Master Class

Deciphering the biology of human musicality through state-of-the-art genomics

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www.mcg.uva.nl/musicality2019

amsterdam brain & cognition · MAX PLANCK INSTITUTE FOR PSYCHOLINGUISTICS · Institute for Logic, Language and Computation · University of Amsterdam SMART Cognitive Science

Master Class Program

12:30 [Registration and Coffee]
12:50 Welcome (Honing/Fisher)
13:00 Henkjan Honing - *Introduction to musicality*
13:45 Bruno Gingras - *Phenotypic approaches*
14:30 Student talk 1: Kirsty Hawkins
14:45 [Break]
15:00 Simon Fisher - *Genetic and genomic strategies for studying human musicality*
15:45 Student talk 2: Damian Liu
16:00 Reyna Gordon - *Connecting musicality with other traits*
16:45 Student talk 3: Celeste Figaroa
17:00 [Closing and drinks]

Introduction to musicality

Henkjan Honing
www.mcg.uva.nl

First of all, thanks to:

1. University of Amsterdam (UvA)
   - Amsterdam Brain & Cognition (ABC)
   - Institute for Logic, Language & Computation (ILLC)
   - Institute for Interdisciplinary Studies (IIS)
   - Institute for Advanced Study (UvA-IAS);
2. Hungarian Academy of Sciences (MTAPI), International Laboratory for Brain, Music and Sound Research (BRAMS), Universidad Nacional Autonoma de México (UNAM), Institute of Biology Leiden (IBL);
3. Funding, e.g., UvA-ABC and NWO-Horizon.

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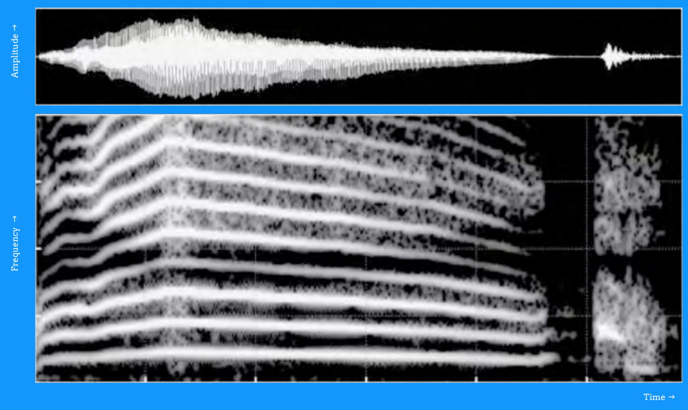

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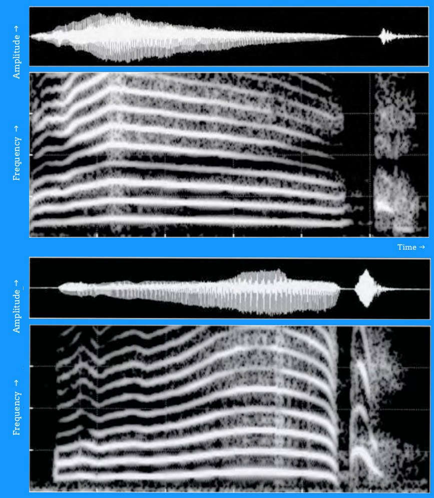
A



B

German baby

French baby

Mampe *et al.* (2009) *Current Biology*

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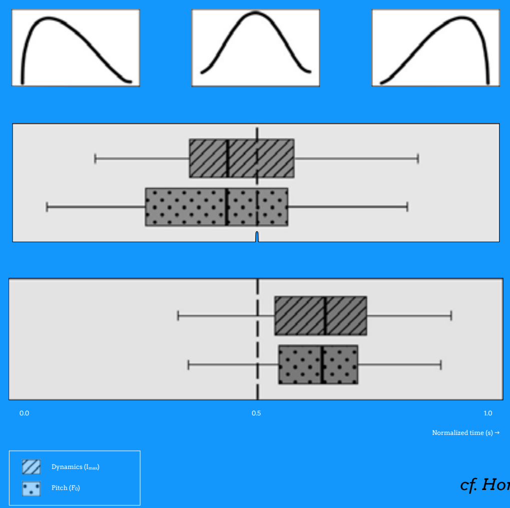

German babies *(N=30)*

French babies *(N=30)*

cf. Honing (2011) *The Illiterate Listener*

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Music vs. musicality

- *Musicality* – in all its complexity – can be defined as a natural, spontaneously developing set of traits (designed for the perception and production of music) based on and constrained by our cognitive and biological system;
- *Music* – in all its variety – can be defined as a social and cultural construct based on that very musicality;
- In short: *without musicality no music.*

Honing (2018) *NYAS*

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Origins of music/ality

'There is no reason to believe there is a universally shared, innate basis for music perception. Clearly, music is a cultural artifact.' (Repp, 1999)

'We may safely infer that music is among the most ancient of human cognitive traits.' (Zatorre & Salimpoor, 2013, PNAS)

Conard *et al.* (2009) *Nature*

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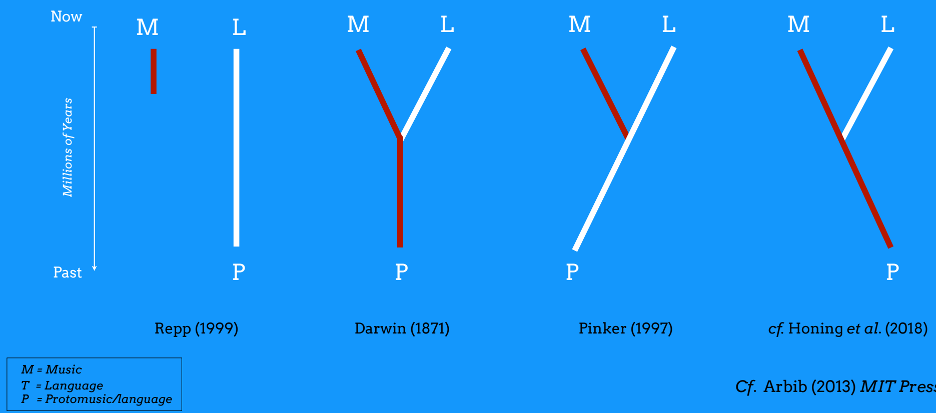
Origins of music/ality



Cf. Arbib (2013) *MIT Press*

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Levels of explanation

1. Mechanistic causes (*How does a trait work?*)
2. Ontogeny (*How does it develop over an organisms lifetime?*)
3. Phylogeny (*How is it acquired/modified over evolutionary history?*)
4. Function (*How does it help to survive or reproduce?*)
5. …

Tinbergen (1963) *Z. für Tierpsychologie*

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Theories on the origins of music/ality

1. Adaptationist: *reproductive benefits*
   - Sexual selection (Darwin, 1872; Miller, 2000; Charlton *et al.*, 2012)
2. Adaptationist: *survival benefits*
   - Bonding parent/child (Dissanayake, 2000; Brown, 2000)
   - Social cohesion (Cross, 2003; Kirschner & Tomasello, 2010)
   - Music as social grooming (Dunbar, 2010; 2012)
3. Nonadaptationist accounts
   - Supernormal stimulus (Pinker, 1997; 2007)
   - Transformative technology (Patel, 2010; 2018)

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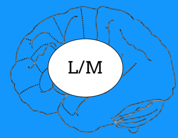
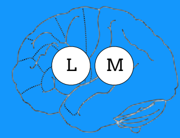
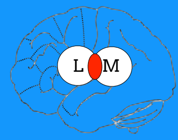
1. Formal identity hypothesis
(identical functions/networks)
Fitch (2014); Katz & Pesetsky (2009)



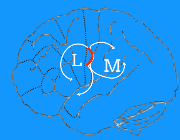
2. Dissociation hypothesis
(distinct brain regions)
Peretz & Coltheart (2003)



3. Neural sharing hypothesis
(some function/networks are shared)
Patel (2008; 2014)



4. Neural overlap hypothesis
(dissociation locations and networks)
Peretz et al. (2015); Honing (2018)



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Example studies

1. Musical structure: 'Statistical universals' (e.g., Savage *et al.*, 2015, *PNAS*)
2. Musical structure: Form/function relations (e.g., Mehr *et al.*, 2017, *Current Biology*)
3. Cultural transmission / Iterated learning (e.g., Jacoby & McDermott, 2017, *Current Biology;* Ravignani, 2018, *Trends in Ecology and Evolution*)
4. Biology: Cross-species comparison (e.g., Honing *et al.*, 2015, *Phil Trans B)*
5. Biology: Genetics of musicality (e.g., Gingras *et al.*, 2015, *Phil Trans B)*

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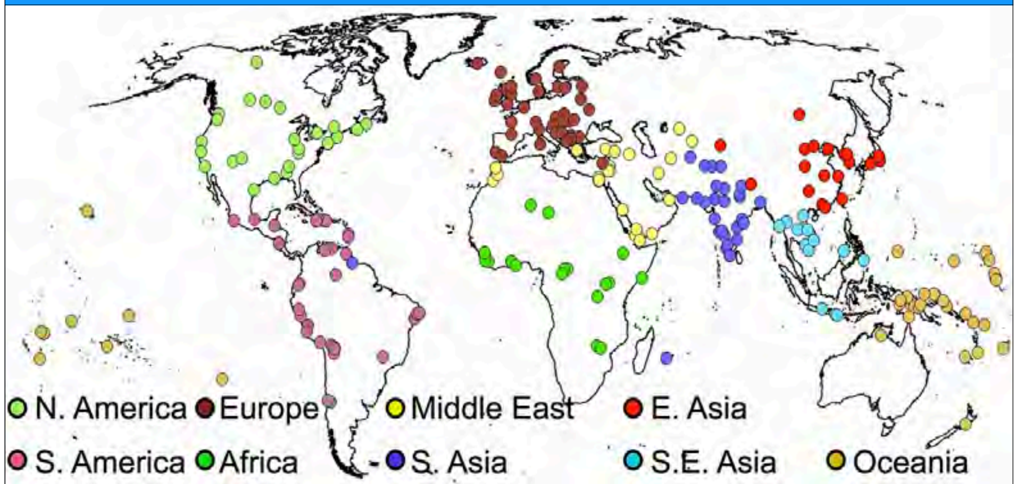

Recordings from: *Garland Encyclopedia of World Music* (Nettl *et al.*, 1998/2002)

Savage *et al.* (2015) *PNAS*

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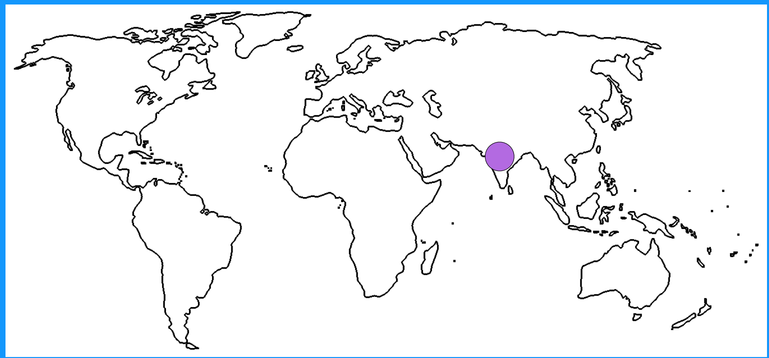
From which region is this music fragment?



Recordings from: *Garland Encyclopedia of World Music* (Nettl *et al.*, 1998/2002)

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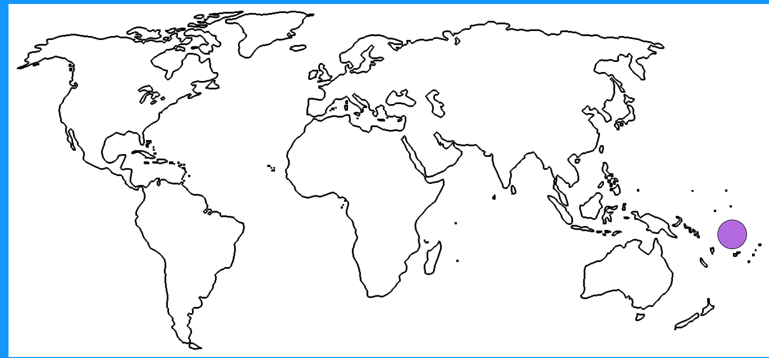
From which region is this music fragment?



Recordings from: *Garland Encyclopedia of World Music* (Nettl *et al.*, 1998/2002)

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Pie charts for the 32 musical features in sample of 304 recordings ranked according to their frequencies.
(White = presence, Black = absence)

N.B. The sample of musical recordings cannot be considered statistically independent. Hence:

1. Need to limit the potential impact of *horizontal transmission* (i.e., cross-cultural borrowing);
2. Using phylogenetic tree based on language as a proxy for the *historical relationships* among the cultures from which these recordings came;
3. The evolution of a binary trait (i.e., a trait taking states 0 or 1) is modeled as a continuous-time Markov process;
4. The evolution of two binary traits over a phylogenetic tree is modelled using Pagel's coevolutionary method.

Savage *et al.* (2015) *PNAS* —

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'Statistical universals'

- In the pitch domain, these include discrete pitches, a limited pitch set (seven or fewer pitches), division of the octave into unequal intervals, and small intervals.
- In the rhythm domain, these include an isochronous beat (i.e., equal timing between beats), two- or three-beat subdivisions (e.g., duple or triple meter), and limited duration values.
- Performances occurred primarily in groups that featured male vocalists and instrumental accompaniment (also by males) (*cf.* Trehub, 2015, *PNAS*)

Savage *et al.* (2015) *PNAS* —

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Universal links between form and function?

Key

Song type	Inclusion criteria, from ethnographic text	Similar examples that were excluded
Dance	Sung with the goal of a person or persons dancing along to it	Songs that happen to be accompanied by dancing but are used for other goals
Healing	Sung in a healing ceremony with the goal of curing sickness	Songs describing sick people or a past epidemic
Love	Sung to express love directly to another person or to describe currently felt love	Songs about unrequited love, deceased loved ones, or love for animals or property
Lullaby	Sung to an infant or child with the goal of soothing, calming, or putting to sleep	Songs designed to excite the listener (e.g., "play songs"); singing games

Mehr *et al.* (2018) *Current Biology*

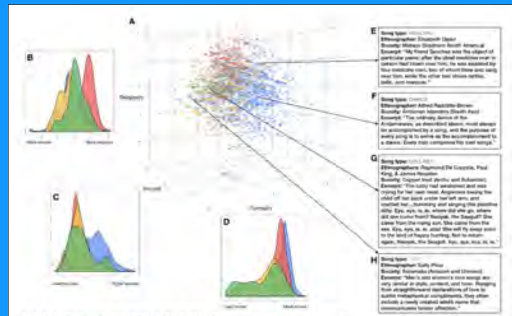
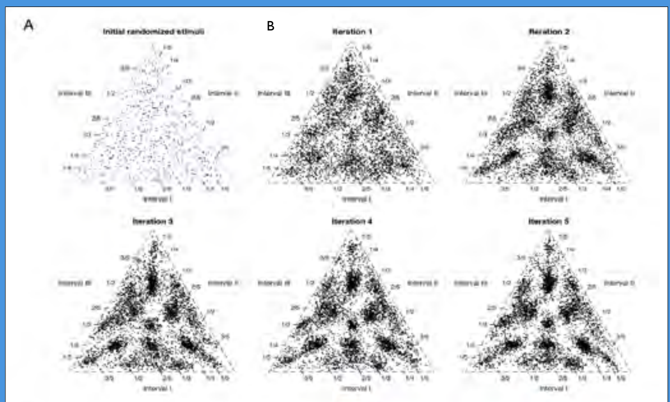


Fig. 2. Patterns of variation in the *NHS Ethnography*. The figure depicts a projection of the *NHS Ethnography* onto three principal components (**A**). Each point represents the posterior mean location of an excerpt, with points colored by which of four types (identified by a broad search for matching keywords and annotations) it falls into: dance (blue), lullaby (green), healing (red), or love (yellow). Excerpts that do not match any single search are plotted in gray. Density plots (**B, C, D**) show the differences between song types on each dimension. Criteria for classifying song types from the raw text and annotations are presented in Table S16. The raw text is provided for four cases to demonstrate their consistency with their locations in dimensional space, each corresponding to one of the four clusters of known song types recovered from the dimensional space (**E, F, G, H**). An interactive version is available at http://themusiclab.org/nhsplots.

1. Universal features of human psychology lead people to produce and enjoy songs with certain kinds of rhythmic or melodic patterning that naturally go with certain moods, desires, and themes;
2. These patterns do not consist of concrete acoustic features, such as a specific melody or rhythm, but rather of relational properties like accent, meter, and interval structure.

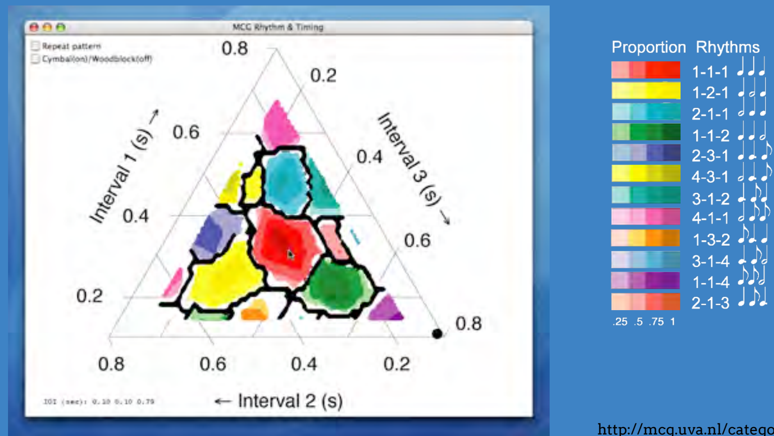
Mehr *et al.* (2019) http://osf.io/jmv3q

'Iterated learning' as alternative method



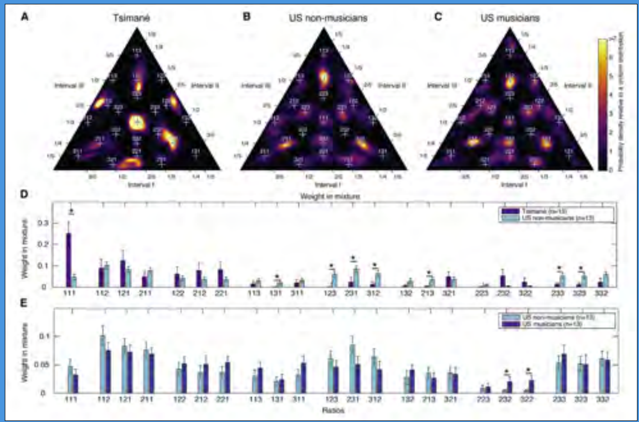
Jacoby & McDermott (2017) *Current Biology*

Chronotopological map (or *rhythm space*)

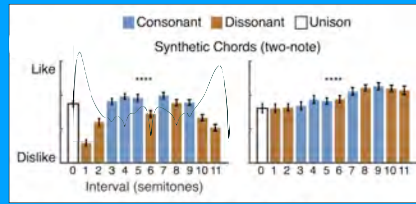


http://mcg.uva.nl/categorization

Perceptual priors on rhythm perception



Jacoby & McDermott (2017) *Current Biology*



US (N=47) *Tsimane' (N=64)*

McDermott *et al.* (2016) *Nature*

Approaches to studying the origins of music/ality

1. Musical structure: 'Statistical universals' (e.g., Savage *et al.*, 2015, *PNAS*)
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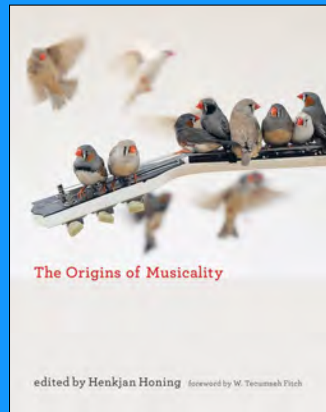
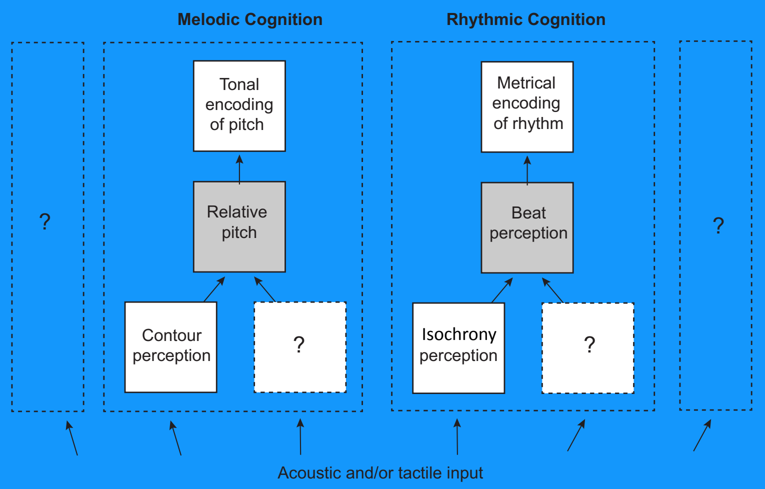


Honing(ed.)(2018) *MIT Press*



Honing(ed)(2018): Ch. 1

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Absolute and relative pitch

- Absolute pitch
  - a) Identifying a sound by its fundamental frequency
  - b) The ability to name a tone without a reference note
  - c) Consists of :
    1. Classifying a sound as having a certain pitch (N.B. independent of timbre);
    2. Memory for pitch;
    3. Be able to assign a label to it (e.g., A#).
- Relative pitch
  - a) The ability to recognise a transposed melody
  - b) Perception of relations between pitches and intervals instead of frequency by itself (*contour* and *interval* perception)
  - c) Octave equivalence (or pitch *chroma*)

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Four levels of explanation

- Development
  - RP is widespread and implicitly learned without training
  - AP is rare, though possibly innate, but memory for pitch is widespread
- Mechanisms
  - RP seems to use frontal areas and working memory
  - AP uses association areas (*planum temporale*)
- Phylogeny
  - Most animals have some AP capacities
  - RP is rare!
- Function
  - Pitch provides information about object identity, emotional information, and used in perceptually separating and identifying simultaneous sound sources

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Function of Pitch

- Pitch provides information about object identity, including body size (Duellman & Trueb, 1986), age (Harnsberger *et al.*, 2008), and gender (Childers & Wu, 1991)
- Pitch contours carry emotional information in speech and music (Trainor *et al.*, 2000)
- Pitch analysis critical for perceptually separating and identifying simultaneous sound sources
- Physical sounds that give rise to the sensation of pitch typically have energy at integer multiples of a fundamental frequency, f_0.

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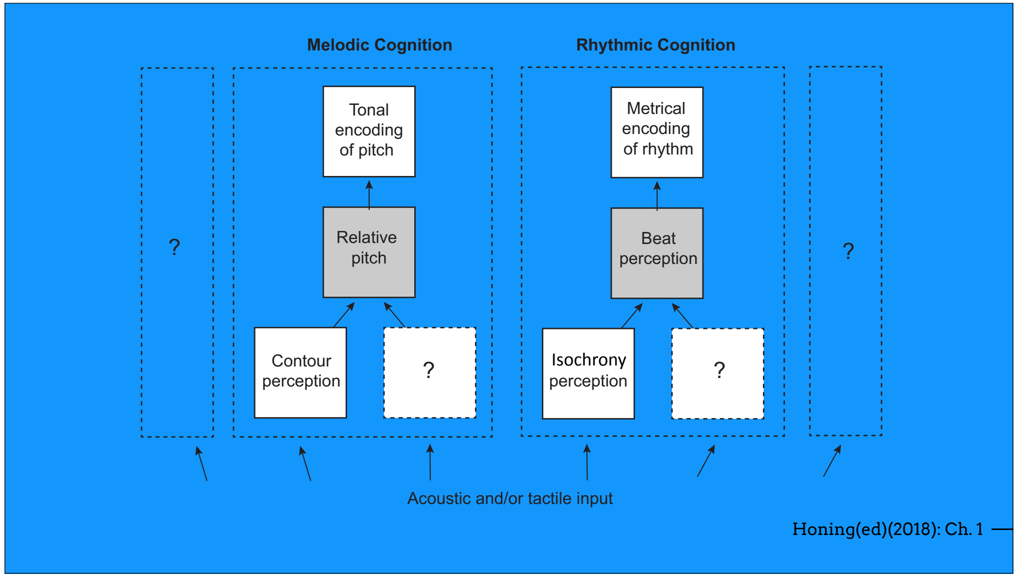

Melodic Cognition
Rhythmic Cognition
Tonal encoding of pitch
Relative pitch
Contour perception
?
Metrical encoding of rhythm
Beat perception
Isochrony perception
?
?
?
Acoustic and/or tactile input
Honing(ed)(2018): Ch. 1

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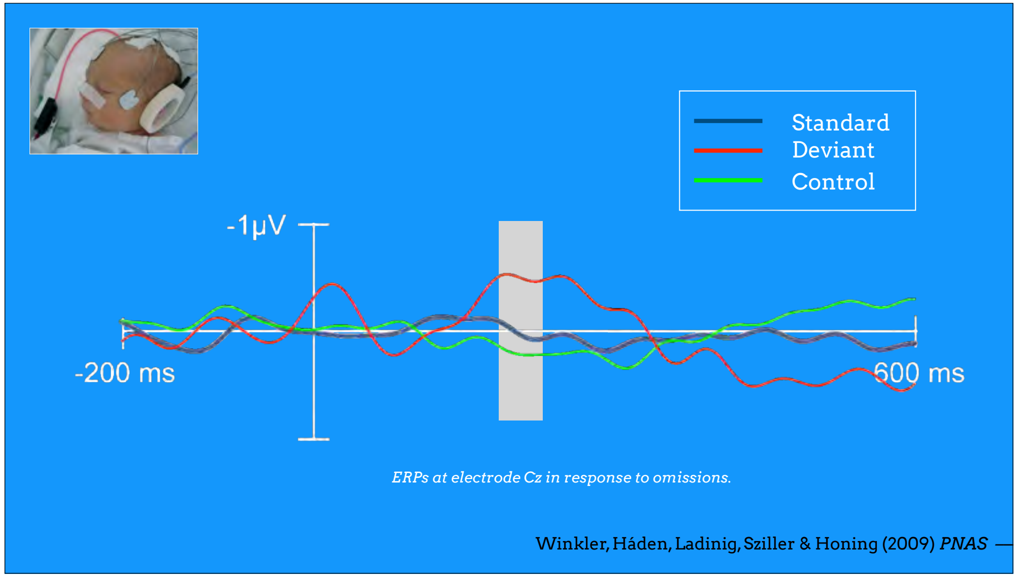

Standard
Deviant
Control
-1μV
-200 ms
600 ms
ERPs at electrode Cz in response to omissions.
Winkler, Háden, Ladinig, Sziller & Honing (2009) PNAS

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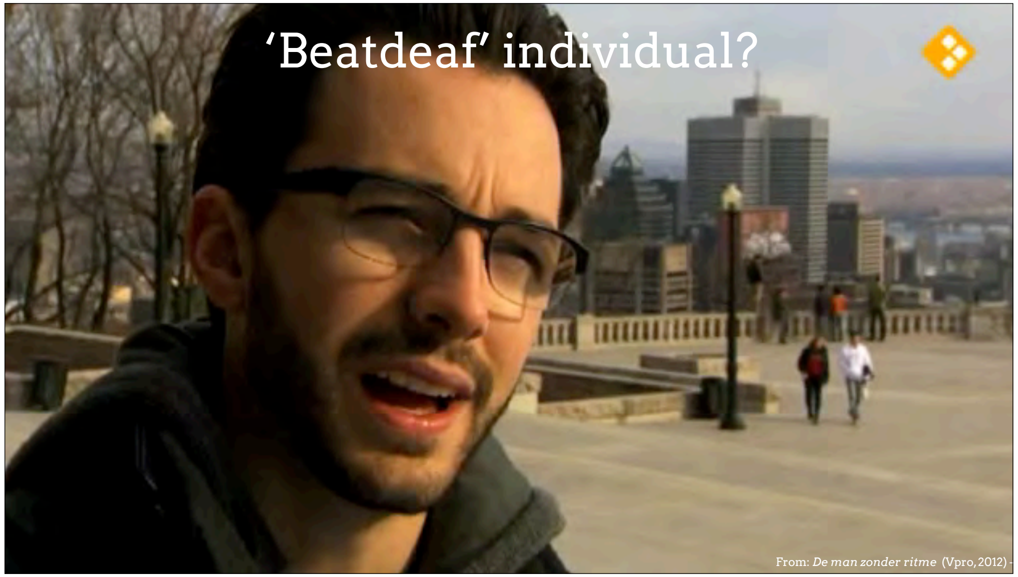

'Beatdeaf' individual?
From: De man zonder ritme (Vpro,2012)

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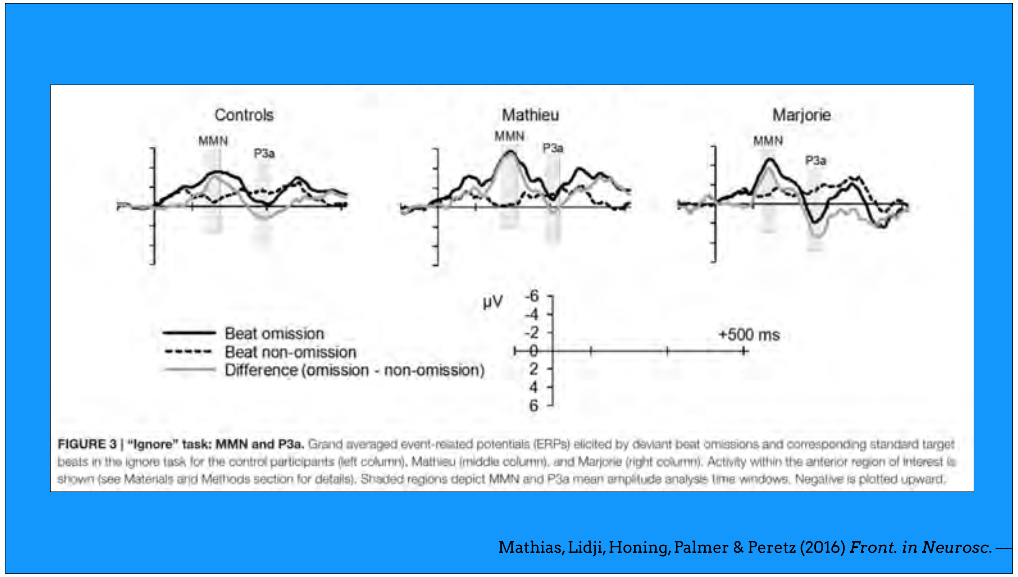

Controls
Mathieu
Marjorie
MMN
P3a
μV
-6
-4
-2
0
2
4
6
+500 ms
Beat omission
Beat non-omission
Difference (omission - non-omission)
FIGURE 3 | "Ignore" task: MMN and P3a. Grand averaged event-related potentials (ERPs) elicited by deviant beat omissions and corresponding standard target beats in the ignore task for the control participants (left column). Mathieu (middle column), and Marjorie (right column). Activity within the anterior region of interest is shown (see Materials and Methods section for details). Shaded regions depict MMN and P3a mean amplitude analysis time windows. Negative is plotted upward.
Mathias, Lidji, Honing, Palmer & Peretz (2016) Front. in Neurosc.

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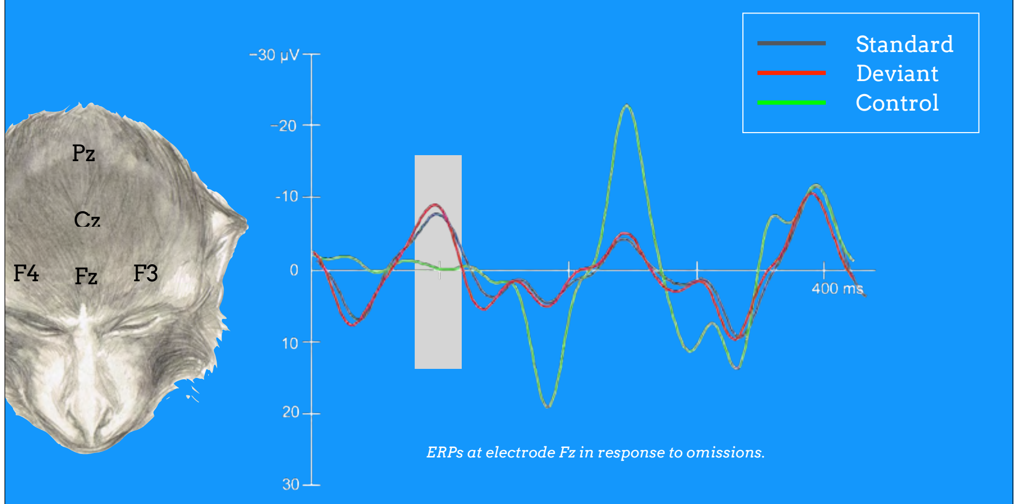

Honing *et al.* (2012) *PLOS ONE;* Honing *et al.* (2018) *Front Neurosc*

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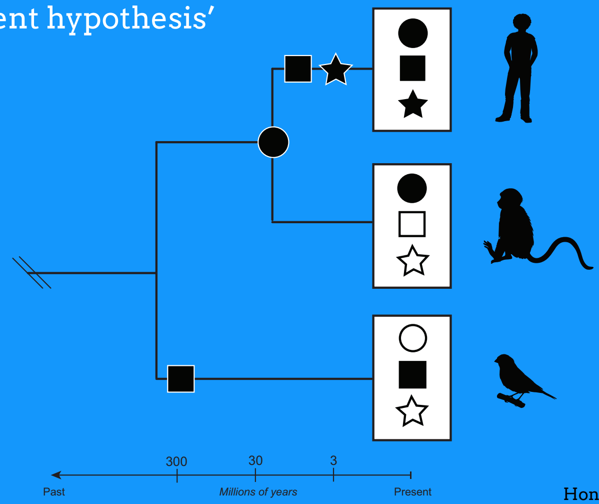
'Multicomponent hypothesis'



Honing (2018) *NYAS*

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Research questions

1. What is the most promising means of carving musicality into component skills?
2. What kinds of natural behavior in other species might be related to musicality?
3. How can we more clearly differentiate biological and cultural contributions to musicality?
4. What is the neuronal circuitry associated with different aspects of musicality?
5. How do the relevant genes contribute to building a musical brain (i.e., using functional studies to bridge the gap between genes, neurons, circuits, and behavior)?
6. Can we use such genes to trace the evolutionary history of our musical capacities in human ancestors and study parallels in nonhuman animals?
7. Can nonhuman animals detect higher-order patterns in sounds (e.g., auditory grouping), as humans do?
8. Is entrainment or beat induction restricted to species capable of vocal learning?
9. Can nonhuman animals generalize across timbres?
10. Do absolute and relative processing of pitch, duration, and timbre depend on context, stimuli, or species?
11. How can we study the evolution of musicality relative to language?

Honing(ed)(2018): Table P. 1

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Honing(ed)(2018): Table P. 1

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Summary

Despite criticisms (Lewontin, 1998; Bolhuis & Wynne, 2009) and numerous pitfalls (Fitch, 2010; Honing & Ploeger, 2012) in studying the evolution and/or biological basis of music/ality, one way to proceed is:

1. Distinguish between music and musicality;
   (Trehub, 2003, *Nature Neuroscience*; Honing *et al.*, 2015, *Phil. Trans. B*)
2. Identify the constituent components of musicality, their function, mechanism and development | Towards a phenomics of musicality;
   (e.g., Peretz, 2006, *Cognition*; Gingras *et al.*, 2015, *Phil Trans B*; Honing, 2018, *NYAS*)
3. Genetics/genomics as powerful method to investigate its biological basis;
   (e.g., Peretz *et al.*, 2007, *Am. Hum. Gen.*; Lense *et al.*, 2013, *Front. Psych.*; Järvelä, 2018, *NYAS*)
4. Will contribute to 1) an understanding of the biological basis of musicality and 2) the study of the evolution of musicality.