Rhythmic Auditory Stimulation

Investigating the Clinical Efficacy of RAS in Improving Gait During Neurorehabilitation

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Objectives

After this Voicethread presentation, learners will be able to:

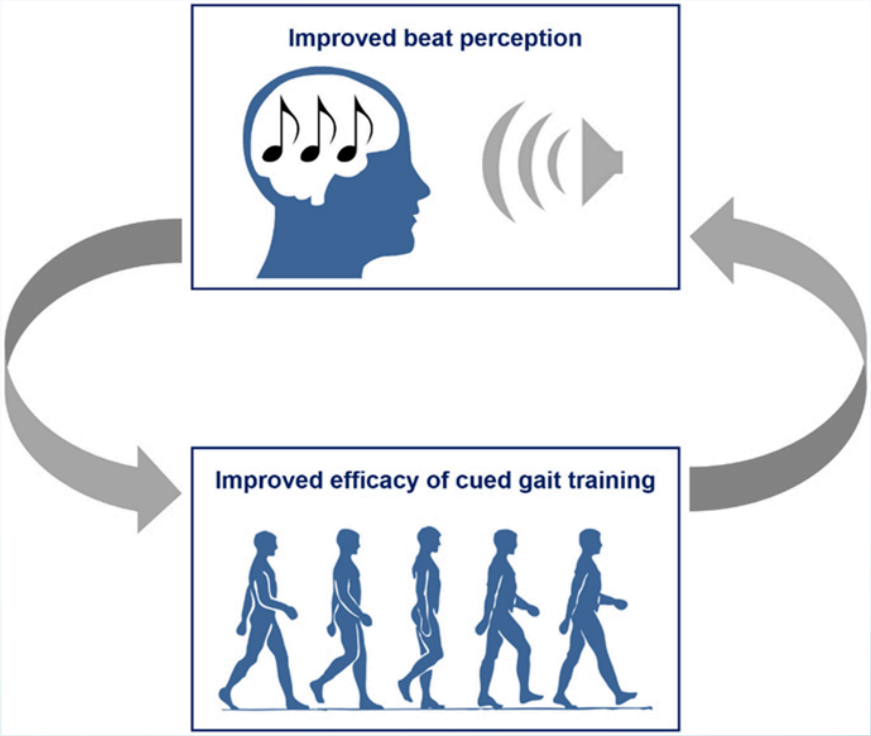
- Explain what RAS is and why it works
- Describe, in general, how RAS is utilized in neurorehabilitation
- Summarize evidence-based RAS-associated improvements in gait among patients who have experienced stroke
- Summarize evidence-based RAS-associated improvements in gait among patients who have Parkinson disease
- Be able to identify and access helpful resources for future clinical use of RAS

"I thought we should start with rhythm…and the observation that, when rhythmic sound somehow activates the motor system, it's almost instinctive to move rhythmically, so there must be some connections between the auditory system and the motor system."[1]

-Michael Thaut, PhD, former director of the Center for Biomedical Research in Music at Colorado State University in Fort Collins

What is Rhythmic Auditory Stimulation (RAS)?[2-4,6]

- Developed by Thaut, McIntosh, & Rice at the Center for Biomedical Research in Music at Colorado State University
- Technique that utilizes the physiological effect of auditory rhythmic cues on the motor system via the reticulospinal pathway
- Movements begin to anticipate and synchronize with the rhythm
- Mostly used with gait, including arm swing



For which neurological conditions does evidence demonstrate RAS-related gait improvements?[4-7]

- **Stroke**
- **Parkinson disease**
- Multiple Sclerosis
- Cerebral Palsy
- Traumatic Brain Injury

Common Gait Impairments Following Stroke[7,8]

- Reduced gait velocity
- Decreased stride length
- Decreased cadence
- Temporal and/or spatial asymmetry
- Impaired balance and posture
- Overall impaired motor function

In general, gait parameters are about ½ those of a "healthy" adult

Thaut, McIntosh, & Rice, 1997[9]

- First study to demonstrate improvements in motor control after using RAS as a training device during gait training
- 20 participants, all within first 3 weeks post-stroke at study's onset and within 3 months post-stroke at study's termination
- RCT comparing RAS + conventional gait training vs. conventional gait training alone
- Statistically significant findings for RAS-training group compared with control group:
  - Increase in gait velocity
  - Increase in stride length
  - Decrease in EMG amplitude variability of gastrocnemius
- Differences in improvements of stride symmetry between groups not statistically significant

Nascimento et al., 2015[8]

- Systematic review, 7 studies
- External cueing: metronome beats, music beats, or metronome beat-enhanced music
- Comparison: Gait training with RAS vs. gait training alone
- Significant improvements:
  - Gait velocity: improved by avg. of 0.23 m/s more than control
  - Stride length: improved by avg. 0.21 m more than control
- Greater improvements in cadence and gait symmetry in RAS-group compared to control group but statistical heterogeneity of these results was too high to determine significance

Clinical Implications of Nascimento et al., 2015[8,10]

- RAS was the only difference in interventions for all chosen studies, so with fewer confounding factors, the studies' outcomes are more easily attributed to RAS
- MCID for gait speed is 0.16 m/s for individuals who are 20-60 days post-stroke with severe gait impairments
- Increased stride length indicates that stride quality did not lessen with increased gait speed
- RAS demonstrated more favorable outcomes than treadmill training or virtual reality

What about the chronic stages of stroke?[11-13]

- Cha et al., 2014
  - 20 patients, ~14 mos post-stroke
  - Metronome and specifically-prepared music
  - RAS group demonstrated significantly larger improvements in spatiotemporal gait parameters and functional balance (Berg)
- Ko, Lee, & Song, 2016
  - 15 participants, ≥ 6 mos post-stroke
  - Sensors on ankles connected to RAS smartphone app detected heel strike during gait
  - +10% RAS tempo associated with greatest improvements in gait speed, cadence, and gait cycle duration
- Kim & Oh, 2012
  - 20 participants, ≥ 3 mos post-stroke
  - Home-based auditory stimulation training (metronome)
  - Comparison of RAS group to control group showed significant differences in spatiotemporal gait parameters post-training (affection/non-affected step length, step length ratio, affected/non-affected single support time, single support time ratio, & gait velocity)

“Parkinsonian Gait” Characteristics[5,14]

- Shuffling
- Freezing
- Rigidity
- Festinating gait
- Turning “en bloc”
- Forward flexed trunk
- Flexed knees
- Narrow BOS
- Reduced arm swing

https://www.youtube.com/watch?v=wrGkXzL-E5M[15]

The RESCUE Trial Nieuwboer et al., 2007[16]

- Purpose: To explore benefits and training effects of home-based cueing program on the gait, function, and quality of life of individuals with Parkinson disease
- 153 patients with Parkinson disease, RCT with crossover design
  - Early group: 3-week gait training with rhythmical cueing → 3 wks of no training
  - Late group: 3 wks of no training → 3-week gait training with rhythmical cueing
- 3 forms of rhythmical cueing
    - Auditory (beeping)—67% of participants preferred this
    - Visual (flashing light)
    - Somatosensory (pulse vibrations)—33% preferred this
- Outcomes measures: Primary (posture and gait score); Secondary (gait parameters, balance, ADL, participation)
  - Outcomes measured at baseline, 3 weeks, 6 weeks, and 12 weeks

Study Results (Nieuwboer)[16]

- No significant differences between groups
- Posture-gait score improved 4.2% after training
- Significant improvements in gait speed (+5 cm/s) & step length (+4 cm) after training
- Significant decrease of freezing frequency percentage on Freezing of Gait Questionnaire among participants categorized as “freezers”
- Overall, small & specific treatment effects
  - Short treatment
  - Training intensity
  - Home setting limitations
  - Training effects did not persist

Kadivar, et al., 2011[17]

- Investigates training effects of multidirectional step training with or without RAS
- 16 participants with Parkinson disease assigned to two groups:
  - Externally-paced stepping (RAS)
  - Internally-paced stepping (self-selected cadence, no RAS)
- 6 weeks of training with 3 follow-up post-training tests:
  - 1 week post
  - 4 weeks post
  - 8 weeks post
- Outcome measures
  - Primary: Dynamic Gait Index (DGI)
  - Secondary: Unified Parkinson Disease Rating Scale (UPDRS)-motor, UPDRS-ADL, Tinetti, TUG, Freezing of Gait Questionnaire

Study Results (Kadivar)[17]

- Significant improvements on DGI in the RAS group compared with “no RAS” group directly after 6 weeks of training and at all three post-tests
- RAS group also demonstrated sustained improvements on DGI through 8 weeks post-training, whereas the “no RAS” group’s scores returned to pre-test levels after 1 week post-training
- Secondary outcomes also demonstrated maintained improvements for the RAS group throughout many of the post-tests, though not significantly larger than the “no RAS” group
- Conclusion: Multidirectional step training with RAS appears to be effective in improving and maintaining functional gait and balance, as well as in decreasing risk of falls among patients with Parkinson disease

RAS in Action[18]

This video briefly demonstrates the difference in gait quality between using RAS versus not in an individual with Parkinson disease:

https://www.youtube.com/watch?v=uDjQ7IKmH3s

Steps to Take for RAS Gait Training[2]

- Assessment of patient's current gait parameters
- Pre-gait acquaintance to and synchronization of tempo
- Incremental progression of frequency (5-10%)
- Advanced gait activities
- Fading
- Reassessment

Gait Parameter Assessment$_2$

- Cadence
  - Count steps during 60-second walk (no music)
  - Cadence = steps/minute
  - Time can be modified if patient in unable to walk for 60 seconds
- Velocity
  - Meters/minute or feet/minute
- Step length/stride length
  - Can use previous values to find this instead of having patient walk again
  - Step length = velocity divided by cadence
    (Stride length = step length x 2)
- Can also assess gait deviations (subjectively or with outcome measures like TUG)

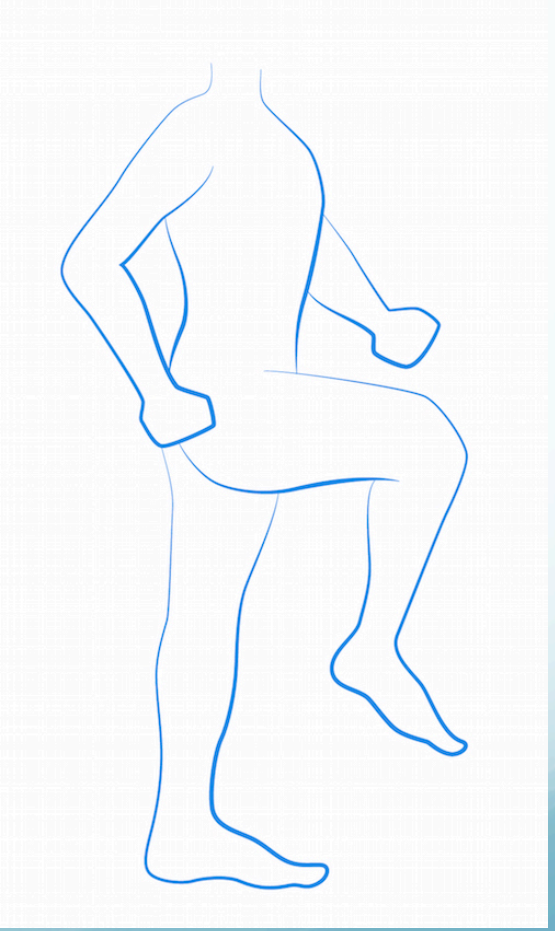
Pre-gait & Other RAS Applications[2,19]

Possible pre-gait exercises that can be performed with RAS include:

- Weight shifting
- Stationary marching
- Long arc quads
- Arm swings
- Unilateral stepping (forward/backward)

Other activities that RAS could potentially enhance:

- Reaching for targets
- PNF patterns
- Sit<>Stand



Gait advancements during RAS-training[2]

- Various surfaces of differing difficulty
- Obstacle course
- Stairs
- Retro gait
- Turning, figure 8s
- Starting and stopping with music

Why does RAS work?[20,21,22]

"We listen to music with our muscles." –Nietzsche

- Rhythmic entrainment
  - Physical and biological phenomenon—one system synchronizes to signal frequency of another system
  - Humans subconsciously re-program movement patterns and synchronize them to the rhythmic cueing
- Period entrainment
  - Rhythmic cueing results in the brain's anticipatory measurements of time
  - Motor period "entrains" to auditory rhythmic period
  - Brain plans movement according to rhythmic interval, which is both internally clocked and externally cued
- Wide distribution of fiber connections between the auditory system and motor centers
- Neural activation in response to music/rhythm
  - Grahn & Brett—Functional imaging of motor areas of the brain demonstrated activation in pre-SMA/SMA, dorsal premotor areas, basal ganglia, cerebellum, superior temporal gyrus, and ventrolateral prefrontal cortex
  - Daly et al.—Variance of tempo correlated significantly with the strength of EEG activity over the motor cortex (even while participants were not moving)
  - Thus, auditory rhythm can modify activation of the brain's motor areas

Dance for Parkinson Disease[23,24]

- Research shows that dance can improve balance, gait, endurance, multi-task performance, and quality of life among patients with PD
- Similar to RAS, the rhythm of the music can facilitate automatic walking movements
- In addition to auditory cueing, dancing with music provides somatosensory and visual cueing, along with cues from a partner if the type of dance requires partners
- Most studies of dance for PD have participants who are in the earlier stages of PD before falls and impaired balance take over function
- http://danceforparkinsons.org/

Feasibility & Applicability of RAS[8,16,25,26]

- Inexpensive: metronomes, music, smart phone applications
- Can be utilized in clinic, home, community
- Non-invasive
- Not limited to use under supervision of PT
- Can be combined with other interventions to enhance gait training (bodyweight-supported treadmill training, aquatic therapy, stationary cycling, strength training, functional e-stim)
- Though potentially not as effective for humans, additional types of rhythmical stimulation exist for patients who may have auditory deficits

Mobile Apps for In the Clinic[27,28]

1. RockMyRun
2. PaceDJ

   https://www.youtube.com/watch?v=WUIq1SXKIJ8 (stop at 1:16)

3. Pro Metronome (Also available on Apple watch)
   https://www.youtube.com/watch?v=u3Onh2ZDWJY

Patient-friendly technology

Soundbrenner

SEIKO

In-EarMetronome

IN-EAR METRONOME

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