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The Neurosciences and Music Conferences. An overview 2011-2017.

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An overview of three conference proceedings:

The Neurosciences and Music Conference IV in Edinburgh 2011.
Learning and Memory.
Annals of the New York Academy of Sciences 2012, vol. 1252.

The Neurosciences and Music Conference V in Dijon 2014.
Cognitive Stimulation and Rehabilitation.
Annals of the New York Academy of Sciences 2015, vol. 1337.

The Neurosciences and Music Conference VI in Boston 2017.
Music, Sound and Health.
Annals of the New York Academy of Sciences 2018, vol. 1423.

For an overview of
The Neurosciences and Music Conferences in Venice 2002, Leipzig 2005 and Montreal 2008
see Christensen, E. (2012) *Music Listening, Music Therapy, Phenomenology and Neuroscience,* pp. 64-100 and 196-282. Available at https://www.mt-phd.aau.dk/phd-theses/

Abstract

The present text provides brief documentation of the 122 papers published in the three proceedings of **The Neurosciences and Music Conferences 2011, 2014 and 2017**.
The intention of this internet publication is to facilitate quick access to information about music-related neuroscience for interested students, educators and researchers.

Part one indicates the themes and objectives of the three conferences, prominent areas of investigation, and cultural references. Summaries highlight selections of papers from each conference.

Part two provides three schematic surveys of the papers in the conference proceedings.
The surveys report, for each paper: the aim of the study, its musical material, cultural references and categories of investigation, the applied technology and procedure, and the main focus and conclusion of the study.

Keywords:
neuroscience, music, culture, research methods, neural functions, cerebral networks, embodiment, emotion, entrainment, development, music education, music therapy, deficits, disorders, training, rehabilitation, recovery.

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Brief introduction

The present text provides an overview and a documentation of the 122 papers published in the proceedings of three Neurosciences and Music Conferences, NM IV (2011), NM V (2014) and NM VI (2017). The intention of this internet publication is to facilitate quick access to information about music-related neuroscience for interested students, educators and researchers.

The text serves as the continuation of a chapter in a previous publication, Christensen (2012) which has provided similar documentation of 193 papers published in the proceedings of the Conferences NM I (2002), NM II (2005) and NM III (2008).

The seventh Neurosciences and Music Conference, originally planned for 2020, was postponed due to the outbreak of the Covid-19 pandemic. The conference takes place in Aarhus, Denmark in June 2021.

Part one of the text outlines the characteristics of each conference, including prominent domains of investigation and cultural references, as well as summaries of selected papers.
Additional tables permit comparisons of data from all six conferences 2002-2017.

Part two of the text consists of schematic surveys which indicate the aim, procedure, technology and conclusion of each paper. It may be useful to search for specific keywords in the electronic document in order to retrieve particular topics of interest.

The overview of the conferences shows a progression from basic to applied research. In all of the conferences, the investigations of *deficits, disorders, therapy, and potential recovery* constitute prominent fields of applied research.

The **Conference NM IV** highlights relationships between music neuroscience and the related disciplines of *music therapy, music education, musical behavior and music performance.* A large number of papers on *culture, development and training* reflect the general conference theme, **Learning and Memory.** See pages 7-10.

In the **Conference NM V**, the general theme **Cognitive Stimulation and Rehabilitation** gives rise to a particular focus on *the plasticity of the brain* and the approaches for *recovering brain and motor functions after brain damage or disease.* Predominant groups of papers address *embodiment and emotion* and the neural and motor response to *musical beat and groove.* See pages 23-26.

In accordance with the general theme of the **Conference NM VI**, **Music, Sound, and Health,** the conference editors point out the importance of research on the beneficial effects of music for the individual, for social groups, and for health, such as *enjoyment, interaction and social bonding, mood regulation and possible healing.* Prominent research fields are *music interventions for deficits and disorders* and *the impact of musical training on language learning.*

In this conference, innovative research strategies are an important factor, including *critical discussions of previous research, focus on cerebral networks,* and *longitudinal studies of the effects of music-related activities.* See pages 39-42.

Cultural references of the 122 papers
are summarized in three tables displayed on pages 10, 25 and 41, and reported in the schematic surveys in Part two.

The predominant cultural reference is *Western major-minor tonality.* 75 out of 122 studies employ or report tonality in scales, melodies and harmonies, and pieces of classical, popular and traditional music. 35 papers do not indicate cultural references.

Eighteen papers deal with other types and genres of music:

A study of music-evoked emotions (NM V no. 28) includes pieces of *Western music of the* 20^{th} *Century* that do not conform to major-minor tonality. A study of musical sensitivity (NM IV no. 45) employs melodies composed in *a new, unfamiliar musical system.*

Two studies compare the brain activations of *jazz, classical, rock/pop and rap* performers (NM IV no. 17 and NM VI no. 14). A study of metrical expectation (NM IV no. 10) employs variants of *a rhythmic rock pattern.*

Two studies mention *music that is not related to a regular beat,* an Indian Raga introduction (NM IV no. 19) and a European piece from the Baroque era (NM VI no. 37).

Twelve papers investigate or report music from various music cultures, including *Latin American music, African and Arabic songs, Balkan dance music, Indian melodies and Chinese songs.* See pages 8, 24 and 39.

The studies listed above are comparatively few in number. It is suggested that the following fields of music deserve further neuroscientific investigation:

- Large domains of *traditional music* and *contemporary compositions* worldwide
- *Rock music and related genres*
- *Music that is not related to an underlying beat*, including Indian Raga introductions, Japanese Gagaku music, Chinese Guqin music, free vocal and instrumental improvisations, gesture-related music, and numerous works by composers of the 20^{th} and 21^{st} Centuries.
- *Percussion music* in contemporary compositions and traditional cultures.

Applied technologies

Concise descriptions of familiar and novel technologies reported in the conference papers are provided in the boxes below.

Familiar technologies

EEG: *Electroencephalography*. The recording of electrical activity in the brain.

MMN: *Mismatch Negativity*. A response measured by EEG, elicited when a deviant stimulus occurs in a sequence of repeated identical stimuli.

MEG: *Magnetoencephalography*. The recording of magnetic fields produced by electrical activity in the brain.

PET: *Positron Emission Tomography*. A scanning procedure that produces images of neural activity in the brain, based on measuring the regional cerebral blood flow. The procedure implies the injection of a slightly radioactive liquid.

fMRI: *functional Magnetic Resonance Imaging*. A scanning procedure that produces images of neural activity in the brain, based on measuring the contrast between oxygen-rich and oxygen-poor blood.

Novel and comparatively novel technologies:

NM IV, page 8
DTI: *Diffusion tensor imaging*. A technique based on magnetic resonance imaging used to create images of white matter connections in the brain.

NM V, page 24
TMS: *Transcranial magnetic stimulation*. A technique for noninvasive stimulation of the brain. A high-intensity magnetic field is employed to excite or inhibit a small brain area.

tDCS: *Transcranial direct current stimulation* and *tACS: Transcranial alternating current stimulation.* Noninvasive techniques that may result in modifications of perceptual, cognitive, and behavioral functions.

Interactive audio player: A computer-controlled system that uses wireless sensors to adapt music tempo or metronome beats to a person's walking pace.

fNIRS: *functional near-infrared spectroscopy.* A noninvasive portable technology that measures changes in oxygenated and deoxygenated hemoglobin in the cortical surface related to cerebral activity.

NM VI, page 39
VBM: *Voxel-based morphometry*. A computational method for measuring tissue differences throughout the entire brain, based on comparisons of multiple brain images.

EEG hyperscanning: The simultaneous recording of electrical activity in two or several brains.

Genetics: The study of genes, genetic variation, and heredity.
Genomics: The study of the structure, function, and mapping of all genetic material of an organism.

Machine learning involves a computer that builds a model based on the input of relevant training data. This model enables the computer to carry out particular tasks, such as categorization or pattern recognition.

References

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The Neurosciences and Music IV: Learning and Memory.
Conference 2011 in Edinburgh. (NM IV)

Conference proceedings:
***Annals of the New York Academy of Sciences* 2012, vol. 1252**
edited by Katie Overy, Isabelle Peretz, Robert J. Zatorre, Luisa Lopez, and Maria Majno.

Conference themes

Workshops:	**1. Experimental methods.**
	2. Social / real world methods.
Symposia:	**1. Mechanisms of rhythm and meter learning over the life span.**
	2. Impact of musical experience on cerebral language processing.
	3. The cultural neuroscience of music.
	4. Memory and learning in music performance.
	5. Mind and brain in musical imagery.
	6. Brain plasticity and malplasticity in health and disease.
	7. The role of music in stroke rehabilitation: Neural mechanisms and therapeutic techniques.
	8. Music: A unique window into the world of autism.
	9. Learning and memory in musical disorders.

In the introduction to the proceedings, the editors state that music neuroscience is expanding, driven by advanced brain imaging technology and increasing scientific and public interest. In particular, music neuroscience research can inform, and be informed by, the disciplines of music therapy, music education, musical behavior and music performance. The 2011 conference has benefited from interaction with these related research areas. In addition, the editors emphasize that the papers in the conference proceedings represent only a small fraction of ongoing research internationally.

A survey of the 47 papers published in the NM IV proceedings: *Annals of the New York Academy of Sciences* 2012, vol. 1252, is provided in Part two.
The survey indicates the aim of each study, its musical material, cultural references and categories of investigation, the applied technology and procedure, and the main focus and conclusion of the study. For easy identification, the papers are numbered 1-47.

A comparatively novel technology is reported in the NM IV: *Diffusion tensor imaging (DTI)* (nos. 31 and 42).

A specification of the **categories of investigation** applied in the papers is displayed on page 9. For further documentation, see the survey in Part two.

Culture, development and training were the predominant themes in the conference, encompassing 29 out of 47 of papers.

Deficits, disorders, therapy and recovery are the themes in another predominant group of papers. Various studies investigate how music can be used in treatments of aphasia (nos. 31 and 39), tinnitus (no. 33), stroke (nos. 35, 36, 37 and 38), autism (nos. 40 and 41) and amusia (nos. 43, 44, 45 and 46).

Papers on *social/real world methods* focus on education through music (nos. 5 and 6), musical experiences and social interaction in everyday situations (no. 7), and music as a therapeutic resource for children in zones of conflict (no. 8).

Music processing in infancy is discussed in a group of papers (nos. 1, 2, 3 and 4). Several papers report investigations of *the effects of musical expertise*, including effects on auditory working memory (no. 12) and phonetic processing (nos. 13 and 14), and the import of practiced musical style (no. 17) and early musical training (no. 21).

A specification of the **cultural references** in the papers is displayed on page 10. For further documentation, see the survey in Part two.

The predominant cultural reference is *Western major-minor tonality*, employed in 30 out of the 47 papers. Five papers specify classical pieces, including music by *Bach, Haydn, Mozart, Beethoven, Tchaikovsky* and *Saint-Saëns*, and three papers indicate popular songs such as *White Christmas, Brother John* and *Jingle Bells.* In the remaining papers, the applied music is not specified.

One study (no. 17) compares the auditory skills of classical, jazz, and rock/pop musicians.

One study (no. 10) employs variants of a rhythmic rock pattern to investigate beat and meter induction.

Non-western music is a cultural reference in five studies, including Latin American music for symphony orchestra (no. 6), African and Arabic songs and dances (no. 8), and non-isochronous Balkan dance music (no. 11). Two studies (nos. 19 and 20) compare participants' responses to Western and Indian melodies; no. 19 includes improvised raga melodies in the investigation.

Melodies composed in *a new, unfamiliar musical system*, different from major-minor tonality, are employed in a study of acquired musical sensitivity (no. 45).

Categories of investigation NM IV 2011

The Neurosciences and Music IV – Conference 2011: Learning and Memory

Experimental Methods 1-4	Social / Real World Methods 5-8	Rhythm and Meter Learning 9-11
Music and Language 12-15	Cultural Neuroscience 16-20	Memory, Learning, Performance 21-25
Musical Imagery 26-29	Plasticity and Malplasticity 30-34	Stroke Rehabilitation 35-39
Autism 40-42	Learning, Memory, Disorders 43-46	Neurodynamics 47

Categories of investigation	Number of papers	Papers no. (a paper may indicate several categories)
A1. Neural correlates of sound		
1. Pitch, melody, scales, intervals	**4**	19 28 40 47
2. Harmony, consonance / dissonance	**1**	18
3. Complex sounds: acoustic instruments, timbre	**0**	
Complex sounds: noise, environmental sounds	**1**	40
4. Timing, tempo, rhythm, meter, beat, groove	**3**	9 10 11
A2. Neural correlates of vocal sound		
5. Song	**1**	31
6. Phonetic sounds, language, speech, infant sounds	**5**	12 13 14 15 31
B. Culture, development, training		
7. Cultural influence, cultural differences	**9**	5 6 7 11 16 17 18 19 20
8. Musicians, non-musicians, different musicians	**10**	8 12 13 14 17 18 21 24 25 30
9. Child development	**5**	1 2 3 4 21
10. Training effect, learning	**13**	5 6 10 13 15 16 21 22 23 32 44 45 46
C. Deficits, disorders, therapy, recovery		
11. Deficits, disorders	**17**	8 25 31 33 34 35 36 37 38 39 40 41 42 43 44 45 46
12. Therapy, recovery, rehabilitation	**8**	8 31 33 35 36 37 38 39
D. Cognition, attention, memory		
13. Cognition, attention, expectation, prediction, recognition	**5**	12 26 27 28 29
14. Memory, auditory imagery	**6**	24 26 27 28 30 43
15. Musical form and structure	**0**	
E. Embodiment, motion, entrainment, emotion		
16. Audiovisual integration	**1**	23
17. Sensorimotor processing, entrainment, synchronization	**11**	7 9 22 24 25 27 31 32 34 42 43
18. Bodily impact	**0**	
19. Emotion, feeling, mood, motivation, preference	**0**	
20. Musical expression	**1**	16
21. Improvisation	**1**	19

Cultural references NM IV 2011

The Neurosciences and Music IV – Conference 2011: Learning and Memory

Experimental methods 1-4
Social / real world methods 5-8
Rhythm and meter 9-11
Language processing 12-15
Cultural neuroscience 16-20
Music performance 21-25
Musical imagery 26-29
Plasticity and malplasticity 30-34
Stroke rehabilitation 35-39
Window into autism 40-42
Musical disorders 43-46
Neurodynamics 47

Cultural references **Papers no. (a paper may indicate several cultural references)**

Neutral or not indicated: **14** 1 2 4 9 12 13 14 15 21 23 30 31 34 42

Western major-minor: **24** 2 3 5 16 17 18 22 24 25 26 27 28 32 33 35 36 37 39 40 41 43 44 46 47

Specified music:
6: Saint-Saëns: *The Carnival of the Animals*
16: Thomas Attwood: (1765-1838): *Sonatina.* Chopin: *Waltz op. 69 no. 1*
24: Novel pieces in 4/4 meter, conforming to the conventions of Western polyphonic music
25: J.S.Bach: *The Well-tempered Clavier Part 1, Preludes V, VI and IX.* Haydn: *Piano Sonata no. 52 in Eb major*
26: First minute of Beethoven: *5th Symphony.* Tchaikovsky: *Waltz of the Flowers.*
Mozart: *Allegro from Eine kleine Nachtmusik*
32. Mozart: *Sonata facile*
33: Self-chosen, enjoyable music
36: Pleasant music selected by the patient

Western popular: **9** 7 10 17 29 33 35 38 40 43

Specified music:
10: Variants of a rhythmic rock pattern.
29: *"White Christmas"* and *Theme from "Pink Panther"*
33: Self-chosen, enjoyable music
35: Pleasant music selected by the patient
38: Participant-selected music
43: *"Gens du pays"* (Canada), *"Brother John", "Jingle Bells", "Sto lat"* (Poland)

Western traditional: **2** 19 29
19: European folk song excerpts
29: *Greensleeves*

Western non-tonal: **2** 16 45
16: Atonal version of Thomas Atwood: *Sonatina*
45: Electronic melodies, based on a new musical system, which uses a 3:1 ratio instead of the 2:1 octave

Cross-cultural: **5** 6 8 11 19 20

6: Western and Latin American music for symphony orchestra and choruses
8: North Ugandan dances. A West African folk song. An old Arab song *"Zeyn al Abidin".* Novel songs in Thai scales
11: Non-isochronous Balkan dance music
19: European folk song excerpts. Melodic improvised introductions to North Indian ragas
20: Western: Excerpts of J. Stamitz and G.B. Sammartini. Indian: Excerpts of N. Banerjee and U.R. Shkan

Animal sounds: **0**
Environmental sounds: **1** 40

A selection of papers in NM IV 2011

This paragraph summarizes some noteworthy papers from the 2011 conference. To facilitate an overview, the categories of investigation are grouped as follows:

Neuroanatomy and neural functions
Culture, development and training
Deficits, disorders, therapy and recovery

Neuroanatomy and neural functions

Neuroplasticity of the Planum Temporale

Martin Meyer, Stefan Elmer and Lutz Jäncke (NM IV no. 14, pp. 116-123) have investigated the relationship between musical expertise and structural as well as functional changes in the planum temporale (PT) which is an auditory-related association cortex that receives signals from the primary and secondary auditory cortices (core and belt areas).

Current research has indicated that the PT is involved in auditory, audio-visual, purely visual, sensorimotor and linguistic functions. As proposed in a seminal paper by Griffiths and Warren (2002), the PT can be considered a "computational hub" concerned with analysis of sounds that are spectrally and temporally complex, such as speech, music and environmental sounds. According to this model, the computation of incoming auditory patterns in the PT directs further processing in other brain regions, including distinct cortical mechanisms for sound-object identification and localization.

Referring to fMRI studies of their group (Jäncke et al. 2002; Meyer et al. 2005), the authors state that the processing of acoustic signals including speech, laughter, music and environmental sounds is mediated by both the left PT and the right PT. According to the model "Asymmetric sampling in time" developed by Poeppel (2003), any acoustic signal is processed simultaneously via two temporal resolution frames. Left auditory areas preferentially extract information from short temporal windows, approximately 20-40 msec, and right auditory areas preferentially extract information from longer temporal windows, approximately 150-250 msec (Poeppel 2003, p. 245).This implies that in speech, the left PT preferentially processes rapidly changing phonetic features, in particular combinations of consonants and vowels, and the right PT preferentially processes the slower changes of speech prosody and speech rhythm in words and sentences. Similarly, in music, it is suggested that the left PT preferentially processes fine-grained rapidly changing acoustic information, and the right PT preferentially processes the slower changes of melodic contour and phrasing.

Further studies by the authors' group have investigated the responses of musicians and non-musicians who were presented with rapidly changing speech and non-speech stimuli. Results of fMRI scanning indicated that the left PT acts as a primary processor of transient acoustic features. The musicians were significantly better than the non-musicians at decoding these features, suggesting that learning-induced neuroplasticity in musicians improves musical as well as phonetic hearing skills. The authors have published detailed reports of their studies (Elmer et al. 2012, 2013).

Mental imagery in music performance

Peter Keller (NM IV no. 27, pp. 206-213) examines the role of mental imagery in music performance, motivated by self-reports by musicians that covert auditory, motor, and/or visual imagery can facilitate multiple aspects of music performance.

Musical imagery is assumed to be a multimodal process by which an individual generates the mental experience of auditory features of musical sounds and the visual, proprioceptive, kinesthetic, and tactile properties of music-related movements. Musical imagery involves the interplay of brain regions implicated in auditory and motor processing, and general brain functions subserving attention, memory and the prediction of future events (p. 207).

For a solo performer, it is important to imagine the ideal sound before playing or singing it, and to simulate the bodily action that will produce the desired sound. During the music performance, action simulation entails running internal mental models that trigger auditory and motor images of one's upcoming actions. In musical ensemble playing, anticipatory auditory imagery enables performers to predict each others' actions (p. 209).

The author concludes that the deliberate use of anticipatory imagery during performance may benefit the musician's control of timing, intensity, articulation, and intonation, and contribute to optimal ensemble coordination (p. 211).

Working with musical thoughts

Robert Zatorre (NM IV no. 29, pp. 222-228) reports studies of mental manipulation of melodies that elicits neural activity in the Interparietal Sulcus (IPS). The IPS is the main sulcus on the lateral surface of the posterior parietal cortex. It is known to be involved in sensorimotor organization, visuospatial and attentional processing and tasks requiring manipulation of items in working memory.

Zatorre points out that two processing pathways originate in the auditory cortex. One is more ventrally directed, leading along the temporal gyri to the inferior frontal cortex, known to deal with identification of sounds and their meaning. Another pathway is known to deal with sound localization and sensorimotor integration and control in general. It is more dorsally directed, leading through parietal and premotor areas to the dorsolateral frontal cortex. Evidence from other domains indicates that the dorsal stream, especially regions within the posterior parietal cortex, is implicated in tasks requiring manipulation of information (p. 223).

Previous studies of musical imagery, such as evoking familiar melodies in the mind or comparing perceived and imagined timbres, have documented the contribution of auditory cortex to musical imagery (Zatorre et al. 1996; Halpern et al. 1999, 2004). Further studies by Zatorre and colleagues investigate the recruitment of additional neural resources for musical tasks that involve an active manipulation component. In one study, the participants were asked to compare a short melody, e.g. the beginning of "Greensleeves" with a true or an incorrect reversal of the melody. fMRI scanning showed that this mental reversal task activated the IPS, the frontal cortex, and the anterior cingulate cortex. In a second study, the participants were asked to compare a novel, unfamiliar melody with a correct or an incorrect transposition of the melody. The study showed strong activation within the IPS during the transposition condition, compared to the non-transposition condition. A replication combining the reversal and transposition tasks in tests of the same individuals confirmed that each task yielded strong activation of the IPS.

The researchers conclude that interactions between auditory cortical areas and the dorsal processing auditory pathway, including the IPS, are critical for the ability to actively manipulate musical imagery, work with musical thoughts and create novel musical structures (Zatorre et al. 2010; Foster and Zatorre 2010).

Practiced musical style shapes auditory skills

Peter Vuust and colleagues (NM IV no. 17, pp. 139-146) have studied the neural responses to musical features in different groups of musicians and non-musicians by means of EEG. They have developed a new paradigm for measuring the mismatch negativity (MMN) response to six different types of musical change; pitch, timbre, location, intensity, rhythm, and pitch slide. The MMN response is pre-attentive, automatically elicited in the absence of the subjects' attention towards the stimuli.

The paradigm consists of four-tone "Alberti bass" patterns, a four-tone broken chord accompaniment used in classical keyboard music, played with piano sounds, alternating between standard sequences and deviant sequences. In the deviant sequences, the third tone is changed. This permits comparison between the event-related potential (ERP) responses to the third tone of the standard sequence and the third tone of the deviant sequence. One example of the paradigm is the following:

standard / rhythm deviant / standard / location deviant / standard / pitch deviant /
standard / timbre deviant / standard / pitch slide deviant / standard / intensity deviant

The new paradigm is more musically interesting than traditional one-tone paradigms, and it permits recording of MMN responses to six different musical deviants within a comparatively short time. The authors point out that they have observed no differences in recorded responses using the new paradigm, compared to the traditional oddball paradigm, which only applies one type of deviant.

11 non-musicians, 7 classical musicians, 10 jazz musicians, and 14 rock musicians participated in the experiment. Their MMN responses were recorded by EEG while they listened to 20-minute blocks of randomized sequences, watching a silent movie. After the EEG recording, the musical skills of the participants were tested by means of a standardized test procedure, the Advanced Measure of Musical Audiation (AMMA).

The MMN findings showed that jazz musicians had larger MMN amplitude than the other groups across the six different sound features. This indicates a greater sensitivity to sound changes in jazz musicians compared to other types of musicians. In particular, the results showed enhanced processing of pitch and pitch slide in jazz musicians. In the AMMA tests, jazz musicians and classical musicians scored higher than rock musicians and non-musicians. The authors suggest that the development of musicians' brains is influenced by the type of training, musical genre, and listening experiences (Vuust et al. 2011, 2012).

Culture, development and training

Behavioral methods in infancy

Sandra Trehub (NM IV no. 3, pp. 37-42) outlines and discusses methods used to study music processing in infants, in particular the head-turn preference procedure. According to his procedure, the infant sits on its parent's lap facing two loudspeakers, one located to their left, the other to their right. A flashing light attracts the child's attention to one loudspeaker, where a musical pattern is played until the child looks away. Subsequently, the child's attention is attracted to the other loudspeaker, and a contrasting musical pattern is played. This procedure has served to investigate preferences for high-pitched or low-pitched lullabies and play songs, consonant versus dissonant music, familiar and novel musical patterns. Researchers commonly interpret longer listening times as a preference for the musical pattern in question. However, Trehub points out that other factors than preference may attract infant attention, in particular the onset of a novel and salient stimulus which leads to heightened stimulus processing. She concludes that reliance on looking measures alone results in incomplete or misleading information about music processing in infancy, and recommends the use of several convergent types of measurement in order to verify interpretations.

Moreover, Trehub questions the use of artificial stimuli, such as sinus tones and inexpressive synthesized tones, suggesting that greater use of ecologically valid stimuli such as infant-directed singing is likely to increase the generality of the findings.

Laurel Trainor (NM IV no. 2, pp. 25-36) exemplifies EEG and MEG methods for studying musical development in children, taking into consideration plasticity, maturation and musical experience. She provides an informative general introduction to EEG and MEG, and discusses advantages and limitations of different approaches, including the elimination of artifacts in experimental data, machine-learning approaches, and voxel-based waveform analysis. Trainor concludes that EEG and MEG data can contribute substantially to the understanding of musical development and the effects of musical training, and suggests that new data analysis techniques offer great promise for future studies.

Learning unfamiliar rhythms

Erin Hannon and colleagues (NM IV no. 11, pp. 92-99) have examined how passive exposure to music from a foreign culture influences perception of rhythm and meter at different ages. Five groups of American participants, approximately 5, 7, 9, 11, and 18+ years participated in two similarity judgment tests. The participants listened to Western-type isochronous and foreign-type non-isochronous meters in unaltered and altered versions. They first heard a familiarization stimulus for 2 minutes, followed by four test renditions of the same song: unaltered, structure-preserving, structure-disrupting, and severely structure-disrupting. The participants rated how similar each test stimulus was to the original stimulus. After the first test, the participants listened at home to CD recordings of non-isochronous dance music from Macedonia, Bulgaria and Bosnia for two weeks. Subsequently, they performed the same test.

Results showed that after exposure to the CD recordings, performance in the non-isochronous condition improved significantly among the 5-year old children, but not among the other groups of children and adults. The authors conclude that greater susceptibility to perceptual experience, previously documented among 12-month-old infants by Hannon & Trehub (2005), appears to extend to the first five years of childhood. Further research, comparing American and Turkish listeners, confirms the crucial role of culture-specific listening experience and acquired musical knowledge in rhythmic pattern perception (Hannon et al. 2012).

Deficits, disorders, therapy and recovery

A music training strategy for alleviating tinnitus

Christo Pantev et al. (NM IV no. 33, pp. 253-258) describe the development of a music training strategy that reduces cortical tinnitus-related neuronal activity and alleviates subjective tinnitus perception. During the training, tinnitus patients listen daily to self-chosen, enjoyable music that is filtered to contain no energy in a frequency area of one octave surrounding the individual tinnitus frequency. It is the basic assumption behind the treatment that tinnitus is the result of maladaptive plasticity in the central auditory pathway, and that this maladaptation can be reversed.

In an experiment designed to test the treatment, thirty-three tinnitus patients were assigned to three groups: 1) a target group hearing music with tinnitus-related filtering, 2) a placebo group of persons hearing music with filtering not related to their tinnitus, and 3) a monitoring group hearing unfiltered music. The test persons listened to music daily for one or two hours via closed headphones over the course of one year.

Measurements by means of magnetoencephalography (MEG) after 6 and 12 months of listening permitted the evaluation of auditory-evoked brain waves from the primary and secondary auditory cortex, reflecting the tinnitus perception. In addition, the persons' subjective tinnitus experience was assessed by means of a standard tinnitus questionnaire. The results showed significant reductions of tinnitus loudness and tinnitus-related cortical activity in the target group, but no reductions in the placebo group and the monitoring group.

The authors suggest that prolonged exposure to tinnitus-related modified music activates inhibition of the hyperactive neurons in the auditory cortex areas, thus reversing the annoying maladaptation. Furthermore, they underline that the release of dopamine initiated by enjoyable music promotes cortical plasticity.

Music: a unique window into the world of autism

Istvan Molnar-Szakacs and Pamela Heaton (NM IV no. 40, pp. 318-324) review studies of individuals with autism spectrum disorders (ASD), characterized by deficits in communication and understanding of emotions, impairments in social interactions, and restricted and repetitive patterns of behavior.

Earlier studies by Heaton et al. (1999, 2008) suggest that ASD children are able to recognize emotions in music, even if they display difficulties in recognizing emotions in voices and faces. In continuation, the authors have conducted two observational pilot studies. The first study tested patterns of attention in ASD children and typically developing (TD) children, comparing responses to 1) short sentences, 2) environmental noises such as a door opening and closing, and 3) short excerpts of classical music. The ASD children showed statistically significant increase in their response to music, compared to speech and environmental sound.

In the second study, ASD and TD children were asked to identify happy, sad and fearful emotions in 1) musical excerpts, 2) nonverbal affective vocalizations, and 3) three-digit numbers (e.g. 758) spoken with affective intonation. The results did not indicate any emotion recognition deficits in the ASD children.

In a further study, high-functioning ASD children and matched TD controls listened to happy, sad and peaceful music, while their brain activity was recorded using fMRI. Preliminary results show that in both groups, listening to emotional music activated auditory cortex areas and a network including areas of the putative human mirror neuron system (MNS), as well as structures implicated in the processing of emotion. Button-press responses during the study indicated that ASD children identified the emotional music excerpts as well as the TD children.

In this study and related studies, the authors find support for the Shared Affective Motion Experience (SAME) model of emotional music perception (Overy & Molnar-Szakacs 2009, Molnar-Szakacs et al. 2011). According to the SAME model, music perception relies not only on the acoustic signal, but also on the expressive motor acts behind the signal. At the neural level, it is suggested that a network including the anterior insula, the MNS and limbic areas allows the evaluation of incoming information in relation to the perceiving person's autonomic and emotional state.

The authors conclude that even if ASD individuals display impaired emotion recognition in other domains, their understanding and appreciation of musical emotions is intact (p. 322)

Impaired learning of event frequencies in tone deafness

Psyche Loui and Gottfried Schlaug (NM IV no. 45, pp. 354-360) have investigated whether difficulties in pitch and melody discrimination among tone-deaf individuals could be related to learning difficulties. In order to create an experiment that is not confounded by the test persons' previous exposure to Western musical sounds, they employ a new system of pitches with frequencies and probabilities that are different from Western music, the Bohlen-Pierce scale. This scale is based on the 3:1 frequency ratio (a ”tritave” instead of the 2:1 octave). The tritave is divided into 13 logarithmically even divisions, different from the 12 logarithmically even divisions of the equal-tempered Western scale.

In the experiment, eight tone-deaf (TD) individuals were compared with eight matched non-tone-deaf (NTD) individuals. All auditory stimuli were melodies consisting of eight tones in the new system of pitches. The experiment was conducted in three phases: 1) Pre-test: listening to 13 melodies, each followed by a probe tone. The test persons were asked to rate how well the probe tone fit the preceding melody. 2) Exposure: within half an hour, the test persons listened to 400 melodies in the new system. 3) Post-test: similar to the pre-test.

Comparisons of the two groups showed that NTD individuals improved their ratings in the post-test after exposure, whereas the TD individuals showed no such improvement. The results suggest that the NTD persons were able to learn the frequency structure of the new system after half an hour of exposure, but the TD persons did not display this ability. The authors conclude that insensitivity to musical pitch in tone-deaf persons may arise from learning difficulties, specifically in the learning of frequency information (p. 358).

In accordance with this study, Isabelle Peretz and colleagues (NM IV no. 46, pp. 361-367) report results of experiments which show that persons with congenital amusia can learn novel words as easily as controls, whereas they systematically fail on musical materials.

Music as a therapeutic resource for children in zones of conflict

As a contribution to the conference workshop on ”real world” methods, Nigel Osborne (NM IV no. 8, pp. 69-76) presented examples of music as a therapeutic resource for children in zones of conflict and reflections on the relationship between neuroscience and the practice of music therapy.

Numerous children in conflict and post-conflict societies have been witnesses to murder, rape, abduction, ethnic cleansing and the recruitment of child militias and prostitutes. These kinds of violent experience can induce posttraumatic stress disorder (PTSD) in the children leading to symptoms such as increased heart rate and blood pressure, cardiac arrhythmias, irregularities in breathing and dysregulation of movement and systems dealing with stress and relaxation.

The paper records three anecdotes of work in the field:

1) The Ayoma camp in North Uganda 2007, housing children after a civil war. The author and local musicians play Ugandan dances, inducing the children to laugh, smile and dance, using their voices, breathing well and moving fluently, being energized as well as relaxed.

2) In the Palestinian West Bank 2007, singing and creating Arab songs with children, and running training workshops for social workers with ”angry” instruments (djembes, bongos, cowbells) and ”gentle” sounds (metal chimes, shakers, crotales) which can be used in emotional musical games with extremes of aggressive and caressing sounds.

3) The village Klong Loi in Thailand in 2010, housing a displaced minority. Creating songs with teenagers in traditional Thai scales, based on words that express their situation and feelings, offer a collective musical experience and an opportunity to build self-respect and a sense of identity. Nigel Osborne states that music has proven to be an agent of change in many areas of psychosocial and social interventions, based on the co-occurrence of motor, emotional, and social responses to music.

As promising models and fields of research for ”real world” methods, he points to the theory of communicative musicality (Malloch and Trevarthen 2009) and the emerging neuroscience of intersubjectivity (Redcay et al. 2010; Guionnet et al. 2012). For a review of two-brain studies on social interaction, see Konvalinka and Roepstorff (2012). For a comprehensive overview of psychobiological methodologies aiming at using music to help regulate motor activity, the autonomic nervous system, and endocrine and respiratory systems, see Osborne (2009).

Beneficial effects of music listening after stroke

Teppo Särkämö and David Soto (NM IV no. 35, pp. 266-281) summarize investigations of the neural basis of music listening and report two studies on the effect of music listening after stroke.

Study one investigates the potential use of pleasant music to aid recovery of visual neglect. Visual neglect is characterized by impaired awareness of the visual field contralateral to the site of the brain lesion. No effective treatment has been established. Three patients participated in behavioral studies, comparing the effects of music listening on a computerized visual task, listening to 1) pleasant music selected by the patient, 2) unpreferred music selected by the experimenter, and 3) a silence condition. The results showed that listening to self-selected pleasant music significantly reduced the degree of visual neglect.

An fMRI scanning of one of the patients while performing a visual task showed enhanced activity in the orbitofrontal cortex and the cingulate gyrus associated with emotional responses, when tasks were performed with preferred music compared to unpreferred music. The findings suggest that positive affect, generated by preferred music, can decrease visual neglect by increasing attentional resources (Soto et al. 2009).

Study two reports investigations of the rehabilitative effects of music listening on the recovering brain (Särkämö et al. 2008; Forsblom et al. 2010, Särkämö 2011). In order to determine whether everyday music listening can facilitate the recovery of cognitive functions and mood after stroke, they designed a randomized controlled trial. 60 patients with a middle cerebral artery stroke were randomly assigned to a music group, a language group, or a control group.

A clinical neuropsychological assessment was performed three times on all patients, one week after stroke onset, and three months and six months post-stroke. An extensive battery of tests and questionnaires was used to assess verbal memory, short-term and working memory, language, visuospatial cognition, music cognition, executive functions, focused attention, and sustained attention.

All patients received standard treatment for stroke in terms of medical care and rehabilitation. For two months, the music group listened daily to self-selected music, while the language group listened daily to audio books. Of the music selections, 62 % were pop, rock or rhythm and blues, 10 % jazz, 8 % folk music, and 20 % classical or spiritual music. Results showed that patients who listened to their favorite music 1-2 hours a day showed greater improvement in focused attention and verbal memory than patients who listened to audio books or received no listening material. Moreover, the music group also experienced less depressed mood.

Music therapists interviewed all patients before and after the two-month-intervention. Analysis of the interviews showed that music listening was specifically associated with enhanced relaxation, increased motor activity, and improved mood. The authors suggest that everyday music listening during early stroke recovery offers a valuable addition to patient care.

Preliminary results of auditory MEG and structural MRI investigations seem to indicate that daily music listening after stroke may also induce neuroplastic changes in the brain, especially in brain areas implicated in the processing of emotion, musical structure, and musical memory (p. 274).

Finally, Särkämö and Soto discuss four potential neurobiological mechanisms underlying the therapeutic effect of music listening after stroke:

1) Improved mood and arousal through modulation of the pleasure and reward system of the brain, the dopaminergic mesolimbic system.

2) Alleviation of anxiety, depression and psychological stress experienced by the patients, related to reduced cortisol levels.

3) Positive effects on cognition and memory, possibly due to enhanced neurotransmission mediated by glutamate, the primary excitatory neurotransmitter in the cortex which plays an essential role in learning and memory.

4) Increased neural plasticity evoked by environmental enrichment, enhancing the genesis and growth of new neurons and stimulating the areas surrounding the brain lesion. However, the authors emphasize that no direct experimental evidence yet supports these hypothesized mechanisms (pp. 274-275).

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The Neurosciences and Music IV
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The Neurosciences and Music V: Cognitive Stimulation and Rehabilitation. Conference 2014 in Dijon. (NM V)

Conference proceedings:
***Annals of the New York Academy of Sciences* 2015, vol. 1337**
edited by Emmanuel Bigand, Barbara Tillmann, Isabelle Peretz, Robert J. Zatorre, Luisa Lopez, and Maria Majno.

Conference themes

1. **Musical rhythm and language development: basic research and implications for rhythm-based interventions.**
2. **Temporal expectations in a developmental perspective.**
3. **The beat: a structured environment for movement, communication, and socialization.**
4. **Moving on the beat of music: bridging training, rehabilitation strategies, and technology.**
5. **Individual differences in movement coordination: effects of training, aptitude, and neurological disorders.**
6. **Dance and the brain: a new window into the study of brain plasticity.**
7. **Musical expertise and more?**
8. **The role of music in promoting infants' well-being: clinical and research perspectives.**
9. **Music and emotion: implications for therapy and rehabilitation.**
10. **Music cognition in dementia.**
11. **Musical applications: workshops.**

In the introduction to the proceedings, Emmanuel Bigand and Barbara Tillmann, initiators of the conference in Dijon, present the conference theme, *Cognitive stimulation and rehabilitation:*

> The concept of cognitive stimulation builds upon an important corpus of research that demonstrates that the human brain manifests neural plasticity throughout life and that neural plasticity still occurs in individuals affected by for example, mild cognitive impairment, Alzheimer's disease, or stroke. (…)
>
> In neurological patients, cognitive stimulation provides nonpharmacological approaches for recovering brain and motor functions after brain damage, disease, or delayed mental development. It opens new perspectives for therapeutic interventions designed to improve the well-being of patients suffering from various diseases (p. VII).

Furthermore, Bigand and Tillmann indicate the progression of the research domains of the Neurosciences and Music conferences (p. VIII):

The first conferences were mainly focused on fundamental research:

New York 2000: The biological foundations of music
NM I, Venice 2002: Cerebral organization of music-related functions[1]
NM II, Leipzig 2005: From perception to performance

The following conferences showed the progression from basic to applied research, bringing together laboratory and clinical work:

NM III, Montreal 2008: Disorders and plasticity
NM IV, Edinburgh 2011: Learning, memory, music rehabilitation and therapy
NM V, Dijon 2014: Cognitive stimulation and rehabilitation

A survey of the 34 papers published in the NM V proceedings: *Annals of the New York Academy of Sciences* 2015, vol. 1337, is provided in Part two. The survey indicates the aim of each study, its musical material, cultural references and categories of investigation, the applied technology and procedure, and the main focus and conclusion of the study. For easy identification, the papers are numbered 1-34.

Novel technologies and approaches reported in the NM V include *Transcranial magnetic stimulation (TMS), Transcranial direct current stimulation (tDCS) and Transcranial alternating current stimulation (tACS)* (nos. 15 and 16), *interactive audio players that adapt to a person's steps* (nos. 12 and 15), and *functional Near Infrared Spectroscopy* (no. 19).

A specification of the **categories of investigation** applied in the papers is displayed on page 25.

A considerable number of papers deal with *deficits, disorders, therapy and recovery:* Parkinson's disease (nos. 9, 11 and 15), stroke (no. 10), cerebral lesions (no. 14), dystonia (no. 16), neonatal intensive care (no. 24) dementia (nos. 29, 30, 31 and 32), disorders of consciousness (no. 33), and amusia (no. 34).

Another predominant group of papers address *embodiment and emotion* (nos. 13, 18, 19, 25, 26, 27, 28, 30 and 32).

The neural and motor response to *musical beat and groove* is the particular focus of a number of papers (nos. 6, 7, 8, 9, 11, 12, 14 and 15).

A specification of the **cultural references** in the papers is displayed on page 26.
Similar to the previous conferences, classical and popular music based on *Western major-minor tonality* is predominant, employed in 23 out of 34 papers.

As informative supplements to two studies (nos. 8, and 28), complete lists of musical stimuli are available online. Copies of the lists are included in the summaries below.

Four studies report cross-cultural use of music: Classical ballet and Latin American dance (no. 19), Western and Indian classical music (no. 23), and lullabies from different cultures (nos. 24 and 25).

It is a novelty that no. 28, an investigation of music-evoked emotions, includes eight pieces of *Western art music of the 20th Century*.

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[1] For overviews of the conferences NM I, NM II and NM III, see Christensen (2012), pp. 64-100 and 196-282. Available at http://www.mt-phd.aau.dk/phd-theses/

Categories of investigation NM V 2014

The Neurosciences and Music V – Conference 2014: Cognitive Stimulation and Rehabilitation

Keynote address 1	Rhythm and language 2-3	Temporal expectations 4-5
The beat 7-9	Moving on the beat 10-13	Movement coordination 14-17
Dance and the brain 18-19	Musical expertise 20-23	Music and infants' well-being 24-25
Music and emotion 26-28	Music cognition in dementia 29-32	Musical applications 33-34

Categories of investigation	Number of papers	Papers no. (a paper may indicate several categories)
A1. Neural correlates of sound		
1. Pitch, melody, scales, intervals	**2**	31 34
2. Harmony, consonance / dissonance	**0**	
3. Complex sounds: acoustic instruments, timbre	**1**	31
Complex sounds: noise, environmental sounds	**2**	21 33
4. Timing, tempo, rhythm, meter, beat, groove.	**16**	2 3 4 5 6 7 8 9 11 12 13 14 15 17 24 25
A2. Neural correlates of vocal sound		
5. Song	**3**	24 25 34
6. Phonetic sounds, language, speech, infant sounds	**8**	2 3 4 5 9 21 22 23
B. Culture, development, training		
7. Cultural influence, cultural differences	**1**	23
8. Musicians versus non-musicians or different musicians	**0**	
9. Child development	**6**	2 3 7 21 22 23
10. Training effect, learning	**10**	1 8 10 11 17 19 20 21 22 23
C. Deficits, disorders, therapy, recovery		
11. Deficits, disorders	**13**	9 10 11 14 15 16 27 29 30 31 32 33 34
12. Therapy, recovery, rehabilitation	**10**	5 6 9 10 15 16 24 26 32 33
D. Cognition, attention, memory		
13. Cognition, attention, expectation, prediction, recognition	**7**	1 4 5 20 26 28 31
14. Memory, auditory imagery	**3**	26 29 31
15. Musical form and structure	**0**	
E. Embodiment, motion, entrainment, emotion		
16. Audiovisual integration	**2**	18 19
17. Sensorimotor processing, entrainment, synchronization	**12**	6 7 10 11 12 13 14 15 18 19 27 28
18. Bodily impact	**5**	13 18 24 27 33
19. Emotion, feeling, mood, motivation, preference	**8**	8 25 26 27 28 29 30 32
20. Musical expression	**1**	28
21. Improvisation	**0**	

Cultural references NM V2014

The Neurosciences and Music V – Conference 2014: Cognitive Stimulation and Rehabilitation

Keynote address 1	Rhythm and language 2-3	Temporal expectations 4-5
The beat 7-9	Moving on the beat 10-13	Movement coordination 14-17
Dance and the brain 18-19	Musical expertise 20-23	Music and infants' well-being 24-25
Music and emotion 26-28	Music cognition in dementia 29-32	Musical applications 33-34

Cultural references **Papers no. (a paper may indicate several cultural references)**

Neutral or not indicated: **7** 2 4 13 14 16 17 22

Western major-minor: **17** 3 5 7 9 10 11 20 21 26 27 28 29 30 31 32 33 34

Specified music:
5: A *Bach solo sonata for violin*
9: Thomas Koschat: *Schneewalzer*
27: Purcell: *Dido's lament*
28: Twenty-seven excerpts of classical music, including 20th century composers. See table p.
29: Excerpts of familiar melodies, e.g. *Silent Night* and *Blue Danube*.

Western popular: **11** 1 6 7 8 12 15 18 27 29 32 33

Specified music:
7: The Beatles: *Twist and Shout*
8: Twenty-six high-groove and low-groove music clips. See table p.
15: High-groove and low-groove music clips
18: Eight dance sequences from the game *Dance Central 2*
27: Pharrell Williams: *Happy*
29: Excerpts of familiar melodies, e.g. *Happy Birthday* and *Pop goes the Weasel.*

Western traditional: **1** 11

11: A German folk song without lyrics

Western 20th Century **1** 28
Bela Bartok: *Piano Sonata.* Gustav Holst: *The Planets.* Charles Ives: *The Unanswered Question.*
György Kurtag: String Quartet op. 1. Bohuslav Martinu: *String Quartet no. 3.*
Arvo Pärt: *Cantus in memoriam Benjamin Britten.* Arvo Pärt: *Fratres for 12 violoncelli.*
Dimitri Shostakovich: *String Quartet no. 8.* See table p.

Cross-cultural: **4** 19 23 24 25

19: Reviewed studies include *Classical ballet, Tango, Brazilian Capoeira dance*, and *dance video games.*
23: A reviewed study includes *Western and Indian classical music.*
24: Studies include *parent-preferred lullabies from different cultures.*
25: Studies include *play songs and lullabies from different cultures.*

Animal sounds: **0**
Environmental sounds: **1** 21

A selection of papers in NM V 2014

This paragraph summarizes some noteworthy papers from the 2014 conference. To facilitate an overview, the categories of investigation are grouped as follows:

Training, rehabilitation and entrainment
Music therapy interventions
Music and evoked emotion

Training, rehabilitation and entrainment

A number of papers report gait training cued by music, including treatment strategies for Parkinson's Disease (nos. 11 and 15), as well as music entrainment tested in healthy persons (nos. 8 and 12)

Gait training in Parkinson's disease. Two temporal processing brain networks
Simone Dalla Bella and colleagues (NM V no. 11, pp. 77-85) summarize a study of musically cued gait training published by their group (Benoit et al. 2014). Fifteen patients showing moderate symptoms of Parkinson's Disease (PD) took part in the training program, three 30-minute sessions per week for one month. The patients were asked to walk continuously or intermittently while listening to a familiar German folk song without words. Pre- and post- assessment of gait showed that the training significantly increased stride length. Additional tests by means of a Battery for the Assessment of Auditory Sensorimotor and Timing Abilities (BAASTA) showed improvement of perceptual and motor timing abilities after training, indicating that the benefits of the training extended beyond gait.

The researchers refer to a model of timing and temporal predictions based on two networks. The first network includes the basal ganglia, thalamus and cortical areas (BGTC). It is engaged in the self-generation of movements, and the functionality of this network breaks down in Parkinson's disease due to lack of dopamine in the basal ganglia. The second network, including the cerebellum, thalamus and cortical areas (CTC), is involved in event-related, automatic temporal processing (Schwartze & Kotz 2013, Teki et al. 2011). The researchers suggest that coupling movements to an external auditory stimulus can reinforce the CTC network, thus affording compensation for a dysfunctional BGTC timing system (pp. 78-79).

Similarly, in a case study of a Parkinson's disease patient, Sonja Kotz and Thomas Gunter (NM V no. 9, pp. 62-68) infer that stimulation with a marching rhythm may lead to a stronger engagement of the CTC circuit that compensates dysfunctional timing of the BGTC circuit.

Rehabilitation and treatment strategies in Parkinson's disease
Michael Hove and Peter Keller (NM V no. 15, pp. 111-117) point out that PD patients have difficulties in spontaneous synchronization with auditory rhythms due to impaired synchronization abilities. In order to overcome this problem, they conducted a study (Hove et al. 2012) based on the interactive WalkMate system which uses sensors in a person's shoes to send step-timing

information to a computer. The computer controls an auditory metronome which adapts the metronome beats to the person's walking pace.

In the experiment, PD patients walked with 1) no auditory stimulation, 2) a fixed-tempo metronome, and 3) the interactive system. Results showed that the PD patients synchronized with the audio rhythm in the interactive condition, but not in the fixed-tempo condition. The researchers conclude that interactive rhythmic auditory stimulation is a promising therapeutic tool for improving the gait of PD patients.

Moreover, Hove and Keller report their study on the neural underpinnings of groove (Stupacher, Hove, Keller et al., 2013), examining participants' motor system activity while they listen to high-groove versus low-groove music. The music was selected from a pool of music clips rated by Janata et al. (2012) as having high or low groove. The results suggest that high-groove music engages the motor system more strongly and that corticospinal excitability is modulated in time with the beat of a high-groove song (p. 114).

A further study (Hove, Marie, Bruce & Trainor 2014) based on the Mismatch Negativity (MMN) response to high and low-pitched tones investigated why bass-ranged instruments often lay down the foundation of musical rhythms. The study indicates that lower-pitched tones have a greater influence on the perception of timing as well as auditory-motor synchronization. In conclusion, Hove and Keller suggest that rhythmic auditory stimulation treatment for Parkinson patients can be improved by an adaptive system using groove music and low-pitched pulses.

A music player that functions as a mediator between music and locomotion rhythms

In line with Hove and Keller, Bart Moens and Marc Leman (NM V no. 12, pp. 86-93) present a test of D-Jogger, a novel technology based on an interactive music player that can detect a person's footfall by means of wireless motion sensors, and is able to increase or decrease the tempo of a song to fall in synchrony with the person's walking pace. Their results indicate that D-Jogger can be used as an assistive technology for treatment of Parkinson patients who have difficulties in synchronizing to music, and for physical exercise and rehabilitation in general.

Effects of familiar music on gait

Li-Ann Leow et al. (NM V no. 8, pp. 53-61) have assessed how initially familiar and unfamiliar low-groove and high-groove music affected synchronization accuracy and gait in healthy individuals (Leow, Parrot & Grahn 2014).

Participants were 11 university students, mean age 22 years. For the experiment, the researchers selected 26 music clips from the Billboard Top 100 and other online sources. For the list of music and criteria for selection, see table 1.

Leow et al. (NM V no. 8) Supplemental Materials

Assumed high familiarity stimuli were chosen from the Billboard Top 100 for 2007-2013. Assumed low familiarity stimuli were either made by independent artists who posted their music free for downloading on www.soundcloud.com or from film soundtrack compositions. All clips were non-lyrical. The selected clips were judged to be homogenous in groove (either low or high) and tempo.

Table 1. List of stimuli used. Stimuli tempo was altered to match individual participants baseline step tempo, which ranged from 98 steps per minute to 150 steps per minute (M= 126.91, SD = 15.76). Thus, the largest possible stimuli tempo change involved speeding up the stimuli tempo from 80 beats per minute (bpm) to 150 bpm, or slowing down the stimuli tempo from 144 bpm to 98 bpm.

Song Name	Artist	Original Tempo
Lullaby	Tokyo Demons	80
Ol' Country	609 Productions	85
Say Something	A Great Big World ft. Christina Aguilera	95
Reflection	Christina Aguilera	96
Dust In The Wind	Kansas	99
Zumba Latina	Nick Vinzentz	110
La La La	Nimai J.	111
My Heart Will Go On	Celine Dion	114
Metal	Avitus	120
California Gurls	Katy Perry	125
Midnight Storm	Steve King	125
My Immortal	Evanesence	125
Remember	ATB	126
Drifting	Andy McKee	127
Like You'll Never See Me Again	Alicia Keys	128
Moves Like Jagger	Maroon 5	128
We Found Love	Rihanna	128

Song Name	Artist	Original Tempo
Notes	Thieta	128
Merengue Mambo	Normatik Musik	130
Party Rock Anthem	LMFAO	130
Kiss From A Rose	Seal	130
Gangnam Style	Psy	132
Someone Like Yous	Adele	132
I Won't Give Up	Jason Mraz	137
Winter Serenade	Yamaha Demo	140
Let Her Go	Passenger	144

Each participant rated the 26 music clips on familiarity, groove, enjoyment, and beat salience using a 100-point Likert scale. For rating, the researchers asked the following questions:

Familiarity: How familiar are you with this piece of music?
Groove: How much does this piece of music make you want to move to it?

> This question is consistent with a working definition of groove provided by Janata et al.: The groove is that aspect of the music that induces a pleasant sense of wanting to move along with the music (Janata et al. 2012, p. 56).

Enjoyment: How much do you enjoy listening to this piece of music?
Beat salience: How strong is the beat in this piece of music?

Subsequently, for each individual participant, clips were selected that represented four different conditions:

/ low familiarity, low groove / low familiarity, high groove /
/ high familiarity, low groove / high familiarity, high groove /.

Measurements of tempo-matching, gait speed and gait variability showed that familiar music elicited faster stride velocity, less variable strides, and better synchronization performance. High-groove music led to faster stride velocity than low-groove music. The researchers suggest that their results may contribute to optimize future interventions for gait rehabilitation.

For a review of investigations of syncopation, body-movement and pleasure in groove music, see Witek et al. (2014).

Music therapy interventions

A number of papers deal with the practice and effects of music therapy. Nos. 24 and 25 report the therapeutic impact of song on infants, and no. 32 reviews the efficacy of musical interventions in dementia.

NICU music therapy: Song of kin as critical lullaby

Joanne Loewy (NM V no. 24, pp. 178-185) reports a study of music therapy for infants and parents in neonatal intensive care units (Loewy et al. 2013) based on data collected from 272 premature infants in 11 NICUs. Interventions by trained music therapists included sounds of rhythm, breath and lullabies. The application of particular instruments, ocean disc and gato box, aimed at simulating the fluid sounds and heartbeats heard in the womb before birth.

In addition to the therapeutic interventions, the therapists encouraged parents to sing lullabies for the infants, in particular songs of kin, melodies that had been used within the family's history, representative of the culture of the family's community. Controlled measurements showed that the therapeutic use of live sound and lullabies can influence cardiac and respiratory function and may improve feeding behaviors, sucking patterns and sleep patterns. Moreover, parent-preferred lullabies, sung live, can enhance bonding and reduce parents' stress and anxiety.

For a review of music therapy for premature infants, see Standley (2014).

Musical affect regulation in infancy

Sandra Trehub et al. (NM V no. 25, pp. 186-192) describe research that explores the consequences of singing for affect regulation in infancy. Studies of 6 to 9-month old infants show that listening to recordings of infant-directed singing can prolong positive or neutral affect and delay visible signs of distress.

A study of 10-month old infants (Ghazban 2013) includes a stress-inducing still-face procedure. After an initial phase of playful interaction between mother and infant, the mother becomes unresponsive, maintaining a motionless facial expression for 15 seconds. This situation induces distress and high arousal in the infant. Subsequently, the mother resumes interaction with speech or singing to comfort the infant.

Maternal singing proved to be more effective than maternal speech in ameliorating the distress of the infants. Most mothers elected to distract their infants with lively play songs rather than to soothe them with lullabies (p. 189). The authors suggest that adults who experience parenting difficulties should be encouraged to animate and soothe their infants with singing.

Efficacy of musical and other pleasant interventions in dementia

Séverine Samson et al. (NM V no. 32, pp. 249-255) report randomized controlled trials of the efficacy of musical activities and other pleasant activities in dementia (Clément et al. 2012; Narme et al. 2014).

The general design of both studies was very similar, including patients with moderate to severe stages of dementia. Patients engaged in either music or cooking activities twice a week (two hours each session) for one month. During each intervention, receptive phases (listening to music or tasting recipes) and productive phases (clapping hands or singing with music or preparing a recipe) were alternated. Before and after an intervention, the emotional state of each patient was determined by assessing discourse content, emotional facial expressions and mood. The second study was carried out in order to reveal methodological weaknesses in the first study

The results of the first study (Clément et al. 2012) showed positive effects of the music intervention, but no significant benefit of cooking interventions on emotional state. However, the person who interviewed the patient was the therapist in charge of the music intervention. She was not blind to the patient's group, and well-known by the patients. Thus, the change in emotional state observed in the music group might have been due to bias (p. 252). To overcome this problem, the investigators carried out another study.

In the second study (Narme et al. 2014), the investigators used the same three emotional indices to examine patients' emotional state, but also measured cognitive and behavioral functioning, as well as caregiver distress. In this study, a single person supervised both music and cooking interventions, and all assessors (interviewer, psychologist, caregivers, and raters) were blinded from the patients' group affiliation.

The results of the second study showed that both music and cooking interventions resulted in improved emotional state in the patients, and that the beneficial effect of music was not different from that in cooking. These findings suggest a possible bias in study one, and emphasize the importance of using blinded assessors. Furthermore, both interventions reduced the severity of behavioral disorders and diminished professional caregiver distress.

The researchers conclude that enjoyable or pleasant nonpharmacological interventions, such as music and cooking, can improve emotional and behavioral functioning in dementia patients and reduce caregiver distress (pp. 253-54).

Music and evoked emotion

Principles underlying the evocation of emotion with music

Stefan Koelsch (NM V no. 26, pp. 193-201) provides an overview of numerous studies of emotions related to music, including his own research (Koelsch 2012, 2014). He proposes seven principles which he considers fundamental for the evocation of emotions with music: evaluation, resonance, memory, expectancy/tension, imagination, understanding, and social functions.

1) Evaluation may be pre-cognitive as well as cognitive, based on perceptual features, context, interpretation, musical structure, performance quality, affective functions and social functions.

2) Emotional resonance encompasses the impact of sound on arousal and body movement, as well as the mirroring of other persons' emotional expressions.

3) Memory implies that music may evoke conditioned responses and autobiographical and semantic memories.

4) Musical expectancy and tension may be evoked by acoustical features as well as musical structure.

5) Imagination implies that a piece of music may evoke visual images, narratives, and emotionally laden personal experiences.

6) Understanding may imply emotional effects arising from ”aha moments” and feelings of reward and pleasure provided by the understanding of musical structure or extra-musical meaning.

7) The social functions of music are manifold, including contact, mutual understanding, empathy, communication, coordination of actions, cooperation and group cohesion.

Koelsch proposes that the framework emerging from these principles is a starting point for a systematic, coherent, and comprehensive theory on music-evoked emotions that considers both music reception and music making (p. 199).

Furthermore, Koelsch underlines the relevance of music's emotion-evoking qualities for music therapy, such as mood regulation, calming and relaxing effects, spared musical memories in dementia patients, and the experience of images, narratives and personal memories evoked in receptive music therapy.

Neural activation underlying complex music-evoked emotions

Patrik Vuilleumier and Wiebke Trost (NM V no. 28, pp. 212-222) review literature on music and emotions and report their own neuroimaging studies (Trost et al. 2012, 2014) which were aimed at revealing the differentiated recruitment of neural substrates underlying the variety of musical emotions, and the role of rhythmic entrainment in emotion induction. They point out that music evokes complex emotions beyond the dichotomies pleasant / unpleasant or happy / sad usually investigated in neuroscience, and beyond the “classic” basic emotions such as fear, anger and joy.

As a basis for their investigations, they refer to the study by Zentner et al. (2008) which proposes that nine main affective states are commonly elicited by music. These affective states can be regrouped under three factors as follows: *Vitality (Power, Joyful activation), Unease (Tension, Sadness)* and *Sublimity (Wonder, Transcendence, Tenderness, Nostalgia, Peacefulness).*

While the factors *Vitality and Unease* may correspond to the previously reported dimensions arousal and valence, the factor *Sublimity,* understood as a sense of beauty and perfection, suggests a wider spectrum of emotional experiences.

The first study by Trost and colleagues (2012) examined brain activity patterns with fMRI as well as subjective emotion ratings while sixteen music amateurs listened to 27 excerpts of classical instrumental music from the last four centuries, chosen to elicit a wide range of musical emotions. For a list of the music excerpts, see Table 2 below. After each music piece, the participants rated whether they felt any of the nine emotion categories proposed by Zentner et al., as well as the dimensions valence, arousal and familiarity.

Brain activation patterns indicated that positive emotions correlated with activation of left striatum and insula when high-arousing *(Wonder, Joy),* but right striatum and orbitofrontal cortex when low-arousing *(Nostalgia, Tenderness).* Irrespective of their positive or negative valence, high-arousal emotions *(Tension, Power, Joy)* also correlated with activations in sensory and motor areas, whereas low-arousal categories *(Peacefulness, Nostalgia, Sadness)* selectively engaged ventromedial prefrontal cortex and hippocampus. (2012, p. 2769).

Seven of the nine reported affective states are characterized by high valence: *Wonder, Joy and Power* correspond to *Vitality* (high arousal) whereas *Nostalgia, Peacefulness, Tenderness, and Transcendence* correspond to *Sublimity* (low arousal). Two affective states, corresponding to *Unease,* are characterized by low valence: *Tension* (high arousal) and *Sadness* (low arousal).

The results suggest that complex emotions emerge through a combination of activation in emotional and motivational brain systems with activation in other areas, including motor, attention, or memory-related regions (p. 212).

As a remarkable example of the impact of music in the brain, the authors point out the activation in several relays of the motor system, which occurs without overt movement (p. 216). A study by the authors and colleagues (Trost et al. 2014) investigated the entrainment of brain activity by music, exploring how musical rhythm makes the brain act in synchrony with the music, and whether this effect depends on subjective pleasantness.

To study the neural underpinnings of rhythmic entrainment, they engaged a group of eighteen participants in an fMRI paradigm, performing a visuomotor attentional task while listening to pieces of classical piano music with a binary 2/4 or 4/4 time signature. During this task, half of the visual targets appeared synchronously with a strong beat of the music meter, whereas the other half appeared on a weak beat. The fMRI investigation showed increased activation of bilateral caudate nucleus in the subcortical basal ganglia when responding on strong beats. Thus, the sensitivity of basal ganglia circuits indicates entrainment to the meter of natural music.

Moreover, the music was presented in a normal consonant version, considered emotionally pleasant, and an altered dissonant version, considered emotionally unpleasant. The fMRI investigation showed that consonance enhanced activity in parietal and frontal cortical networks associated with attention control. In addition, dissonance enhanced the caudate nucleus activation by the strong beats of the music. The authors propose that consonant music may establish a sustained pleasant state, in which attention is globally broadened, whereas dissonant music makes attention more focused on rhythmical musical features (2014, p. 63).

Vuilleumier and Trost summarize the therapeutic potential of music as a training tool to modulate behavior and cognition (p. 219). For patients with Parkinson's disease, music-based therapies may improve gait and movement difficulties. Musical interventions may be beneficial for patients who suffer from motor impairment after a stroke. Cognitive functions may benefit from music exposure, including selective attention and executive function (Miendlarzewska & Trost 2013). In patients with dementia, music-based interventions may reduce behavior disturbances and depressive symptoms and increase well-being.

The authors conclude that music provides a rich cognitive, sensory and motor experience, with strong affective and motivational components. Music tends to evoke a wide range of complex emotions such as wonder, transcendence, and nostalgia. However, neuroimaging results indicate that music-induced emotions are organized along the same two basic dimensions of valence and arousal as the other more basic emotions, such as joy, sadness, fear and anger. The combination of widespread activation in motor and cognitive systems, including memory and limbic circuits associated with emotion and reward, might constitute the distinctive nature of music-induced responses and contribute to their unique subjective richness (p. 219).

Bach, Johann Sebastian: Musikalisches Opfer. Canon a 2 per augmentationem.
Bach, Johann Sebastian: Piano Concerto, No. 3, 1st movement.
Bartok, Bela: Piano Sonata BB88, 1st movement.
Berlioz, Hector: Harold en Italie, Op. 16, IV. Orgie de brigands.
Brahms, Johannes: Intermezzo for piano, Op. 117.
Brahms, Johannes: Violin Concerto, 3rd movement.
Chopin, Frédéric: Piano Concerto in e minor, No. 1, 2. Larghetto.
Delibes, Léo: Coppélia. Ballet in 3 Acts. 1st act, Prelude.
Dvorak, Antonin: Symphony No. 9, Op. 95, "From the New World":
1st movement, Adagio – Allegro molto.
Dvorak, Antonin: Symphony No. 9, Op. 95, "From the New World":
2nd movement, Largo.
Fauré, Gabriel: Ballade for piano and orchestra, Op. 19.
Fauré, Gabriel: Elegie Op. 24 for violoncello and piano.
Holst, Gustav: The Planets, Op. 32. Mars, the bringer of war.
Ives, Charles: The Unanswered Question.
Kurtag, György: String Quartet, Op. 1: II. Con Moto.
Liszt, Franz: Bénédiction de dieu dans la solitude.
Mahler, Gustav: Symphony No.6, 3. Andante moderato.
Martinů, Bohuslav: String Quartet, No 3, H 183, Vivo.
Mendelssohn, Felix: Violin Sonata in F, 3. Assai vivace.
Pärt, Arvo: Cantus in memoriam Benjamin Britten.
Pärt, Arvo: Fratres, version for 12 violoncelli.
Schubert, Franz: Fantasie in f-Moll, D940, for 4 hands, 1. Allegro molto moderato.
Schubert, Franz: Piano Trio No.1, 1. Allegro moderato.
Schubert, Franz: Quartett “Der Tod und das Mädchen”, 2nd movement.
Shostakovich, Dimitri: String Quartet, No. 8, Op. 110, 1. Largo.
Tschaikovski, Peter: Rokoko-Variations, Variation No. 8.
Vivaldi, Antonio: Cello Sonata No. 3, 3. Largo.

Table 2. Trost et al. (2014). Excerpts of classical and 20th Century instrumental music.

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The Neurosciences and Music VI: Music, Sound, and Health
Conference 2017 in Boston. (NM VI)

Conference proceedings:
***Annals of the New York Academy of Sciences* 2018, vol. 1423.**
edited by Psyche Loui, Aniruddh Patel, Lisa M. Wong, Nadine Gaab, Suzanne B. Hanser, and Gottfried Schlaug

Conference symposia

1. **Tracking the influence of music training on speech processing, language learning, and executive functions.**
2. **Auditory short-term memory in healthy and pathological brains.**
3. **Predictive processing in music and its significance for health and development.**
4. **Born to be musical: What we can learn from studying musical prodigies.**
5. **Rhythm and optimal development: translation of basic research to the development of evidence-based interventions.**
6. **Very early musical interventions to support infant development – evidence from brain and language skills.**
7. **On the biological basis of musicality.**
8. **Towards evidence-based practice of music interventions in stroke rehabilitation: feasibility, efficacy, and neural mechanisms.**
9. **Perspectives on the extra-musical benefits of music training across the lifespan: convergent evidence and lingering questions.**
10. **Interpersonal, inter-brain coordination among musicians.**
11. **Building the audio-motor brain: from movements to multisensory integration.**

In the introduction to the conference proceedings, the editors point out the importance of research for understanding the beneficial effects of music for the individual, for social groups, and for health:

> Music perception and music making change activity in many brain regions typically involved in emotion, reward, cognition, sensations, and movement. Music is a multisensory and motor experience, with a unique ability to further strengthen an already strong bond between brain regions that perceive with those that plan and execute motor commands.
>
> (…) Music brings people together in a multitude of social situations; its many uses include enjoyment, social bonding, and mood regulation. In recent years, the neurosciences of music have systematically investigated how, why, and for whom music and sound may influence the brain and the body. (…)

> Thus, there is a need for theoretical as well as empirical work that aims to understand music and sound, their relationship to health and well-being, and how the relationship can be leveraged to increase human connections, interactions, and possibly healing. (p. 7)

A survey of the 41 papers published in the NM VI proceedings: *Annals of the New York Academy of Sciences* 2018, vol. 1423, is provided in Part two. The survey indicates the aim of each study, its musical material, cultural references and categories of investigation, the applied technology and procedure, and the main focus and conclusion of the study. For easy identification, the papers are numbered 1-41.

Novel technologies and approaches reported in the NM VI include *voxel-based morphometry* (nos. 14 and 32), *EEG hyperscanning of two, three or four brains* (no. 20)*, transcranial stimulation,* including *TMS, tDCS and tACS* (no. 13), *genetics* (nos. 9, 28 and 40), and *machine learning* (nos. 32 and 37).

A specification of the **categories of investigation** applied in the papers is displayed on p. xx.

A considerable number of papers report *the impact of musical training on language learning* (nos. 1, 10, 15, 17, 22, 29, and 33).

Another group of papers focus on *music interventions for deficits and disorders*: stroke (nos. 6, 26, 29, 31 and 34), Parkinson's (no. 30), and autism (no. 23).

Studies of *cognitive domains* investigate prediction (nos. 2, 11, 17, 37 and 38), executive functions (nos. 8 and 12), memory (nos. 16 and 41), and attention (no. 34).

Across categories, **particular research strategies** are conspicuous:

Focus on cerebral networks: executive networks (nos. 8, 12, 14 and 41) and interbrain networks (nos. 20 and 25).

Critical discussion of previous research, including possible publication bias (no. 15), the importance of genetically determined abilities versus training (no. 28), and the potential effects of music-supported therapy (MST) for stroke patients (nos. 6, 26 and 31)

Longitudinal studies of the effects of music-related activities (nos. 4, 8, 10, 12 and 15).

A specification of the **cultural references** in the papers is displayed on page 41.

Music based on *major-minor tonality* is predominant, employed in 22 out of 39 papers.

Six studies employ or refer to *music across cultures and genres:* Western music and songs in Chinese and Japanese (no. 19), German and Chinese folk songs (no. 37), popular music, jazz and classical music (nos. 14, 15 and 39), an Argentinian tango and a Canadian piece in tango style (no. 20).

A few studies enlarge the scope of the conferences by including *birdsong* (nos. 5 and 9), *environmental sounds* (no. 41), *emotional bursts and human nonspeech sounds* (nos. 32 and 41, and a piece of *music that is not related to a regular beat*, the *Prélude non mesuré no. 7* by Couperin (no. 37).

Categories of investigation NM VI 2017

The Neurosciences and Music VI – Conference 2017: Music, Sound and Health

Perspectives 1-6	Concise Review 7	Reviews 8-17
	Concise Original Report 18	Original Articles 19-41

Categories of investigation	Number of papers	Papers no. (a paper may indicate several categories)
A1. Neural correlates of sound		
1. Pitch, melody, intervals, scales	**5**	5 9 13 14 19
2. Harmony, consonance / dissonance	**0**	
3. Complex sounds: acoustic instruments, timbre	**2**	32 41
Complex sounds: noise, environmental sounds	**1**	41
4. Timing, tempo, rhythm, meter, beat, groove	**9**	2 3 5 7 9 17 18 30 39
A2. Neural correlates of vocal sound		
5. Song	**4**	7 10 19 29
6. Phonetic sounds, language, speech, infant sounds.	**14**	1 10 11 15 16 17 19 22 23 24 29 32 33 41
B. Culture, development, training		
7. Cultural influence, cultural differences	**2**	18 37
8. Musicians, non-musicians, different musicians	**8**	4 12 14 20 21 25 28 41
9. Development, Child development	**6**	4 5 7 8 10 15
10. Training effect, learning	**7**	1 4 8 15 24 28 35
C. Deficits, disorders, therapy, recovery		
11. Deficits, disorders	**11**	3 6 16 19 22 23 26 29 30 31 34
12. Therapy, recovery, rehabilitation	**7**	6 22 23 26 30 31 34
D. Cognition, attention, memory		
13. Cognition, attention, expectation, prediction, recognition	**12**	2 8 9 11 12 17 24 27 34 36 37 38
14. Memory, auditory imagery	**7**	12 13 16 24 29 34 41
15. Musical form and structure	**0**	
E. Embodiment, motion, entrainment, emotion		
16. Audiovisual integration	**1**	11
17. Sensorimotor processing, entrainment, synchronization	**14**	3 6 7 14 20 21 25 26 27 31 33 36 38 39
18. Bodily impact	**2**	2 39
19. Emotion, feeling, mood, motivation, preference	**4**	6 31 32 39
20. Musical expression	**0**	
21. Improvisation	**1**	14
22. **Genomics**	**3**	9 28 40
23. **Creative projects**	**0**	

Cultural references NM VI 2017

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Cultural references — **Papers no. (a paper may indicate several cultural references)**

Neutral or not indicated: **14** 1 3 4 12 16 18 21 23 27 28 32 33 36 38

Western major-minor: **20** 5 6 8 9 10 11 13 14 17 19 22 24 26 29 30 31 34 35 37 39

Specified music:
10: Self-selected songs and melodies in parental singing
14: Jazz and classical improvisations, memorized novel melodies, improvised freestyle rap
22: A Suzuki violin lesson program
29: Novel melodies composed to be simple
30: Mozart's *Turkish March* and highly familiar military marches
37: A chorale harmonized by J.S. Bach. Schubert: *Octet for Strings and Winds in F major.* English hymns.
Couperin: *Prélude non mesuré No. 7.*
39: J.S. Bach: *Air on the G string.* Arvo Pärt: *Spiegel im Spiegel.*

Western popular: **12** 2 6 8 11 14 17 19 24 26 31 34 39

Specified music:
2: 34 syncopated drum patterns transcribed from real funk tracks, plus 16 patterns constructed for the experiment
14: Jazz and classical improvisations, memorized novel melodies, improvised freestyle rap
39: Stevie Wonder: *Superstition.* Benny Goodman: *Sing sing sing.* Loreena McKennit: *Full circle.* Brian Setzer: *The dirty boogie.*
The sound stylistics: *Big pieces.* The Innocent Mission: *What a wonderful world.*

Western traditional: **2** 10 25
10: Finnish children and folk songs, and self-selected songs and melodies
25: The melody *Frère Jacques ("Brother John")*

Western 20th Century **1** 39
39: Arvo Pärt: *Spiegel im Spiegel.*

Cross-cultural and divergent genres: **9** 7 14 15 19 20 37 39 40 41
Specified music:
14: Jazz and classical improvisations, freestyle rap, see above
15: Classical music, playschool music, Heavy metal, Latin American music
19: Western: Rimsky-Korsakov: *Flight of the Bumble Bee.* Vivaldi: *Spring, from The Four Seasons*
Western popular: Black Dawn: *Sound of an Angel.* Alan Menken: *Beauty and the Beast.* K.A. and R Lopez: *Let it Go.*
Twelve songs in Mandarin Chinese, Taiwanese and Japanese by Tao, Tsai, Hsiao, Huang, Jiang, Wang, Qu, Ye and Li
20: Astor Piazzolla: *Libertango,* Patrick Roux: *Comme un Tango*
37: German and Chinese folk songs
39: Popular music, jazz and classical music, see above

Animal sounds: **2** 5 9
5 and 9: Zebra Finch song

Environmental and other sounds: **2** 32 41
32: Instrumental emotional bursts and short vocal affect bursts on the vowel "a", expressing *happiness, sadness, fear, and neutral*
41: Environmental sounds, e.g. *siren and water drops.* Human nonspeech sounds, e.g. *coughing and laughing*

A selection of papers in NM VI 2017

This paragraph summarizes some noteworthy papers from the 2017 conference, grouped as follows:

Effects of music activities and training
Music interventions in stroke rehabilitation
Music, embodiment and emotion
Music, executive functions and brain networks
Music and genetics
Music and machine learning

Effects of music activities and training

A number of papers report positive effects of music activities, including enhanced language processing (nos. 1, 10, 15, 17 and 22), cognitive development (no. 8), and gait performance in Parkinson's disease patients (no. 30)

How music ameliorates the auditory system
Minna Huotilainen and Mari Tervaniemi (NM VI no. 15, pp. 146-154) have reviewed studies indicating that various musical activities result in positive changes in brain structure and function, becoming helpful especially for individuals with deficits that may compromise auditory processing. The authors report a longitudinal study of children starting a musical hobby at approximately 7 years of age (Putkinen et al. 2014). EEG tests at 7 and at 9 years suggest that enhanced reactivity of the auditory cortex is caused by music training and is not innate (p. 150).

Based on their review of studies, the authors conclude that music-based training in infancy and childhood is beneficial generally, and especially in cases of dyslexia, learning and language disabilities. However, in their review of ameliorating and training studies, the authors found a multitude of error sources. They suggest that positive effects of studies are contaminated with publication bias. This may be due to the demand to publish something novel with positive results, which infers that a plenitude of experimental evidence remains unpublished due to negative findings (p. 152). The authors discuss some future improvements of these issues.

Music training, speech processing, and word learning
Stefan Elmer and Lutz Jäncke (NM VI no. 1, pp. 10-18) have reviewed studies of the relationships between music training, speech processing and word learning, in order to extend these findings to a perspective of possible networks that exert a modulatory influence on the auditory cortex (AC). They report and discuss numerous studies applying fMRI, Diffusion Tensor Imaging and EEG that show how functional and structural connectivity can be used to model simple neural circuits exerting a modulatory influence on AC activity.

In their conclusion, the authors recommend extending future research from local changes in the auditory cortex to a better understanding of simple neural networks contributing to a modulation of AC activity as a function of music training.

Rhythm and reading development

Ola Ozernov-Palchik and Aniruddh Patel (NM VI no. 17, pp.166-175) have reviewed and discussed child studies on links between rhythm processing and reading-related skills, in particular the role of beat-based processing in music.

The authors have conducted a study (Ozernov-Palchik et al. 2018) of 74 kindergarten children, mean age 5,8 years, measuring their rhythm discriminating ability, using patterns with or without a beat-based structure (p. 169). They conclude that the ability to process beat-based rhythms predicts enhancement of reading-related abilities in young children, probably because beat-based processing and linguistic processing both involve making predictions based on rich contextual structure in rapidly unfolding sequences (p. 172).

The impact of music training after two years

Assal Habibi et al. (NM VI no. 8, pp. 73-81) have investigated the effects of music training on cognitive development as part of a longitudinal study (Habibi et al. 2017).

68 children from low-income areas of Los Angeles participated in the reported 2-year project. They were 6-7 years old when the project began. 21 children enrolled in a music training program, receiving free instruction 6-7 hours weekly for two years. 23 children enrolled a sports education program, receiving regular weekly soccer training or swimming instruction for two years. A control group of 24 children received no systematic afterschool training.

The children were tested individually before and after the project period. Tests included behavioral assessments, a tonal discrimination task, and fMRI scanning. Results showed that children in the music group outperformed children in the two other groups in the tonal discrimination task, but not in other tasks. Furthermore, children in the music group, compared with children in the control group, showed greater neural activity in a network of brain regions that are known to be involved in response inhibition (Hennessy et al. 2019). The authors conclude that music training induces brain and behavioral changes in children, and those changes are not attributable to pre-existing biological traits.

Very early music interventions in at-risk infants

Paula Virtala and Eino Partanen (NM VI no. 10, pp. 92-101) have reviewed findings on the possible effects of music supporting auditory and language development in healthy children and at-risk children.

In the DyslexiaBaby study by the authors, infants at familial risk for dyslexia were followed from birth onward. The material consisted of Finnish children's and folk songs in vocal and instrumental versions recorded by the researchers. At-risk infants were pseudo-randomized to three groups: 1) Music listening intervention with sung material; 2) Music listening intervention with instrumental material; 3) A no-intervention control group.

Comparison of event-related potentials recorded with EEG at birth and again at 6 months demonstrated very modest or non-existing effects of the music listening interventions, suggesting that passive exposure to music may not be enough to support auditory and language development in infancy. The authors point out that learning from music in infancy may benefit largely from social interaction (p. 99). For a related study, see Habib et al. (2016).

Rhythmic auditory cueing in Parkinson's Disease

Simone Dalla Bella et al. (NM VI no. 30, pp. 308-317) have investigated the effect of music-based rhythmic auditory cueing in Parkinson's Disease (PD). They underline that the effect of rhythmic cueing varies considerably, probably due to the heterogeneity of PD patients' symptom evolution.

In a study by the authors (De Cock et al. 2018), 39 PD patients and 39 matched controls were asked to walk together with rhythmic stimuli which had a salient beat structure, were pleasant, and conducive to movement. 22 patients showed a positive response to cueing, while 17 patients displayed a nonpositive response. Six patients showed significantly worsened gait performance in the presence of cues.

The authors conclude that this result calls for individualized rhythmic cueing, which can be achieved via assistive mobile technologies compensating for rhythmic deficits by delivering cues that adapt in real time to patients' gait kinematics (Garzo et al. 2018).

See also http://www.euromov.eu/beathealth/publications/public-publications

Measuring music treatment fidelity

Natalie Wiens and Reyna Gordon (NM VI no. 22, pp. 219-228) discuss studies which test the benefits of active music making. They underline the importance of measuring and reporting treatment fidelity, including administration of the treatment's active ingredients, dosage, procedure, and quality.

The authors describe the design of a novel music intervention for children with specific language impairment (SLI), the Music Impacting Language Expertise (MILEStone), which applies a 20-week Suzuki violin lesson program. The MILEStone program includes a behavioral coding system, a treatment manual, activity checklists, provider training and monitoring, a home practice log, and teacher ratings of participant engagement. In a pilot study, two children with SLI, five and six years old, were trained according to this music intervention.

The authors conclude that to sufficiently address treatment fidelity, four elements should be reported: treatment design, provider training, treatment administration, and treatment receipt (p. 226).

Music interventions in stroke rehabilitation

Papers on stroke rehabilitation investigate the effects of music-supported therapy (nos. 6, 26 and 31), sung melody as a mnemonic aid (no. 29) and mindful music listening (no.3)

Sung melody enhances verbal learning after stroke

Vera Leo et al. (NM VI no. 29, pp. 296-307) have investigated whether coupling novel verbal material with a musical melody can aid in learning and recall in stroke patients with cognitive deficits. All participants underwent neuropsychological testing and an MRI within 3 weeks of the stroke (acute stage) and at the 6-month post-stroke stage.

Short novel narrative stories were written and composed for the study. They were presented in both sung and spoken formats to 31 persons with stroke at the acute stage and the 6-month post-stroke stage to determine the mnemonic efficacy of songs at the two stages of recovery (p. 297).

The learning and recall of the stories were tested by a Sung-Spoken Story Recall Task (SSSRT) developed by the authors. The main finding was that subjects affected by stroke benefited from the sung melody as a mnemonic aid at 6 months post-stroke, but not at the acute stage. The benefit of the sung melody on story learning at 6 months was seen especially in patients with mild aphasia (p. 304).

Music-supported therapy for chronic stroke

Takako Fujioka et al. (NM VI no. 26, pp. 264-274) have investigated the effects of music-supported therapy (MST) in chronic stroke compared to conventional physical training, an exercise program of Graded Repetitive Arm Supplementary Program (GRASP).

Both the MST group and the GRASP group received 30 hours of training over a 10-week period. No superior effects on motor functions were observed for either therapy, but self-reported assessment of quality of life in the mobility domain improved overall. Assessments 3 months after training support a beneficial effect of MST on cognitive flexibility (p. 272).

Jennifer Grau-Sánchez et al. (NM VI no. 31, pp. 318-328) have conducted a randomized controlled trial (RCT) in order to test the effect of adding music-supported therapy (MST) to a standard rehabilitation program in subacute stroke patients. In addition to a usual rehabilitation program, an MST group and an active control group received 20 extra individual sessions during a 4-week period.

The participants in the MST group were trained in playing a keyboard and an electronic drum with the affected arm, and the active control group received individual conventional training of the affected arm. Thus, equal conditions were provided for the two groups. Both groups improved their motor function, and no difference between groups was found. MST enhanced patients' motivation to enjoy musical activities.

Music-supported therapy: theoretical and practical considerations

Joyce Chen (NM VI no. 6, pp. 57-65) discusses knowledge and evidence for a role of music in supporting the rehabilitation of movements after stroke, in relation to information about stroke recovery in general. In available studies, systematic reviews and meta-analyses, comparisons of the effects of rhythmic auditory stimulation (RAS) with other dose-matched therapies demonstrated no significant difference in motor performance of stroke survivors. Similarly, randomized controlled trials (RCTs) have not shown superior effects of a music-supported therapy (MST) intervention compared with conventional therapy. These observations suggest that stroke recovery may be dominated by endogenous spontaneous brain repair mechanisms rather than therapeutic interventions.

Chen concludes that MST may have promise to enhance motor stroke recovery, but the quality of the current published evidence is low (p. 63). She suggests that more carefully controlled trials are needed, beginning with modeling trials which delineate the active ingredients of the therapy, and followed by exploratory trials that manipulate and evaluate these ingredients.

Participants' experiences of music, mindful music, and audiobook listening

Satu Baylan et al. (NM VI no. 34, pp. 349-359) have investigated the feasibility and acceptability of combining music listening and a brief mindfulness training for people recovering from stroke. 56 participants with ischemic stroke were randomized in three groups to receive an 8-week listening intervention one hour daily at home:

(1) Mindful music listening involving doing one of two 5-minute mindfulness exercises, “Body Scan” or “Following the Breath” immediately before listening to self-selected music, or (2) Listening to self-selected music without any particular goal or instruction, or 3) Listening to self-selected audiobooks.

After the intervention, qualitative interviews were carried out in the patients’ homes. Themes emerging from the interviews were positive impact on mood, relaxation, cognition and increased activity. Participants in all groups reported that the intervention provided positive distraction from thoughts and worries. Listening to self-selected music was associated with lifting mood, evoking memories from the past, and increased engagement in other activities. Mindful music listening seemed related to increasing relaxation and concentration, enjoyment, and improved emotion regulation, and in particular related to improved attentional control (p. 357).

Music, embodiment and emotion

The effect of musical groove is the focus of papers no. 2 and 39.

Dancing to “groovy” music enhances the experience of flow

Nicolò Bernardi et al. (NM VI no. 39, pp. 415-426) have investigated whether dancing influences the emotional response to music, compared to when music is listened to in absence of movement.

40 participants listened to excerpts of eight categories of music:

Familiar groovy music:	Lyrics:	*Superstition* (Stevie Wonder)
	No lyrics:	*Sing sing sing* (Benny Goodman)
Unfamiliar non-groovy music:	Lyrics:	*Full circle* (Loreena McKennit)
	No lyrics:	*Spiegel im Spiegel* (Arvo Pärt)
Unfamiliar groovy music:	Lyrics:	*The dirty boogie* (Brian Setzer)
	No lyrics:	*Big Pieces* (The sound stylistics)
Familiar non-groovy music:	Lyrics:	*What a wonderful world* (The Innocent Mission)
	No lyrics:	*Air on the G String* (J.S. Bach)

The authors state that the dimension of groove expresses the degree to which a certain piece of music urges the listener to generate movements, referring to research by Janata et al. (2012) and Witek et al. (2014).

The participants were tested in various conditions during motion capture recording, including standing still without music, listening while dancing, listening while standing still, and copying their own movements while watching the motion capture recording without music. After the end of each music excerpt, the participants provided ratings of their emotional experience and their experience of flow, the strongly rewarding experience of deep absorption and energized, focused attention.

For the emotional assessment, the Geneva Emotional Music Scales (Zentner et al. 2008) was utilized, asking the participants to rate their experience of nine emotions: power and joyful activation (the factor "vitality"); wonder, transcendence, tenderness, nostalgia, and peacefulness (the factor "sublimity"); tension and sadness (the factor "unease"). The experience of flow was quantified by means of the Core Flow Scale Questionnaire (Martin & Jackson 2008). Four rating scores were submitted to statistical analysis: vitality, sublimity, unease and flow.

The results of the investigation showed that the music in general evoked emotions in the realms of vitality and sublimity, whether participants moved or not.

Dancing to groovy music produced a distinct state of heightened flow, which was not present when the same music was listened to without engaging the body. Flow states have been shown to correlate positively with self-esteem and perceived ability. Therefore, dance may offer an accessible and engaging tool to promote and sustain experiences of flow in the context of psychological interventions as well as physical rehabilitation (p. 424)

Predictive coding of rhythmic incongruity

Peter Vuust et al. (NM no. 2, pp. 19-29) discuss how brain processing of rhythm can be seen as a special case of predictive coding, and present a model of Predictive Coding of Rhythmic Incongruity (PCRI) which proposes that rhythm and meter processing is based on prior information, predictions, and prediction error.

In predictive coding, top-down connections provide lower levels with predictions in the form of prior expectations about states of the world, whereas bottom-up connections carry prediction errors that update posterior expectations in higher levels to provide better predictions (p. 19).

In studies by the authors (Witek et al 2014, 2017), musicians and non-musicians listened to a battery of groove-based drum patterns, selected to represent a continuum from weakly to strongly syncopated patterns. The studies indicate that medium syncopation evokes the strongest sensation of groove, as well as a strong feeling of pleasure and urge to move. The body reacts on the incongruity between syncopation: the appearance of a surprising beat followed by a surprising rest, and groove: repeated rhythmic patterns that establish the musical meter. For a syncopation to obtain its characteristic effect, it must be experienced as contradicting the meter, yet not so strongly that the experience of the meter falls apart (p. 22).

Measurements by means of magnetoencephalography (MEG) during listening to syncopated patterns showed two event-related potentials: Mismatch negativity (MMN) and the P3a component, known as the novelty P3. The results suggest that the P3a reflects a neural network that acts on the error signal of the MMN (p. 23).

On the basis of their investigations, the authors present the Predictive Coding of Rhythmic Incongruity (PCRI) model. This model proposes that the explainable prediction error processed by the brain depends on a combination of syncopation and the uncertainty of the meter perception (p. 27).

Music, executive functions and brain networks

Papers dealing with brain networks investigate memory and neural efficiency (nos. 12 and 41), creativity (no 14) and possible synchronization of musicians' brains in ensemble playing (no. 20).

Neural correlates of enhanced executive functions: is less more?
Vesa Putkinen and Katri Saarikivi (NM VI no. 12, pp. 117-125) have conducted a selective review of neuroimaging studies on plasticity and typical maturation of executive functions, with the aim of investigating how proficient performance in executive function tasks is reflected in brain activity.

Executive functions encompass top-down control mechanisms that support higher order processes, such as planning, decision making, and self-control. In adults, executive functions rely heavily on the frontal lobe, but also recruit parietal regions as well as subcortical structures such as the thalamus, basal ganglia, and the cerebellum. Research indicates that working memory, inhibition, and set-shifting tasks activate these regions (pp. 117-118).

A study by the authors (Saarikivi et al. 2016) compared the proficiency of 9 -15 year-old children and adolescents with and without musical training, using tests of inhibition tasks and set-shifting tasks which involve switching between response strategies. They found that the musically trained participants outperformed the untrained ones in these tasks.

In their review, the authors have found relatively strong empirical support for the assertion that expert performance requires fewer neural resources in the domain of executive functions than the performance of novices. They found evidence in favor of this neural efficiency hypothesis from studies that have linked reduction in frontal and parietal activity with experience-induced enhancement of inhibition, set shifting, and working memory. However, they point out that the scarce available literature does not permit definite conclusions (p. 122).

Brain networks in musicians and bilinguals
Claude Alain et al. (NM VI no. 41, pp. 435-446) have investigated whether musical training and bilingualism benefit executive functioning and working memory. In line with Putkinen and Saarikivi, they point out that executive functions refer to processes that are important for the regulation and control of cognitive processes, including attentional control, working memory, reasoning, task flexibility, problem solving, planning and motor execution (p. 435).

In an fMRI experiment, the authors have assessed working memory (WM) for spatial auditory information (sound location) and non-spatial auditory information (sound category) in 1) musician monolinguals, 2) non-musician bilinguals, and 3) non-musician monolinguals (controls).

During scanning, participants performed spatial versus non-spatial WM tasks and WM load tasks (1-back versus 2-back memory tasks). Stimuli in the tasks were a) human non-speech sounds, e.g. coughing and laughing, b) musical instruments, e.g. flute and clarinet, and c) environmental sounds, e.g. siren and water drops. Results indicate that musicians and bilinguals compared to controls showed lower activation in prefrontal lobe areas associated with attentional and WM demands. This suggests that musicians and bilinguals require less effort to successfully perform the WM tasks than controls.

Furthermore, results showed that musicians outperformed both groups of non-musicians on the WM sound category task, but not on the spatial task. Bilinguals also showed enhanced activity in language-related brain areas compared to musicians and controls. This could be associated with the need to suppress competing semantic activations from different languages. These findings suggest that auditory WM advantages in musicians and bilinguals are mediated by different brain networks.

Brain networks subserving creativity in musical improvisation
Psyche Loui (NM VI no. 14, pp. 138-145) has reviewed research in the neuroscience of musical improvisation, focusing on creative processes in the brain. fMRI studies include jazz pianists improvising in the scanner, improvising freestyle rap artists, classically trained pianists improvising on a given melody, and comparisons between improvising jazz pianists and classical pianists.

Creativity has been defined as the ability to produce output that is novel, useful, beneficial, and desired by an audience (Sternberg and Lubart 1999). In an improvised performance, musical ideas have to be rapidly generated and evaluated in the musical flow. Improvising requires the simultaneous execution of several processes in real-time, including sensory and perceptual encoding, motor control, performance monitoring, and memory retrieval. Improvisation can be understood as a series of generative and evaluative processes (Pressing 1988).

Current research suggests that the interplay of idea generation and evaluation entails the coordinated activity of the default mode network[2] and the executive control network in the brain (Beaty 2015). As ideas in improvised music are implemented as auditory-motor sequences, improvisation further engages the auditory perception-action network (Loui 2015).

Whereas the default mode and the executive control networks can show an antagonistic relation, they tend to cooperate during creative cognition and artistic performance. Default network activity during creative cognition appears to reflect the spontaneous generation of candidate ideas, or potentially useful information derived from long-term memory. The executive control network may couple with the default network during idea generation or evaluation to constrain cognition to meet specific task goals (Beaty et al. 2016)

For a further discussion of a standard model of improvisation, describing bottom-up networks (auditory processing and output monitoring), and top-down networks (spontaneous creativity and social improvisation), see Faber & McIntosh (2020).

Hyperbrain networks during quartet playing
Viktor Müller et al. (NM VI no. 20, pp. 198-210) have applied advanced EEG technology to record EEG simultaneously from four guitarists during quartet playing, in order to explore the extent and the functional significance of synchronized activity across four brains. EEG measurement took place while the quartet played *Libertango* by Astor Piazolla and *Comme un Tango* by Patrick Roux.

The aim of the study was to describe hyperbrain networks and synchronization patterns of the guitarists indicating mechanisms of interpersonal action coordination. In the recorded synchronization patterns, drawn as circles with points connected by lines, so-called hyperbrain

[2] The Default Network is active when an individual is not focused on the external environment, but rather engaged in self-generated activity such as autobiographical memory, imaginative and creative thinking, daydreaming and future-oriented thoughts.

modules were identified, composed of nodes from two brains. Nodes may point to brain regions that are strongly interconnected.

The study indicated that the most important characteristic of the network organization is the existence of hyperbrain modules sharing EEG electrodes from two, three, or even four brains. These modules are characterized by strong connections or information flow within the modules and weak connections or information flow between modules. The network architecture is never stable. Both coupling strengths and community structures change their patterns over time, dependent on the musical situation (p. 207).

Music and genetics

Genetic influence on musical specialization

Miriam Mosing and Fredrik Ullén (NM VI no. 40, pp. 427-434) have conducted a twin study (Mosing & Ullén 2016) in order to investigate genetic influence on musical specialization.

In a nation-wide investigation of twins in Sweden, they found 1259 same-sex twin pairs reported to play an instrument or sing, including 45 different instruments, song, choir and whistling. Participants playing an instrument were asked whether they performed or practiced a) classical Western art music, b) modern Western art music, c) jazz music, d) pop/rock, e) folk and world music, f) other types of music.

The authors calculated the difference in concordance rate between the group of identical twins (monozygotic, n= 803) and the group of nonidentical same-sex twins (dizygotic, n= 456). Results indicated that identical twins are more likely to engage in the same type of music-related behavior than are nonidentical twins. The results suggest significant genetic influence on music specialization.

Nature versus nurture

In line with Mosing and Ullén, David Hambrick et al. (NM VI no. 28, pp. 284-295) discuss whether expertise reflects genetically determined innate ability or culturally determined training history. They find that the latter view has gained tremendous popularity, in particular in numerous publications of the Swedish psychologist K.A. Ericsson and colleagues, e.g. Ericsson & Pool (2016).

In order to contradict the view that talent merely has negligible effects on ultimate performance, they report and discuss verbatim quotations from a range of publications. They argue that current evidence does not support the view that expertise is exclusively determined by a person's training history, and propose a multifactorial gene-environment interaction model (MGIM) based on the assumption that expertise is multiply determined.

Genomics studies on music-related traits

Irma Järvelä (NM VI no. 9, pp. 82-91) presents genome studies on music aptitude, music perception and practice. In subjects with no specific music education, she has searched for genetic markers inherited together with musical aptitude.

In a genome-wide analysis (Oikkonen et al. 2015), 76 families were defined for auditory structuring ability, perception of pitch and time in music, and a combined test score. Next, DNA from each participant underwent an analysis which indicated the characteristics of the participant's genome. Comparisons of the music tests and the genome analysis showed the presence of genetic loci linked to musical aptitude. A particular finding was a gene named GATA2 which contributes to the function of the inner ear and the processing of sound in the brain.

In another study (Kanduri et al. 2015), a genome-wide analysis based on blood tests of professional musicians before and after a 2-hour concert performance indicated upwards regulation of genes found to affect dopaminergic neurotransmission, motor behavior, neuronal plasticity, learning, and memory (p. 85).

In summary, the candidate regions for positive selection of musical aptitude contained genes affecting inner-ear development, auditory perception, cognitive performance, memory and reward mechanisms, as well as the song perception and production of songbirds (p. 87).

Music and machine learning

Cross-classification of musical and vocal emotions

Sébastien Paquette et al. (NM VI no. 32, pp. 329-337) have employed machine learning to investigate whether emotions carried by voice or music are processed by similar brain mechanisms.

During fMRI scanning, twenty participants listened to 40 short affective vocal bursts produced by actors, portraying different emotions on the vowel “a”, and 80 short musical bursts, 40 on clarinet and 40 on violin, expressing four emotions: happiness, sadness, fear and neutral. After scanning, the participants performed a four-alternative forced-choice emotion categorization task on the 120 stimuli.

In order to document how neural networks were engaged by the musical and vocal stimuli, a multivoxel pattern analysis (MVPA) of the fMRI patterns was performed (Haxby et al. 2014; Kotz et al. 2013). Subsequently, machine learning classifiers were trained at classifying the emotions corresponding to the voice-related and the music-related fMRI multivoxel patterns, and cross-classification was used as a test of shared neural networks.

The researchers found that in auditory cortex and premotor regions in both hemispheres, classifiers trained at categorizing emotions based on local fMRI patterns measured for voice stimuli were also successful at categorizing emotions in fMRI patterns measured for musical stimuli, and vice versa. They conclude that fMRI patterns of cerebral activity can be used to decode emotions in novel stimuli, even from a different category. The results of the investigation constitute evidence for a shared neural code for auditory emotion processing across different timbres: violin, clarinet, and voice (p. 334).

Enculturation: statistical learning and prediction

Marcus Pearce (NM VI no. 37, pp. 378-395) has reviewed research that uses a computational model of probabilistic prediction based on statistical learning, the Information Dynamics of Music Model (IDyOM), and describes the information theory underlying the IDyOM software. Computational models provide a means of developing a theory about a complex process that is not directly observable.

Pearce reviews a selection of studies, including a music analysis of Schubert’s *Octet for Strings and Winds* by Leonard B. Meyer, a study of listeners’ experience of performance timing and perceived tension in the *Prélude non mesuré no. 7* by Louis Couperin, and a study of cultural distance between Western and Chinese listeners.

Two hypotheses guide Pearce's approach at understanding music cognition:
1) Statistical Learning: Listeners acquire internal cognitive models of statistical regularities present in the music to which they are exposed.
2) Probabilistic Prediction based on these acquired models enables listeners to organize and process their mental representations of music.

When a computer programmed with the IDyOM model is trained on a corpus of music, IDyOM learns the syntactic structure present in the corpus in terms of sequential regularities determining the likelihood of a particular event appearing in a particular context, e.g. the pitch of a note appearing at a particular point in a melody (p. 380).

Pearce concludes that many different aspects of music perception can be simulated in terms of a single underlying process of probabilistic prediction, implemented in IDyOM. Simulation can include expectation, emotional response, recognition memory, phrase boundary perception, and perceptual similarity (p. 391).

As limitations, Pearce points out that research to date has focused on modeling melodic music, and that the IDyOM model requires its musical input to be represented symbolically, which means that it cannot process aspects of music that rely on timbral, dynamic, or textual changes (p. 383). Current research aims at extending IDyOM to modeling aspects of polyphonic music and interactions between harmony and melody.

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The tables displayed on the following pages permit comparisons of the six conferences 2002, 2005, 2008, 2011, 2014, and 2017.

Categories of investigation	NM I	NM II	NM III	NM IV	NM V	NM VI
	Interaction Development	Perception Performance	Disorders Plasticity	Learning Memory	Stimulation Rehabilitation	Sound Health
	Papers 2002	Papers 2005	Papers 2008	Papers 2011	Papers 2014	Papers 2017
A1. Neural correlates of sound						
1. Pitch, melody, scales, intervals	**14**	**5**	**10**	**4**	**2**	**5**
2. Harmony, consonance / dissonance	**7**	**7**	**3**	**1**	**0**	**0**
3. Complex sounds	**7**	**2**	**2**	**1**	**3**	**3**
4. Timing, tempo, rhythm, meter, beat, groove	**9**	**3**	**11**	**3**	**16**	**9**
A2. Neural correlates of vocal sound						
5. Song	**0**	**2**	**4**	**1**	**3**	**4**
6. Phonetic sounds, language, speech, infant sounds, animal sounds	**8**	**5**	**7**	**5**	**8**	**14**
B. Culture, development, training						
7. Cultural influence, cultural differences	**7**	**0**	**4**	**9**	**1**	**2**
8. Musicians, non-musicians, different musicians	**13**	**6**	**5**	**10**	**0**	**8**
9. Development, Child development	**5**	**0**	**7**	**5**	**6**	**6**
10. Training effect, learning	**6**	**4**	**11**	**13**	**10**	**7**
C. Deficits, disorders, therapy, recovery						
11. Deficits, disorders	**8**	**7**	**23**	**17**	**13**	**11**
12. Therapy, recovery, rehabilitation	**0**	**4**	**7**	**8**	**10**	**7**
D. Cognition, attention, memory						
13. Cognition, attention, expectation, prediction, recognition, localization	**4**	**3**	**5**	**5**	**7**	**12**
14. Memory, auditory imagery	**3**	**5**	**13**	**6**	**3**	**7**
15. Musical form and structure	**1**	**0**	**2**	**0**	**0**	**0**
E. Embodiment, motion, entrainment, emotion						
16. Audiovisual integration	**1**	**2**	**2**	**1**	**2**	**1**
17. Sensorimotor processing, motion, entrainment, synchronization	**4**	**4**	**7**	**11**	**12**	**14**
18. Bodily impact	**2**	**2**	**4**	**0**	**5**	**2**
19. Emotion, feeling, mood, motivation, preference	**0**	**10**	**10**	**0**	**8**	**4**
20. Musical expression	**1**	**2**	**1**	**1**	**1**	**0**
21. Improvisation	**0**	**0**	**0**	**1**	**0**	**1**
22. **Genomics**	**0**	**0**	**0**	**0**	**0**	**3**
23. **Creative projects**	**4**	**0**	**0**	**0**	**0**	**0**

Cultural references	NM I Interaction Development	NM II Perception Performance	NM III Disorders Plasticity	NM IV Learning Memory	NM V Stimulation Rehabilitation	NM VI Sound Health
	Papers 2002	Papers 2005	Papers 2008	Papers 2011	Papers 2014	Papers 2017
Total number of papers	61	53	79	47	34	41
Neutral or not indicated	23	25	28	14	7	14
Western major-minor	29	28	40	24	17	20
Western popular	4	4	11	9	11	12
Western traditional	3	0	1	2	1	2
Western non-tonal and 20th Century	2	0	1	2	1	1
Cross-cultural	7	0	4	5	4	9
Animal sounds	2	2	0	0	0	2
Environmental and other sounds	1	0	3	1	1	2

Cultural references NM I 2002

The Neurosciences and Music I – Conference 2002: Mutual Interactions and Implications on Developmental Functions

Cerebral organization 1-29 | Brain sciences versus music 30-44 | Music and development 45-61

Cultural references **Papers no.**

„„

Neutral or not indicated: **23** 7 11 13 16 17 19 21 29 | 31 32 33 34 36 38 39 40 44 | 45 50 56 57 59 61

„„

Western major-minor: **29** 1 2 3 4 5 6 8 9 10 12 14 15 18 20 22 23 24 25 27 28 | 37 43 | 47 49 51 52 53 54 55

Specified music:
8: Excerpts from A. Scarlatti: *Sonata Terza in C minor for Treble Recorder, Strings and Basso Continuo.*
9: Mozart: Clarinet Concerto K. 622
10: Mozart: *Twinkle Twinkle Little Star*, Bach: *Two-part invention no. 8*
18: Ravel: *Bolero*
37: Bach, Haydn and Mozart minuets. Extracts from four sonatas by Haydn.

„„

Western popular: **4** 18 | 41 | 46 48

Specified music:
18: Bee Gees: *Stayin' alive*
41: Relaxing music excerpts from Enya, Vangelis, and Yanni
46: Instrumental excerpts from TV programs: *E.R., Friends, Jeopardy, Law & Order, The Simpsons, X-files*
48: 6 French songs: *Milord, On cherche un Auguste, Flamandes, Comme, Besoin de personne, Comédie*

Western traditional: **3** 18 | 46 58

18: Instrumental folk music 46: English folk melodies
58: Two English folk songs, *The Country Lass* and *The Painful Plough*

„„

Western non-tonal: **2** 35 37

35: Electronically synthesized tones made up of streams or clouds of sonic particles
37: Specially composed canons in the style of Webern

„„

Cross-cultural: **7** 8 9 23 26 | 46 48 60

8: Western classical and Chinese music: Excerpts from A. Scarlatti and a traditional Chinese piece, *Liu Qin Niang.*
9: Western classical and African-American scores: Performances by professional musicians
23: Western, Thai, and Turkish scales
26: Thai and Chinese language: Syllables of two tonal languages
46: Responses by Western and Japanese children. English folk melodies, instrumental excerpts from TV programs
48: 6 Tunisian songs: *Maftoun, Ya Kassi, Ain, Ya meziana, Sultan, Aghrab,* plus 6 French songs, specified above
60: Early infant sounds by Italian and Moroccan babies

„„

Animal sounds: **2** 30 42

30: Monkey communication (Coo sounds)
42: Bird songs

Environmental sounds: **0**

Cultural references NM II 2005

The Neurosciences and Music II – Conference 2005: From Perception to Performance

Ethology / Evolution 1-5
Music and language 6-10
Mental representations 11-19
Development 20-27
Music therapy 28-31
Disorders 32-35
Performance 36-43
Emotion 44-53

Cultural references		**Papers no.**
Neutral or not indicated:	**25**	1 2 3 4 5 8 9 15 16 19 27 28 29 30 31 34 35 36 37 38 40 41 42 43 44
Western major-minor:	**28**	6 7 10 11 12 13 14 17 18 20 21 22 23 24 25 26 32 33 39 45 46 47 48 49 50 51 52 53

Specified music:
12: Schubert: *Piano trio*, excerpt
17: Mozart: *Sonata facile*
20: Mozart: *String Quintet in D major K. 593,* last movement 10 min.
46: Twenty-seven classical excerpts, specified in Bigand et al. (2005)
47: Thirty J.S. Bach *piano pieces*
49: Mahler: *Symphony no. 2, 4th movement "Urlicht",* three excerpts
52: Six Bach *chorales* containing unexpected harmonies
53: Stravinsky: *Clarinet piece*

Western popular: **4** 13 20 46 49

Specified music:
13: Favorite CDs, self-selected, not specified
20: Blur: *Country House.* Mark Morrison: *Return of the Mack.* PJ & Duncan: *Stepping Stone*
46: Pop/rock, not specified
49: 7 Different musical styles: Mozart, Bach, Pop music, Film music, Cello-Rockband, Death Metal, and Bossa Nova.

Western traditional: **0**

Western non-tonal: **0**

Cross-cultural: **0**

Animal sounds: **2** 2 3

2: Songs of whales, seals, and birds
3: Songs of birds, whales, dolphins, and seals. Ape drumming

Environmental sounds: **0**

Cultural references NM III 2008

The Neurosciences and Music III – Conference 2008: Disorders and Plasticity

Rhythm 1-9	Singing 10-15	Training 16-30	Memory 31-42
Emotions 43-55	Recovery 56-65	Music, language, motor 66-76	Cochlear implants 77-79

Cultural references **Papers no.**

Neutral or not indicated: **28** 1 2 3 4 5 6 7 8 14 15 16 26 28 30 37 38 40 43 55 57 59 60 63 66 67 69 74 76

Western major-minor: **40** 10 11 12 13 17 18 20 21 22 23 24 25 27 29 31 32 33 34 35 36 39 41 42 44 45 46 47 48 49 50 51 52 53 54 58 61 62 64 65 68

Specified music:
19: Excerpts from Bach *Partitas.* Excerpts of *Symphonies* by J. Stamitz and G.B. Sammartini
33: Familiar excerpts: Bach, Rossini, Mozart, Brahms, Dvorak, Ravel, Shostakovitch, Bizet, Schubert, Strauss.
Unfamiliar excerpts: Söderman, Olson, Rebel, Berwald, Kraus, Bengtsson, Norman, Scriabin, Beethoven, Alfvén.
Training items: Wagner, Mendelssohn, Schmelzer, Rubenson.
51: Mozart: From *Requiem: Lacrimosa, Rex Tremendae, Confutatis, Tuba Mirum, Dies Irae.*
Bach: *Motet, Unser Leben ist Schatten.* Puccini: *Requiem.*
46, 62: Music selected by participants

Western popular: **11** 9 31 34 44 46 47 49 54 62 73 78

Specified music:
9: Variants of a rhythmic rock pattern.
31: Popular music 1935-1994.
73: Three excerpts from Drum and Bass, Folk, Jazz
78: TV theme songs
46, 62: Music selected by participants

Western traditional: **1** 62

62: Music selected by participants

Western non-tonal: **1** 56

56: Excerpts from *piano pieces* by Arnold Schönberg and Anton Webern

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Cross-cultural: **4** 19 71 78 79

19: Western: Excerpts of J. Stamitz and G.B. Sammartini. Indian: Excerpts of N. Banerjee and U.R. Shkan
71: Words spoken in a tonal language, Mandarin Chinese. Four tone contours; level, mid-rising, dipping, high-falling.
78: Western and Japanese *TV theme songs*
79: Mandarin Chinese language: Three tone contours; level, rising, and dipping

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Animal sounds: **0**

Environmental sounds: **0**

Cultural references NM IV 2011

The Neurosciences and Music IV – Conference 2011: Learning and Memory

Experimental methods 1-4
Social / real world methods 5-8
Rhythm and meter 9-11
Language processing 12-15
Cultural neuroscience 16-20
Music performance 21-25
Musical imagery 26-29
Plasticity and malplasticity 30-34
Stroke rehabilitation 35-39
Window into autism 40-42
Musical disorders 43-46
Neurodynamics 47

Cultural references **Papers no. (a paper may indicate several cultural references)**

Neutral or not indicated: **14** 1 2 4 9 12 13 14 15 21 23 30 31 34 42

Western major-minor: **24** 2 3 5 16 17 18 22 24 25 26 27 28 32 33 35 36 37 39 40 41 43 44 46 47

Specified music:
6: Saint-Saëns: *The Carnival of the Animals*
16: Thomas Attwood: (1765-1838): *Sonatina.* Chopin: *Waltz op. 69 no. 1*
24: Novel pieces in 4/4 meter, conforming to the conventions of Western polyphonic music
25: J.S.Bach: *The Well-tempered Clavier Part 1, Preludes V, VI and IX.* Haydn: *Piano Sonata no. 52 in Eb major*
26: First minute of Beethoven: *5th Symphony.* Tchaikovsky: *Waltz of the Flowers.*
Mozart: *Allegro from Eine kleine Nachtmusik*
32. Mozart: *Sonata facile*
33: Self-chosen, enjoyable music
36: Pleasant music selected by the patient

Western popular: **9** 7 10 17 29 33 35 38 40 43

Specified music:
10: Variants of a rhythmic rock pattern.
29: *"White Christmas"* and *Theme from "Pink Panther"*
33: Self-chosen, enjoyable music
35: Pleasant music selected by the patient
38: Participant-selected music
43: *"Gens du pays"* (Canada), *"Brother John", "Jingle Bells", "Sto lat"* (Poland)

Western traditional: **2** 19 29
19: European folk song excerpts
29: *Greensleeves*

Western non-tonal: **2** 16 45
16: Atonal version of Thomas Atwood: *Sonatina*
45: Electronic melodies, based on a new musical system, which uses a 3:1 ratio instead of the 2:1 octave

Cross-cultural: **5** 6 8 11 19 20

6: Western and Latin American music for symphony orchestra and choruses
8: North Ugandan dances. A West African folk song. An old Arab song *"Zeyn al Abidin".* Novel songs in Thai scales
11: Non-isochronous Balkan dance music
19: European folk song excerpts. Melodic improvised introductions to North Indian ragas
20: Western: Excerpts of J. Stamitz and G.B. Sammartini. Indian: Excerpts of N. Banerjee and U.R. Shkan

Animal sounds: **0**
Environmental sounds: **1** 40

Cultural references NM V 2014

The Neurosciences and Music V – Conference 2014: Cognitive Stimulation and Rehabilitation

Keynote address 1
Rhythm and language 2-3
Temporal expectations 4-5
The beat 7-9
Moving on the beat 10-13
Movement coordination 14-17
Dance and the brain 18-19
Musical expertise 20-23
Music and infants' well-being 24-25
Music and emotion 26-28
Music cognition in dementia 29-32
Musical applications 33-34

Cultural references **Papers no. (a paper may indicate several cultural references)**

Neutral or not indicated: **7** 2 4 13 14 16 17 22

Western major-minor: **17** 3 5 7 9 10 11 20 21 26 27 28 29 30 31 32 33 34

Specified music:
5: A *Bach solo sonata for violin*
9: Thomas Koschat: *Schneewalzer*
27: Purcell: *Dido's lament*
28: Twenty-seven excerpts of classical music, including 20th century composers. See table p.
29: Excerpts of familiar melodies, e.g. *Silent Night* and *Blue Danube*.

Western popular: **11** 1 6 7 8 12 15 18 27 29 32 33

Specified music:
7: The Beatles: *Twist and Shout*
8: Twenty-six high-groove and low-groove music clips. See table p.
15: High-groove and low-groove music clips
18: Eight dance sequences from the game *Dance Central 2*
27: Pharrell Williams: *Happy*
29: Excerpts of familiar melodies, e.g. *Happy Birthday* and *Pop goes the Weasel.*

Western traditional: **1** 11

11: A German folk song without lyrics

Western 20th Century **1** 28
Bela Bartok: *Piano Sonata.* Gustav Holst: *The Planets.* Charles Ives: *The Unanswered Question.*
György Kurtag: String Quartet op. 1. Bohuslav Martinu: *String Quartet no. 3.*
Arvo Pärt: *Cantus in memoriam Benjamin Britten.* Arvo Pärt: *Fratres for 12 violoncelli.*
Dimitri Shostakovich: *String Quartet no. 8.* See table p.

Cross-cultural: **4** 19 23 24 25

19: Reviewed studies include *Classical ballet, Tango, Brazilian Capoeira dance*, and *dance video games.*
23: A reviewed study includes *Western and Indian classical music.*
24: Studies include *parent-preferred lullabies from different cultures.*
25: Studies include *play songs and lullabies from different cultures.*

Animal sounds: **0**
Environmental sounds: **1** 21

Cultural references NM VI 2017

The Neurosciences and Music VI – Conference 2017: Music, Sound and Health

Perspectives 1-6 Concise Review 7 Reviews 8-17
Concise Original Report 18 Original Articles 19-41

Cultural references **Papers no. (a paper may indicate several cultural references)**

Neutral or not indicated: **14** 1 3 4 12 16 18 21 23 27 28 32 33 36 38

Western major-minor: **20** 5 6 8 9 10 11 13 14 17 19 22 24 26 29 30 31 34 35 37 39

Specified music:
10: Self-selected songs and melodies in parental singing
14: Jazz and classical improvisations, memorized novel melodies, improvised freestyle rap
22: A Suzuki violin lesson program
29: Novel melodies composed to be simple
30: Mozart's *Turkish March* and highly familiar military marches
37: A chorale harmonized by J.S. Bach. Schubert: *Octet for Strings and Winds in F major.* English hymns.
Couperin: *Prélude non mesuré No. 7.*
39: J.S. Bach: *Air on the G string.* Arvo Pärt: *Spiegel im Spiegel.*

Western popular: **12** 2 6 8 11 14 17 19 24 26 31 34 39

Specified music:
2: 34 syncopated drum patterns transcribed from real funk tracks, plus 16 patterns constructed for the experiment
14: Jazz and classical improvisations, memorized novel melodies, improvised freestyle rap
39: Stevie Wonder: *Superstition.* Benny Goodman: *Sing sing sing.* Loreena McKennit: *Full circle.* Brian Setzer: *The dirty boogie.*
The sound stylistics: *Big pieces.* The Innocent Mission: *What a wonderful world.*

Western traditional: **2** 10 25
10: Finnish children and folk songs, and self-selected songs and melodies
25: The melody *Frère Jacques ("Brother John")*

Western 20th Century **1** 39
39: Arvo Pärt: *Spiegel im Spiegel.*

Cross-cultural and divergent genres: **9** 7 14 15 19 20 37 39 40 41
Specified music:
14: Jazz and classical improvisations, freestyle rap, see above
15: Classical music, playschool music, Heavy metal, Latin American music
19: Western: Rimsky-Korsakov: *Flight of the Bumble Bee.* Vivaldi: *Spring, from The Four Seasons*
Western popular: Black Dawn: *Sound of an Angel.* Alan Menken: *Beauty and the Beast.* K.A. and R Lopez: *Let it Go.*
Twelve songs in Mandarin Chinese, Taiwanese and Japanese by Tao, Tsai, Hsiao, Huang, Jiang, Wang, Qu, Ye and Li
20: Astor Piazzolla: *Libertango,* Patrick Roux: *Comme un Tango*
37: German and Chinese folk songs
39: Popular music, jazz and classical music, see above

Animal sounds: **2** 5 9
5 and 9: Zebra Finch song

Environmental and other sounds: **2** 32 41
32: Instrumental emotional bursts and short vocal affect bursts on the vowel "a", expressing *happiness, sadness, fear, and neutral*
41: Environmental sounds, e.g. *siren and water drops.* Human nonspeech sounds, e.g. *coughing and laughing*