MUSIC, LANGUAGE, INTELLIGENCE AND THE BRAIN:

THEORY, RESEARCH FINDINGS AND PRACTICAL APPLICATIONS FOR EARLY INTERVENTION

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How We Hear

1. Auditory canal amplifies sound waves.
2. Eardrum vibrates.
3. Bones in middle ear vibrate, intensifying sound.
4. Hair cells in spiral organ convert vibration into electrical signals.

Sound waves are converted in the ear to nerve impulses that are carried to the brain’s auditory center.
Comparison of the Frequency and Intensity of Various Environmental and Speech Sounds

Frequencies in Cycles Per Second

Hearing Loss in Decibels
Area of Audibility

- **Auditory area**
- **Threshold of feeling**
  - **Music**: 50-8,500 Hz; 75 dB
  - **Speech**: 170-4,000 Hz; 42 dB

- **Sound-pressure level - dB**
- **Frequency - Hz**

A: Threshold of hearing
B: Area of audibility
Audible frequency range of various instruments & voices
Language & Music: Similarities 101

A. Characteristic to human species that seem to be universal to all humans and specific to humans:
   1. Universal: humans have a general capacity to acquire linguistic and musical competence
   2. Specific: no parallel in animal world

B. Capable of generating an unlimited number of novel sequences
C. Children seem to have a natural ability to learn the rules of language & music through exposure to examples

1. ±1 to ±2 years of age: Spontaneous speech and spontaneous singing are first exhibited around the same age
2. ±2 to ±5 years of age: Language develops through intermediate forms of grammar
3. ±5 years of age: Adult grammar
D. Natural medium for both is Auditory-Vocal (Aud-Voc)

1. Both are primarily received as sequences of sounds and produced as sequences of vocal movements which create sounds

2. Many neural mechanisms for analyzing input and producing output must be shared

3. Most universal of all musical forms is the SONG: words & music are intimately combined
Language & Music: Similarities 104

E. Although Aud-Voc mode is primary, many cultures have developed written form

1. Notational system using written symbols in visual form to convey message
2. Message is retrieved and decoded by receiver
3. Reading & writing is usually taught after person is competent user of Aud-Voc mode
4. Acquisition of literacy profoundly alters cognitive functioning
小燕子

小燕子穿花衣，年年春天来这里。我问燕子你为啥来，燕子说，这里的春天最美丽。小燕子，告诉我，今年这里更美丽。我们盖起了大工厂，装上了新机器，欢迎你长期住在这里。
(mantener un pulso regular y constante)
(no cortar la emisión del sonido anexado)
Teclado en relieve
Tactofonía de Aschero para ciegos:

Escritura en relieve

Los puntos indican la altura del sonido
Language & Music: Similarities 105

F. Receptive skills precede productive skills in development

G. Forms taken by natural language & natural music differ across cultures, but some universal features constrain these forms

1. Native English speaker cannot understand Chinese

2. Role of Language: to express thought
Language & Music: Similarities 106

H. Language & Music are both comprised of 3 components:
1. Phonology: way of characterizing the basic ‘sound’ units
2. Syntax: rules governing the way in which ‘sound’ units are combined
3. Semantics: way in which meaning is assigned to ‘sound’ sequences
<table>
<thead>
<tr>
<th>Phonology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Language</strong></td>
</tr>
<tr>
<td>- Phonemes: c-a-t</td>
</tr>
<tr>
<td>- Can be thought of certain sound patterns, with certain frequency and duration parameters</td>
</tr>
<tr>
<td>- Specific cultures have specific sound patterns</td>
</tr>
<tr>
<td>- Produced by characteristic combination of lip, tongue and vocal chord motion</td>
</tr>
<tr>
<td><strong>Music</strong></td>
</tr>
<tr>
<td>- Note: do-re-mi or C-D-E</td>
</tr>
<tr>
<td>- Characterized by frequency and duration parameters – these parameters tend to be broader in music than language</td>
</tr>
<tr>
<td>- Different cultures choose different subsets of possible notes for their music (ie. Pentatonic scale)</td>
</tr>
<tr>
<td>- Produced by vocal, body or instruments</td>
</tr>
</tbody>
</table>
Syntax

<table>
<thead>
<tr>
<th>Language</th>
<th>Music</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grammar</strong></td>
<td><strong>Grammar</strong></td>
</tr>
<tr>
<td>• Structural unit: ie. Agent + active verb + recipient</td>
<td>• Structural unit: Musical phrase</td>
</tr>
<tr>
<td>• Prominence contour: assign stress, timing, intonation to a sentence</td>
<td>• Prominence contour: chords and duration</td>
</tr>
<tr>
<td></td>
<td>○ Harmony, tonality</td>
</tr>
<tr>
<td></td>
<td>○ Rhythm, meter</td>
</tr>
<tr>
<td></td>
<td>○ Melody</td>
</tr>
<tr>
<td></td>
<td>○ Repetition</td>
</tr>
<tr>
<td><strong>Recipient/Listener can sort utterance into acceptable &amp; unacceptable categories:</strong> culture &amp; period specific</td>
<td><strong>Acceptable &amp; unacceptable music:</strong> culture &amp; period specific</td>
</tr>
</tbody>
</table>
Semantics

**Language**

- Individual word meanings: lexical semantics
- Word meanings in combination: compositional semantics

**Music**

- Musical meaning – 4 aspects:
  - Emerging from mimicry
  - Arising from suggestion of a particular mood
  - Resulting from extra-musical associations (i.e., national anthem)
  - Attributed to interplay of formal structures in creating patterns of tension and resolution
## Developmental Sequence

<table>
<thead>
<tr>
<th>Language</th>
<th>Music</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Turns towards source of sound</td>
<td>- Turns towards source of sound</td>
</tr>
<tr>
<td>- Babbling</td>
<td>- 1&lt;sup&gt;st&lt;/sup&gt; signs of intentional music-like behavior: mimic the intonational contours of speech – microtonal pitch glides</td>
</tr>
<tr>
<td>- Use of suprasegmentals to convey meaning (ie. displeasure, question, etc)</td>
<td>±18 mos: discrete pitch intervals; beginnings of spontaneous singing</td>
</tr>
<tr>
<td>- Syllabic approximation</td>
<td></td>
</tr>
<tr>
<td>- Jargoning &amp; 1&lt;sup&gt;st&lt;/sup&gt; words: made-up or approx. of true words</td>
<td></td>
</tr>
</tbody>
</table>
Mary Had a Little Lamb

Mary had a little lamb,
Little lamb,
Little lamb,
Mary had a little lamb
It’s fleece as white as snow
## Fundamental Building Blocks

<table>
<thead>
<tr>
<th>Language</th>
<th>Music</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Duration</strong> (rhythm)</td>
<td>Tone (what you hear) or Note (what you see written in musical score)</td>
</tr>
<tr>
<td><strong>Intensity</strong> (stress)</td>
<td>Pitch</td>
</tr>
<tr>
<td><strong>Pitch</strong> (Intonation)</td>
<td>Rhythm: duration of notes/pauses</td>
</tr>
<tr>
<td><strong>D.I.P.</strong></td>
<td>Tempo: speed</td>
</tr>
<tr>
<td></td>
<td>Contour: shape of melody – “up” or “down”</td>
</tr>
<tr>
<td></td>
<td>Timbre: piano vs. saxophone</td>
</tr>
<tr>
<td></td>
<td>Loudness/dynamics</td>
</tr>
<tr>
<td></td>
<td>Spatial location: direction of sound source</td>
</tr>
<tr>
<td></td>
<td>Reverberation</td>
</tr>
</tbody>
</table>
John Jacob Jingleheimer Schmidt
His name is my name, too
Whenever we go out, the people always shout
There goes John Jacob Jingleheimer Schmidt
DA-DA-DA DA-DA-DA-DA-DA

Suggestions:
- Repeat softer each time, with very loud DA-DA-DA
- Hunch down a little bit more as song grows softer; stand straight again for DA-DA-DA
Ô Man Chê Chê

Ô man chê chê (echo)
Chê chê co lê (echo)
Che co lisa (echo)
Lisa lisa manga (echo)

Suggestion:
- Every person that goes to the center of the circle sings in a different way and does different motions while all others imitate.
The Grammars of Music and Language

<table>
<thead>
<tr>
<th>Language</th>
<th>Music</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phoneme: d-o</td>
<td>Note</td>
</tr>
<tr>
<td>Morpheme: smallest linguistic unit that has</td>
<td>Motif: short rhythmic or melodic passage that</td>
</tr>
<tr>
<td>semantic meaning (ie. un-; dis-; -s/-es;)</td>
<td>is repeated or evoked in various parts of a</td>
</tr>
<tr>
<td>Word</td>
<td>composition</td>
</tr>
<tr>
<td>Clause</td>
<td>Phrase</td>
</tr>
<tr>
<td>Sentence</td>
<td>Section</td>
</tr>
<tr>
<td>Piece</td>
<td>Movement</td>
</tr>
<tr>
<td></td>
<td>Piece</td>
</tr>
</tbody>
</table>

A Whole New World
From Walt Disney’s Aladdin

Music by ALAN MENKEN
Lyrics by TIM RICE

Sweetly
ALADDIN:

G/B A/C# Em/G F7 F7/A# Bm Bm/A

I can show you the world, shining, shimmering,
splendid. Tell me princess, now when did you last

G D A7 D

let your heart decide? I can open your

D/F# A D/F# G D/F# G

No one to tell us no or where to go or
Nesta Rua

Nesta rua, nesta rua tem um bosque
Que se chama, que se chama Solidão
Dentro dele, dentro dele mora um anjo
Que roubou, que roubou meu coração

Se eu roubei, se eu roubei teu coração
É porque tu roubaste o meu também
Se eu roubei, se eu roubei teu coração
É porque, é porque te quero bem

Se esta, se esta rua fosse minha
Eu mandava, eu mandava ladrilhar
Com pedrinhas, com pedrinhas de brilhante
Para o meu, para o meu amor passar
The Brain
# Laterization of Brain Functions

<table>
<thead>
<tr>
<th><strong>Left Hemisphere Functions</strong></th>
<th><strong>Right Hemisphere Functions</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Uses logic</td>
<td>Uses feeling</td>
</tr>
<tr>
<td>Detail oriented</td>
<td>“Big picture” oriented</td>
</tr>
<tr>
<td>Facts rule</td>
<td>Imagination rules</td>
</tr>
<tr>
<td>Rational</td>
<td>Intuitive</td>
</tr>
<tr>
<td>Reality based</td>
<td>Fantasy based</td>
</tr>
<tr>
<td>Safe</td>
<td>Impetuous</td>
</tr>
<tr>
<td>Practical</td>
<td>Risk taking</td>
</tr>
<tr>
<td>Analytical</td>
<td>Holistic synthesizing</td>
</tr>
<tr>
<td>Forms strategies</td>
<td>Presents possibilities</td>
</tr>
<tr>
<td>Order/pattern perception</td>
<td>Spatial perception</td>
</tr>
<tr>
<td>Objective</td>
<td>Subjective</td>
</tr>
<tr>
<td>Language: grammar, vocabulary; literal</td>
<td>Language: prosodic features (intonation, accentuation)</td>
</tr>
</tbody>
</table>
Left and Right Brain Functions

Left-Brain Functions
- Analytic thought
- Logic
- Language
- Science and math

Right-Brain Functions
- Holistic thought
- Intuition
- Creativity
- Art and music

3x + 10 = 46
Language in brain

What happens in brain when you
- read?
- listen to speech?
- speak?

Which brain regions are activated?
In which order and how quickly?
Which areas are connected?

Simplified model of language processing in brain

When you read, listen to speech, or speak, a network of thousands of neurons is activated in your brain. This figure gives an overview of brain regions that have been suggested to participate in various stages of language processing.

Reading text
- "S-N-O-W"
- feature analysis
- individual letters
- whole word
- meaning
- sound form

Understanding speech
- "S-N-O-W"
- acoustic analysis of sound waves
- recognition of speech sounds
- recognition of word form
- meaning

Analysis of speech sounds
- auditory cortex

Feature analysis
- (visual cortex)

Analysis of letter strings

Time after seeing/hearing a word
0,1 s
0,15 s

Meaning

Selection of sound form

Articulation of speech sounds
- 'S-N-O-W'

Speaking
- meaning
- selection of sound form
- syllabification
- articulation of speech sounds

Here is a combination of regions that different brain imaging methods have suggested to participate in analysis of meaning of words.

More info:
- in Finnish
  Hämäläinen, Laine, Aalto
  ja Revonsuo (toim.), 2006
  Miel ja aivot
- in English
  Indefrey ja Levelt,
  Cognition, 2004
  Salem elin, Clinical
  Neuropsychology, 2007
How Music Affects Intelligence 101

- Connections in the brain
  - http://www.loni.ucla.edu/~thompson/DEVEL/5to20_NormalDevelopment.jpg
General Coordination Skills – mental and physical coordination

- Playing drums: Left and Right hand keep different beats
- “Rhythmic auditory cueing has also been shown to be effective in facilitating movements, such as walking, in those with neurological disorders.” (Thaut, 2007 as referenced in Chen et al, 2009)
Music on the mind

When we listen to music, it’s processed in many different areas of our brain. The extent of the brain’s involvement was scarcely imagined until the early nineties, when functional brain imaging became possible. The major computational centres include:

- **CORPUS CALLOSUM**
  Connects left and right hemispheres.

- **MOTOR CORTEX**
  Movement, foot tapping, dancing, and playing an instrument.

- **PREFRONTAL CORTEX**
  Creation of expectations, violation and satisfaction of expectations.

- **NUCLEUS ACCUMBENS**
  Emotional reactions to music.

- **AMYGDALA**
  Emotional reactions to music.

- **SENSORY CORTEX**
  Tactile feedback from playing an instrument and dancing.

- **AUDITORY CORTEX**
  The first stages of listening to sounds. The perception and analysis of tones.

- **HIPPOCAMPUS**
  Memory for music, musical experiences and contexts.

- **VISUAL CORTEX**
  Reading music, looking at a performer’s or one’s own movements.

- **CEREBELLUM**
  Movement such as foot tapping, dancing, and playing an instrument. Also involved in emotional reactions to music.

*Source: This is Your Brain on Music: The Science of a Human Obsession*
How Music Affects Intelligence

- Memory functions
- Language skills
  - Prosody
    - Pitch: “Really?” (question; sarcasm; bored; disbelief)
    - Stress: “I want to dance with you.” (stress different word each time)
- Math skills

![Musical notation images]
Why Should I Sing With My Child?

- Social Intelligence: promotes bonding
- Prosody: Songs & Speech
- Auditory Feedback Loop: hears parent’s voice, modulates own voice
- Lyrics (words in the music): promotes child’s vocabulary, understanding of syntax
- Fingerplays: motor coordination & singing
- Songs can teach specific skills: counting/number concept; days of the week; parts of the body; animal names/sounds; colors; sounds of the alphabet; motor coordination;
1 Little, 2 Little, 3 Little Fingers

One little, two little, three little fingers
Four little, five little, six little fingers
Seven little, eight little, nine little fingers
Ten little fingers on my hand

Suggestions:
- Substitute “fingers” and “fingers on my hand” with other words
- Count backwards: 10 little, 9 little, 8 little...
There Are 7 Days in a Week
(tune of: Oh my darling Clementine)

There are seven days,
There are seven days,
There are seven days in a week. (2x)

Sunday, Monday,
Tuesday, Wednesday,
Thursday, Friday, Saturday. (2x)
Head, Shoulders, Knees and Toes

Head and shoulders, knees and toes
Knees and toes
Head and shoulders, knees and toes
Knees and toes … and …
Eyes and ears and
Mouth and nose …
Head and shoulders, knees and toes
Knees and toes.

Head and shoulders, knees and toes
Knees and toes
Head and shoulders, knees and toes
Knees and toes … and …
Eyes and ears and
Mouth and nose …
Head and shoulders, knees and toes
Knees and toes.
Old MacDonald Had a Farm

Old MacDonald had a farm
E – I – E – I – O

And on his farm he had a **cow**
E – I – E – I – O

With a *moo-moo* here, and a *moo-moo* there

Here a *moo*, there a *moo*

Everywhere a *moo-moo*

Old MacDonald had a farm
E – I – E – I – O
I Wanna Eat, Eat, Eat Apples and Bananas

I wanna eat, eat, eat apples and bananas
I wanna eat, eat, eat apples and bananas
I wanna eat, eat, eat apples and bananas
I wanna eat, eat, eat apples and bananas

I wanna ate, ate, ate (sounds like long a)
I wanna eet, eet, eet (sounds like long e)
I wanna ait, ait, ait (sounds like long i)
I wanna ot, ot, ot (sounds like long o)
I wanna oot, oot, oot (sounds like long oo in moot)
O Mar Estava Sereno

O mar estava sereno, sereno estava o mar
O mar estava sereno, sereno estava o mar
Vamos ver la luna, la luna, la luna (4x)

A mar astava sarana ...
Vamos ver la luna, la luna, la luna (4x)

E mer esteve serene ...

I mir istivi sirini ...

O mor ostovo sorono ...

U mur ustuvu surunu ...
O Carro Do Chefe

O carro do chefe tem um furo no pneu

Colemos com chiclete.

Motions:
- carro : pretend you are driving
- chefe : scout salute
- furo : point index finger down, make /f/ sound index, pull hand upward
- pneu : make 2 “C”s with hand, fingers touch
- chiclete: chewing, tongue click, stretching chewing gum out
Research Findings
Current Research Findings

- Long-term Effects of Auditory Training in Severely or Profoundly Deaf Children

- Music training improves pitch perception in prelingually deafened children with cochlear implants
  - Chen, JK et al. *Pediatrics* 2010 Mar 8

- Musician enhancement for speech-in-noise.

- Musicophilia: through illness or accident we gather information on the functioning of the brain with regards to music perception and production
Perfect Pitch: Language Wins Out Over Genetics
Questions?
Bibliography 101

Bibliography 102

Web Resources

- http://www.aschero.com
- http://implantecoclear.org/congreso1/
- http://www.loni.ucla.edu/~thompson/DEVEL/PR.html
- http://en.citizendium.org/wiki/Musical_semantics
- http://books.google.com/books?id=idx62RIQRUC&pg=PA20&lpg=PA20&dq=nesta+rua+bruce+trinkley&source=bl&ots=B96QofMir_&sig=qypEuiMXtPl6s_jep3aizoU8ofY&hl=en&ei=HJLbS82WLYXStAP8x8zxBg&sa=X&oi=book_result&ct=result&resnum=1&ved=0CAkQ6AEwAA#v=onepage&q=nesta%20rua%20bruce%20trinkley&f=false
- http://images.google.com