Strong musical experiences and the brain

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Music, Mind and Medicine:
Creativity and Consciousness in Medical Care

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Strong experiences with music that people relate to and cherish

- **Music-evoked autobiographical memories**
  - A vehicle for nostalgia and other life-affirming thoughts and emotions
  - Individuals with Alzheimer’s disease remain very responsive to music from their past

- **The feeling of being “in the groove”**
  - The urge to move with the music
  - A sense of “being one” with the music or with others with whom one is interacting during a musical experience
Our experiences with music involve many processes

- Multiple brain areas are expected to be involved and interacting, e.g. when experiencing a music-evoked autobiographical memory.
  - **Perception** - hearing the music
  - **Action** - singing along, forming expectations
  - **Visual** - mental images accompanying memories or thoughts evoked by the music
  - **Memory** - retrieval of memory content
  - **Emotion** - nostalgia; enjoyment of a specific piece or a particular genre
Two principles of functional brain organization

- **Principle 1**: The brain is organized to support perception/action cycles
- **Principle 2**: Complementary networks for orienting attention
Perception - Action Cycles

**Attention**
- Listening for a specific melody or sound; guiding expectations and movements
- Overt movements: swaying, clapping, singing
- Covert movements: expecting specific notes, words, and sounds; singing along

**Perception**
- Hearing the music
- Feeling movements

**Action**
- Remembering the melody and words; autobiographical memories

**Memory**
Principle 1: The brain is organized to support perception/action cycles

Fuster (2004) TICS
Principle 2: Complementary networks for orienting attention

Endo-orienting
attention to the self

Exo-orienting
attention to the environment

based on Fox (2005) PNAS
Hypothesis

- Music, memories, and emotions are linked in the **medial prefrontal cortex** (MPFC).
MPFC tracks music’s movement through tonal space

Activation of MPFC in music studies

Parametric variation of consonance


Plailly et al (2007) Cerebral Cortex
The medial prefrontal cortex and Alzheimer’s disease

- Spared musical abilities in severely demented Alzheimer’s patients
  
  - Cuddy & Duffin (2005) Medical Hypotheses

- Slower atrophy of MPFC over the course of Alzheimer’s disease

Thompson et al. (2003) J. Neuroscience
Music-evoked autobiographical memories

- **Stimulus selection**
  - Thirty 30s excerpts from Billboard Pop and R&B charts chosen randomly from period when subject was 7–19 years old.

- **Subject responses**
  - Familiarity, autobiographical salience, valence, visual image salience
  - Weakly and strongly autobiographical ratings are followed-up with several forms and open-ended response options.
Some of the follow-up questions

- Does it remind you of a specific ...
  - event?
  - person?
  - period in your life?
- Does it have emotions associated with it?
  - What emotions?
  - How strongly did you just experience them?
- Subjects also provide written descriptions as they see fit.
On average, 50% of the songs are unfamiliar

On average, 30% of the songs evoke some sort of autobiographical memory
Some memories are detailed ...

- Subject 02wgw86111 - “Pony” by Ginuwine
  - “This was a popular song during the summer when I was in the fourth or fifth grade. It just reminded me of the park where I spent most of my summer.”

- Subject 07coa84091 - “The First Time” by Surface
  - “This is my best friend’s favorite song. A group of girls and I were going to Las Vegas and started playing this song. Immediately, my best friend broke into song and we followed right after. We really got into it and pretended we were all singing into microphones and performing to a crowd. We were all laughing and having a good time.”

- Subject 10hhj86291 - “Awnaw” by Nappy Roots
  - “friend from high school in the car at a specific intersection of Diablo Blvd and Novato Blvd in Novato, Ca waiting at a red light."

- Subject 05mnh85301 - “Move Ya Body” by Nina Sky
  - “this song reminds me of the first time as a freshmen in college I went to my first night club. I could clearly see a picture of the club in my mind.”
A brief comment about neuroimaging methods

MRI scanner
Analyzing fMRI data

- For each location in the brain, the blood oxygen level dependent (BOLD) signal is correlated with a model of the task, stimulus, and subject responses.
- The correlation is assessed for statistical significance. Pairs of conditions may be compared.
- Statistical maps are rendered using a color scale on an image of the brain.
Multiple regression model for fMRI experiment (N=13)

Subject 4

Constant
Affective Valence
Familiarity
Autobiographical Salience
Question/Answer Period
Music Playing

Subject 1

Constant
Affective Valence
Familiarity
Autobiographical Salience
Question/Answer Period
Music Playing

Music On
- Familiar
- Pleasing
- Strong Memory

Music Off
- Neutral Emotion
- Weak Memory

Unfamiliar
- Displeasing
- No Memory
Hearing music
Responding to questions

Medial Prefrontal Cortex
(autobiographical memory; emotion)

Auditory Cortex
(basic hearing)

Auditory Cortex
(basic hearing)

Janata (2009) Cerebral Cortex
Familiar, Autobiographical, Pleasing

- Widespread activation of sensorimotor areas when hearing familiar music

Janata (2009) *Cerebral Cortex*
Familiar, Autobiographical, Pleasing

- Widespread activation of sensorimotor areas when hearing familiar music

Broca’s Area (language production, articulation)

Janata (2009) Cerebral Cortex
Familiar, Autobiographical, Pleasing

Janata (2009) Cerebral Cortex
Familiar, Autobiographical, Pleasing

Janata (2009) Cerebral Cortex
Functions of the MPFC

Van Overwalle (2009) *Human Brain Mapping*
Emotion circuit meta-analysis (N=162 studies)

Can we find a tighter link between music and memories?

- The goal is to identify brain regions that follow pieces of music as they move through tonal space while people listen to the music and experience memories.
- Because the music is the soundtrack for the mental movie that’s playing in the mind, one can try to use a model of the structure of that soundtrack to get at the memories, thoughts, images, and emotions that are being experienced as one listens.
Western tonal music relies on tonal contexts

- **Tonality and keys**
  - e.g. G-major, D-major, b-minor
  - sets of notes (pitch classes) named after the most perceptually “stable” note (tonic or tonal center)

![Diagram of piano keys showing pitch classes and major keys](image-url)
Tonal space

Music theory

Circle of Fifths

Cognitive psychology

Multi-dimensional scaling solution for matrix of subjective distances between key contexts and probe tones

Krumhansl & Kessler (1982) Psychological Review
A toroidal representation of major/minor key relationships

- The torus is a construct that simultaneously reflects music theory, cognitive psychology, and a parsimonious organization of the pitch statistics of Western tonal music.

Krumhansl (1990)
A piece of music creates a pattern of activation on the torus that changes through time.

Thus, the changing pattern is a signature of the piece of music.
“The Girl from Ipanema” - A.C. Jobim
Tonality tracking model for songs
Tonality tracking responses

Auditory Cortex (basic hearing)

Auditory Cortex (basic hearing)

Lateral Prefrontal Cortex (episodic sequencing)

Visual Cortex (visual imagery)

Premotor Cortex (auditory imagery; covert singing)

Auditory Cortex (basic hearing)

Medial Prefrontal Cortex (MPFC) (autobiographical memory; emotion)

Ventrolateral Prefrontal Cortex (structural integration)

based on Janata (2009) Cerebral Cortex
Tonality tracking in the MPFC is biased toward memory-evoking music.

Based on Janata (2009) Cerebral Cortex.
Tonality tracking in the MPFC is biased toward memory-evoking music based on Janata (2009) Cerebral Cortex.
Tonality tracking in the MPFC is biased toward memory-evoking music based on Janata (2009) Cerebral Cortex
Pretty good support for the hypothesis that ...

- music, memories, and emotions are linked in the **medial prefrontal cortex** (MPFC).
The importance of the individual

- Music is an interactive and social phenomenon, as well as a private personal phenomenon.
- When considering strong experiences that people have with music, it makes sense to look for basic principles that are common across a group of individuals, but one must also respect individual differences.
- This poses an extra challenge when studying the neuroscience of music.
Individual differences ...

Familiar, Autobiographical, Pleasing

Tonality Tracking
Can extensive exposure to customized music programming reduce symptoms of agitation and depression in individuals with Alzheimer’s dementia?
Disclosure

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Study design

- Assisted living (memory care) facility
- 16-week randomized controlled trial
  - Music treatment group
    - customized music programming streamed to room 4x/day
  - Control group
    - no music streamed to room
Music intervention

- Customized playlists designed by Coro Health based on age, past listening history, preferred genres, activities of daily living, etc.

- Time-of-day considerations
  - 4 programs/day
    - 6 – 8:30 AM (~30 minutes)
    - 9 – 11 AM (~60 minutes)
    - 2 – 4 PM (~60 minutes)
    - 7 – 10:30 PM (~30 minutes)
Assessments

- Structured interviews with caregivers
  - Interviewers blind to group assignment of participants
  - 6–9 minute sessions using iPads and Ensemble, a web-based data collection system
- Collected 2x/day (AM shift, PM shift)
- Weekly measures
  - Neuropsychiatric Inventory (NPI)
  - Cornell Scale for Depression in Dementia (CSDD)
  - Cohen-Mansfield Agitation Inventory (CMAI)
- Daily measure (PM shift)
  - Sundowning Inventory
Cornell Depression Scale

Figure 1

Intervention Post | Pre | AM | PM
---|-----|-----|-----
 indirect | direct

Janata (2012) *Music and Medicine*
Scale scores before vs during

Neuropsychiatric Inventory
Cornell Depression Scale
Cohen-Mansfield Agitation

AM
PM

Baseline
Baseline
Baseline

Janata (2012) Music and Medicine
Many thanks to ... 

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Spiritual experiences with music
Items from the Mystical Experiences Questionnaire

● Internal unity
  ○ Loss of your usual identity
  ○ Experience of the fusion of your personal self into a larger whole
  ○ Experience of unity with ultimate reality

● External unity
  ○ Experience of oneness or unity with objects and/or persons perceived in your surroundings

● Transcendence of time and space
  ○ Experience of timelessness
  ○ Loss of usual awareness of where you were

● Ineffability and paradoxicality
  ○ Sense that the experience cannot be described adequately in words
  ○ Experience of a paradoxical awareness that two apparently opposite principles or situations are both true
Listening to self-selected spiritual music

- 24 participants selected from 6 target groups that varied in religious/spiritual traditions:
  - Christian (5)
  - Jewish (3)
  - Hindu (3)
  - Yoruba (2)
  - Rave (5)
  - Jam Band (6)

- Age
  - 26 – 80 y
  - Mean ± SD: 44.1 ± 13.6 y

- Gender
  - 10 female
  - 14 male

with Robin Sylvan
Stimulus selection challenges (1)

- What’s spiritual music for one person need not be spiritual for another.
  - Participants may not even like other participants’ spiritual music selections
Stimulus selection challenges (2)

- Need to balance stimuli presented to any given subject on each of the relevant dimensions
  - spiritual salience
  - autobiographical salience
  - valence
  - urge to move
Stimulus selection challenges (3)

<table>
<thead>
<tr>
<th>Need to have sufficiently long excerpts for strong responses/experiences to develop</th>
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<tbody>
<tr>
<td>Need to have a sufficient number of stimuli to achieve balance on the different dimensions</td>
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Stimulus selection

- Each participant identified 1–3 pieces of music that had specific spiritual meaning to them
- 2 min excerpts were extracted and confirmed by the participant to be suitable
- Prescreening library
  - 30 s excerpts extracted from 2 min excerpts
Stimulus prescreening

- Each 30 s excerpt was rated on six 5-point scales:
  - I felt the **urge to move**. (Disagree strongly, Disagree a little, Neither agree nor disagree, Agree a little, Agree strongly)
  - How much did you **enjoy** what was just played? (1 = not at all; 5 = very much)
  - How **familiar** are you with the piece of music you just heard? (Not at all, Weakly, Moderately, Strongly, Extremely)
  - How **aroused** were you by the piece of music you just heard? (Not at all, Weakly, Moderately, Strongly, Extremely)
  - How **autobiographically salient** is the music you just heard for you? (Not at all, Weakly, Moderately, Strongly, Extremely)
  - How **likely** do you think it is that you would have a **spiritual/mystical experience** if listening to a longer version of this piece? (Extremely unlikely, Somewhat unlikely, Neither likely nor unlikely, Somewhat likely, Extremely Likely)
Stimulus counterbalancing

- Stimuli in the MRI scanner: 14 two-minute excerpts
  - self-selected spiritual excerpt (2x)
  - self-selected autobiographical but not spiritual
  - in-group displeasing
  - maximally pleasing from each of 5 other groups
  - maximally displeasing from each of 5 other groups
Music listening response across all excerpts

- Response in this group of listeners is more extensive than usual.
- Recruitment of premotor and subcortical structures such as the basal ganglia

Janata et al. (in prep)
The temporo-parietal junction (TPJ) and self-transcendence

Self-selected spiritual > All other excerpts

Unilateral lesions of the TPJ increase self-transcendence

“Self-transcendence reflects the enduring tendency to transcend contingent sensorimotor representations and to identify the self as an integral part of the universe as a whole.”

Janata et al. (in prep)

Modulation of brain areas by strength of external unity

Modulation of response to self-selected stimuli by degree of external unity experienced with that stimulus

Co-modulation with the temporo-parietal junction (TPJ) as a function of experienced external unity

Janata et al. (in prep)
Tonality-tracking is biased toward self-selected spiritual music

Janata et al. (in prep)
Tonality-tracking is biased toward self-selected spiritual music

Janata et al. (in prep)
In search of neural correlates of being in the groove

- Perception/action coupling
  - fluid functioning of a perception/action cycle
  - optimally distributed attention
- Joint-action with one or more entities (music, others)
- Experienced difficulty of the joint-action
- Positive affect (associated with the sense of unity) arising from seamless joint-action
Synchronization leads to greater subsequent cooperation

Entrainment and the brain

Fairhurst, Janata & Keller (2012) Cerebral Cortex
Synchronizing with an adaptive metronome (virtual partner)

\[ \alpha = 0; 0.25; 0.5; 0.75; 1 \]

\[ t_{\text{tone}_n + 1} = t_{\text{tone}_n} + 500 \text{ ms} + (\alpha \times \text{async}_n) \]

Fairhurst, Janata & Keller (2012) Cerebral Cortex
Standard deviation of asynchrony varies with partner adaptivity

Fairhurst, Janata & Keller (2012) Cerebral Cortex
Variation in brain activity as a function of VP adaptivity

Fairhurst, Janata & Keller (2012) Cerebral Cortex
The big picture

High SD asynchrony: "out of sync"
- SFG
- anterior insula
- premotor
- TPJ
- IFG

Low SD asynchrony: "in sync"
- SMA
- posterior cingulate
- vmPFC
- S1
- hippocampus

Cognitive Control
Exo-orienting

Default-mode
Endo-orienting

Fairhurst, Janata & Keller (2012) Cerebral Cortex

Adapted from Fox et al. (2005)
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