Folie 1

Perception & Attention III

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Folie 2

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When the brain plays music: auditory–motor interactions in music perception and production

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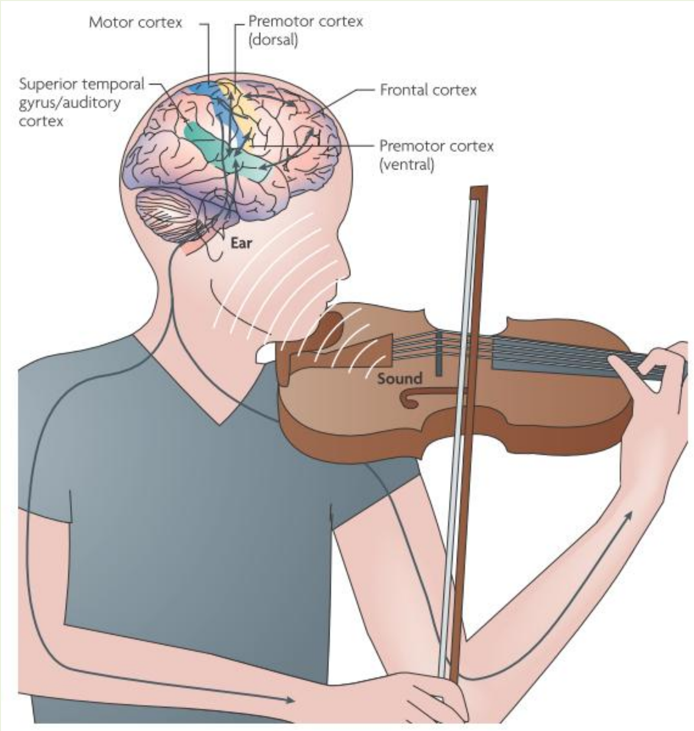
Folie 3



Zatorre et al. (2007), p. 548

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When a musician plays music, what happens in his brain?

- To play the music, his primary motor cortex is sending motoric commands to his hands and fingers
- The sound of the music is processed in the auditory cortex
- To adjust the tone pitch to put more of a soul into the music, interactions between the premotoric and the auditory cortex are necessary

The following presentation will focus first on the music production in the motor system, will then go to the sensoric processing of the auditory system and finally discusses the interactions between both.

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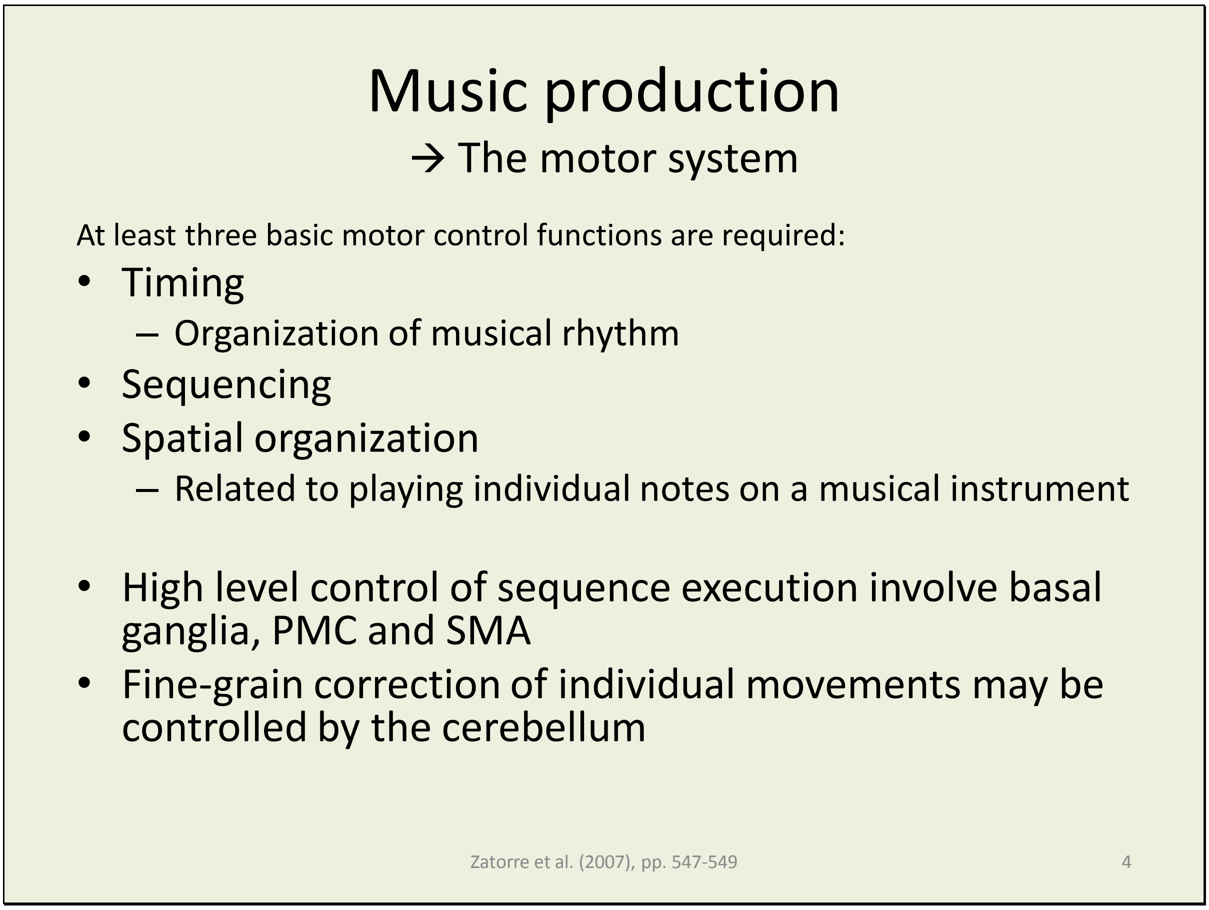


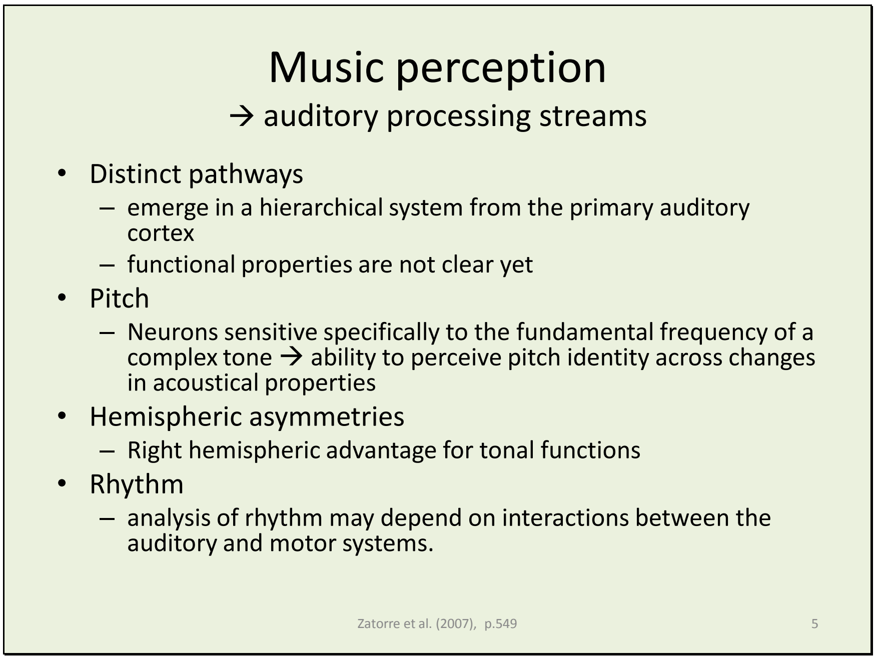
To produce music, at least three basic motor control functions are required:

- Timing
- Sequencing
- Spatial organization of movement

Timing is necessary for the organization of musical rhythm, whereas sequencing and spatial organization are related to play individual notes on a musical instrument

Regions that are linked to the timing of movement are the basal ganglia and the suplementory motor area (SMA) which are involved in high-level control of sequence execution, and the cerebellum, which controls the fine-grain correction of individual movements

Folie 5



1) Distinct pathways:
From the auditory system, distinct pathways emerge in a hierarical system from the primary auditory cortex. A ventral course projects tot he temporal neocortex and a dorsal course reaches targets in the parietal cortex.
The functional properties are not clear yet. One model suggests that ventral and dorsal streams may parallel the visual system in supporting object and spatial processing. So the dorsal stream can also be conceptualized as playing a part in auditory-motor transformations, analogous to the role in proposed for the visual dorsal stream.

2) Pitch:
The pitch is a percept that allows us to order sounds from low to high. A perceived pitch most often corresponds to the fundamental frequency.
There were neurons found lateral to A1, that are specifically to the fundamental frequency of a complex tone. This is thought to be the neural mechanism for the ability to perceive pitch identity across changes in acoustical properties, like for example loudness or across different instruments.

3) Hemispheric asymmetries
There is a right hemispheric advantage for tonal functions. Whether this phenomenom exists because of fundamental differences in acoustical processing or whether it is related to abstract knowledge domains like language is not clear yet.

4) Rhythm
Rhythm and pitch can be perceived separately, but they also interact in creating a musical percept. For example patients with brain injury may be impaired in the processing of melody but not rhythm, or the other way around.
The motor regions play a role in both – the perception and the production of rhythms. For example in studies where subjects only listen to rhythms, the motoric system is often implicated.
The analysis of rhythm may depend on a large extend of interactions between the auditory and the motor system.

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Music performance
→ auditory-motor interactions

- Feedforward interactions
  - Auditory system influences motor output in a predictive way(e.g. tapping to the beat)
- Feedback interactions
  - Auditory system influences motor output to implement appropriately timed motor adjustments

Zatorre et al. (2007), p.550

Auditory-motor interactions can be split into feedforward and feedback interactions

In feedforward interactions, the auditory system influences the motor output in a predictive manner. Examples are tapping one's foot to the beat or the effect of music on movement disorders. In Parkinson's disease or stroke patients, rhythmic auditory stimuli improve the walking ability of these patients.

In feedback interactions, the auditory system influences the motor output in an adjusting manner (e.g. to adjust the pitch of a tone while playing the tone).

When auditory feedback is blocked, musicians can still execute well known pieces, but the expressive aspect of the performance is affected
When the auditory feedback is experimentally manipulated by delays for example, motor performance is significantly changed.

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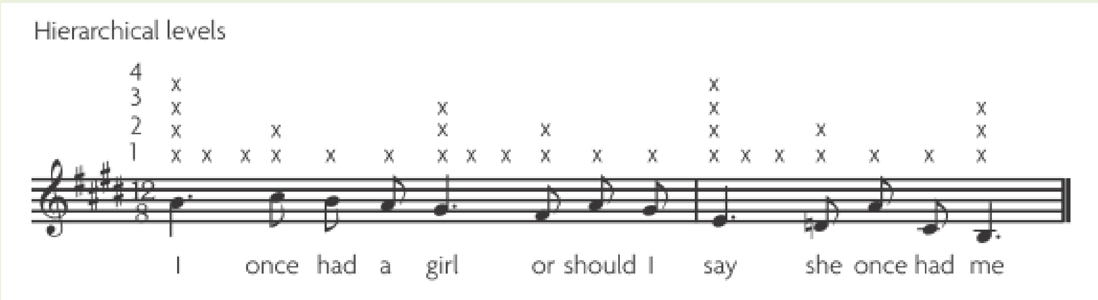
Music performance

→ auditory-motor interactions

- Important difference to speech
  - music has a hierarchical metrical structure
  - This structure creates musical expectations
  - Is unique to music and probably humans



- Mirror/echo neurons and auditory-motor interactions

Zatorre et al., (2007), p. 550-551

The existing models for interactions between auditory system and motor system are specific for speech processing. But there are important differences between speech and music. Music has a hierarchical structure as you can see in this picture.

A regular metrical structure is a common feature of music from many cultures. It consists of a hierarchical framework of perceived beats. Each column of Xs represents a beat and each row represents different hierarchical levels. The lowest level relates to local regularities whereas the higher levels are integer multiples of the lower levels. Most people can extract this periodic higher order organization that allows one to create temporal expectancies.

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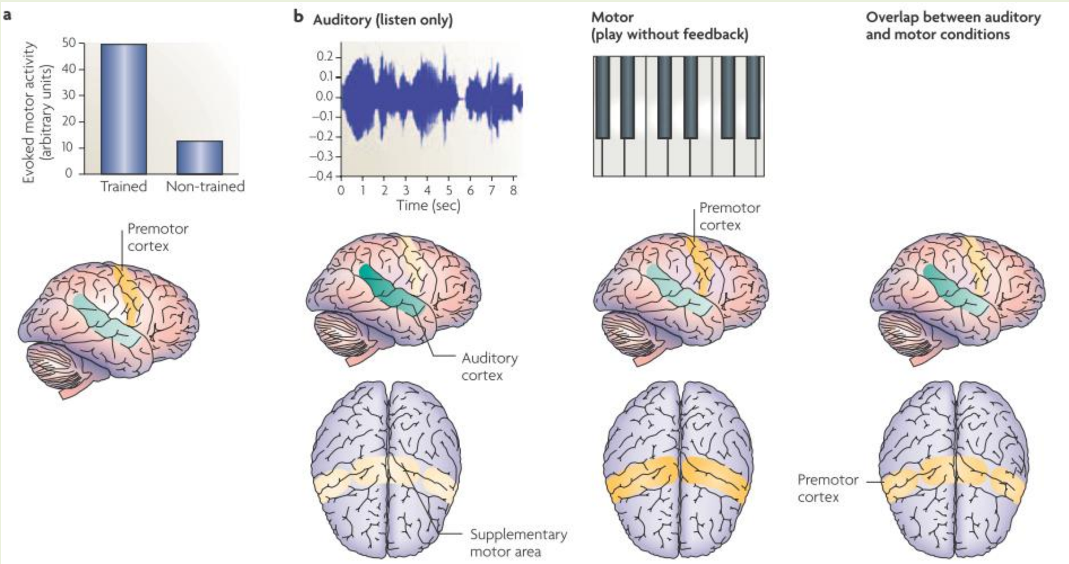
Music performance
→ neural correlates



Zatorre et al. (2007), p.552

Coupling between auditory and premotor cortices in musical contexts:

Several neuroimaging studies demonstrate that activity in auditory and premotor cortices is tightly coupled under certain circumstances.

a) In one study, people without musical training were taught to play a simple melody on a keyboard. After training, on hearing the learned piece, they exhibited not only the expected activity within the auditory cortex, but also activity within premotor areas. This effect was not present when listening to a melody that had not been trained (bar graph).

b) Similarly, several studies have compared the brain activity in musicians while they listened to a piece they knew how to play (left column) with their brain activity while they played the same piece but without auditory feedback (middle column). Significant overlap is observed both in auditory and premotor regions in each condition (right column), suggesting that auditory and motor systems interact closely during both perception and production.

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Functional architecture

→ a hypothesis

- Interactions between posterior auditory cortices and premotor cortices mediate the cognitive representations that are responsible for integrating feedforward and feedback information during performance and perception
- Higher order temporal organization (metricality) emerges from the temporal predictions that are enabled by this system.
- The dPMC may be a crucial neural hub involved in integrating higher order features of a sound with the appropriately timed and organized motor response.
  - Because of its connectivity to both input and output systems
  - And its physiological properties

Zatorre et al., 2007

Literature

- Zatorre R. J., Chen J.L., & Penhune V. B. (2007). When the brain plays music: auditory–motor interactions in music perception and production. *Nature Reviews Neuroscience 8*, 547-558.