles)
  - 3 yrs – ”conversation”
- Song
  - ”musical sounds” 6 months
  - 1 yr – clear singing attempts
  - 2 yrs – clear singing

Laurel Trainor, McMaster Univ, Ontario

From Trainor's home page

Motherese – ”mödriska”

Infant-directed speech – and song

- High pitch– often on a stable level; slow tempo; overarticulated; pauses
- The child attentive
- Universal – similar in ”all” languages
- Reinforces bonding child-mother – survival value in pre-pre-historic ages?

(evolution! – Sandra Trehub)

Lullabies

Sandra Trehub, Toronto University

- Uniformity across cultures
  - melody, rhythm, tempo
- Adults identify lullabies from its character, irrespective of language
- Infants more attentive to lullabies than IDS / motherese
- Infants more relaxed (cortisol in saliva) av from lullabies than from motherese.
- General mother's experience on scientific level!

Vaggsång, lullabies

Sandra Trehub 2003, Toronto University

- ”To the extent that maternal singing optimizes infant mood, it could contribute to infant growth by facilitating feeding, sleeping, and even learning. . . . . Presumably, the healthy and contented offspring of singing mothers would be more likely to pass on their genes than would the offspring of non-singing mothers”.
- Strong evolutionary statement!

”Born with a kind of musical wisdom and appetite”

(Colwyn Trevarthen, Edinburgh)

Sandra Trehub, Toronto:

- Infants do have har musical capacities:
  - Recognize melodies
  - React to unexpected changes in a musical course
  - ”Prefer” asymmetrical scales – unequal steps – before a whole tone scale (the octave in 7 equal step

- ”Music is adaptive, selected by the evolution”, with a biological survival value ! ?

- Musical ability is undoubtedly innate.

EVOLUTION

Why do we have music?

?evolution?

?

Why do we have music?

- The purposeful brain
- What basic biological significance?
- Is music adaptive,

  ”selected” by evolution?
- Or an extraordinary side effect of the extraordinary capacities of the human brain?

Music as an evolutionary adaption?

A number of pros and cons

Music lovers argue for music
being an evolutionary adaption
because they are music lovers.

An embarassing bias?

A bone flute, > 30 000 years old

Ulm, south-west Germany

”The oldest undisputed evidence of music”

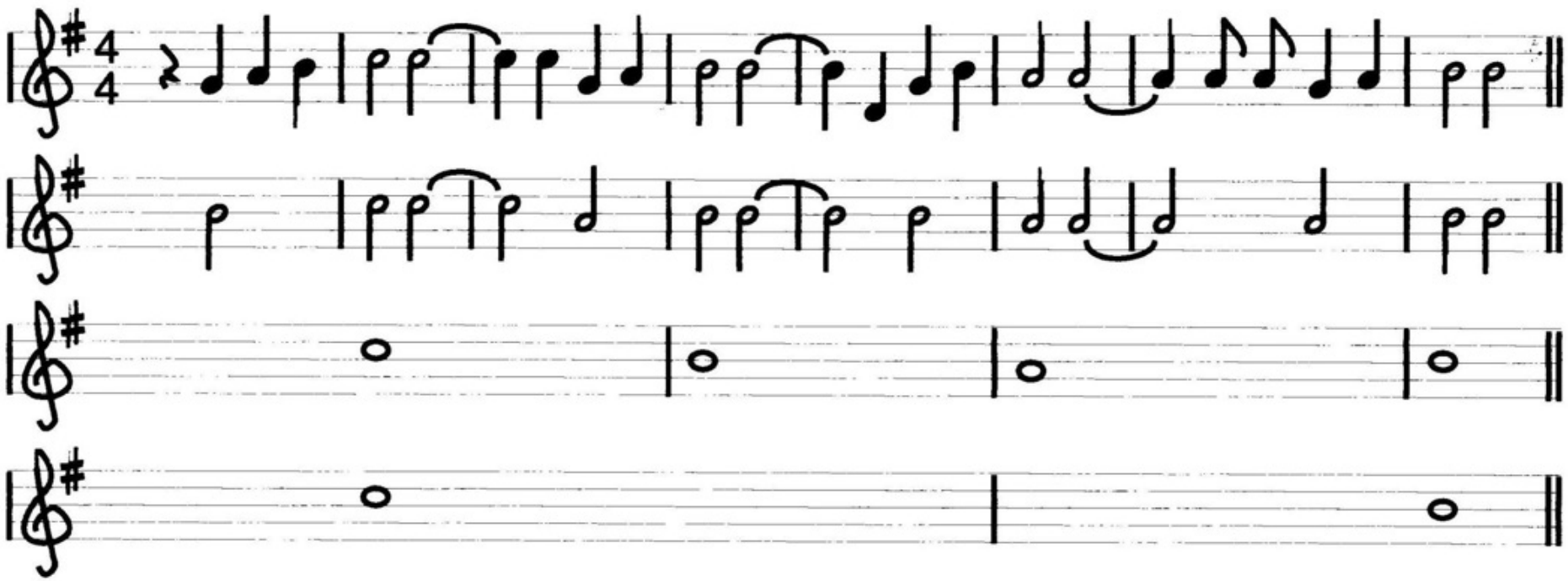
Steven Pinker, How the mind works, 1996

- Biologically, music is useless!
- ”Musical sophistication varies across individuals, cultures and historical periods in ways that language does not”
- ”Music . . . pure pleasure, a cocktail of recreational drugs that we ingest through the ear to stimulate . . . [cerebral] pleasure circuits”
- ” . . a cheesecake . .” (We like sugar, by evolution!)
- ”Music . . the clearest signs of not being adaptational”

Steven Pinker, How the mind works, 1996

Pinker – presumably not a devoted music lover!?

A so-called time-span reduction analysis of a tone sequence, with Pinker's comment



The whole passage is basically a fancy way of getting from C to B.


SÖNDAG 28 JUNI 2009

DAGENS NYHETER.

Teori 1: **Musik och sex hör ihop**

Teori 2: **Musiken skapar vi-känsla**

Teori 3: **Vi fick musiken på köpet**

? Music is adaptive, "selected by the evolution", with a biological survival value ?

All known human civilisations have music in organised form

But:

- 4% of healthy humans are "amusic", tone-deaf, congenital amusia (Isabelle Peretz), without any other detectable defect (*true*?)
- We do survive without music!
- *Homo ludens* – an amusing play with the sounds!

Cave paintings – paleolitic art

Lascaux
15 000 f Kr

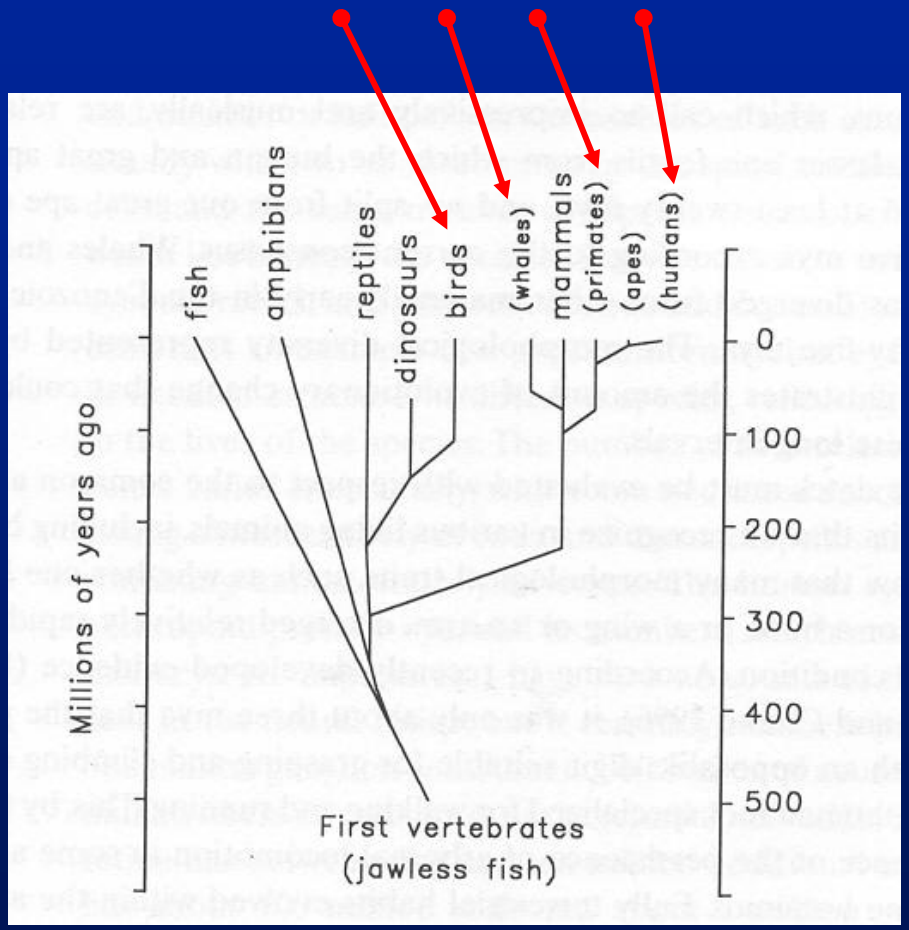
Altamira
15 000 f Kr

Niaux
15 000 f Kr

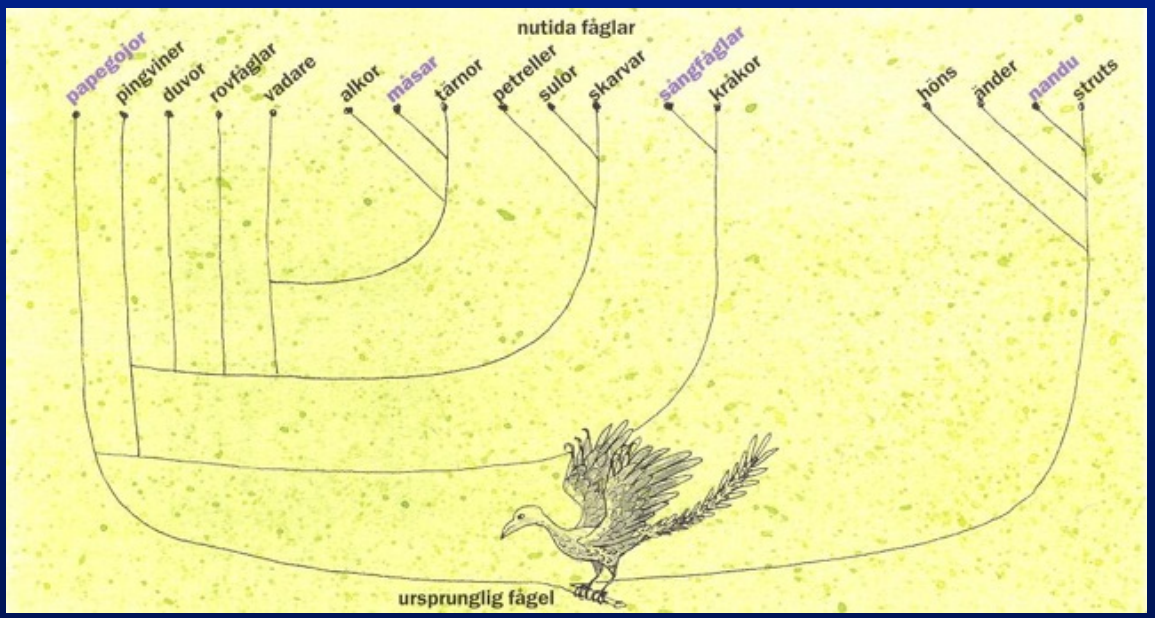
Bourdeilles

Why do we have music?

Singing animals, developmentally far away from each other!



Similar characteristics may develop several times in different developmental chains.
Birds with ability to see short-wave UV-light:



Language and music – a common origin?

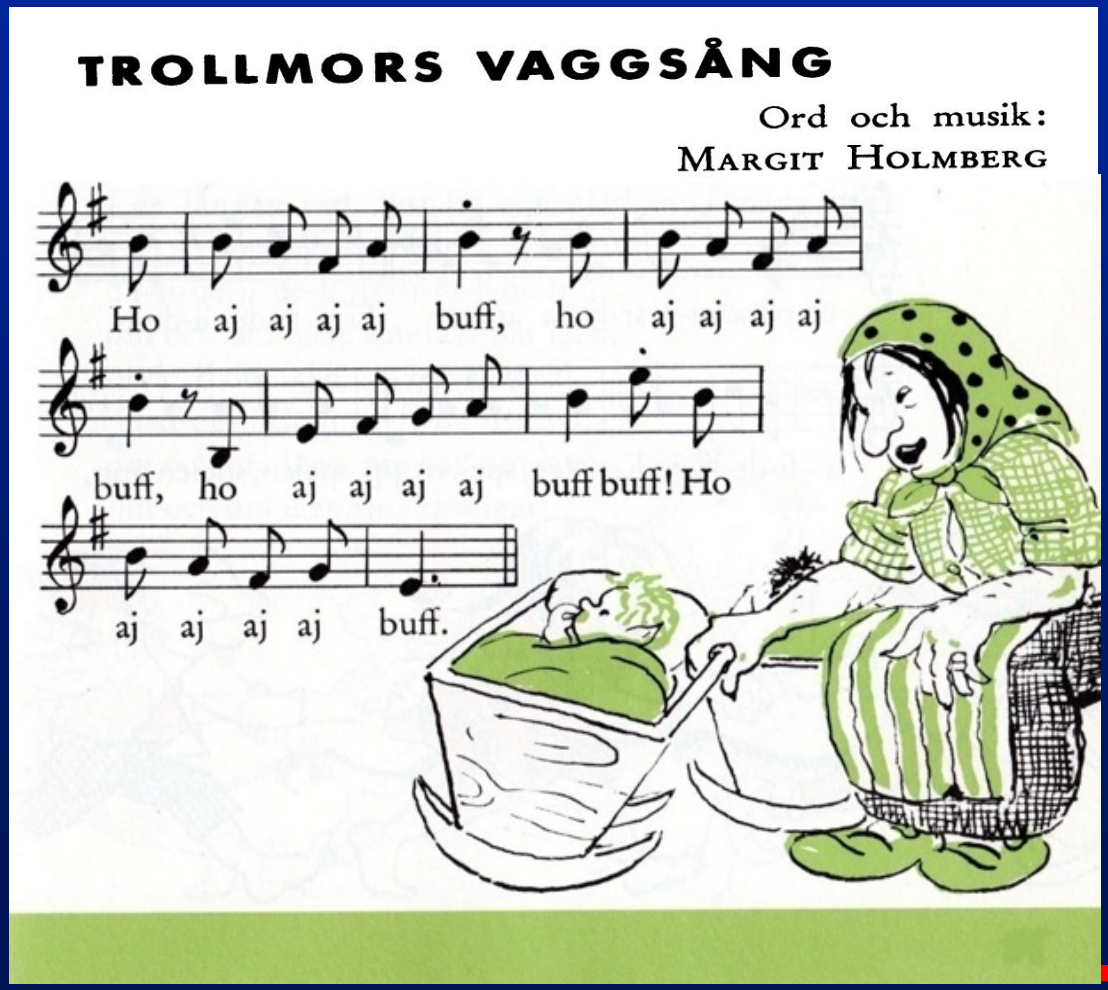
- Hearing and producing *sound*
- Hearing and producing *pitch*
- Hearing (feeling) and producing *rhythm*
  - Sounds of music or language?

BOTH!

Language	Music
Work, survival	Entertainment, quality of life
Homo sapiens	Homo ludens

Why do we have music?

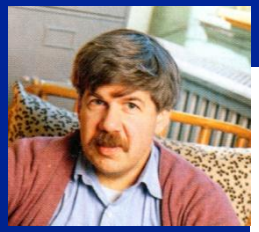
A co-evolution language and song/music



Football fans' song

”The spandrels of San Marco - - - a critique of the adaptionist programme”

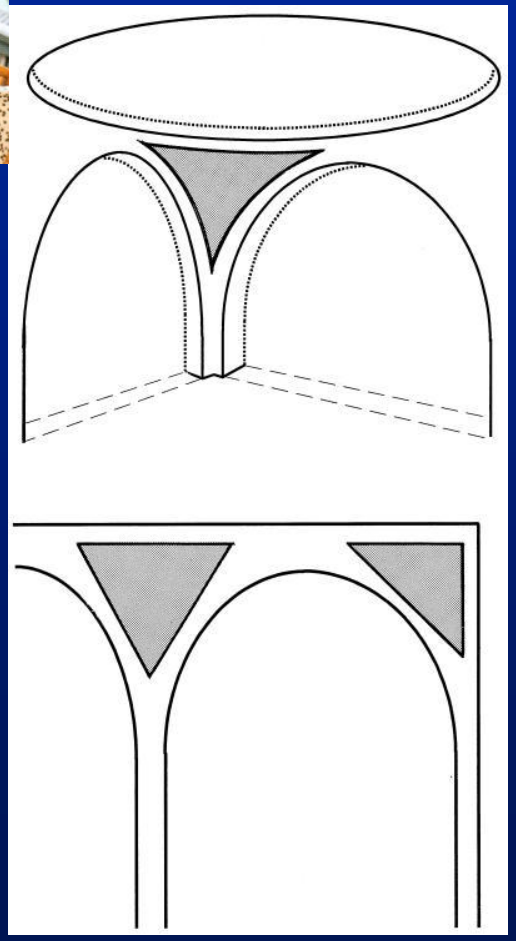
Gould & Lewontin 1979



Stephen Jay Gould
PNAS 1997:

A three-dimensional spandrel: a necessarily triangular space where a round dome meets two rounded arches at right angles.

“Classical” two-dimensional spandrels; the necessarily triangular spaces between rounded arches and the rectangular frame of surrounding walls and ceilings.



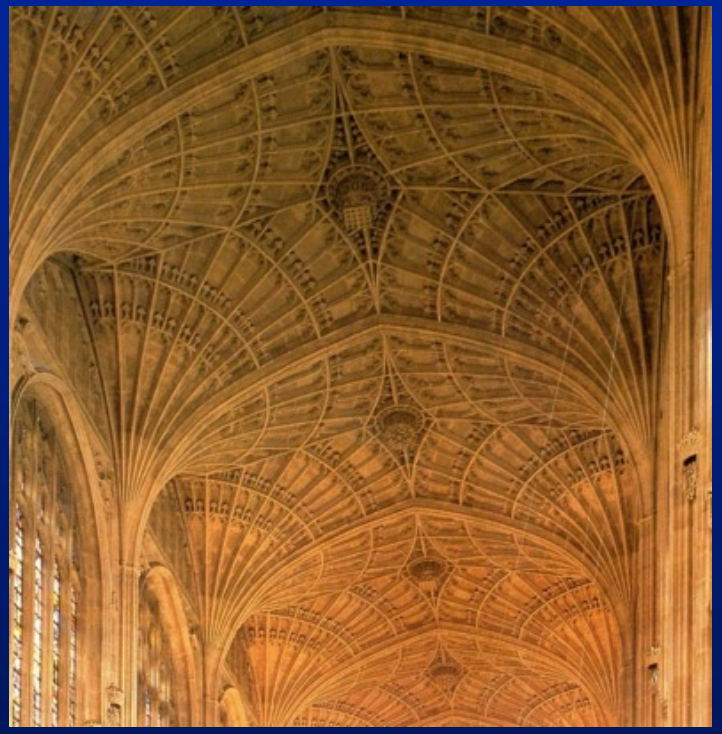
Notre Dame de Paris

Arches and spandrels, Stephen Jay Gould

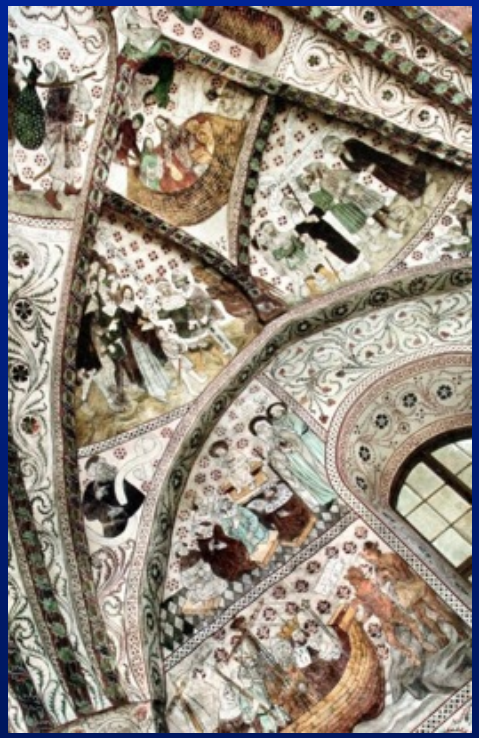
The spandrel can be decorated!

Music!?!

Notre Dame de Paris



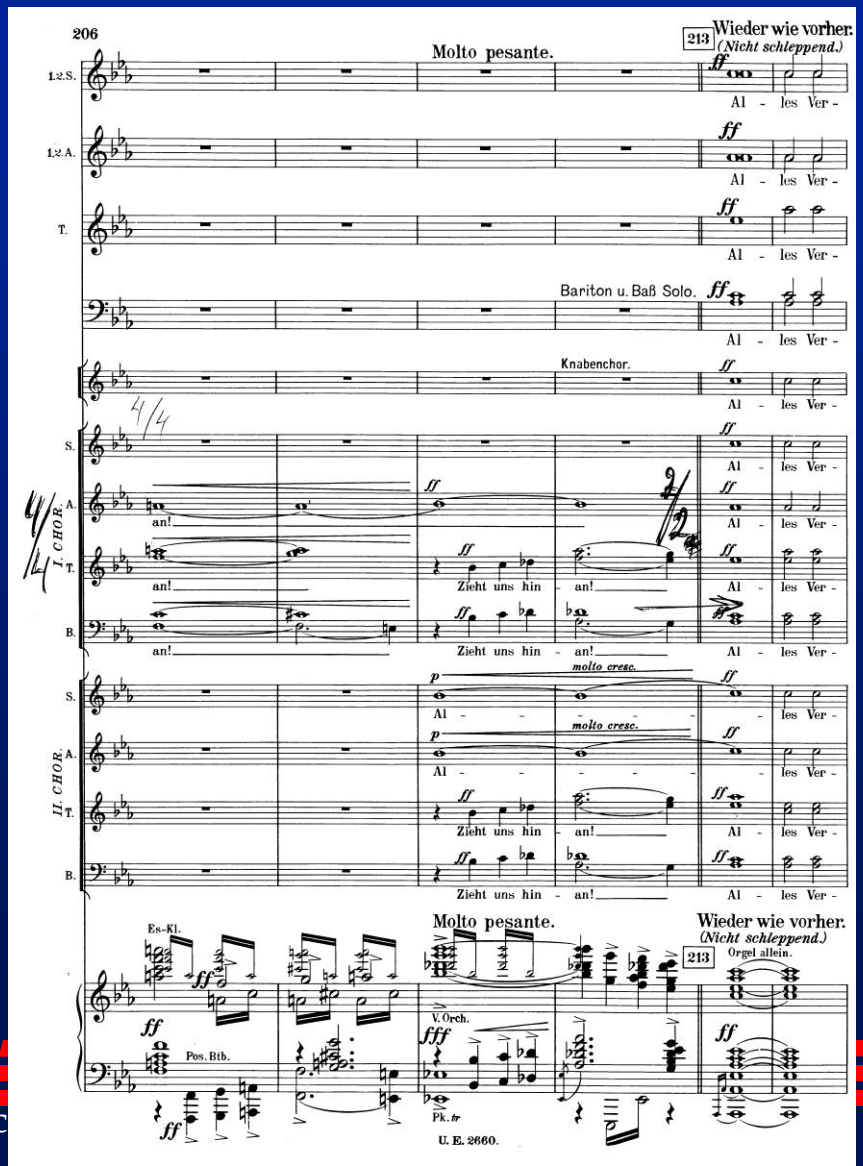
King's College, Cambridge

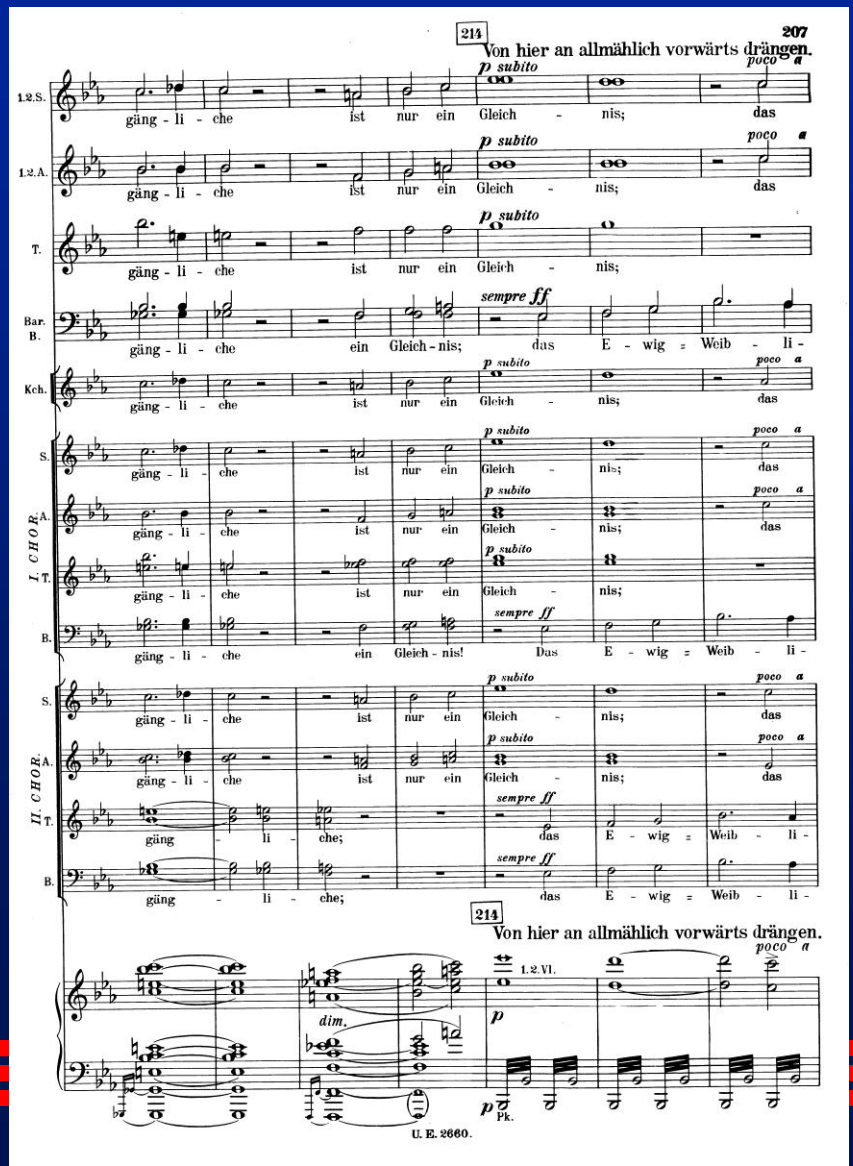


Odensala Church, Albertus Pictor, late 15th century

Homo ludens – the playing has become serious!

Mahler's 8th symphony





Homo ludens – the playing has become serious!

China 4th century B.C. England 19th century A.D.

Why do we have music?

- The purposeful brain
- What basic biological significance?
- Music could be an extraordinary side effect of the extraordinary capacities of the human brain ? !
- A ”spin-off” ! ? !

A Divine Gift!


Martin de Vos:
Apollon och muserna