# Kognitive Neuropsychologie

- 03.11. Geschichte der kognitiven Neurowissenschaft
- 10.11. Funktionelle Neuroanatomie
- 17.11. Methoden der kognitiven Neuropsychologie I
- 24.11. Methoden der kognitiven Neuropsychologie II
- 01.12. Visuelle Wahrnehmung
- 08.12. Objekterkennung
- **15.12. Auditive Wahrnehmung**
- 05.01. Sprache
- 12.01. Aufmerksamkeit und Selektion
- 19.01. Kognitive Kontrolle
- 26.01. Gedächtnis & Lernen
- 02.02. Kognitives Altern

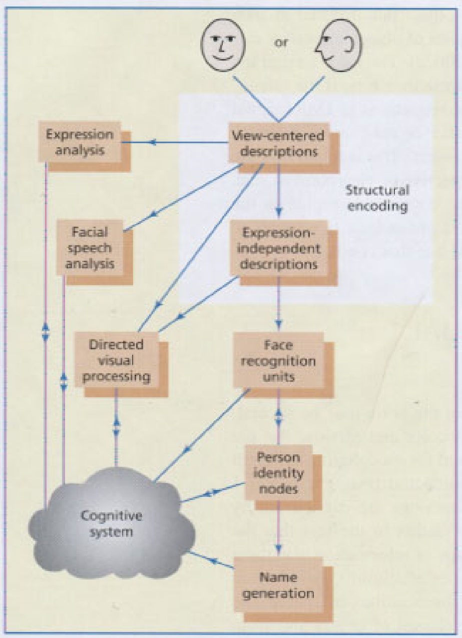
# Assoziative Prosopagnosie

(1) Patienten mit P können verschiedene Ansichten unbekannter Gesichter einander zuordnen und Alter und Geschlecht von Personen bestimmen.

(2) Patienten mit P reagieren auf bekannte Gesichter anders als auf unbekannte Gesichter (z.B. mehr Lernversuche um falsche Namen zu lernen)

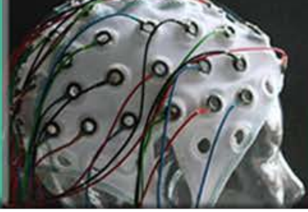
=>Perzeptuelle Analyse und Person-Identity-Nodes sind ok. Dennoch kein Name oder autobio. Inf. abrufbar.

Corrow et al. (2016)




The Bruce and Young (1986) model of face recognition. From Parkin (1996).

# Themen & Literatur für Wahlfach-Essays



(1) Kognitive Kontrolle:

Braver, T.S. (2012)

(2) Aufmerksamkeit & Selektion:

Corbetta & Shulman (2002)

(3) Multisensorische Verarbeitung / Synästhesie:

Hubbard (2005)

(4) Soziale Kognition /Stereotypie:

Amodio et al (2014)

(5) Gedächtnis & Lernen:

Mecklinger & Bader (2020), Stark et al (2019), Frankland & Bontempi (2005)

(6) Prosopagnosie:

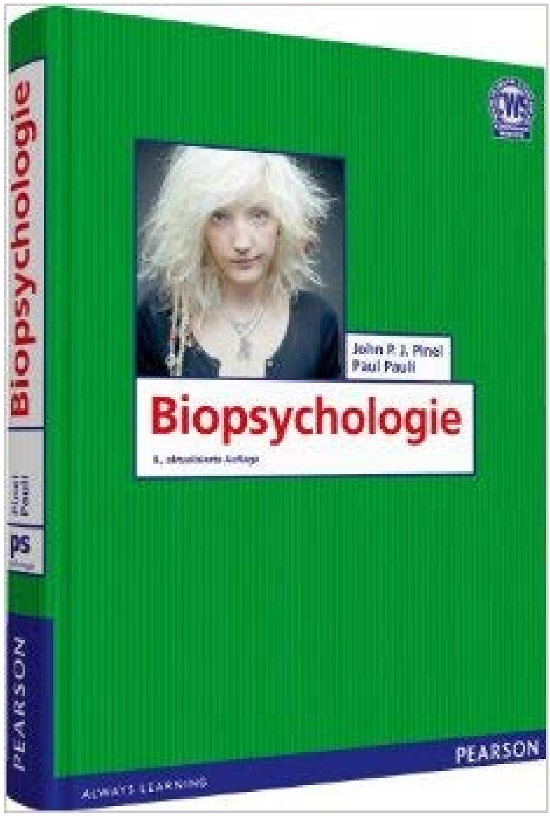
Corrow et al. (2016)

# Face inversion

Gesichtererkennung

| | Kontrollgruppe | Prosopagnosie | |
|---|---|---|---|
| Upright: | 94% | 58% | Holistische Analyse |
| Inverted: | 82% | 72% | Teile Analyse |

# Literatur




Ward, J. (2010). The student's guide to cognitive neuroscience. (2nd Edition) Psychology Press. New York. (Kap. 10)

Gazzaniga, M.S., Ivry, R.B. & Mangun, G.R. (2009). Cognitive Neuroscience (3rd Edition). W.W. Norton & Company: NewYork (Kap. 5)

# Das Auditive System

- Hören
- Vom Ohr zum Gehirn
- Der primäre auditorische Kortex
- Schalllokalisation
- Das „What“ und das „Where“ System
- Auditives Gedächtnis
- Musik
- Stimmen
- Sprache
- Kann man Farben hören?

# Physikalische und wahrgenommene Dimensionen des Schalls

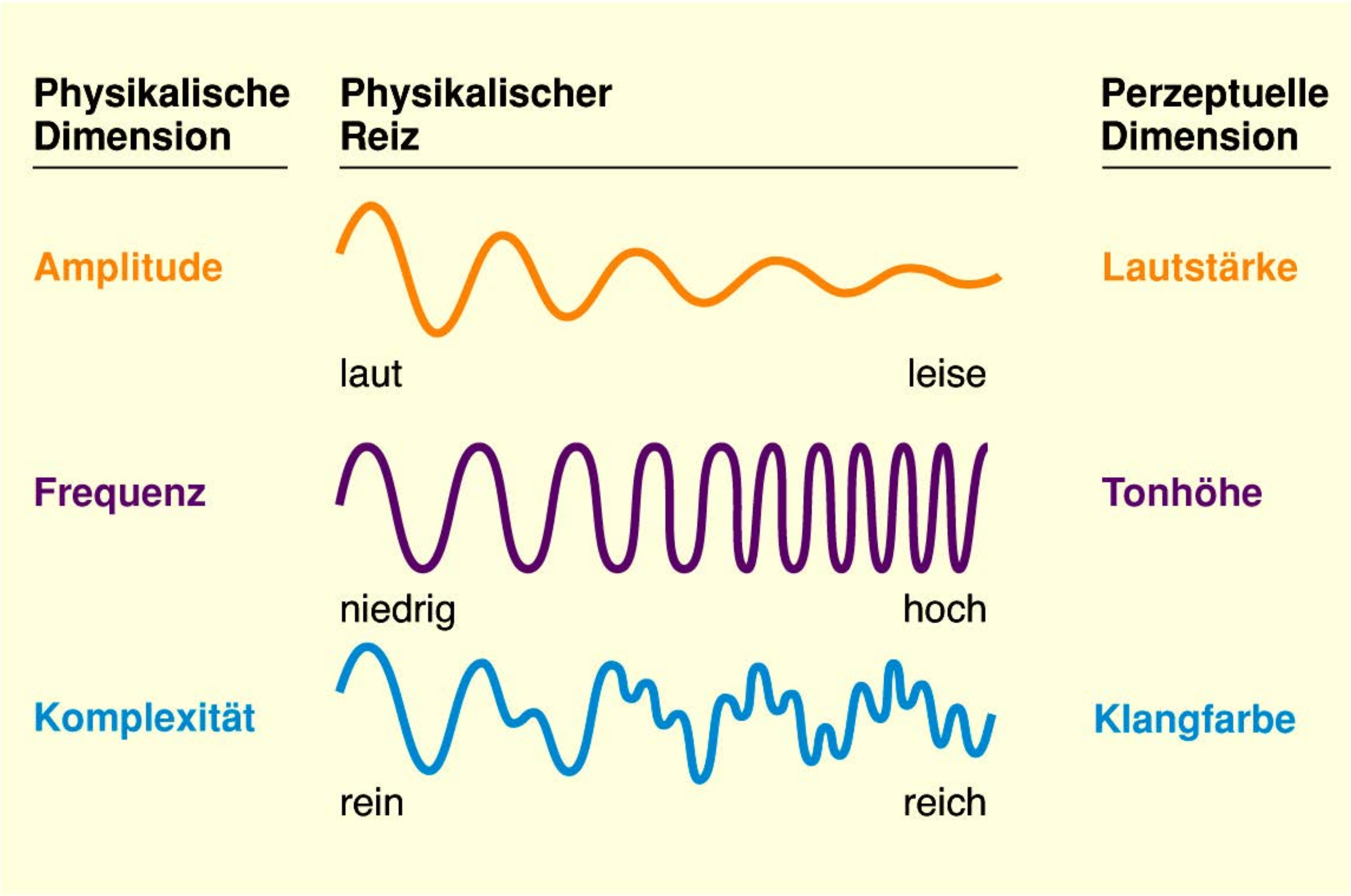



**Abbildung 7.10:** Die Beziehung zwischen den physikalischen und perzeptuellen Dimensionen des Schalls.

# Komplexe Schallwellen – eine Klarinette

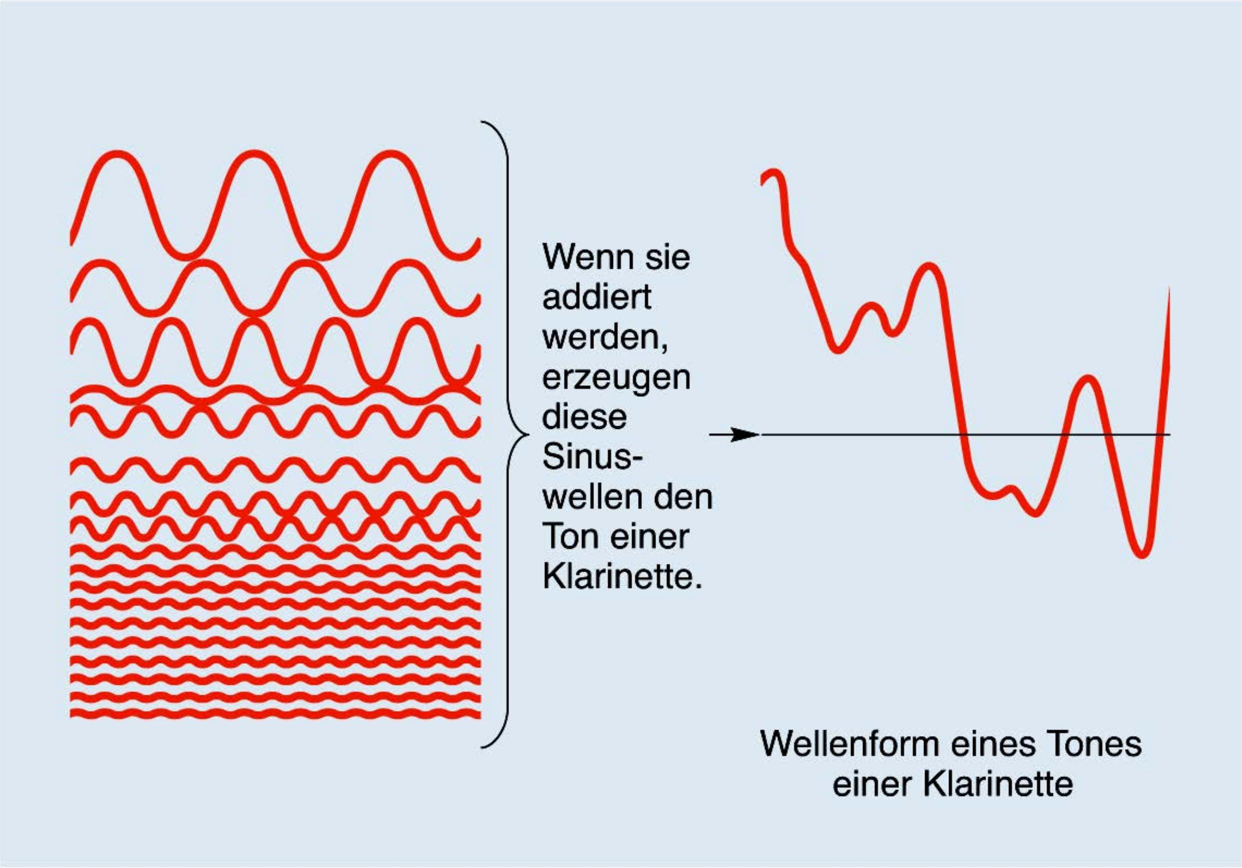
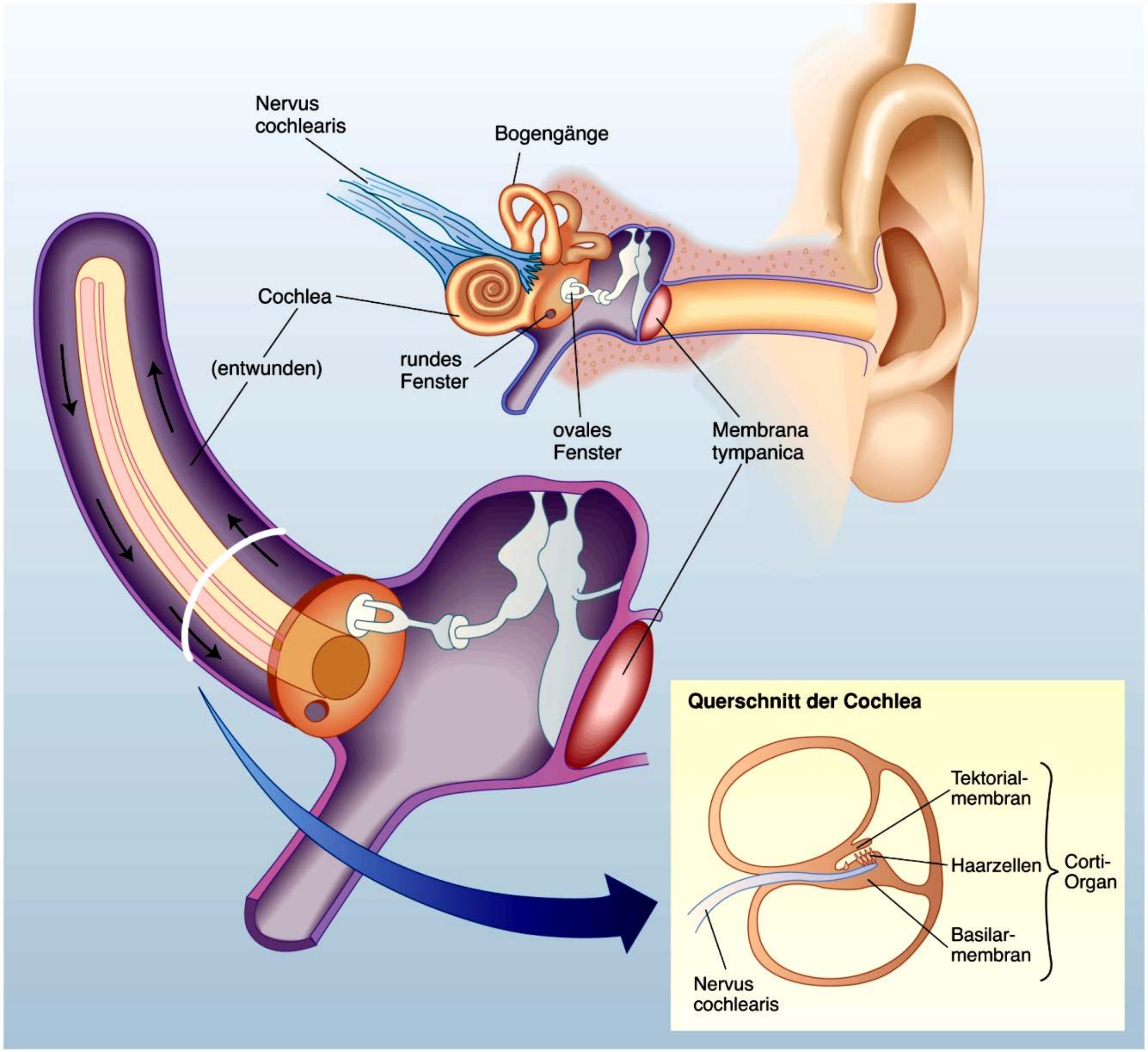



**Abbildung 7.11:** Die Zerlegung eines Tons – in diesem Fall des Tons einer Klarinette – in seine Komponenten von Sinuswellen durch eine Fourier-Analyse. Wenn sie addiert werden, entsteht aus den Sinuswellen die komplexe Schallwelle.

# Die Anatomie des Ohrs



# Vom Ohr zum Cortex

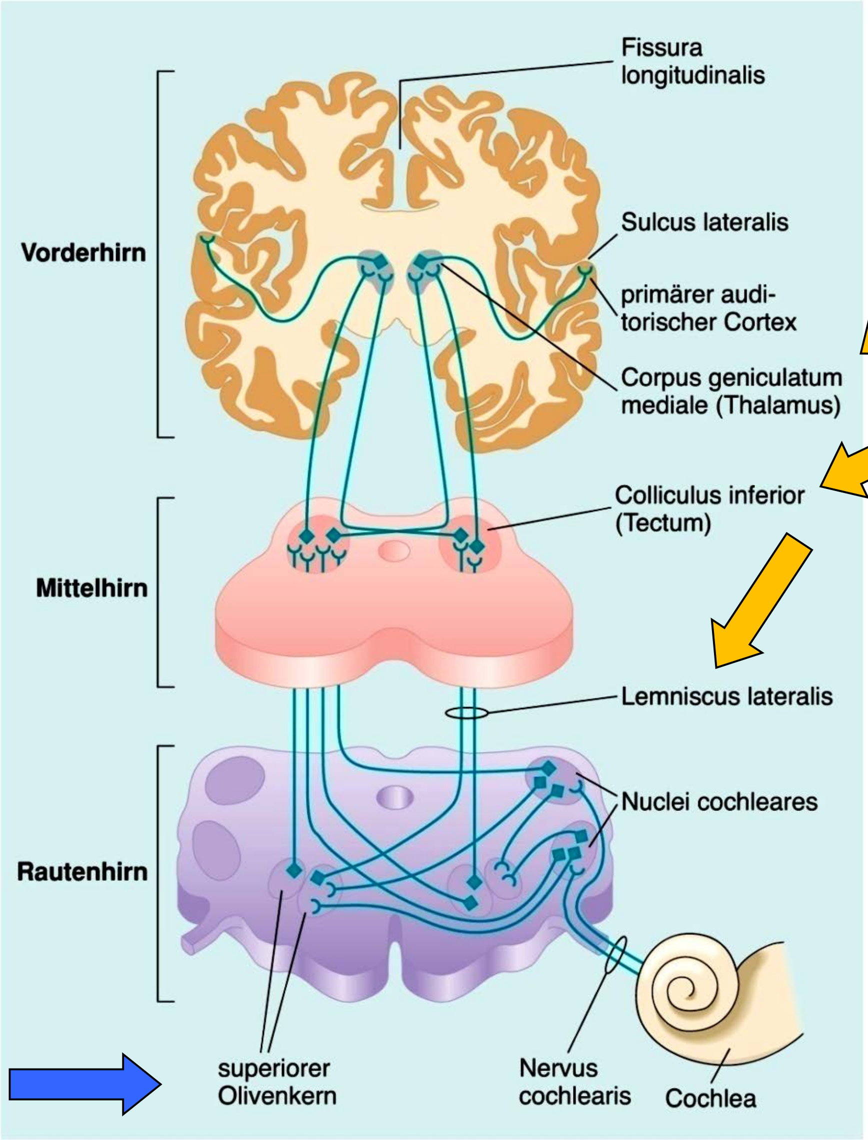
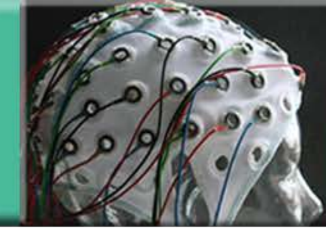


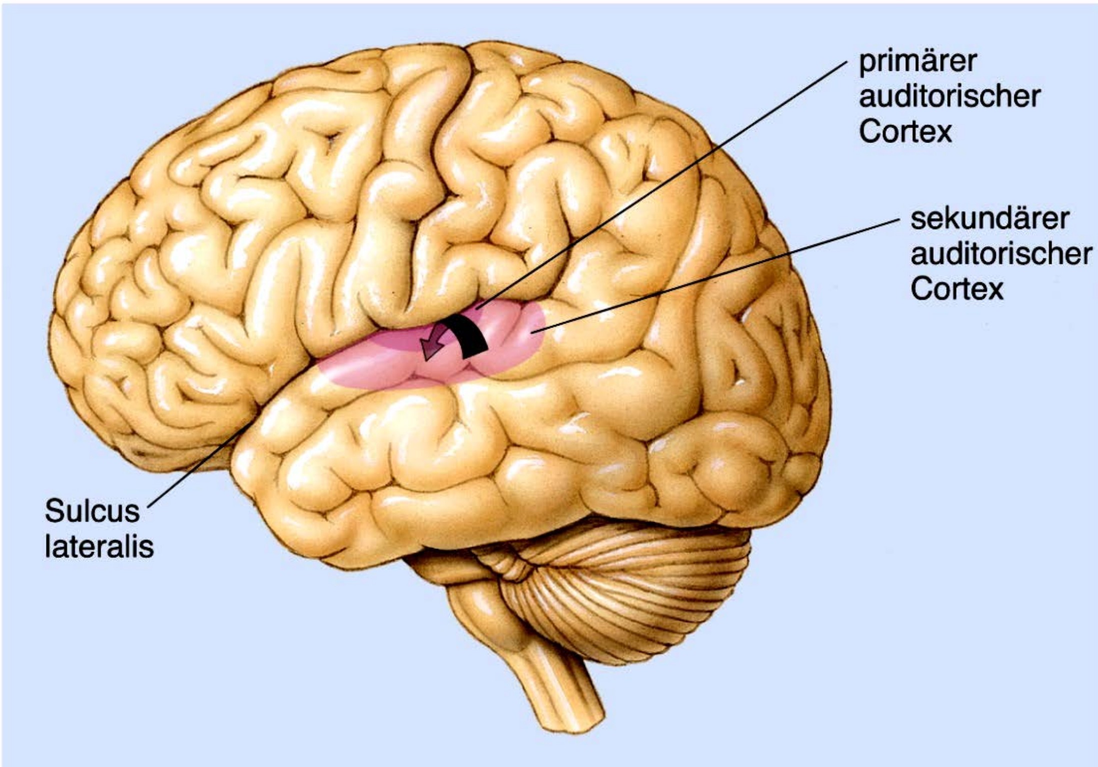

**Abbildung 7.13:** Einige Bahnen des auditorischen Systems, die von einem Ohr zum Cortex führen.

Cochlea: 90.000 N
CGM: 500.000 N
A1: 100.000.000 N.

=> Aktive Extraktion und Synthese von Inf.

# Der primäre und sekundäre auditorische Cortex





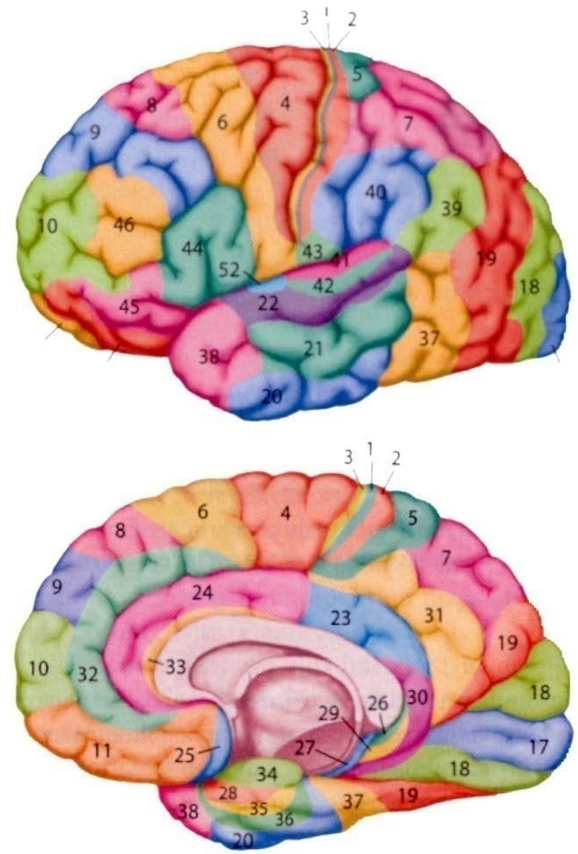
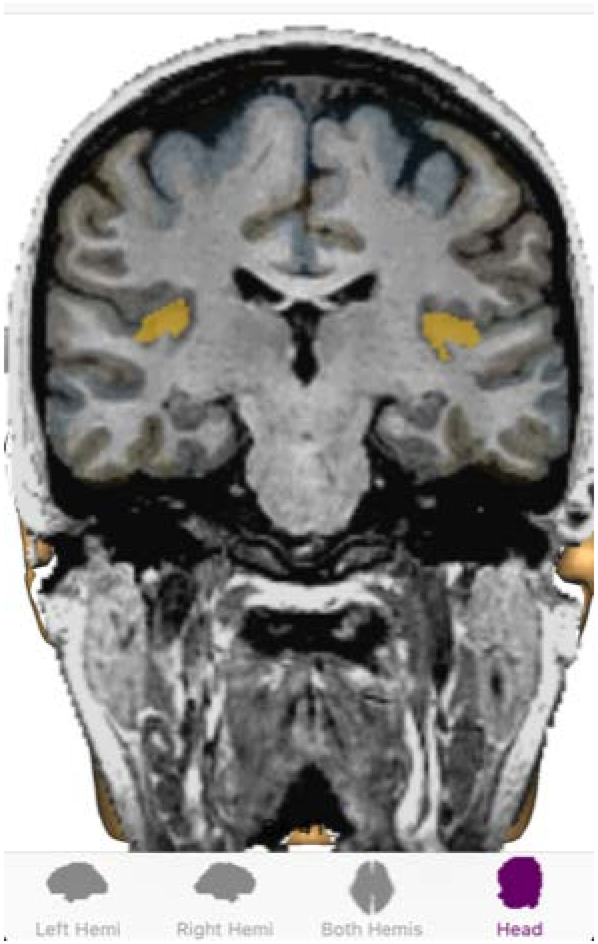



**Figure 3.7** The Brodmann areas of the human cerebral cortex. In Brodmann's original cytoarchitectonic map, there were 52 areas. Over the years, the map has been modified and the standard version no longer includes Areas 12–16 and 48–51.

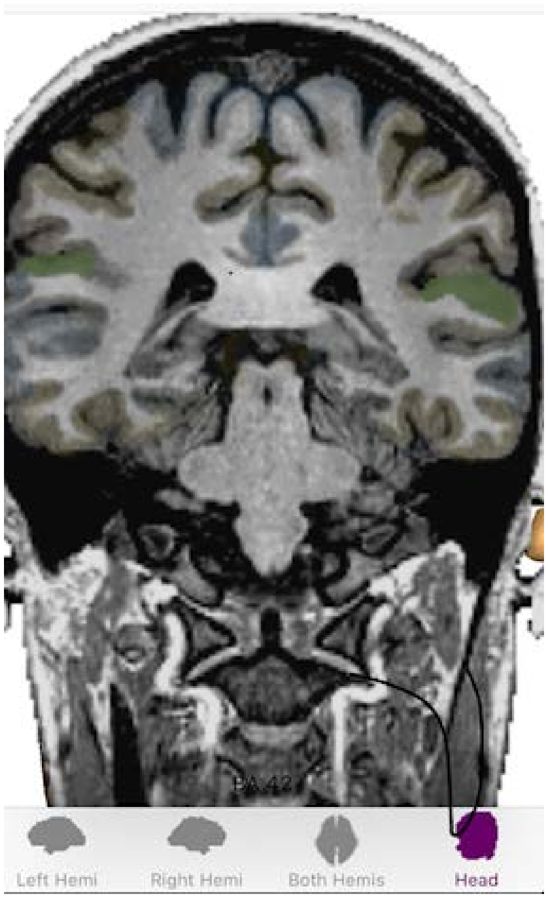
Tonotopie und funktionelle Säulen

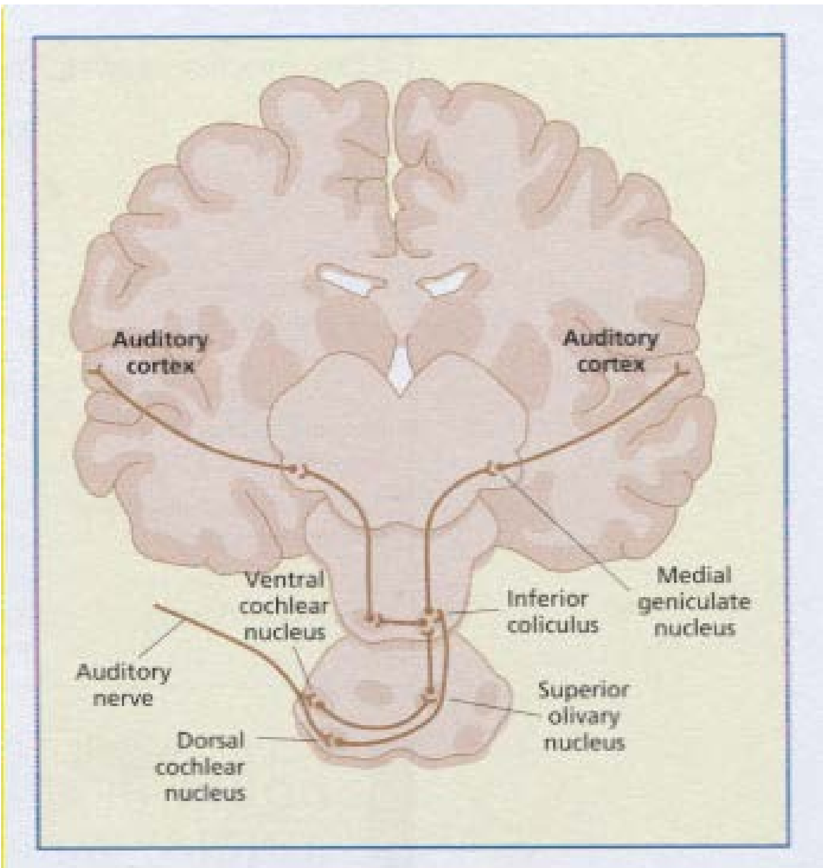
# Der primäre und sekundäre auditorische Cortex

A1

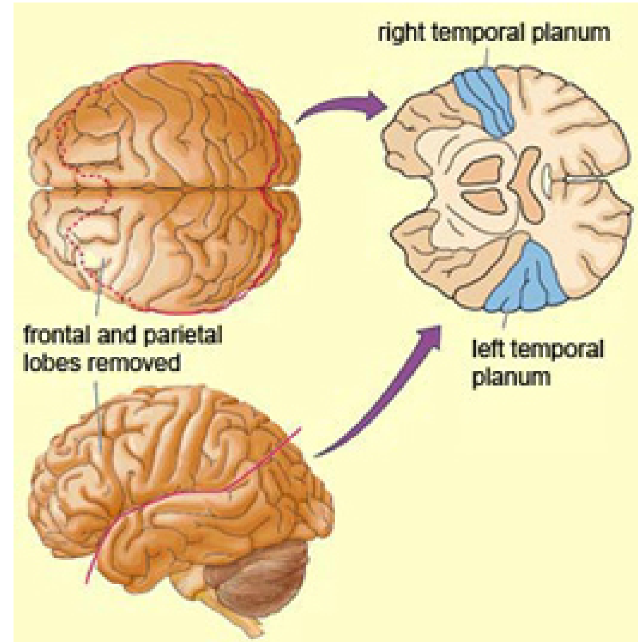



A2

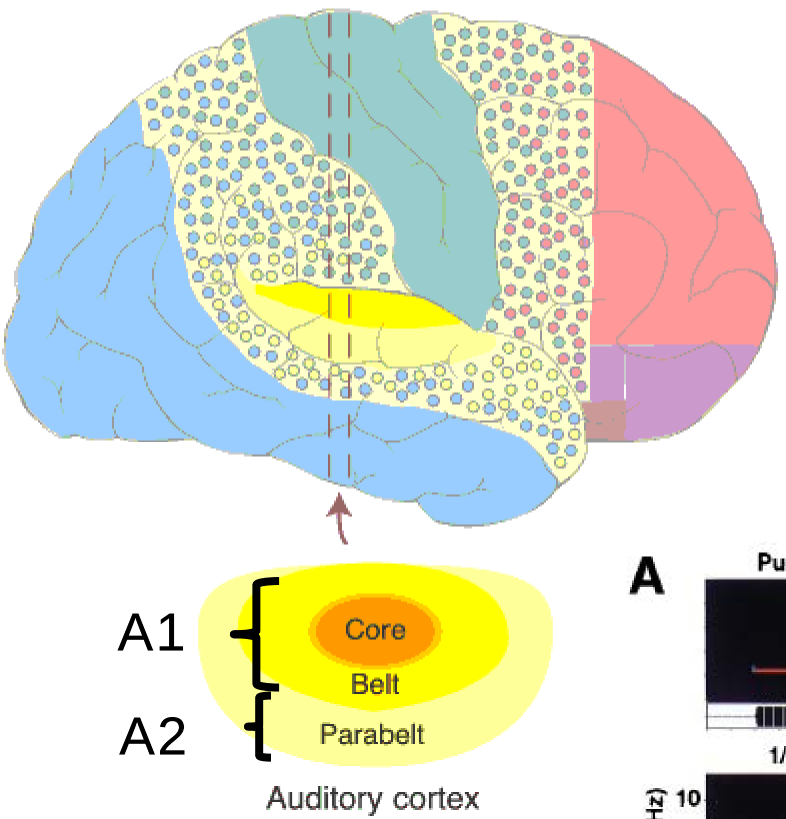


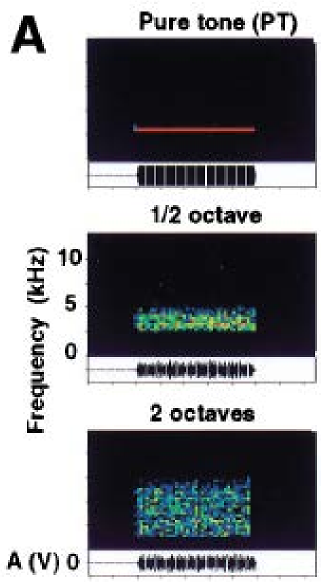



This ascending auditory pathway is not a passive transmission of information from the ear but, rather, is involved in the active extraction and synthesis of information in the auditory signal. From Gazzaniga et al. (2002). Copyright © 2002 W. W. Norton & Company Inc. Reproduced with permission.

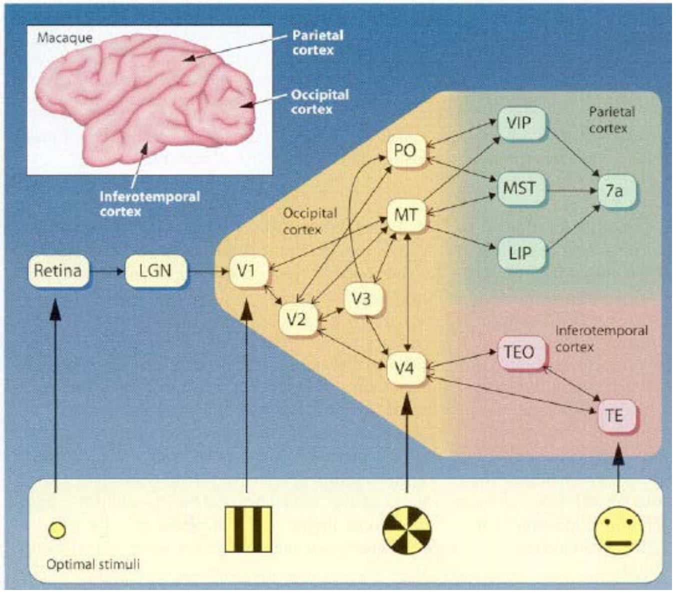


# Der primäre und sekundäre auditorische Cortex

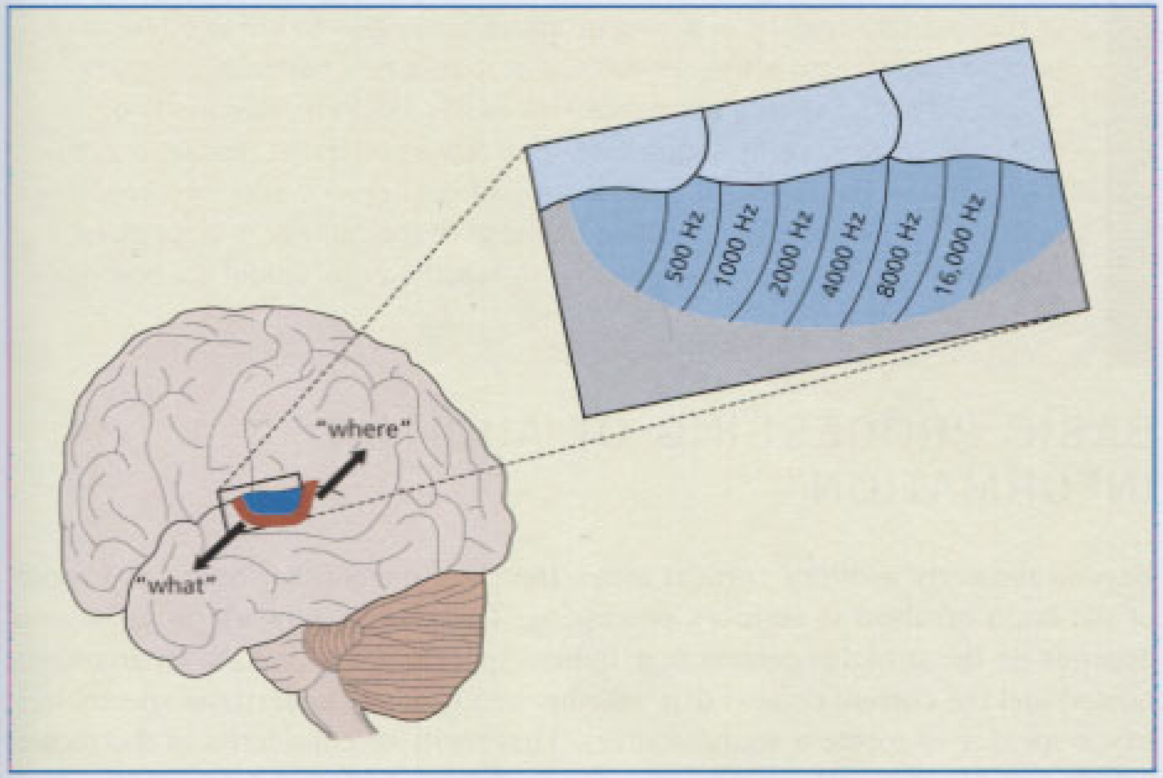



## Visuelles System



# Tonotopie im auditorischen Cortex




The primary auditory cortex lies on the medial surface of both the left and right temporal lobes and is organized tonotopically (i.e. different regions process different frequencies). It is surrounded by secondary auditory cortex (termed belt and parabelt) that processes more complex aspects of the sound and provide the starting point for separate "what" and "where" routes.

# Tonotopie des auditorischen Kortex (fMRI Ergebnisse)

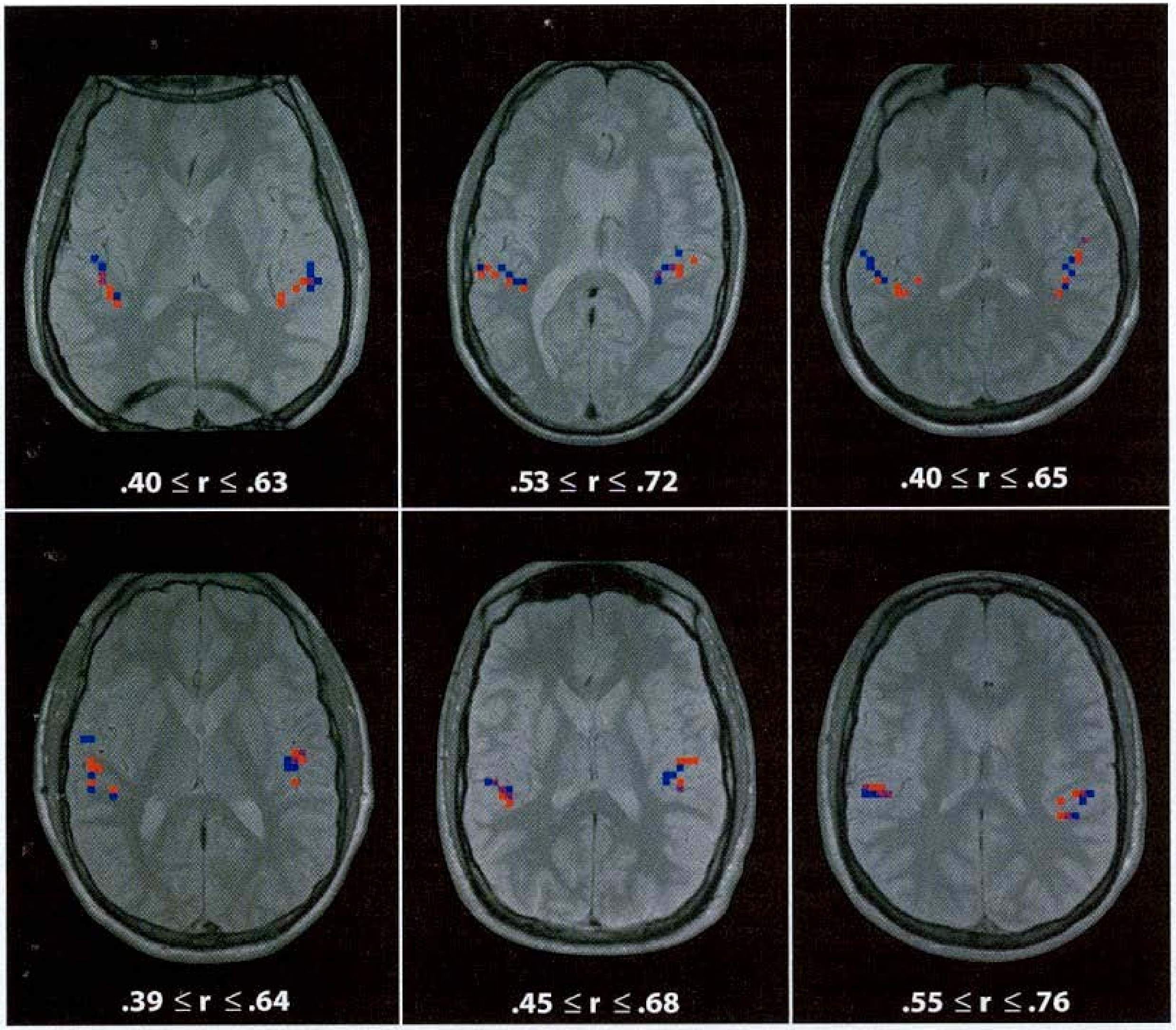
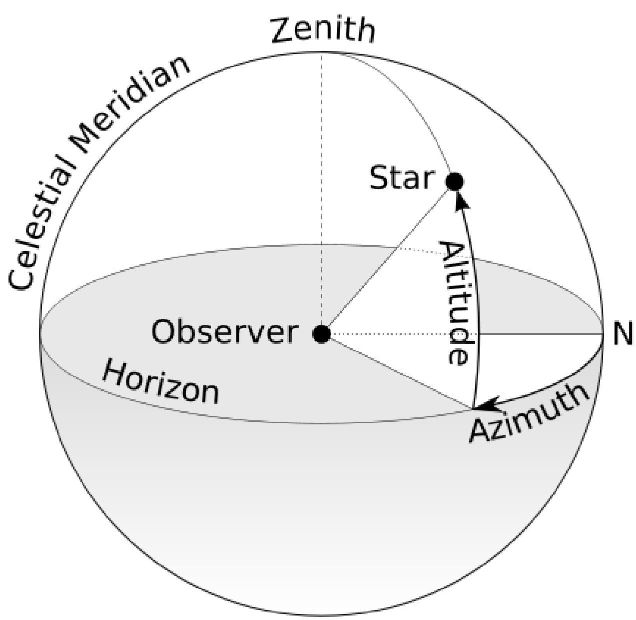
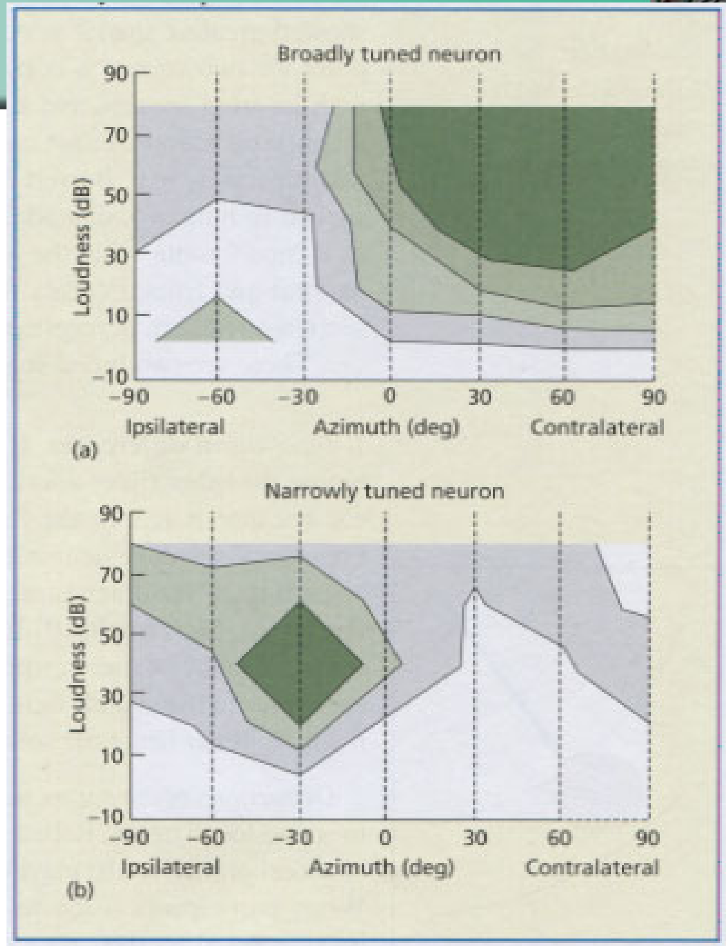



**Figure 5.35** Tonotopic representation revealed with fMRI. In most cases, the region responding to the low tones (blue) is more posterior and medial to the region responding to the high tones (red). Adapted from Wessinger et al. (1997).

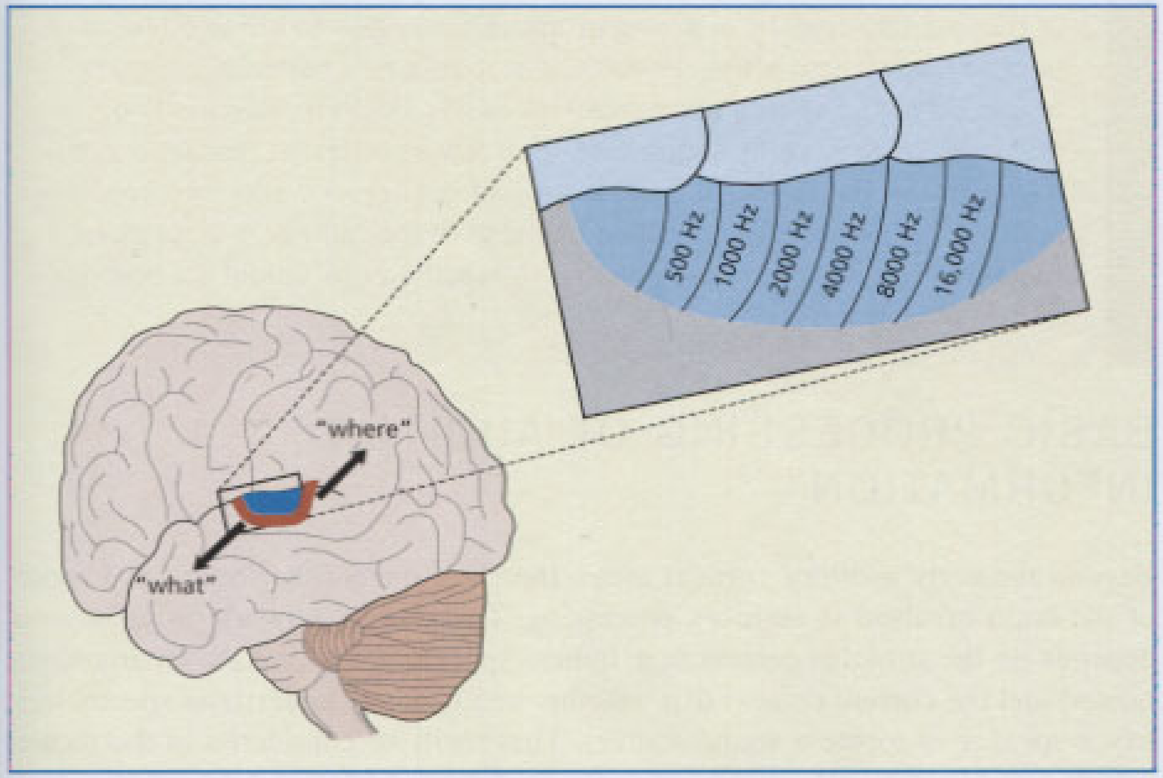
# Tuningkurven von A2-Neuronen des auditorischen Kortex




The density of shading represents the responsiveness of two different neurons in auditory cortex to sounds of different loudness levels presented in different regions of space. Neuron (a) responds to sounds over a broad range of loudness level and in various parts of space, whereas neuron (b) is more finely tuned to a particular loudness level and a particular part of space. From Clarey et al. (1994). Reprinted with permission of APS.

# What & Where

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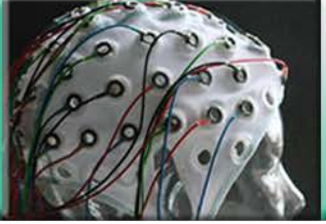


# Rauschecker & Tian (2000)

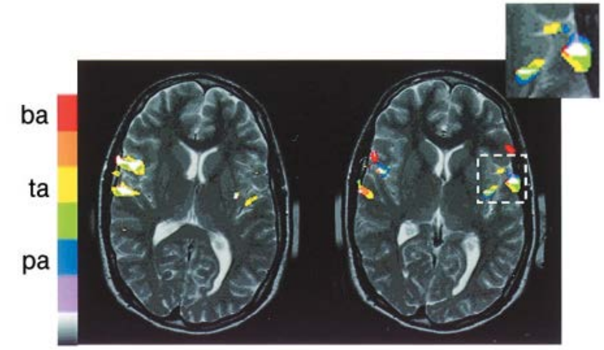



Fig. 4. Functional MRI study of the STG in a human subject while listening to speech sounds. A phonemic map may be recognized anterior of Heschl's gyrus resulting from superposition of activation by three different consonant/vowel combinations [ba, da, ga (64)[†]; courtesy of Brandon Zielinski, Georgetown University].

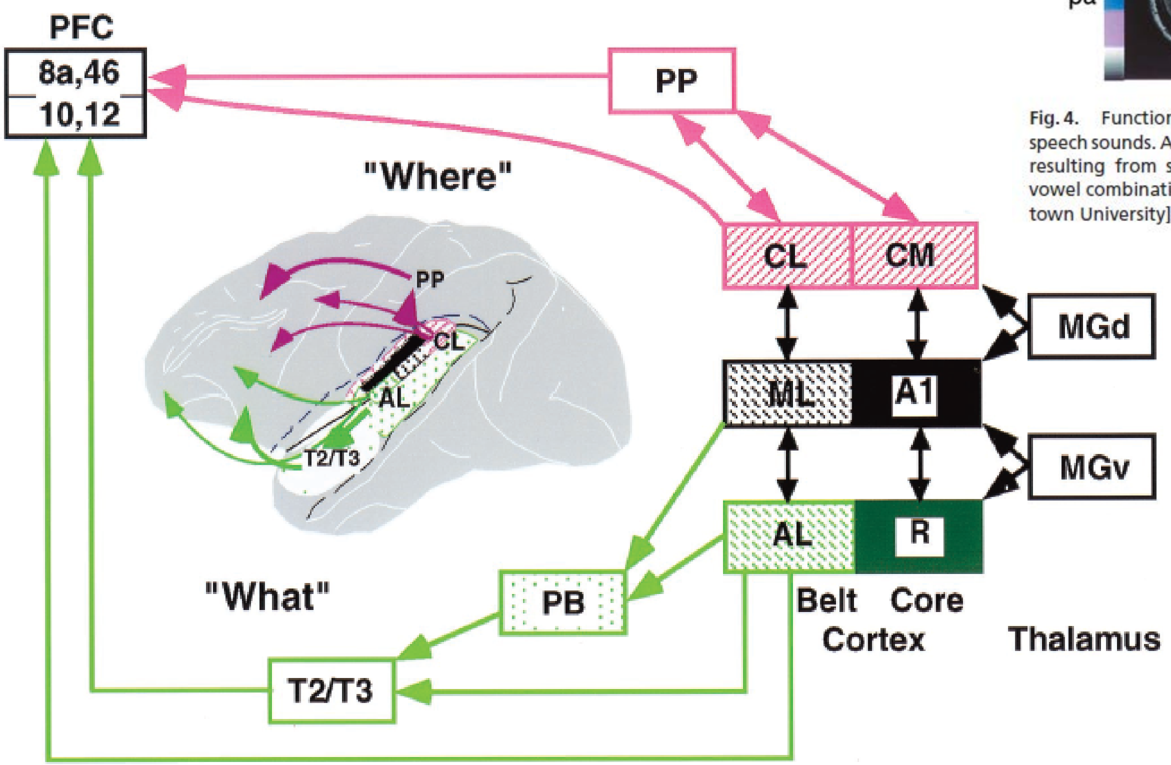
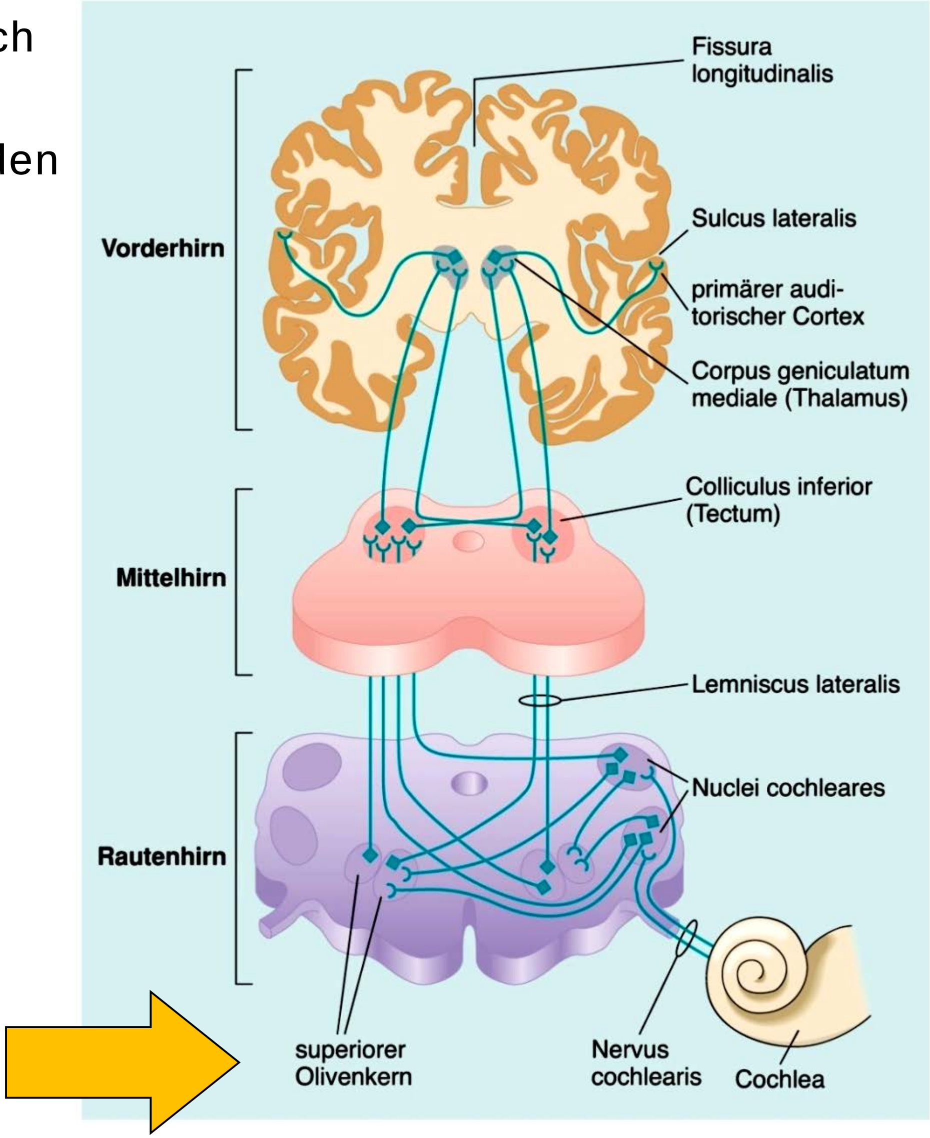



Fig. 6. Schematic flow diagram of "what" and "where" streams in the auditory cortical system of primates. The ventral "what"-stream is shown in green, the dorsal "where"-stream, in red. [Modified and extended from Rauschecker (35); prefrontal connections (PFC) based on Romanski *et al.* (46).] PP, posterior parietal cortex; PB, parabelt cortex; MGd and MGv, dorsal and ventral parts of the MGN.

(1) Lokalisation von Geräuschen durch die Verarbeitung interauraler Zeitdifferenzen in A1 und A2 und in den oberen Olivenkernen.

The sound arrives at the left ear first (inter-aural time difference) and is more intense in the incoming ear (inter-aural intensity difference).



# (1) Interaurale Differenzen

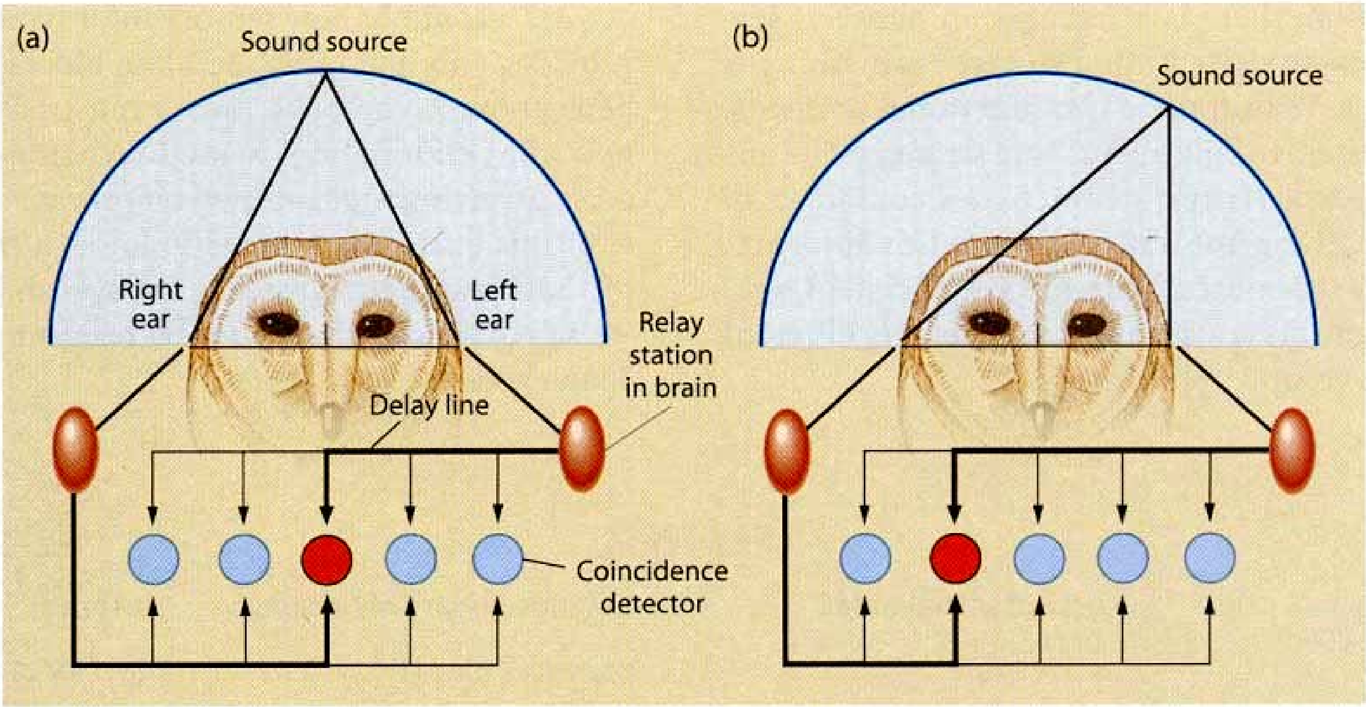
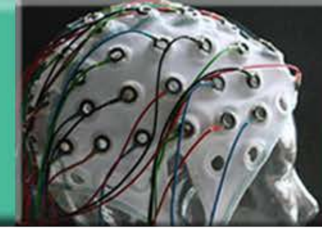



**Figure 5.37** Slight asymmetries in the arrival times at the two ears can be used to locate the lateral position of a stimulus. **(a)** When the sound source is located directly in front of the owl, the stimulus will reach the two ears at the same time. As activation is transmitted across the delay lines, the coincidence detector representing the central location will be activated simultaneously from both ears. **(b)** When the sound source is located to the left, the sound reaches the left ear first. Now a coincidence detector offset to the opposite side receives simultaneous activation from the two ears. Adapted from Konishi (1993).

# Die Lokalisation von Geräuschen (2): Die Rolle der Ohrmuschel

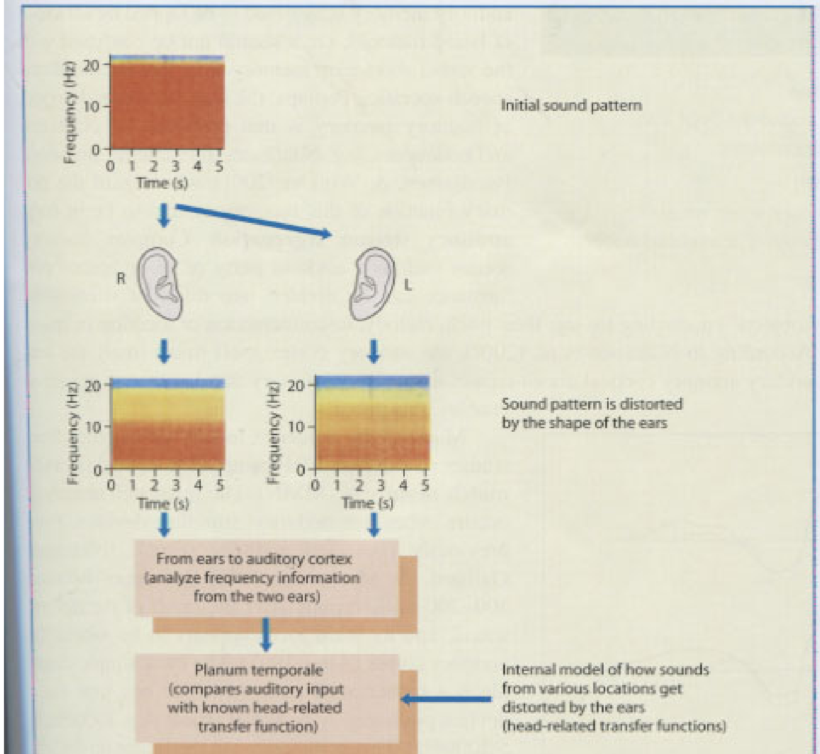


- Aufnahme: Kunstkopf mit/ohne artifizieller Ohrmuschel

- Wahrnehmung mit Kopfhörer: Schalllokalisation nur möglich wenn Aufnahme mit Ohrmuschel.

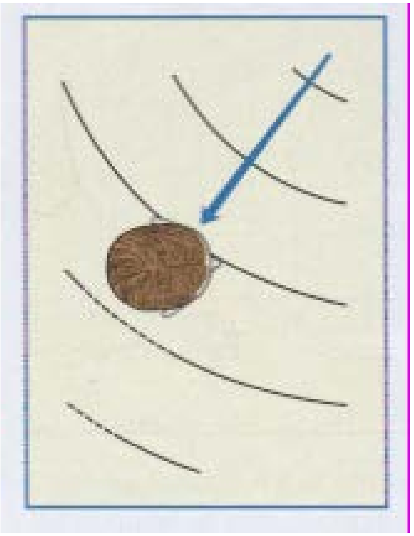
- Modell der Geräusch-ablenkung durch Ohr und Kopf.

- Head-related transfer functions im Planum Temporale.



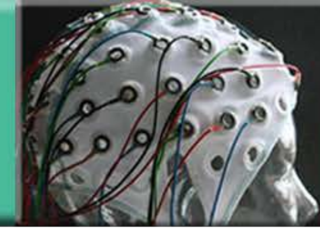

The shape of the ears distorts incoming sounds in predictable ways that depend on the location of the sound. The brain contains an internal model of how the sounds get distorted (head-related transfer function) and it can link the model with the auditory input to infer the location of a sound. Adapted from Griffiths and Warren (2002).

# Die Lokalisation von Geräuschen (2): Die Rolle der Ohrmuschel



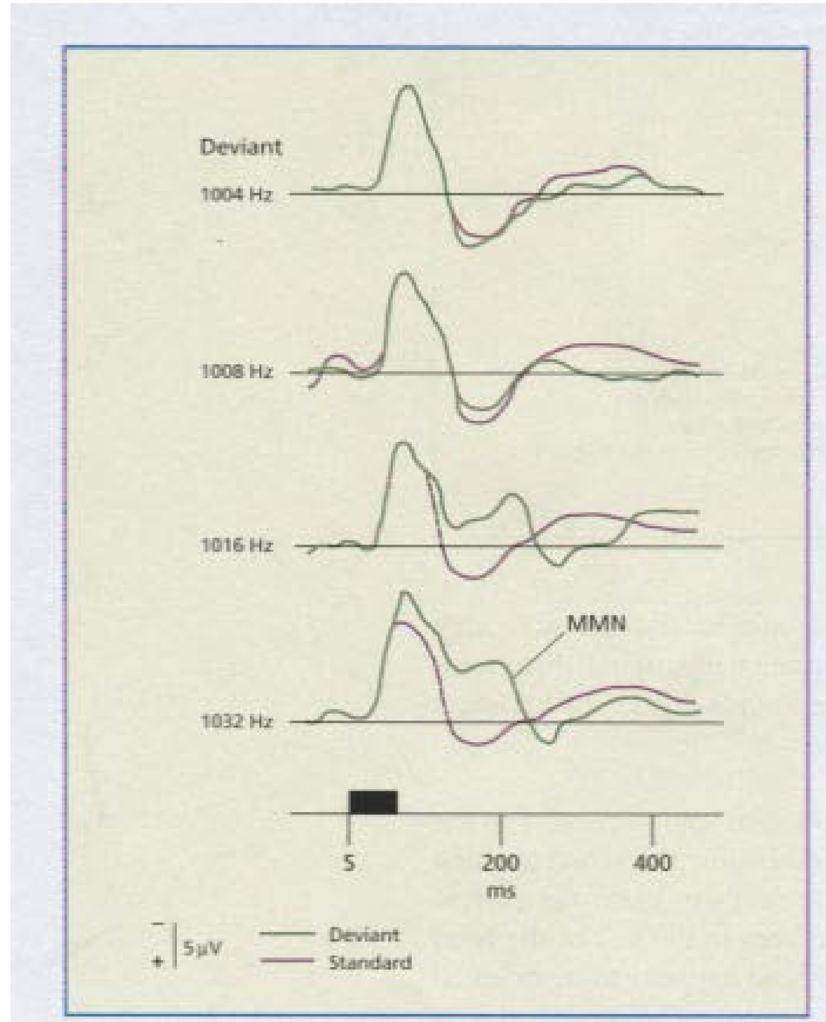
Egozentrische Schalllokalisation funktioniert nach diesen Prinzipien.

Allozentrische Lokalisation muß Koordinaten der Kopfposition mit einbeziehen.

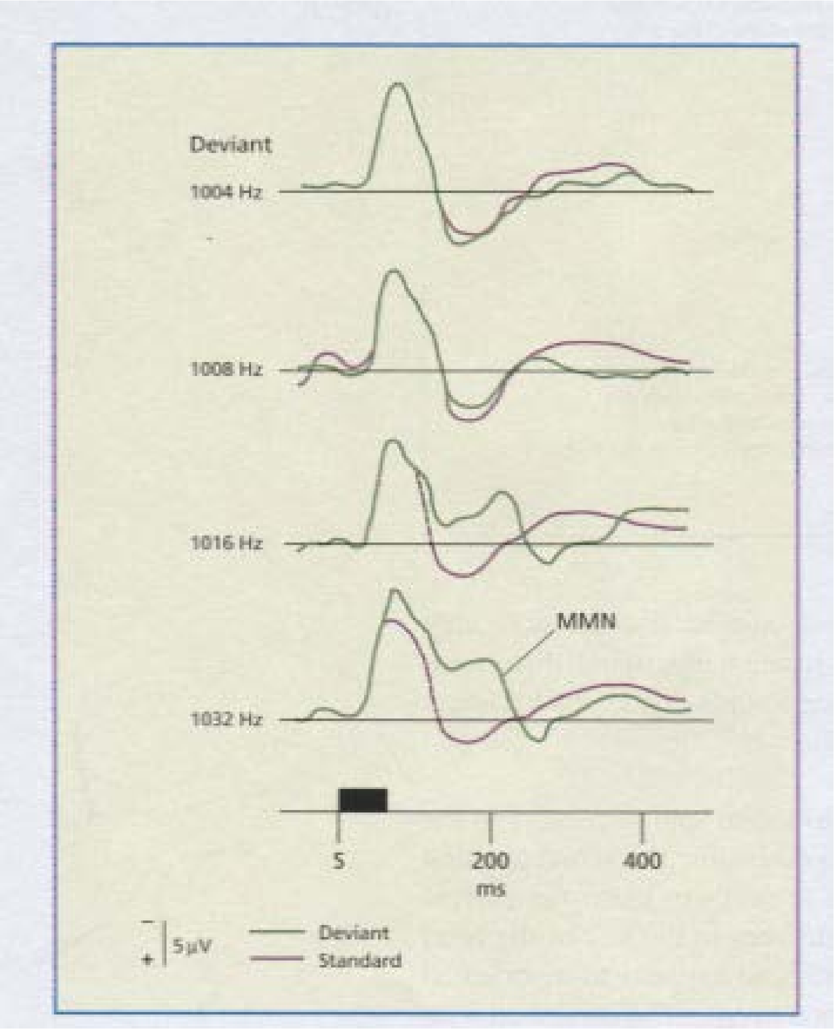


## Die Mismatch-Negativity

If a standard tone of 1000Hz is played repetitively (purple line) but with an occasional deviant tone that is >1000Hz (green lines), then there is a distinct EEG event-related potential detected at the scalp that is termed the mismatch negativity, MMN. This has been attributed to an auditory memory component and the MMN is also found for some more complex auditory patterns. Reprinted from Näätänen et al. (2001), Copyright 2001, with permission from Elsevier.



## Die Mismatch-Negativity



*neuroreport* Learning and Memory

NeuroReport **5**, 844–846 (1994)

# Neural representations of abstract stimulus features in the human brain as reflected by the mismatch negativity

**Mari Tervaniemi,[CA] Sini Maury and Risto Näätänen**

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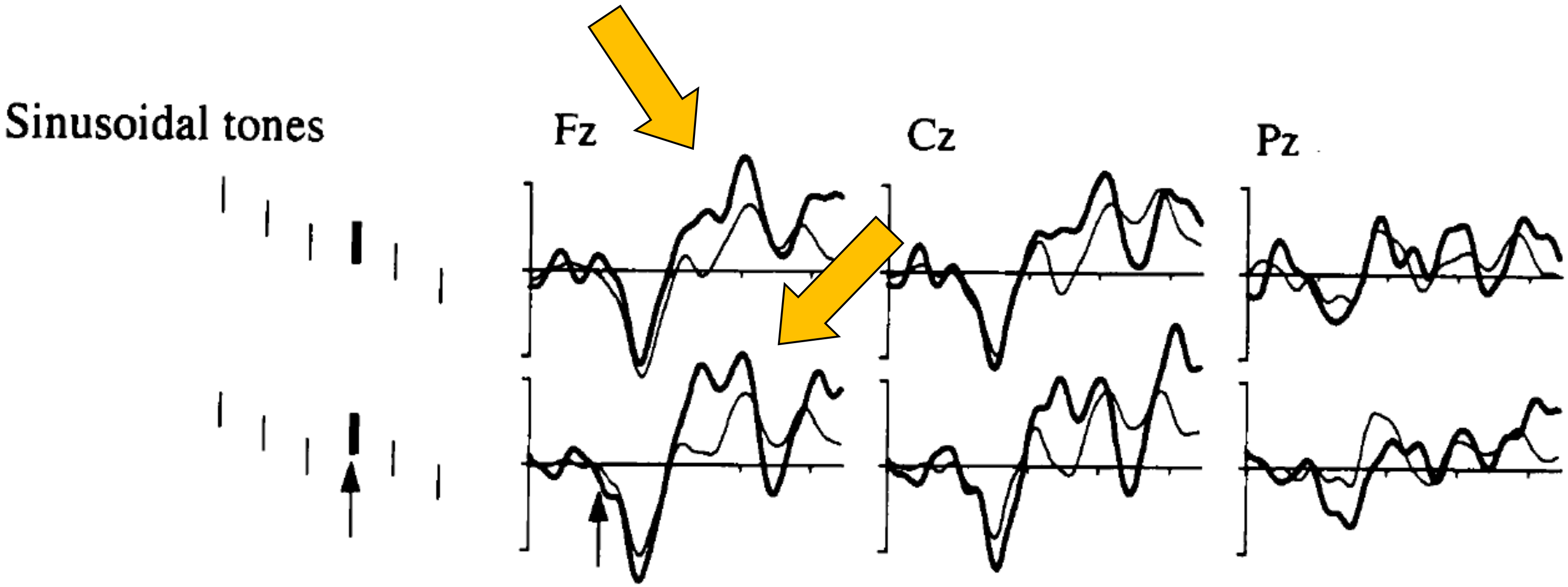
[CA] Corresponding Author

**Neural sensory-memory representations that encode physical properties of incoming stimuli can be probed by recording the change-specific mismatch negativity of the event-related potential (ERP). The present study was aimed at determining whether invariant stimulus features, abstracted from the continuously changing acoustic environment, are encoded in these sensory-memory representations. Regularly descending tone sequences with an occasional ascending tone or tone repetition were presented to reading subjects. A significant MMN was elicited by the ascending tones. When instead of simple tones, Shepard tones creating an illusion of a continuous pitch decrement were used in the same paradigm, the MMN was elicited by both ascending and repeating tones. It was concluded that besides physical stimulus properties, abstract stimulus features are also encoded in the neural representations of sensory memory.**

**Key words:** Audition; Mismatch negativity; Neural representations; Sensory memory


Sinusoidal tones
Fz
Cz
Pz

# Auditive Segregation:
# Richtung der Frequenzänderung



neuroReport

NeuroReport 3, 1149–1151 (1992)

## Representation of abstract attributes of auditory stimuli in the human brain

**Jukka Saarinen,[CA] Petri Paavilainen, Erich Schöger,[1] Mari Tervaniemi and Risto Näätänen**

University of Helsinki, Department of Psychology, Ritarikatu 5, SF-00170 Helsinki, Finland; [1]Ludwig-Maximilians-Universität München, Institut für Psychologie. Allgemeine Psychologie, Leopoldstrasse 13, 8000 München 40, Germany

[CA] Corresponding Author

REPRESENTATIONS of abstract attributes of auditory stimuli in the human brain were demonstrated using the mismatch negativity (MMN), an event-related potential component elicited by a change in a repetitive sound. Stimuli were pairs of sinusoidal tones. There were two types of tone pairs in each block, standard ($p = 85\%$) and deviant pairs ($p = 15\%$), delivered in a random order. Standard and deviant tone pairs differed only in the direction of within-pair frequency change. In addition, the frequency levels of both the standard and deviant pairs varied randomly within a wide range in a block; thus the standard pairs shared the direction of the within-pair frequency change but not the absolute frequency level. Correspondingly, the deviant pairs only shared the opposite direction of the within-pair change. Nevertheless, the deviant tone pairs elicited MMN, implying that even the direction of the within-pair frequency change of the standard stimuli, and not just their absolute frequencies, developed a neural representation.

**Key words:** Neural representations; Audition; Event-related potential; Mismatch negativity

# Auditive Segregation: Richtung der Frequenzänderung

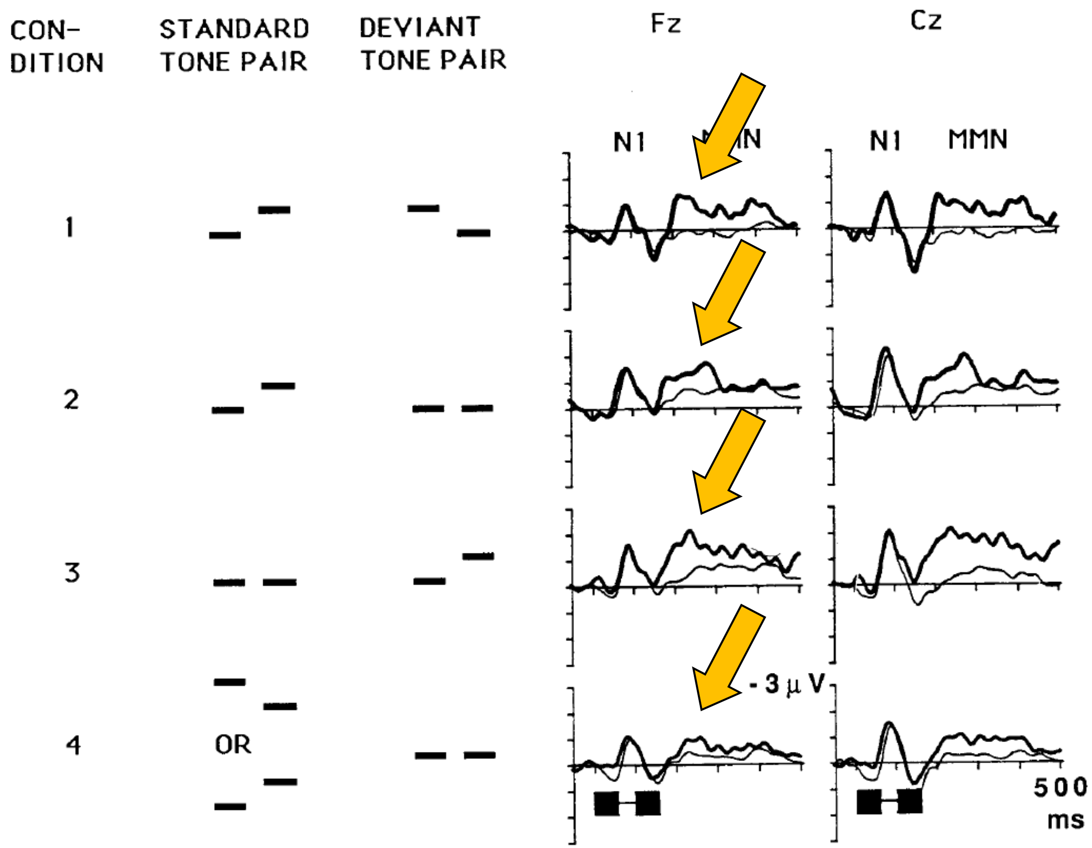



FIG. 1. Grand-average (10 subjects) frontal ($F_z$) and central ($C_z$) ERPs to the standard and deviant tone pairs in the four experimental conditions schematically illustrated on the left. Standard and deviant tone pairs differed in the direction of the within-pair frequency change, but not in the (mean) absolute frequency which was randomly varied. Temporal course of a stimulus pair is shown below. Thin lines represent responses to the standard tone pairs and thick lines represent responses to the deviant pairs. The $N_1$ wave was very similar to the standard and deviant tone pairs, whereas only the deviant tone pairs elicited MMN.

# Auditives Gedächtnis: Zeitliche Charakteristika

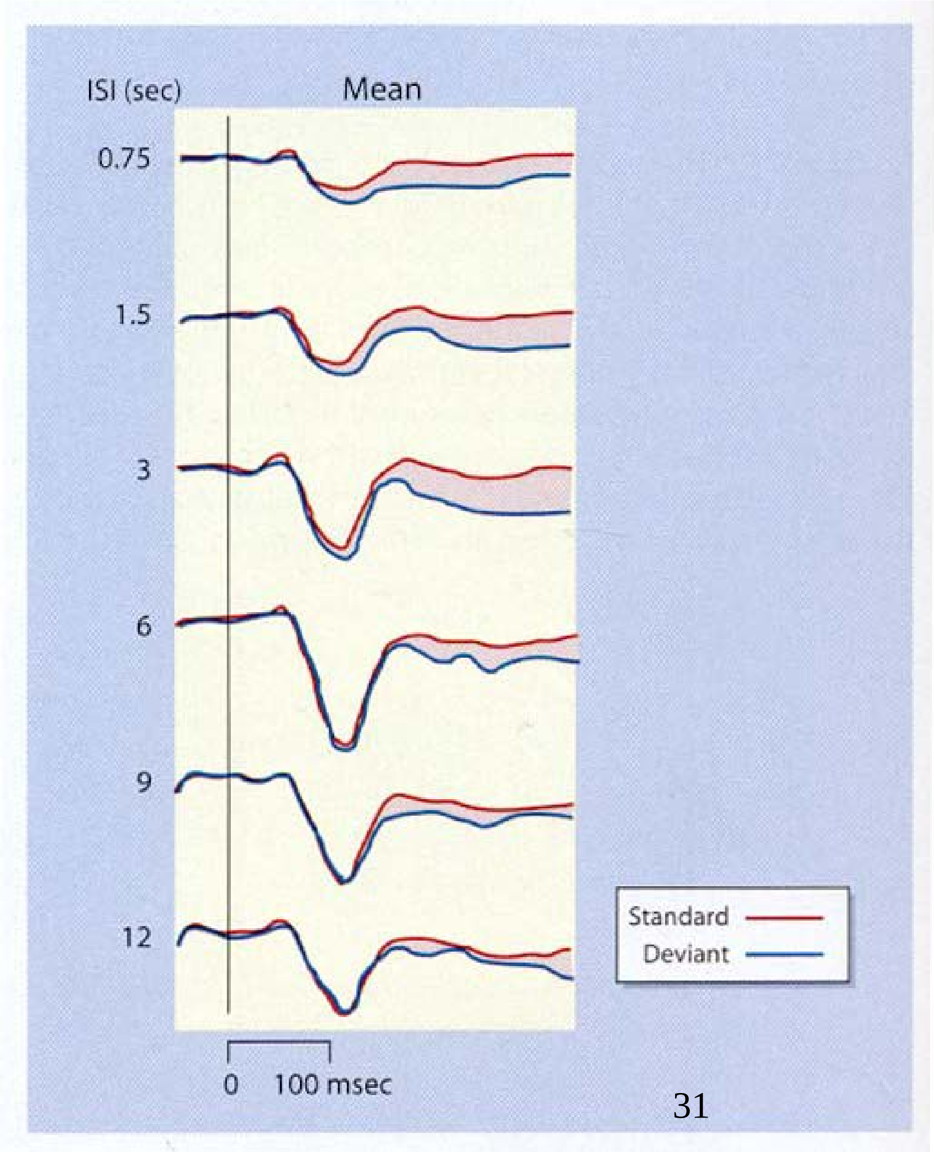



**Figure 8.2** The magnetic responses known as the *mismatch field* (MMF) elicited by deviant tones (blue trace) in comparison to the magnetic responses elicited by standard tones (red traces). The amplitude of the MMF (indicated by the shaded difference between the blue and red traces) declines as the time between the preceding standard tone and the deviant tone increases to 12 seconds. This result can be interpreted as evidence for an automatic process in sensory memory that has a time course on the order of approximately 10 seconds. Adapted from Sams et al. (1993).

# Musik

## Musik und Sprache

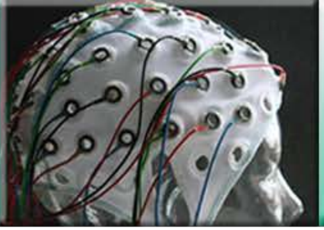
- Universelles crosskulturelles P.
- Frühe Entwicklung ohne Training
- Perzeption vs Produktion

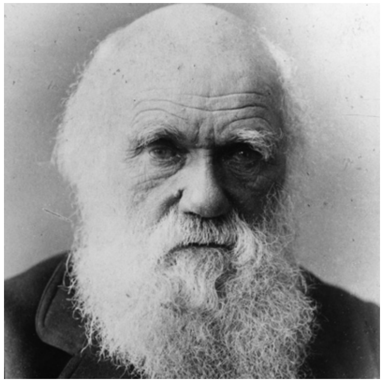
## Merkmale von Musik

- Töne werden zu Noten
- Noten werden zu perzeptuellen Gruppen (z.B. Oktave)
- Gruppierung von Noten (konsonant / dissonant)
- Geringste Dissonanz bei doppelter Grundfrequenz (220 Hz vs. 440 Hz = Oktave
- Oktaven: (geringe Dissonanz)


Möchten Sie auch mal eine Geige mit dem Computer bauen oder ein Werbeplakat entwickeln ? Wenn Sie ernsthaft daran interessiert sind, kann ich Sie unterrichten. Schreiben Sie mir dann bitte eine E-Mail: bdgrafik@gmx.de

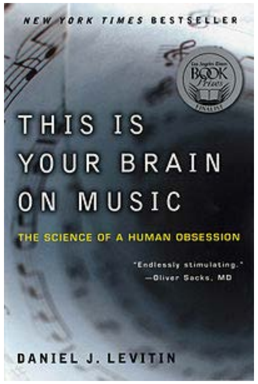


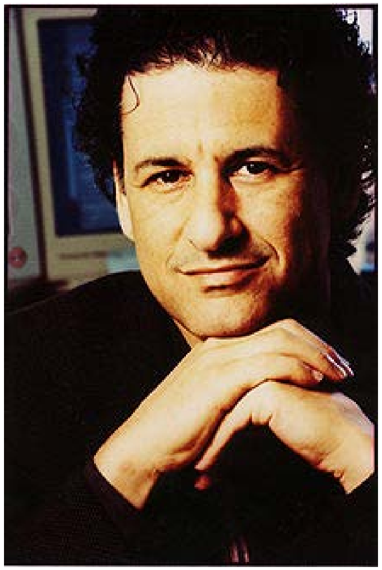





Was ist die Funktion der Musik?

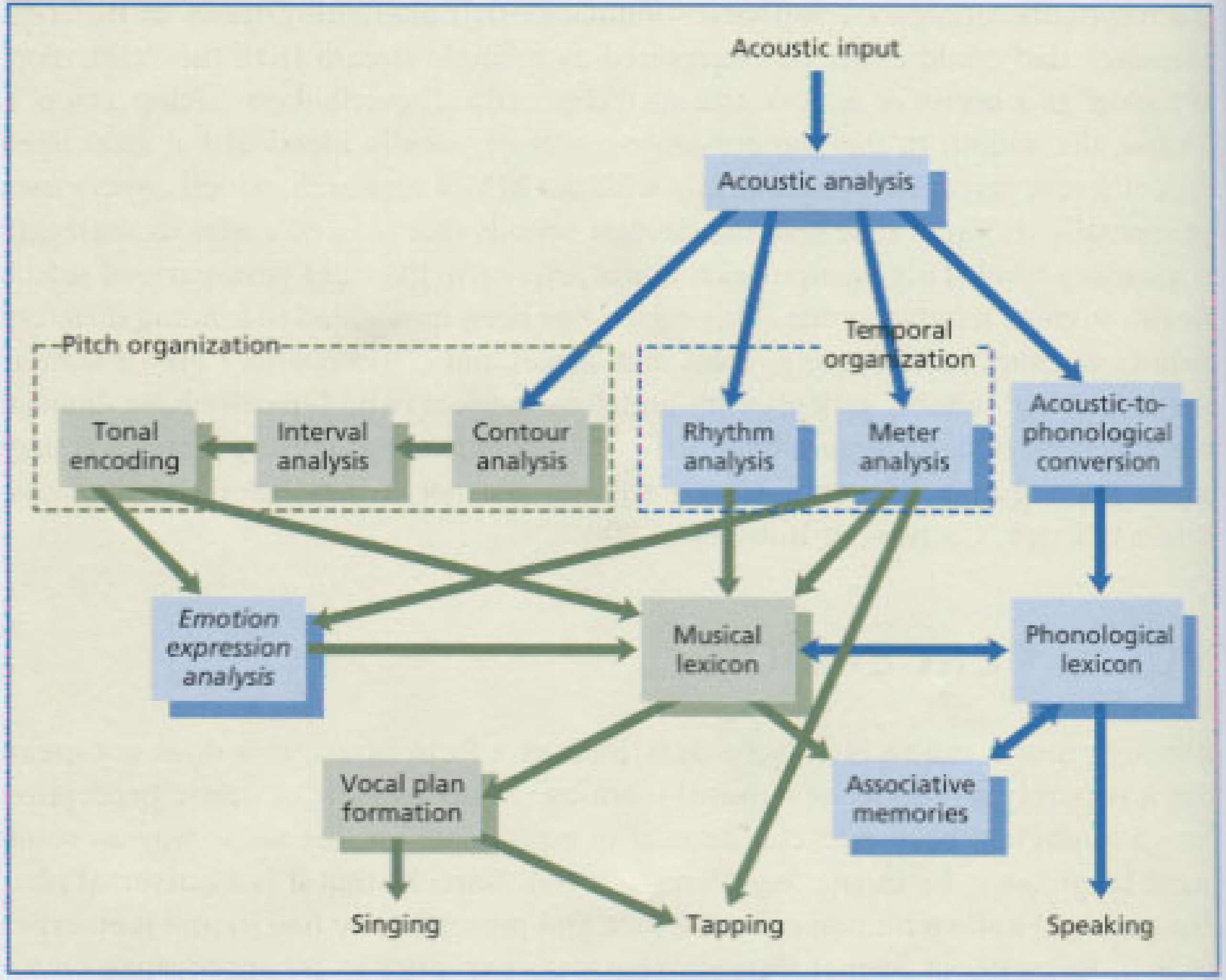
Adaptiver Charakter oder
"auditory cheese cake"



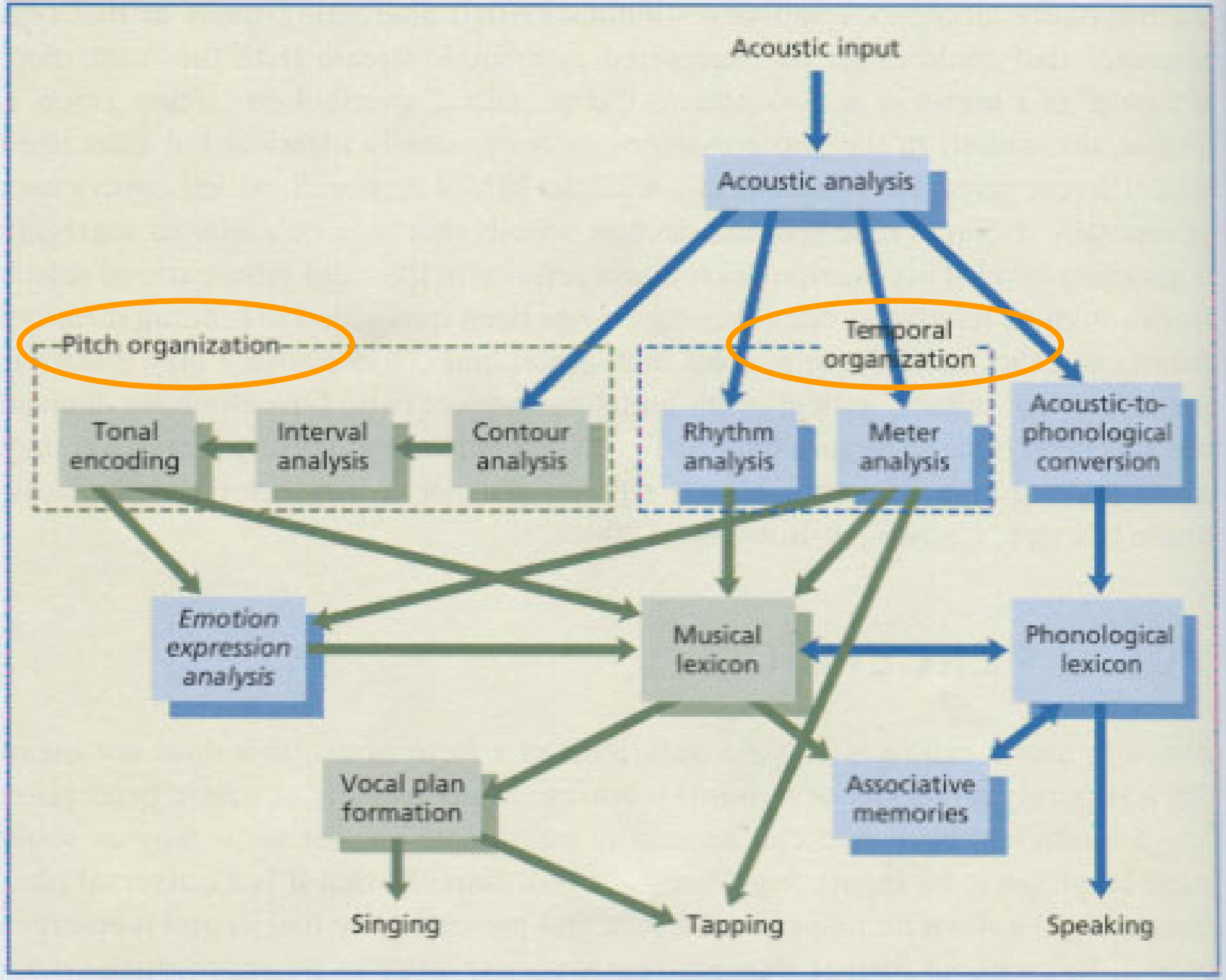
# Ein Modell der Musikverarbeitung

The model of musical cognition by Peretz and Coltheart (2003) contains separate processes for the lyrics versus melody and rhythm of music, as well as a further sub-division between processes for temporal organization (such as rhythm) and pitch-based organization (including melody). From Peretz and Coltheart (2003), by permission of Macmillan Publishers Ltd.



# Ein Modell der Musikverarbeitung

The model of musical cognition by Peretz and Coltheart (2003) contains separate processes for the lyrics versus melody and rhythm of music, as well as a further sub-division between processes for temporal organization (such as rhythm) and pitch-based organization (including melody). From Peretz and Coltheart (2003), by permission of Macmillan Publishers Ltd.



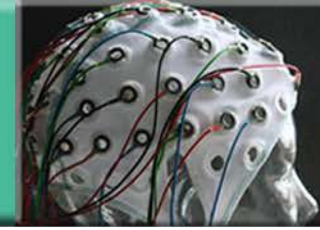
# Musikverarbeitung

- Amusikalität (auditive Agnosie)

CN: Amnesie für Melodien / Defizit im Musiklexikon?

Aber auch:

- Verlust der Rhythmuswahrnehmung
- Tonhöhentaubheit



# Amusikalität

Amusikalität (auditive Agnosie) / Amusia

Patient CN: Amnesie für Melodien
Defizit im Musiklexikon?

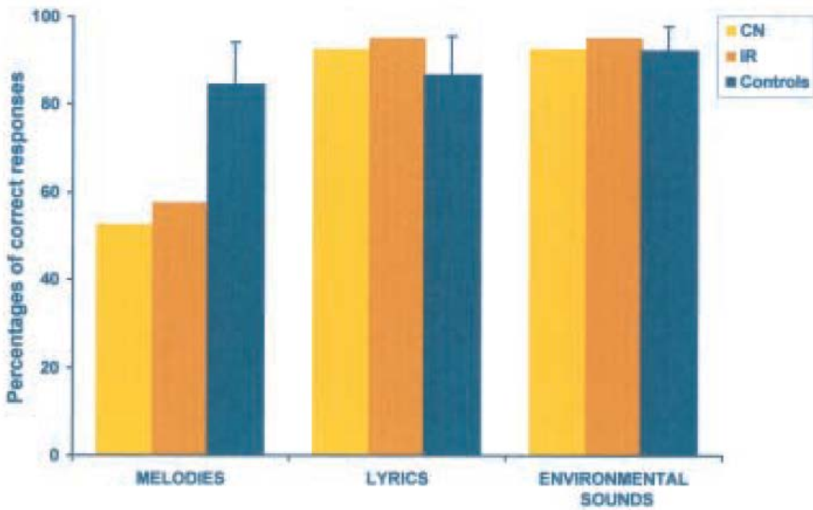
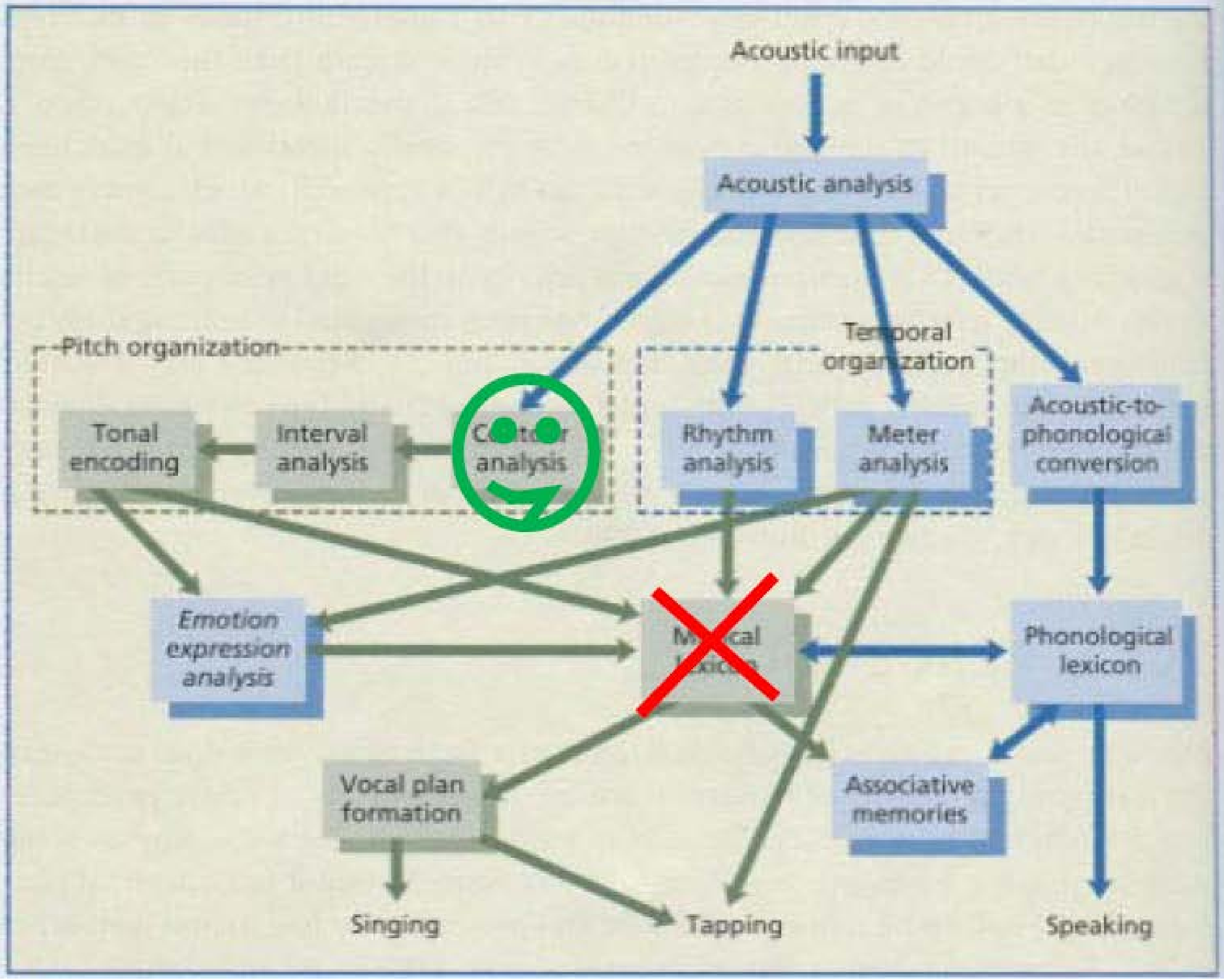



**Fig. 1.** Percentage of correct responses obtained by 2 amusic patients with brain damage (CN and IR) and 29 unselected control adults with no musical experience in the memory recognition of studied melodies, lyrics, and environmental sounds. Error bars represent standard deviation from the mean obtained by controls. Chance performance is 50%.

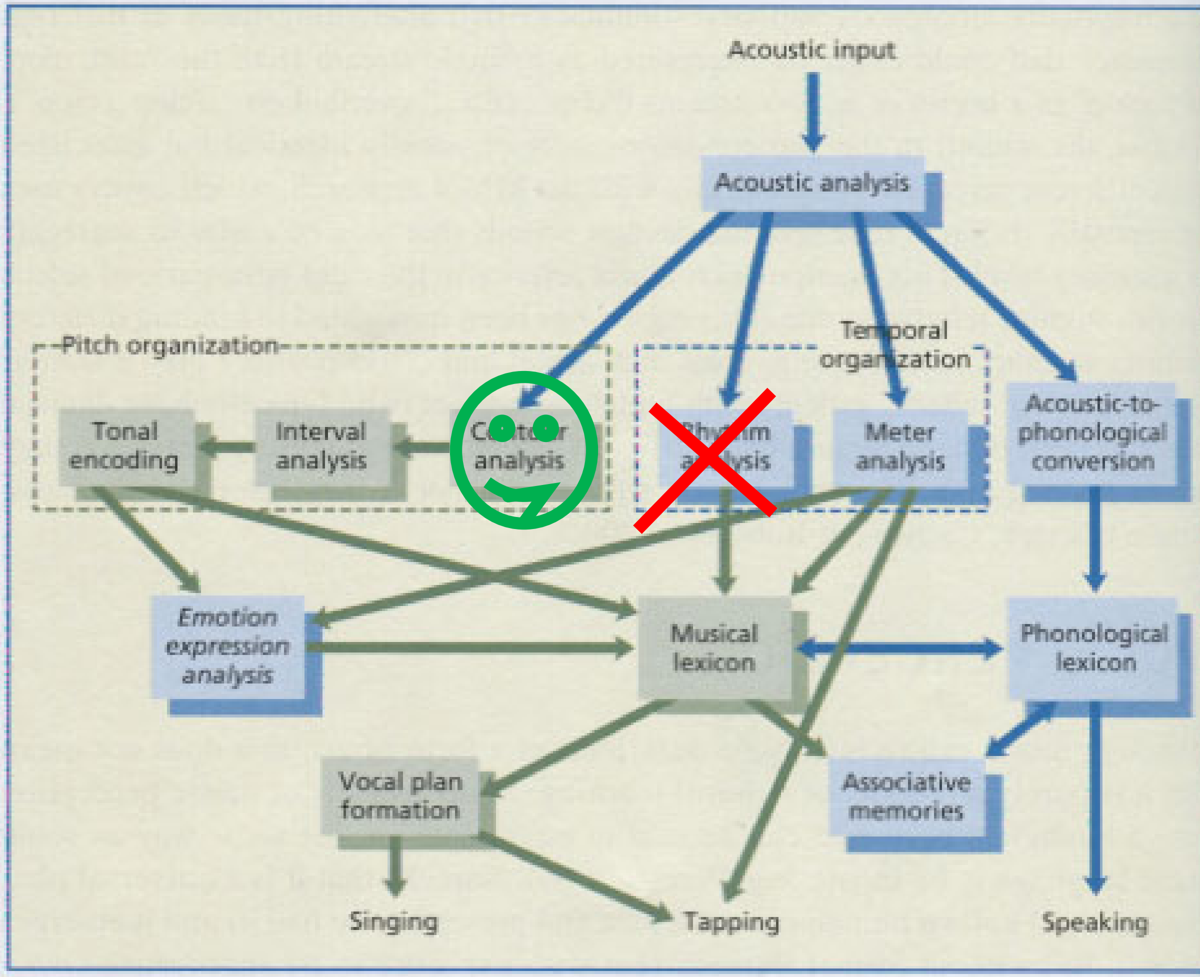
# Amusikalität: Melodien

The model of musical cognition by Peretz and Coltheart (2003) contains separate processes for the lyrics versus melody and rhythm of music, as well as a further sub-division between processes for temporal organization (such as rhythm) and pitch-based organization (including melody). From Peretz and Coltheart (2003), by permission of Macmillan Publishers Ltd.



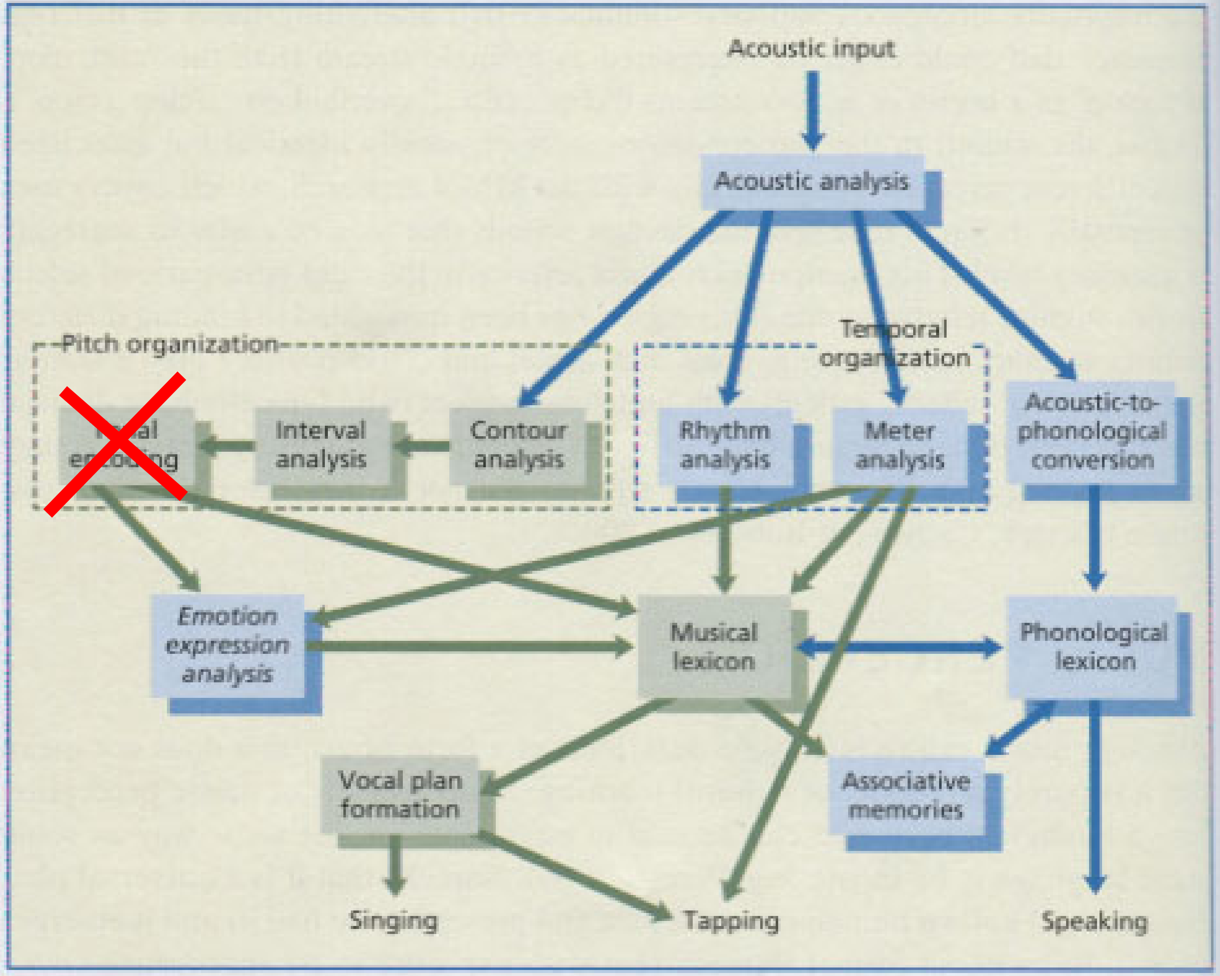
# Amusikalität: Rhythmus

The model of musical cognition by Peretz and Coltheart (2003) contains separate processes for the lyrics versus melody and rhythm of music, as well as a further sub-division between processes for temporal organization (such as rhythm) and pitch-based organization (including melody). From Peretz and Coltheart (2003), by permission of Macmillan Publishers Ltd.

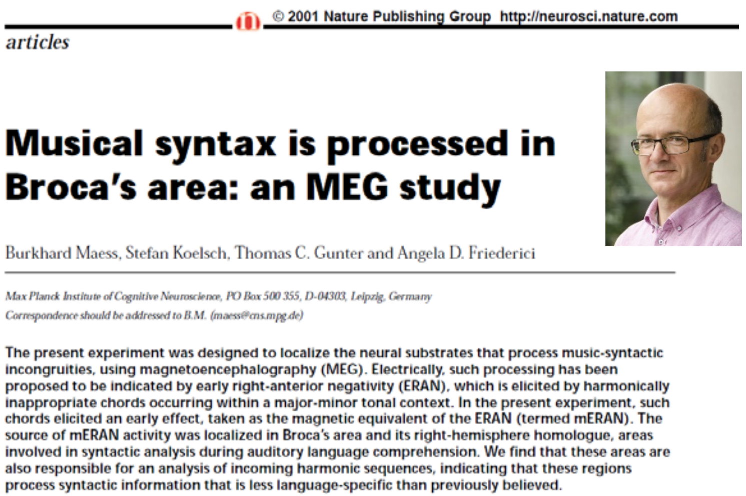


# Amusikalität: Tonhöhen

The model of musical cognition by Peretz and Coltheart (2003) contains separate processes for the lyrics versus melody and rhythm of music, as well as a further sub-division between processes for temporal organization (such as rhythm) and pitch-based organization (including melody). From Peretz and Coltheart (2003), by permission of Macmillan Publishers Ltd.



# Tonale Enkodierung / musikalische Syntax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**Musical syntax is processed in Broca's area: an MEG study**

Burkhard Maess, Stefan Koelsch, Thomas C. Gunter and Angela D. Friederici

*Max Planck Institute of Cognitive Neuroscience, PO Box 500 355, D-04303, Leipzig, Germany*
*Correspondence should be addressed to B.M. (maess@cns.mpg.de)*

**The present experiment was designed to localize the neural substrates that process music-syntactic incongruities, using magnetoencephalography (MEG). Electrically, such processing has been proposed to be indicated by early right-anterior negativity (ERAN), which is elicited by harmonically inappropriate chords occurring within a major-minor tonal context. In the present experiment, such chords elicited an early effect, taken as the magnetic equivalent of the ERAN (termed mERAN). The source of mERAN activity was localized in Broca's area and its right-hemisphere homologue, areas involved in syntactic analysis during auditory language comprehension. We find that these areas are also responsible for an analysis of incoming harmonic sequences, indicating that these regions process syntactic information that is less language-specific than previously believed.**


http://upload.wikimedia.org/wikipedia/commons/b/b9/Neapolitanischersextakkord.ogg

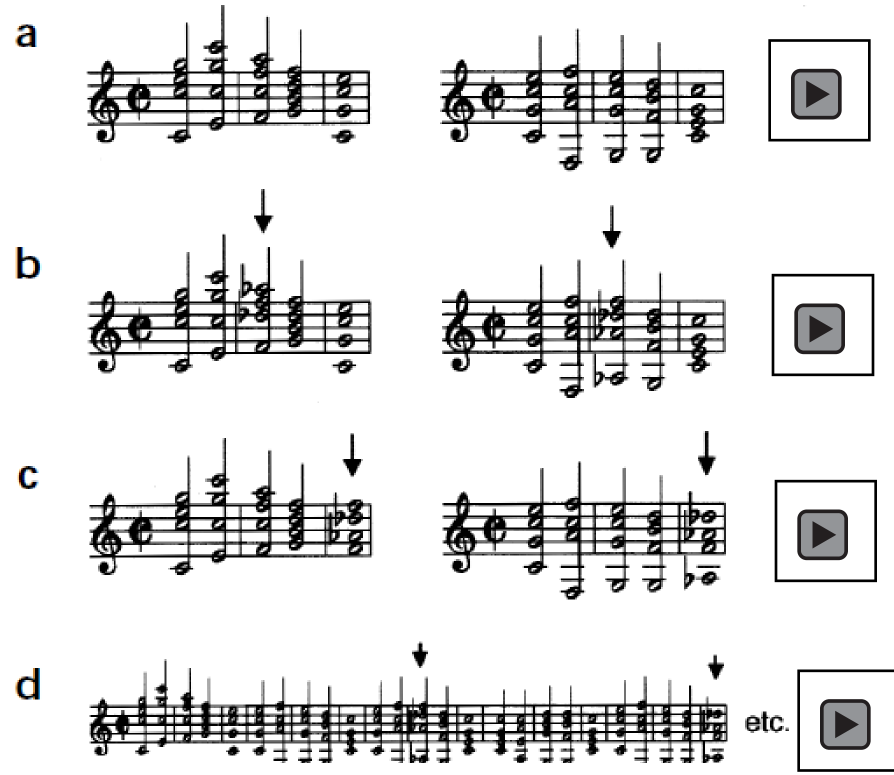
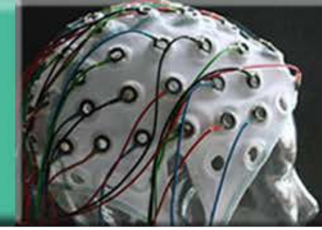
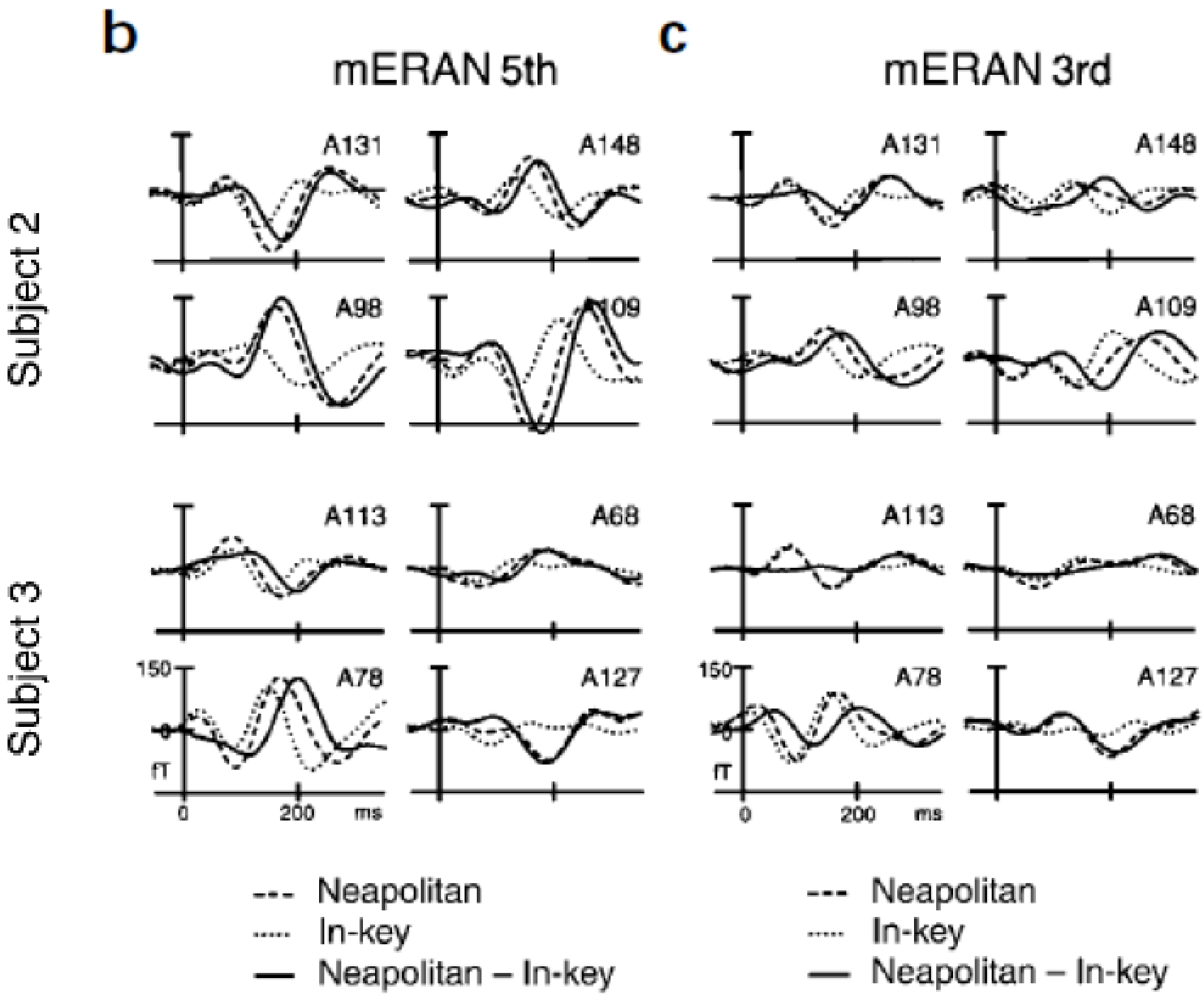


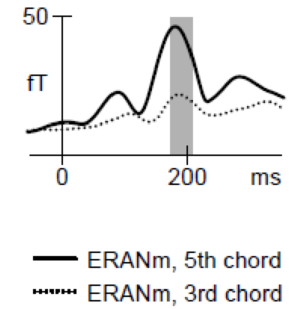

**Fig. 1.** Examples of chord sequences. **(a)** Cadences consisting exclusively of in-key chords. **(b)** Chord sequences containing a Neapolitan sixth chord at the third position. **(c)** Chord sequences containing a Neapolitan at the fifth position; Neapolitan chords are indicated by arrows. **(d)** Example of directly succeeding chord sequences as presented in the experiment.

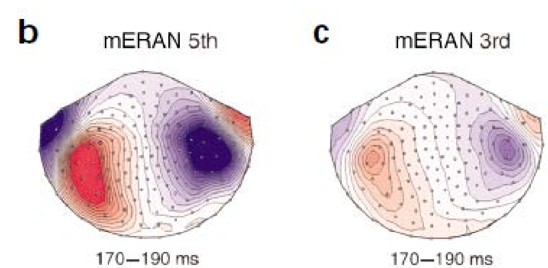
Maess et al. (2001), Nat Neuro, 4, 540-545

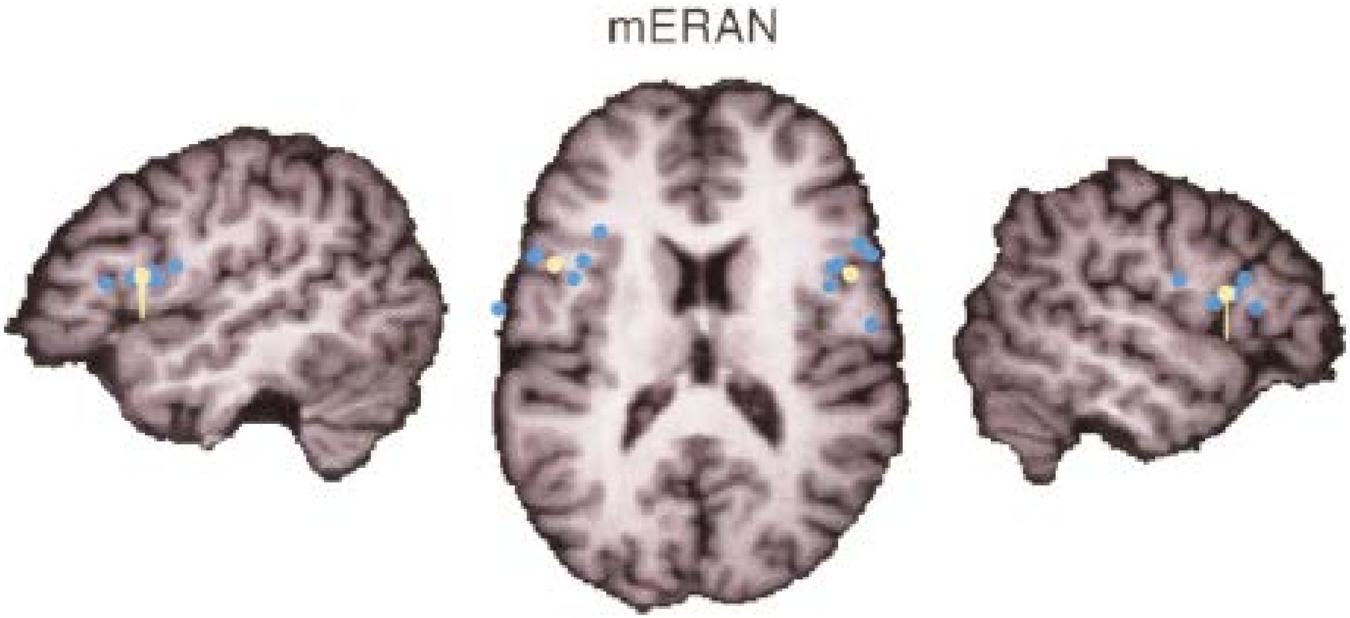
# Tonale Enkodierung und musikalische Syntax-Verletzung: **E**arly **R**ight **A**nterior **N**egativity (ERAN)

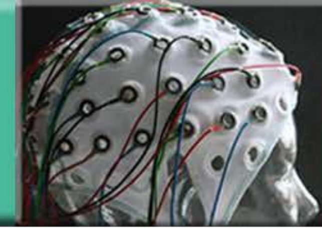





mERAN



PSYCHOLOGICAL SCIENCE

## Research Report

# SINGING IN THE BRAIN: Independence of Lyrics and Tunes

M. Besson,[1] F. Faïta,[2] I. Peretz,[3] A.-M. Bonnel,[1] and J. Requin[1]

[1]*Center for Research in Cognitive Neuroscience, C.N.R.S., Marseille, France;* [2]*University of Bordeaux II, Bordeaux, France; and* [3]*University of Montreal, Montreal, Canada*

Besson, M. et al., (1998) Psychological Science, 9-6, 494-498

# Tonale Enkodierung und lexikalische Verarbeitung

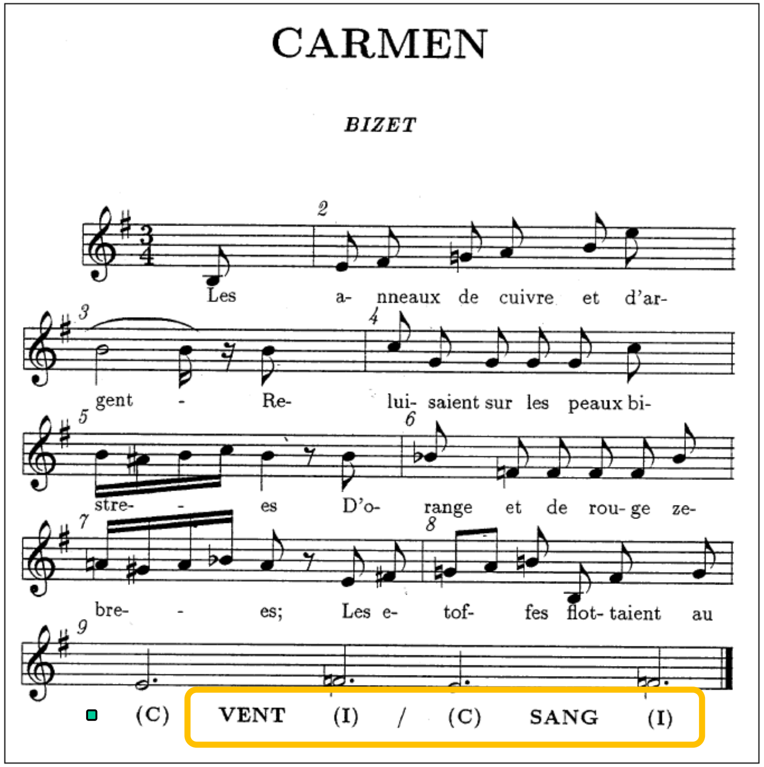


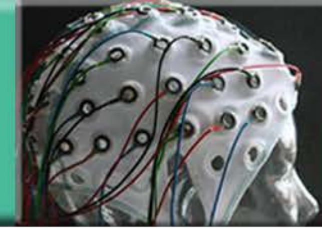

**Fig. 1.** Example of the materials used in the experiment. An approximate English translation of this excerpt from *Carmen* (Bizet) is, "Rings of copper and silver/ Were shining on tanned skins/Of orange and red stripes/The fabric flew in the wind." Note that in French, the incongruous word, "sang" ("blood"), rhymes with the expected completion, "vent" ("wind"). The final note is either congruous (C) or incongruous (I; out of key).

Semantische, harmonische Inkongruenz und doppelte Inkonguenz.

- Congruent / Incongruent („sang" „vent")

- Dur vs Moll (Tonart)

# Ton



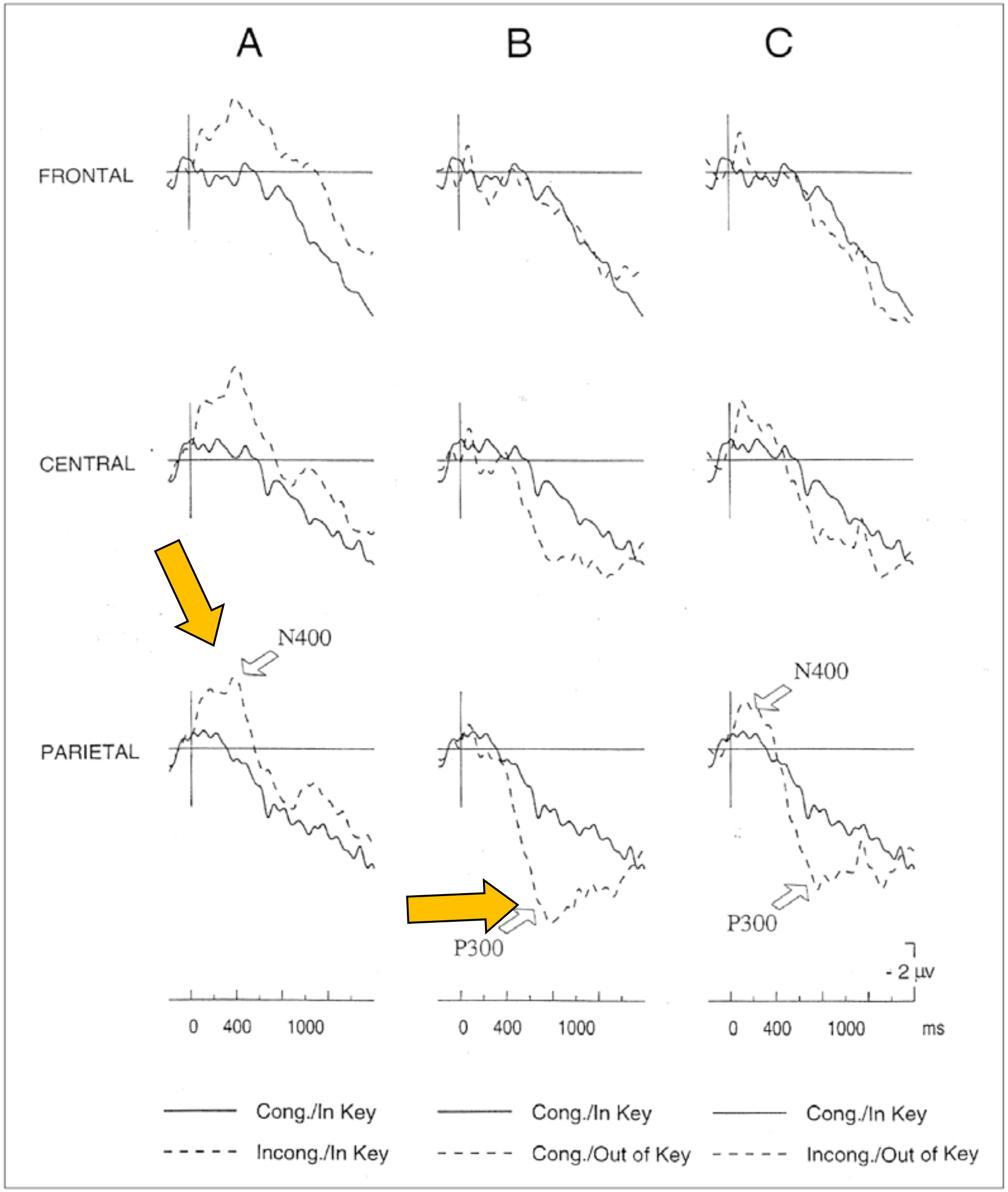
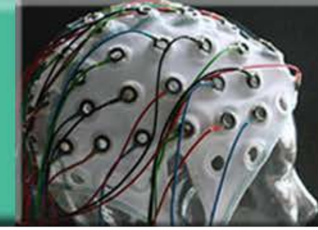
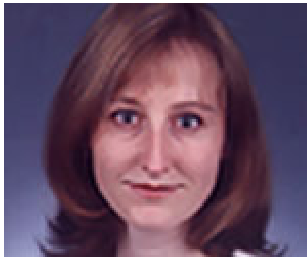


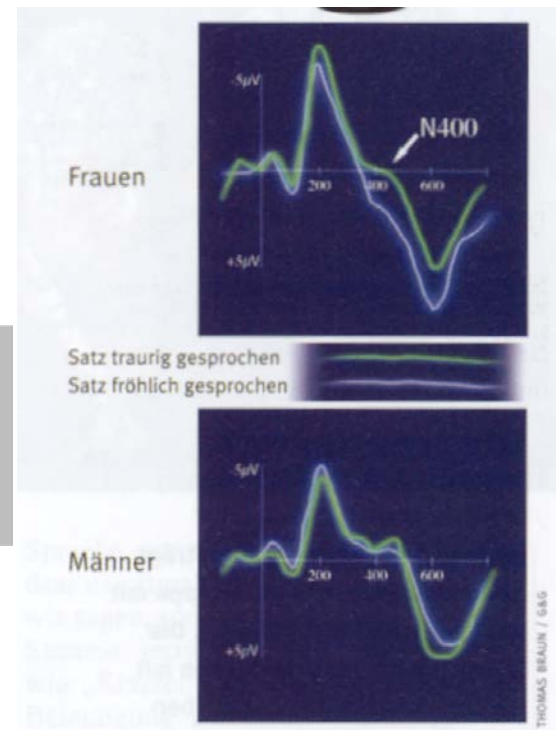

**Fig. 2.** Event-related potentials (ERPs; averaged over 16 professional musicians) associated with the processing of semantic, harmonic, and double incongruities. ERPs elicited by congruous ("Cong.") words sung in key (solid lines) are compared with those elicited by (a) incongruous ("Incong.") words sung in key, (b) congruous words sung out of key, and (c) incongruous words sung out of key. Data presented in this figure are from midline frontal, central, and parietal electrodes, and negative is up. The vertical bars represent the onset of the final word in the excerpts.

# Gender Differences in the Processing of Emotional Prosody



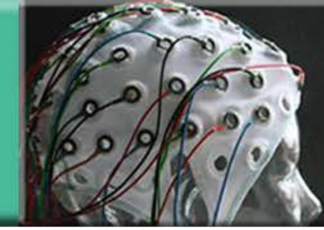


*"Men don 't really understand !"*

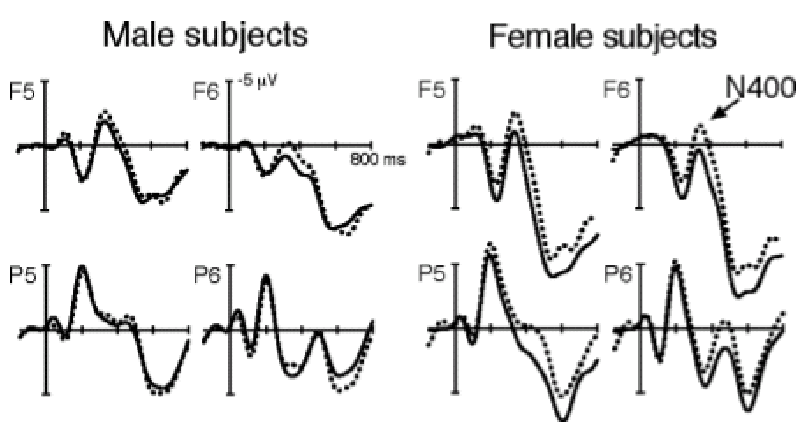



*Schirmer et al. (2002, 2003)*



# Gender Differences in the Processing of Emotional Prosody


## Short ISI






*Schirmer et al. (2002, 2003)*



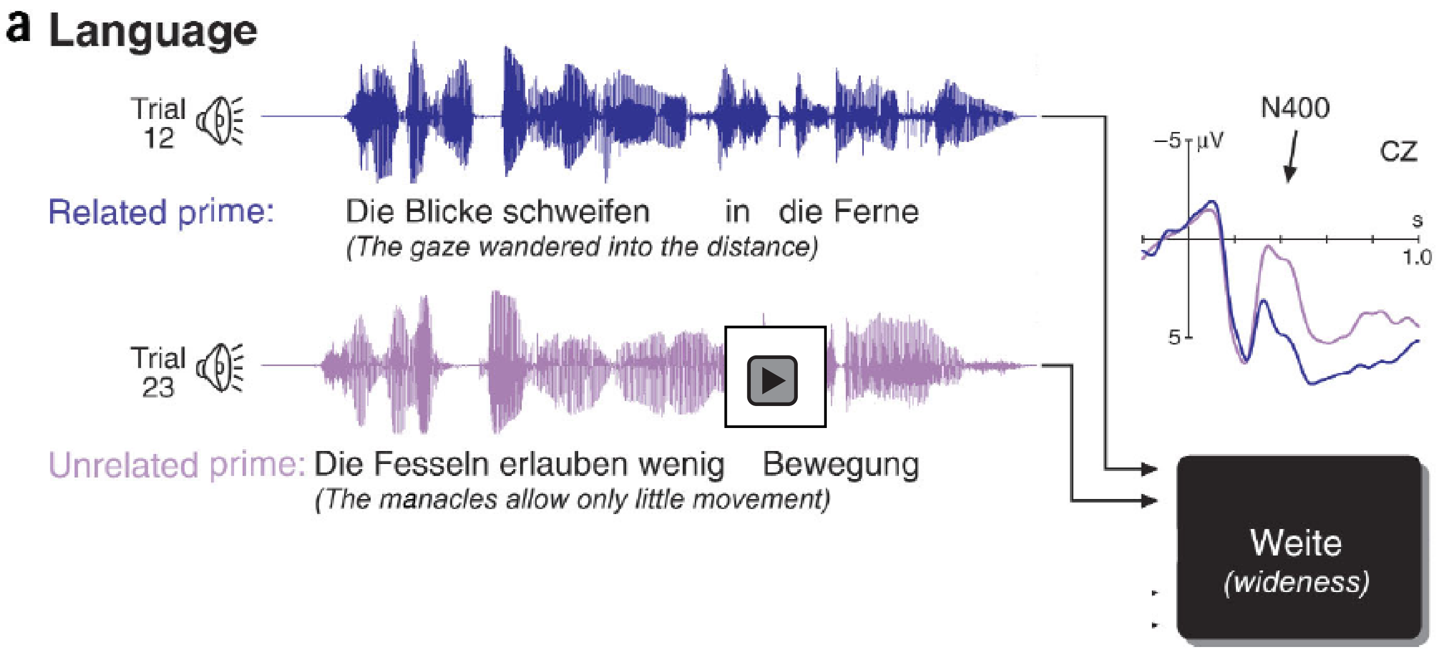
# Music, language and meaning: brain signatures of semantic processing

Stefan Koelsch, Elisabeth Kasper, Daniela Sammler, Katrin Schulze, Thomas Gunter & Angela D Friederici

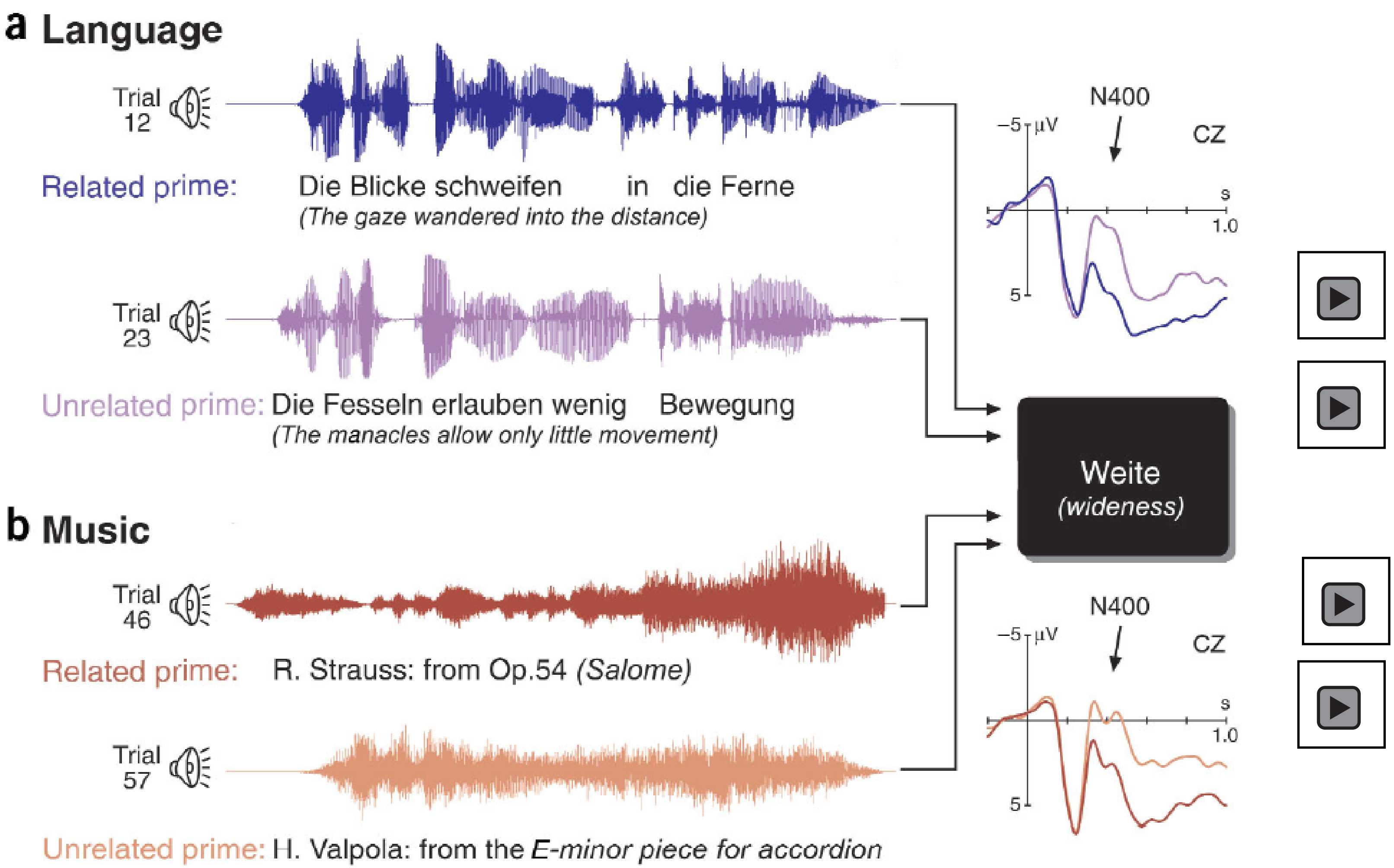
Semantics is a key feature of language, but whether or not music can activate brain mechanisms related to the processing of semantic meaning is not known. We compared processing of semantic meaning in language and music, investigating the semantic priming effect as indexed by behavioral measures and by the N400 component of the event-related brain potential (ERP) measured by electroencephalography (EEG). Human subjects were presented visually with target words after hearing either a spoken sentence or a musical excerpt. Target words that were semantically unrelated to prime sentences elicited a larger N400 than did target words that were preceded by semantically related sentences. In addition, target words that were preceded by semantically unrelated musical primes showed a similar N400 effect, as compared to target words preceded by related musical primes. The N400 priming effect did not differ between language and music with respect to time course, strength or neural generators. Our results indicate that both music and language can prime the meaning of a word, and that music can, as language, determine physiological indices of semantic processing.

Koelsch et al. (2004) Nature Neuroscience, 7-3, 302-307

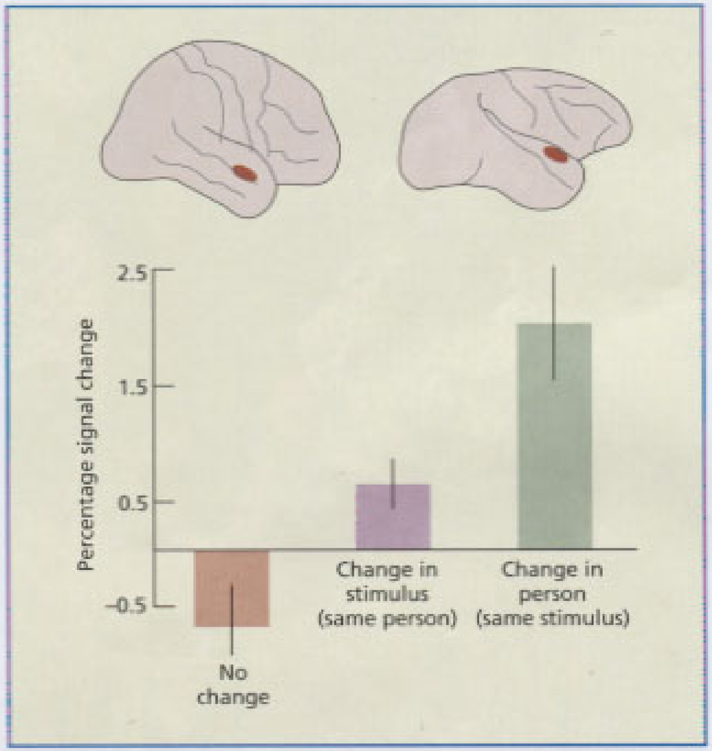
# Musik und semantisches Priming



# Musik und semantisches Priming



# Das Erkennung von Stimmen: Stimmen-selektive Regionen im rechten Temporallappen (STS)

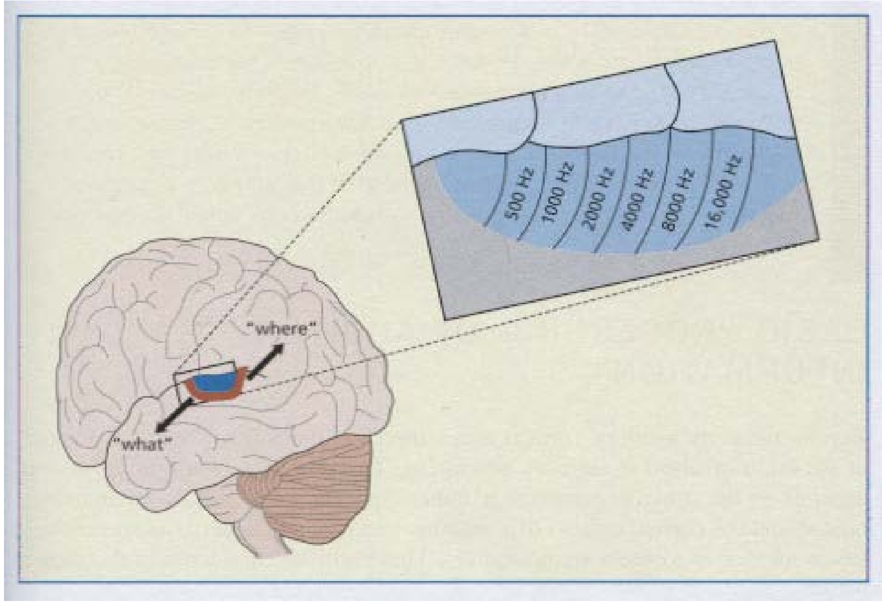



Approximate location of the voice-selective region in the right temporal lobe of humans (left) and macaques (right). This region responds more, in terms of fMRI BOLD signal, when the speaker changes (but the syllable/vocalization is the same) than when the syllable/vocalization changes (but the speaker is the same). Reprinted from Scott (2008), Copyright 2008, with permission from Elsevier.

increased activity in a left te

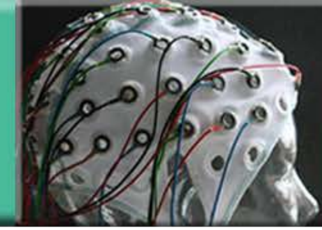
# Die Sprachwahrnehmung

Wo werden Sprachsignale anders verarbeitet als andere auditive Signale?



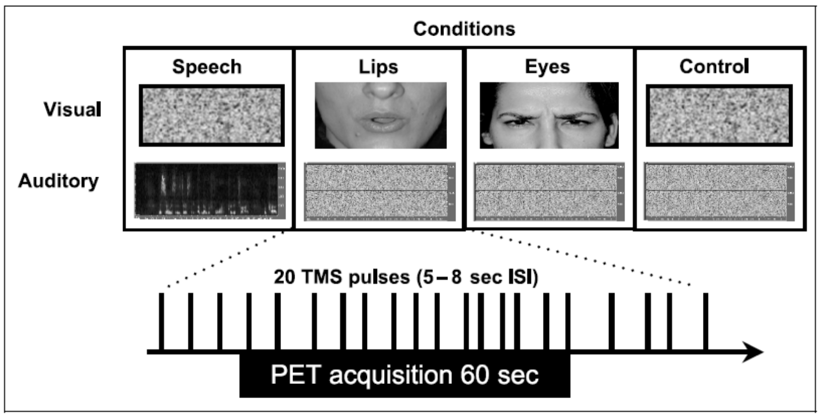

- **What-Route:** Linke Temporal-Region separiert zwischen deutlicher und undeutlich gesprochener Sprache und Klängen mit und ohne Vokale.
- Worttaubheit: Links temporale Regionen.
- Links temporale Region ist spezialisiert auf die Verarbeitung schneller zeitlicher Wechsel des Sprachsignals.

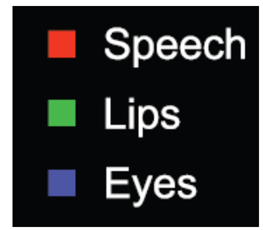
# Motor Theory of Speech Perception

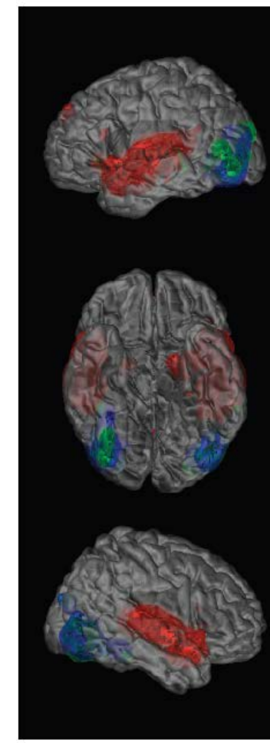


Understanding acoustic signal = matching to stored inputs

Motor representations of how sound is articulated?



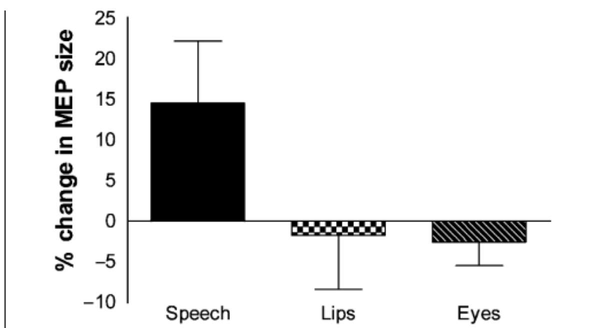
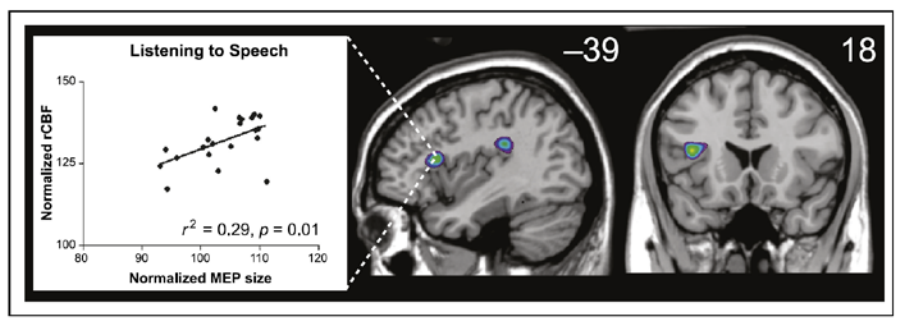


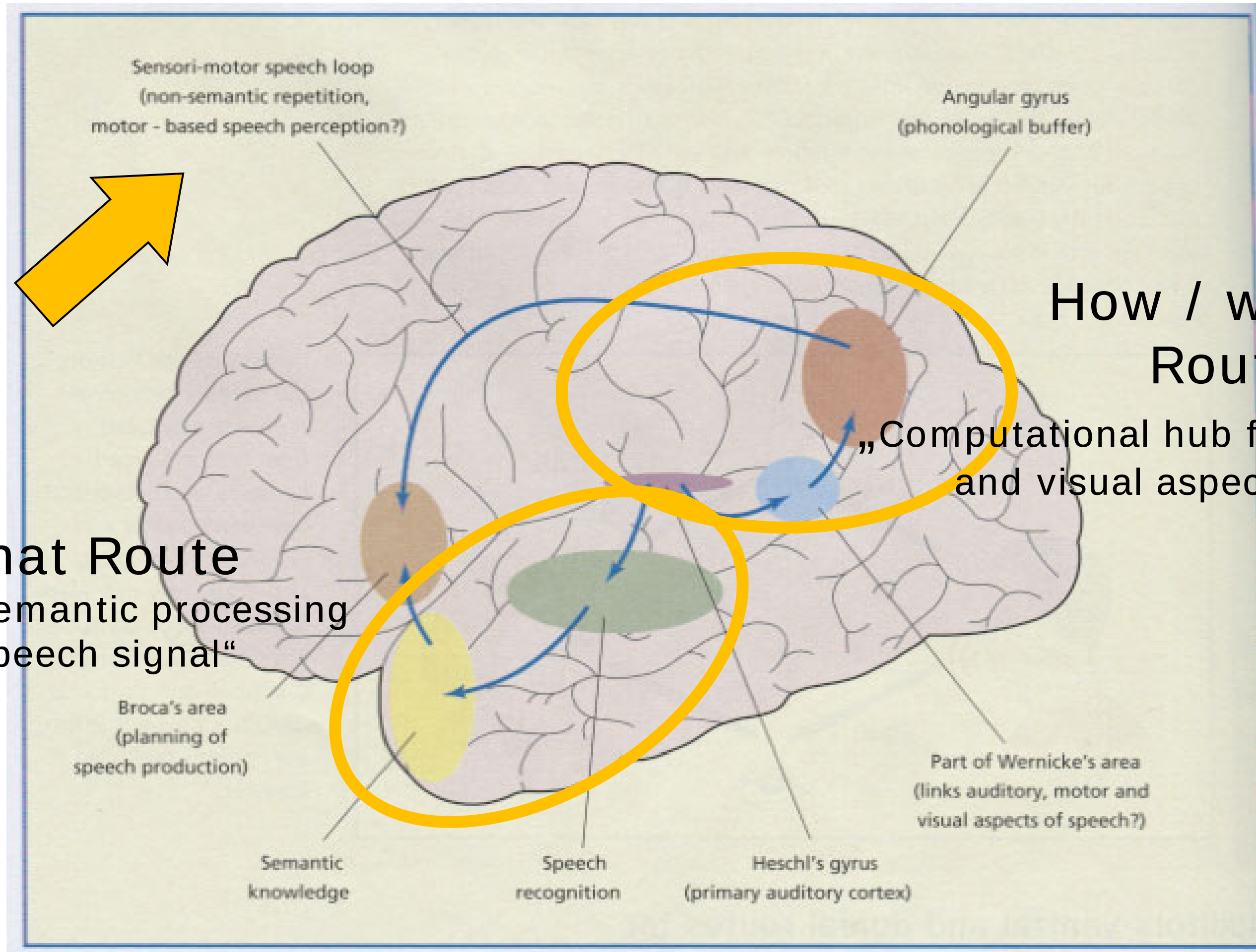

**Figure 2.** Motor excitability changes. The graph shows the mean of the change in size of the motor-evoked potential for the Speech, Lips, and Eyes conditions relative to the Control condition. Error bars represent standard errors of the mean.






Watkins & Paus, (2004), Journal of Cognitive Neuroscience, 16-6, 978-987

# Motor-based speech perception in the „where“ route?




There may be two routes for perceiving and repeating speech: one that is based on lexical-semantic processing and one that is based on auditory-motor correspondence. These have been termed the ventral “what” route and the dorsal “how” route, respectively.

## How / where Route

„Computational hub for auditory, motor and visual aspects of speech

## What Route

„Lexical-semantic processing of speech signal“

# Functional magnetic resonance imaging of synesthesia: activation of V4/V8 by spoken words

J. A. Nunn[1,2], L. J. Gregory[2,8], M. Brammer[3], S. C. R. Williams[2], D. M. Parslow[4], M. J. Morgan[5], R. G. Morris[4], E. T. Bullmore[6], S. Baron-Cohen[6,7] and J. A. Gray[4]

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[2] *Neuroimaging,* [3]*Brain Image Analysis Unit and* [4]*Department of Psychology, Institute of Psychiatry, London SE5 8AF, UK*
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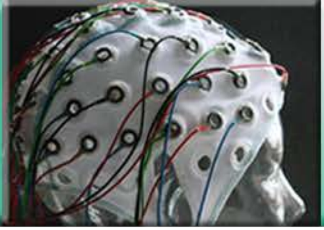
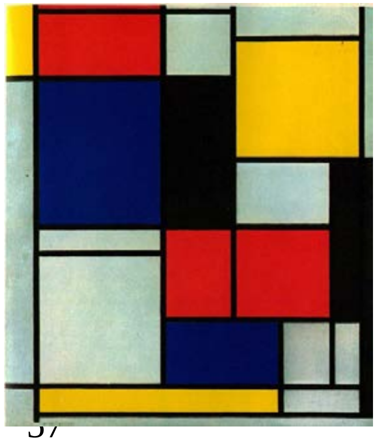
Published online: 25 February 2002, DOI: 10.1038/nn818

**In 'colored-hearing' synesthesia, individuals report color experiences when they hear spoken words. If the synesthetic color experience resembles that of normal color perception, one would predict activation of parts of the visual system specialized for such perception, namely the human 'color center', referred to as either V4 or V8. Using functional magnetic resonance imaging (fMRI), we here locate the region activated by speech in synesthetes to area V4/V8 in the left hemisphere, and demonstrate overlap with V4/V8 activation in normal controls in response to color. No activity was detected in areas V1 or V2, suggesting that activity in primary visual cortex is not necessary for such experience. Control subjects showed no activity in V4/V8 when imagining colors in response to spoken words, despite over-training on word–color associations similar to those spontaneously reported by synesthetes.**

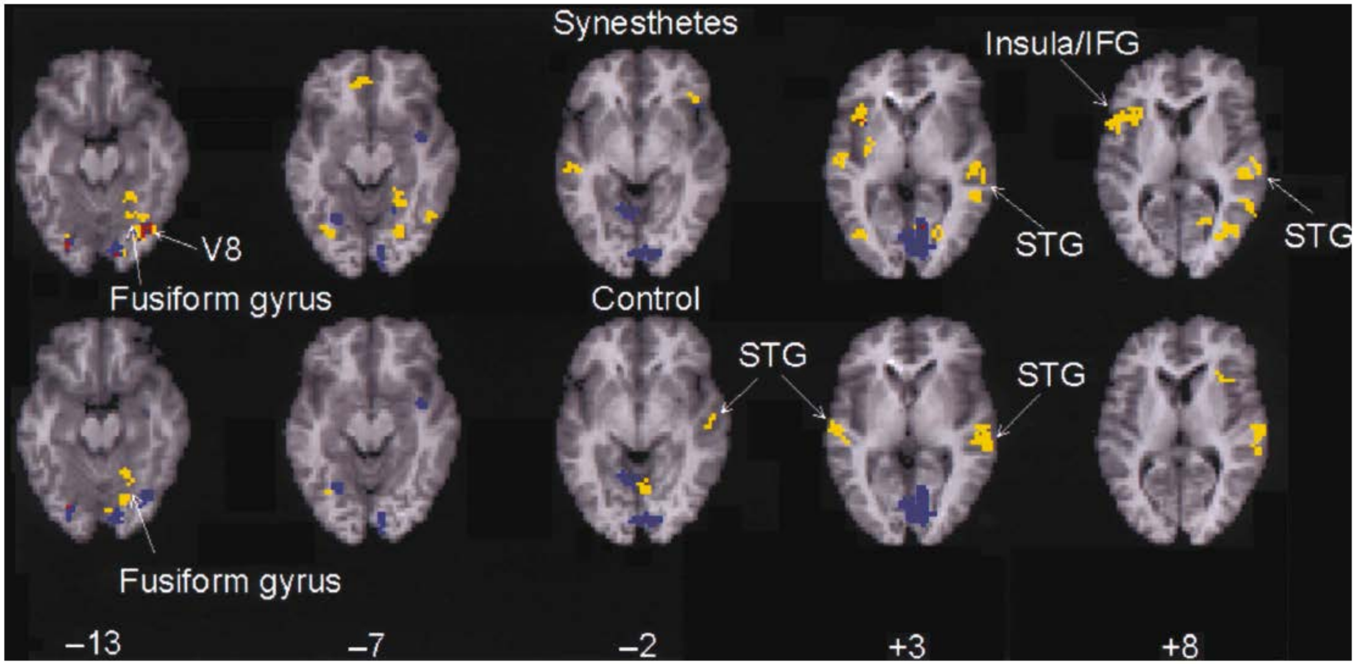
# Hearing colors



- 12 Probanden mit Synästhesie
- Drei Aufgaben:
  - (A1) Wort –Töne (passives Hören)
  - (A2) Farbwahrnehmung (Mondrians)
  - (A3) Farb-Wort Assoziationstest (8 Paare); Farbaktivierung
- Kontrollgruppe: Training der Farb-Wort Assoziationen bis 100% .



# Farbenhören aktiviert V4/8
## Blau: Farbaktivierung (A3)/ Gelb: Wörter-Töne (A1)



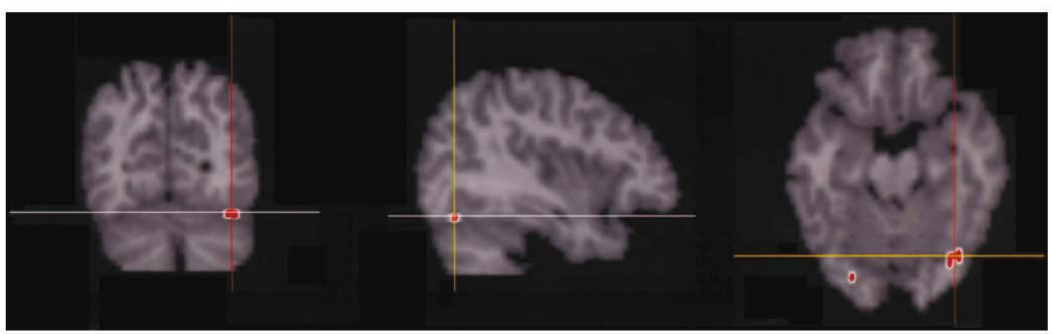
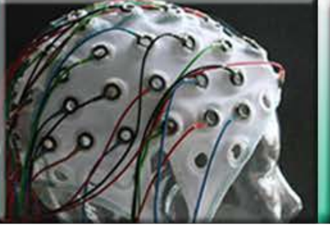



**Fig. 2.** Orthogonal views of the site of overlap between the current experiment and a color activation mapping study[9]. Coronal, sagittal and axial planes are shown.

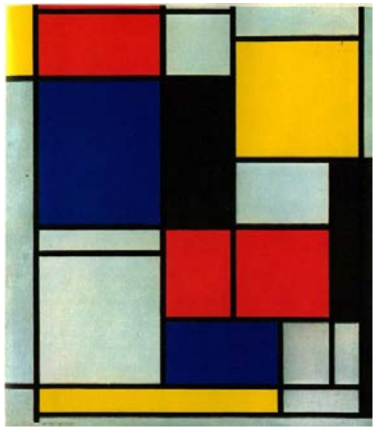
# Hearing Colors



Neural correlates of synesthetic word processing closer to color perception than imagery

Abnormal model of speech processing shows:

- Left-lateralisation similar to normal speech processing
- Visual and auditory systems *can* be directly linked albeit not normally




Danke für Ihre Aufmerksamkeit!