From Confession to Profession
The Evolution of Neurologic Music Therapy
MUSIC AS SCIENTIFIC PHILOSOPHY

Boethius (500 AD) – Musica Mundana, Musica Humana, Musica Instrumentalis (De Institutione Musica) – music as part of the Quadrivium of mathematical disciplines (arithmetics, music, geometry, astronomy)
MUSIC: AN ANCIENT COGNITIVE LABORATORY FOR THE EMERGING MODERN HUMAN MIND

BONE FLUTE FROM HOHLE FELS EXCAVATION SITE

SOUTH WEST GERMANY

CONARD ET AL 2009, NATURE 45,000 YEARS OLD
NEW THEORETICAL DEVELOPMENTS IN MUSIC THERAPY AND MUSIC MEDICINE

A PARADIGM SHIFT....

FROM SOCIAL SCIENCE MODELS....
Music for Human Relationship Building and Well Being
Cultural Role and Values of Music to Achieve Therapeutic Response

TO NEUROSCIENCE MODELS....
Music Engages Brain and Behavior Functions
Based on the Neurobiology of Music Perception

DRIVEN BY....
Advances in the Neuroscience of Music
Evidence Based Medicine
GENERAL FRAMEWORK OF PRINCIPLES

1. THE BRAIN SCIENCE OF MUSIC IS THE FOUNDATION FOR NEUROLOGIC MUSIC THERAPY

2. NMT USES THE FUNCTIONAL PERCEPTION OF ALL PROPERTIES OF MUSIC TO RETRAIN BRAIN AND BEHAVIOR FUNCTION:
   - STRUCTURES AND PATTERNS IN MUSIC
   - EXPRESSIVE QUALITIES

4. TRADITIONAL MUSIC THERAPY RELIES ON CULTURAL INTERPRETATIVE MODELS OF MUSIC
WHAT IS NEUROLOGIC MUSIC THERAPY

• NMT is a comprehensive standardized treatment methodology

• NMT consists of 20 techniques in 3 domains: sensorimotor, speech/language, cognition

• Techniques were developed by a panel of experts around clusters of clinical research evidence

• Techniques are defined by diagnostic goal and function of music in training process

• NMT treatment is based on research evidence (best practice standards)

• NMT is firmly integrated in evidence-based medicine (EBM) and principles of motor and cognitive learning

• NMT is reimbursable (CPT:NMT Codes)
FACTS ABOUT NMT

- Certification through NMT Academy
- Over 2500 NMTs Trained since 1999
- 1500 Maintain Certification – 250 Fellows
- 200 Trainees from Other Disciplines
- 25 Countries
- 10 Universities have Fellows on Faculty
- Endorsed by World Federation of Neurologic Rehabilitation and Recognized as One of 20 Specialty Sections
- Academy is Recognized as Advanced Provider BY CBMT and NACC
- WWW.CBRM.COLOSTATE.EDU
THE ADVENT OF NEUROLOGIC MUSIC THERAPY

• FROM A CULTURAL INTERPRETATIVE MODEL OF MUSIC

• TO A FUNCTIONAL PERCEPTUAL MODEL OF MUSIC

• USING MUSICAL STRUCTURE TO RETRAIN AND REEDUCATE THE INJURED BRAIN
NMT RESEARCH OVERVIEW

• Wan et al. 2010. The therapeutic effects of singing in neurologic disorders. Music Perception
NMT RESEARCH REVIEW

• Malcolm et al. 2009. Rhythmic auditory stimulation improves hemiparetic arm kinematics during reaching movements. Topics in Stroke Rehabilitation
• Grau-Sanchez et al. 2013. Plasticity in sensorimotor cortex induced by music-supported therapy in stroke patients. Front Human Neurosci
NMT RESEARCH OVERVIEW

• Thaut et al. 2007. Rhythmic auditory stimulation improves gait more than NDT/Bobath training in near-ambulatory patients early poststroke: a single blind randomized trial. Neurorehab Neural Repair

• Kadivar et al. 2011. Effect of step training and rhythmic auditory stimulation on functional performance in PD. Neurorehab Neural Repair


• Brandt et al. 2012. Music and early language acquisition. Front Psychol
MUSIC PROCESSING INVOLVES CORE COGNITIVE, MOTOR, AND LANGUAGE SYSTEMS OF THE HUMAN BRAIN
DISTINCT NEURAL NETWORKS FOR MUSIC RHYTHM PERCEPTION

THAUT, TRIMARCHI, PARSONS  Proc Soc Neurosci 2009

PATTERN  TEMPO  METER

DURATION

Midbrain

BA 9

BA 47

BA 45/46

BA 9

BA 40
Cortico-Striatal Networks in Music
Seger et al. J Cogn Neurosci 2013
Music Reshapes and Retrains Brain Function

MUSIC PROCESSING INVOLVES DISTRIBUTED HIERARCHICAL NEURAL NETWORKS WHICH INTERFACE ON MULTIPLE LEVELS WITH MOTOR, COGNITIVE AND SPEECH/LANGUAGE NETWORKS OF THE BRAIN.
SHARED NEURAL SYSTEMS THEORY (SNS)

MUSIC AS AN AESTHETIC SENSORY LANGUAGE

Motor Control

Executive Function

Language

Attention

Memory

Music

Shared Neural Systems

MUSIC AS A REHABILITATIVE SENSORY LANGUAGE
MUSIC OPTIMIZES RETRAINING OF SHARED BRAIN FUNCTIONS
Changes in Trajectory CM – Hemiparetic Stroke Gait

Abiru et al 2007, Neurologic Therapeutics
The Ability to Move to a Beat Is Linked to the Consistency of Neural Responses to Sound
Adam Tierney1,2 and Nina Kraus1,2,3,4,5
PD Patient without RAS
PD Patient with RAS
Velocity Changes Pre/Post Test, Follow Ups

McIntosh et al, Movement Disorders 1999

Percent Increase Pre to Post Test

Percent Reduction After Posttest
Dorsiflexion

- Statistically significant interaction between time and continuous vs. intermittent treatment, $F(2.13,38.32)=7.58$, $p=.001$, partial $\eta^2=.296$. 

![Estimated Marginal Means of treatment](image.png)
Velocity

- statistically significant interaction between time and continuous vs. intermittent treatment, $F(3,54)=21.42$, $p<.001$, partial $\eta^2=.543$
# of Falls

- statistically significant interaction between time and continuous vs. intermittent treatment, $F(1.55, 27.89)=6.35$, $p=.01$, partial $\eta^2=.261$
RAS MODIFIES ANKLE DRIVE IN PD PATIENTS WITH HISTORY OF FALLS

- ANKLE ACCELERATION (Degrees/Sec²)
ANGULAR ACCELERATION CHANGES IN ANKLE ANGLE WITH AND WITHOUT RAS
RAS in Prevention of Falling in Parkinson’s Disease
Thaut, Rice, Hurt, Kenyon, McIntosh
Publication In Preparation

- Significant Reduction of Falls During RAS
- Significant Increase in Falls During RAS Withdraw
- Remaining Significant Difference After RAS Resume
- Regression Points to Dorsiflexion Changes and Velocity as Predictors
- Preparatory Angle Changes For Ground Contact During RAS Before Rhythmic Cue, F=ma
Comparison Data for Treatment Duration

Percent Change of Functional Gait Improvement after 6 Weeks Training

<table>
<thead>
<tr>
<th>Measure</th>
<th>RAS Training</th>
<th>NDT / Bobath</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity</td>
<td>164</td>
<td>107</td>
</tr>
<tr>
<td>Stride Length</td>
<td>88</td>
<td>34</td>
</tr>
<tr>
<td>Cadence</td>
<td>56</td>
<td>45</td>
</tr>
<tr>
<td>Symmetry</td>
<td>32</td>
<td>16</td>
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</tbody>
</table>

Thaut, McIntosh, Rice: Journal of Neurological Sciences 1997

Percent Change of Functional Gait Improvement after 3 Weeks Training

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<tr>
<td>Velocity</td>
<td>128</td>
<td>87</td>
</tr>
<tr>
<td>Stride Length</td>
<td>65</td>
<td>46</td>
</tr>
<tr>
<td>Cadence</td>
<td>53</td>
<td>22</td>
</tr>
<tr>
<td>Symmetry</td>
<td>39</td>
<td>20</td>
</tr>
</tbody>
</table>

Thaut, McIntosh, Rice: Journal of Neurological Sciences 1997
Shifts in Activation of Motor Networks and Attention Networks Due to Rhythmic Task Structure

Stephan et al, Neuroimage 2002

- Isochronous tapping vs. listening to tones
- 20% tapping vs. isochronous tapping
- Random tapping vs. isochronous tapping
Verbal Learning and Memory

Rey’s Auditory Verbal Learning Test (AVLT)

THAUT, PETERSON, HOEMBERG
FRONTIERS HUM NEUROSCI 2014
Percentage Means of Recalled Words at M1 and M2

<table>
<thead>
<tr>
<th>Mode</th>
<th>M1</th>
<th>M2</th>
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</thead>
<tbody>
<tr>
<td>Sung</td>
<td>77</td>
<td>76.6</td>
</tr>
<tr>
<td>Spoken</td>
<td>64.7</td>
<td>59.8</td>
</tr>
</tbody>
</table>

- Two Way ANOVA: $F (1.52) = 4.12$; $p=0.45$; Mean Squared Error .057
Multiple Sclerosis: Music enhances pairwise word order learning and memory

Main effect due to group
(F(1,2)= 4.51, p=0.038)
[2-way ANOVA]
Multiple Sclerosis: Music enhances post-learning memory for long word sequence order

**p < 0.001, two-tailed T-test**
Learning-Related Coherence and Memory

- Can neuronal synchronization also predict correct recall after distractions and 1- and 20-minute delays?
- Network synchronization measured as change in phase-locked oscillations (coherence) between EEG electrodes.
- Coherence between electrodes $i$ and $j$ is defined as

$$ C_{ij} = \frac{|P_{ij}|^2}{P_{ii} P_{jj}} $$

where

- $P_{ij} = \text{cross spectral density between } i \text{ and } j$
- $P_{ii}$ and $P_{jj} = \text{power spectral densities of electrodes } i \text{ and } j$, respectively
Music Enhances Frontal EEG Synchrony during Learning in MS

- Music learners exhibit a bilateral frontal increase in alpha power, non-music learners a decrease.
- Music learners exhibit less left posterior beta synchronization than non-music learners.

- The music group’s enhanced word order learning and memory may result from enhanced recruitment of oscillatory prefrontal networks during learning.

* p<0.05, two-tailed t-test
Neural systems for speech and song in autism
Grace Lai, Spiro P. Pantazatos, Harry Schneider and Joy Hirsch
Brain 2012: 135, 961-975
Enhanced Brain Mechanisms In Music

- **Cognitive Timing**
  - Auditory Scaffolding, Sequencing, Patterning,
- **Motor Timing and Priming**
  - Rhythmic Synchronization, Sonification, Motor Arousal
- **Auditory Perception and Sensory Integration**
  - Attention, Acuity, Sensory Integration
- **Complexity Thinking**
  - Abstract Thinking, Symbolic Thinking, Complex Reasoning
- **Emotional Experience**
  - Emotional Expression, Emotional Adjustment, Cognitive Enhancement
SUMMARY

• NMT IS BASED ON RESEARCH EVIDENCE (RCTs) AND PRINCIPLES OF COGNITIVE AND MOTOR LEARNING THEORIES
• NMT EVIDENCE IS AT LEAST AS STRONG AS OTHER REHAB DISCIPLINES
• NMT PROVIDES A UNIQUE COMPLEX AUDITORY TEMPORAL STIMULUS FOR [RE]-TRAINING BRAIN FUNCTION (RHYTHM-MUSIC)
• NMT MUST BE PART OF MODERN EFFECTIVE NEUROREHABILITATION UNITS
Facts about NMT Training

• 4 Day Training for Basic Certificate
• Must Be Renewed in 4th Year Via Advanced Fellowship Training (Peer Case Review)
• Fellow Certificate Must Be Within 6th Year Post Training
• Certificate Endorsed/Approved by CBMT, WFNMR, CNM, NBCC
• www.cbrm.colostate.edu
Upcoming European Training Dates

• Next Full Training: SRH Hospital Bad Wimpfen/Germany Sept 26-29 (Prof. Hoemberg, Medical Director)
  Registration: katharina.lomb@gbw.srh.

• AMTA Conference Louisville Nov -6
  Registration: AMTA Website

• Next Fellowship Training: CSU – August 22/23
THANK YOU