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The background features a watercolor-style illustration. On the left, there is a profile of an elderly person's head in shades of blue and yellow. The rest of the background is filled with colorful musical notes and abstract patterns in shades of pink, orange, and blue.

Effect of Auditory Imagery-based Rhythm Music Movement Therapy on Cognitive Function of Community-Dwelling Elderly with Mild Cognitive Impairment

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WFOT
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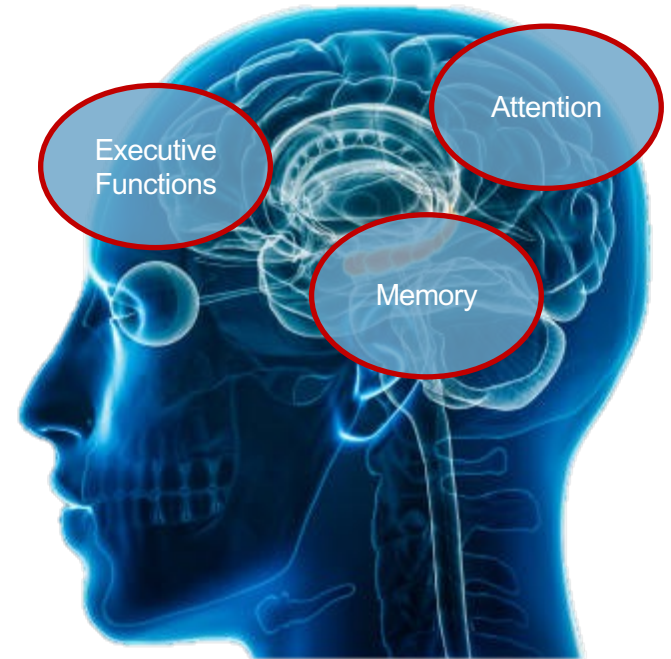
The logo for the WFOT Congress 2026, featuring a stylized illustration of a city skyline with various buildings in shades of orange, yellow, and green.

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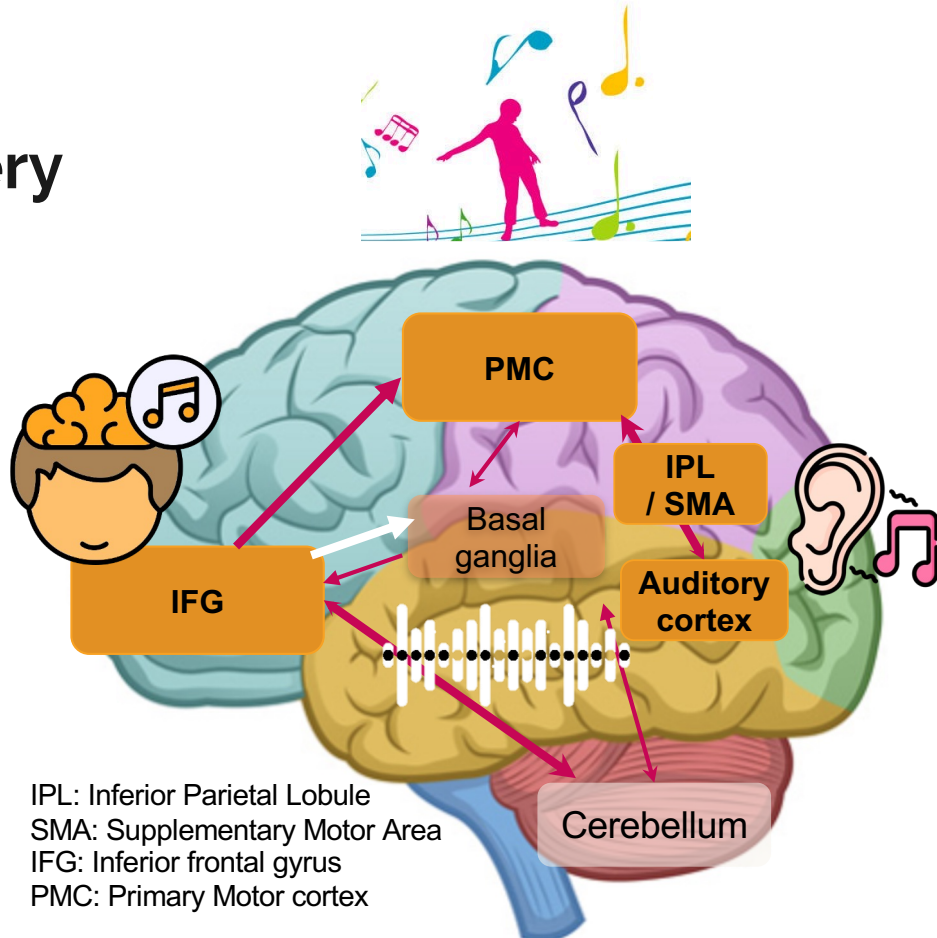
Cognitive Deficits of Mild Cognitive Impairment (MCI)

- Older adults with MCI are reported to have deficits in one or more cognitive functions, including working memory, executive function and attention (Petersen, 2016; Roberts & Knopman, 2013).
- **Attentional control** and **executive functions** appear to deteriorate at earlier phase of deterioration before memory deficits (Parasuraman et al., 1992; Roberts & Knopman, 2013; Twamley et al., 2006).
- Further decline in working memory and executive function could further lead to memory decline (Kirova et al, 2015).



Effects of Auditory-imagery on Cognitive Functions

- Auditory Imagery (AI) refers to the mental simulation of sounds without external auditory stimuli, linking to the concept of “Inner ear”
- **Rhythm** perception plays a crucial role in beat perception, timing, and motor coordination, making it a promising component into AI-based training (Grahn & Brett, 2007; Grahn & Rowe, 2009)
- **Basal ganglia** contributes to beat perception and prediction while the activation of the **IFG** may play a role in executive function, maintaining internal beat and adjusting motor responses accordingly during complex rhythm.



Auditory-related Training for People with Older Adults

- **Multisensory Integration Theory Relevant to Auditory Imagery (Jones et al., 2024)**
 - Biology neuroimaging study investigated how older adults integrate auditory and visual cues. Key findings:
 - Older adults maintain perceptual accuracy but require **stronger cortical activation** across frontal, temporal, and parietal regions.
 - Because auditory imagery recruits similar neural pathways involved in audio-visual integration and auditory perceptual processing, this study provides a neurobiological rationale for imagery-based cognitive training.
- **Cognitive Rehabilitation Technologies Indirectly Supporting Auditory Imagery Use (2025)**
 - A 2025 systematic review on cognitive rehabilitation in MCI highlights the effectiveness of:
 - **Cognitive training**, particularly multi-domain tasks
 - **Neuromodulation** targeting executive and memory networks
 - Even though auditory imagery is not isolated, these findings demonstrate that auditory-based neurocognitive systems are **trainable**, responsive to active intervention, and important in predicting functional outcomes



Study Objectives

Primary Objective

To compare the effects of a **4-week AI-based RMMT program** (RMMT-AI) and RMMT on improving **attention** of older adults with MCI, evaluated by *Digit Span Test (Backward)* (*DST-Backward*), *Color Trails Test (CTT)* and *Stroop Color Word Test (SCWT)*

Secondary Objective

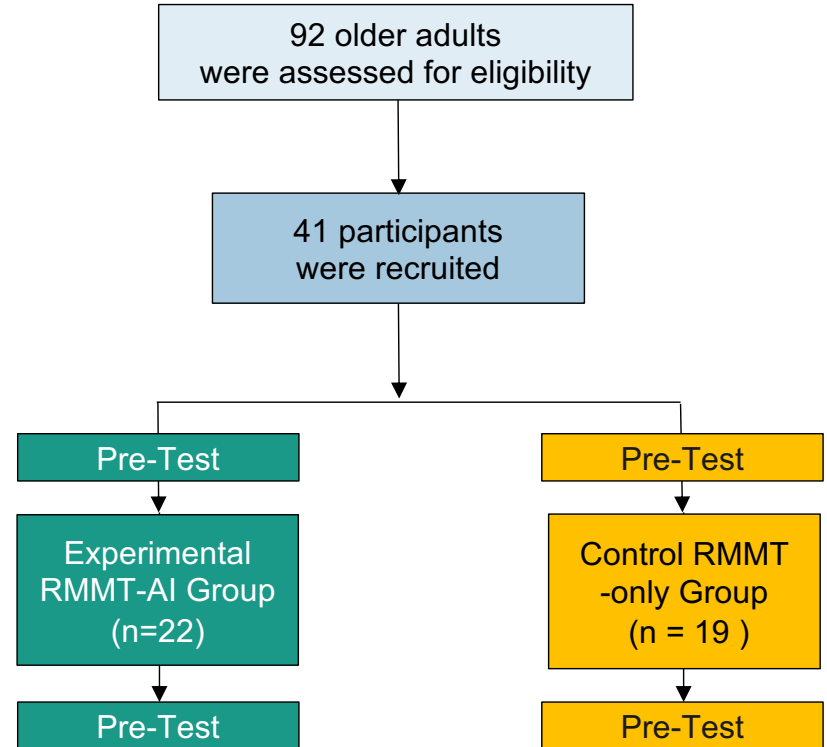
To compare the effects of a **4-week AI-based RMMT program** (RMMT-AI) and RMMT on improving **working memory** and **cognitive flexibility** of older adults with MCI, evaluated by *DST-Backward*, *CTT*, and *SCWT*.

Methods



Study Design

- A quasi-randomized control experimental design with pretest-posttest measurement was adopted
- Complete outcome measure assessments at baseline and post-training



Participants

Inclusion Criteria

- Age between 60 – 80
- MoCA scores of 23 – 29
- MMT of grade 3 or above



Exclusion Criteria

- Currently on cognitive, motor or psychiatric medications
- Had a history of neurological, psychiatric or other chronic diseases
- Visual or hearing impairment

Demographics of the Participants

	RMMT-AI Experimental (n=22)	RMMT Control (n=18)	p-value
Gender [#] (%)			
Male	8 (36.4)	3 (16.7)	0.286
Female	14 (63.6)	15 (83.3)	
Mean Age (SD)	64.27 (8.32)	68.56 (3.68)	0.050
Mean Score on MoCA (SD)	28.09 (1.02)	27.94 (1.55)	0.722
Education Level [#] (%)			
Primary education	1 (4.5)	1 (5.6)	0.624
Secondary education	13 (59.1)	13 (72.2)	
Tertiary education or above	8 (36.4)	4 (22.2)	

Independent t tests or Chi-square[#] was used

Study Procedure



Experimental Group		Week 1		Week 2		Week 3		Week 4		Post-test
Pre-test	Pre-training session	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8	

Control Group		Week 1		Week 2		Week 3		Week 4		Post-test
Pre-test	Waiting	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8	

Program Design: Pre-training session for RMMT-AI Group

- Introduced basic concepts of music (beat and rhythm) and AI
- 2 parts of AI Training:

1. With beats

Play (**metronome** at a specific BPM) → Internalize → Identify

2. With songs

Play (**a song + intermittent metronome**) → Internalize → Identify



Song

Program Design

Guided by the instructors' verbal beat counting and drumstick beat cues.

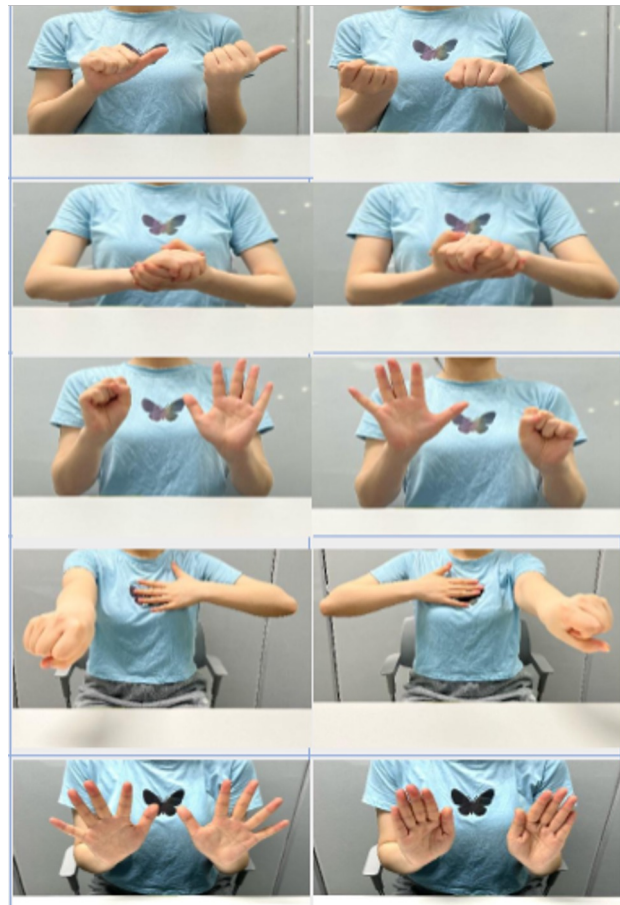
Session Flow	RMMT-AI (experimental)	RMMT (control)	Duration
1	Mini lecture / practice / games on rhythm		5 mins
2	Warm-up exercises		5 mins
3	<u>Part 1 - Practice with music at middle tempo</u> a. Finger exercise b. Rhythm practice	<u>Part 1 - Practice with music at middle tempo</u> a. Finger exercise	20 mins
4	Break		5 mins
5	<u>Part 2 - Practice with music at fast tempo</u> a. Finger exercise b. Rhythm practice	<u>Part 2 - Practice with music at fast tempo</u> a. Finger exercise	20 mins
6	Relaxation		5 mins

Program Design

Finger Exercise

A new set of exercises was introduced weekly

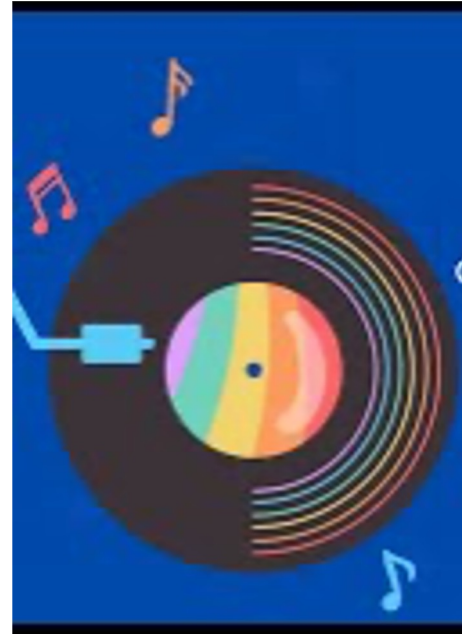
- With increasing difficulty in movement complexity, inter-finger coordination and movement sequence from week 1 to week 4.



Auditory Imagery Training

1. Pay attention to music
2. Capture the rhythm
3. Execution of specific hand movement and coordination with the music
4. Mental Imagery of the rehearsal of rhythm without the music

<https://www.youtube.com/watch?v=S20jTisQsak>





Outcome Measurements

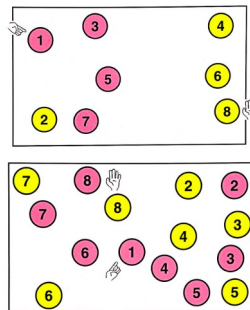
1. Digit Span Test (Backward subtest)

- Working memory, verbal attention & sustained attention
- Sequence & span scores

	Subject's Answer	Sequence score / Span score
5 - 1		/
3 - 7		/
6 - 2 - 9		/
8 - 7 - 2		/
9 - 7 - 1 - 3		/
7 - 8 - 6 - 4		/

2. Colour Trails Test

- Part 1: Sustained attention, processing speed & visual scanning
- Part 2: Divided attention & cognitive flexibility
- Time used, colour & time errors

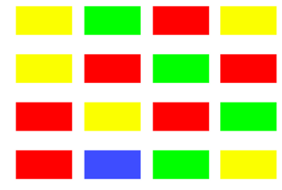


3. Stroop Colour Word Test (Chinese Version)

- Congruent tasks:

- Word-reading (WR)
- Colour-naming (CN)
- Processing speed
- Sustained attention

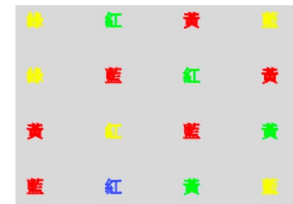
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- Incongruent task:

- Incongruent colour-naming (INC)
- Cognitive flexibility
- Inhibition

- Time used, errors & self-corrections





Results

Data analysis

Descriptive Statistics

- Outcome measures were described using mean (SD)

Outcome Analysis

- 2-way repeated measures ANOVA for analysis of treatment effect
- Significant interaction effects explored via paired t-tests (post hoc)

Significance Level

- Significance: $p < 0.05$; marginal significance: $p < 0.06$.
- Post-hoc Bonferroni correction set at $p < 0.0125$

Mean scores and their standard deviations (in bracket) on scores of different clinical outcome measures of participants in the RMMT-AI (experimental) and RMMT (control) for the baseline and post-training assessments

Tests	Experimental (n = 22)		Control (n = 18)	
	Baseline Mean (SD)	Post-training Mean (SD)	Baseline Mean (SD)	Post-training Mean (SD)
<u>DST-Backward</u>				
Sequence	8.68 (1.64)	8.14 (2.38)		
Span	10.14 (1.42)	9.91(1.90)		
<u>CTT</u>				
CTT1 time (s)	10.19 (5.15)	7.33 (3.34)		
CTT1 error	0.00 (0.00)	0.00 (0.00)		
CTT2 time (s)	15.32 (6.93)	12.08 (4.39)		
CTT2 number error	0.00 (0.000)	0.00 (0.00)		
CTT2 color error	0.23 (0.53)	0.27 (1.01)		
CTT2-CTT1 time (s)	5.13 (8.56)	4.75 (3.63)		
<u>SCWT</u>				
WR time (s)	53.17 (8.46)	51.36 (6.80)		
CN time (s)	69.23 (12.11)	66.08 (10.49)		
INC time (s)	117.52 (21.45)	111.87 (18.08)		
WR error	0.09 (0.29)	0.05 (0.21)		
WR self-correct	0.64 (0.90)	0.32 (0.78)		
CN error	0.45 (1.34)	0.27 (0.55)		
CN self-correct	1.77 (2.31)	1.59 (1.74)		
INC error	0.91(1.07)	0.82 (1.01)		
INC self-correct	2.18 (1.82)	2.14 (1.42)		
CN-WR time (s)	16.06 (9.83)	14.72 (8.06)		
INC-CN time (s)	48.29 (17.36)	45.79 (14.70)		

2-way repeated measures ANOVA revealed the **insignificant Time × Group interaction effects** in the participants' performance in **CTT, DST-Backward & SCWT [F (1,38), p < 0.05]**. **Insignificant improvement on working memory** is revealed in either groups. **Time main effect of CTT1 time(s)** [(F (1,38) = 14.82, p < 0.001] & **Time main effect of CTT2 time(s)** [(F (1,38) = 11.32, p = 0.002] were revealed, suggesting an uptrend of improvement in **sustained & divided attention**. **Marginal significant improvement on cognitive flexibility** is revealed in both groups.

Note. DST-B, Digit Span Test (Backward); CTT, Colour Trail Test; SCWT, Stroop Colour Word Test; WR, Word Reading; CN, Colour Naming; INC, Incongruent Colour Naming.



Discussion

Limited Effect on Attention & Cognitive Flexibility

Beat-counting method → **Inner Voice**

Counting 1 - 2 - 3 - 4

Mental rehearsal of music → **Inner Ear**

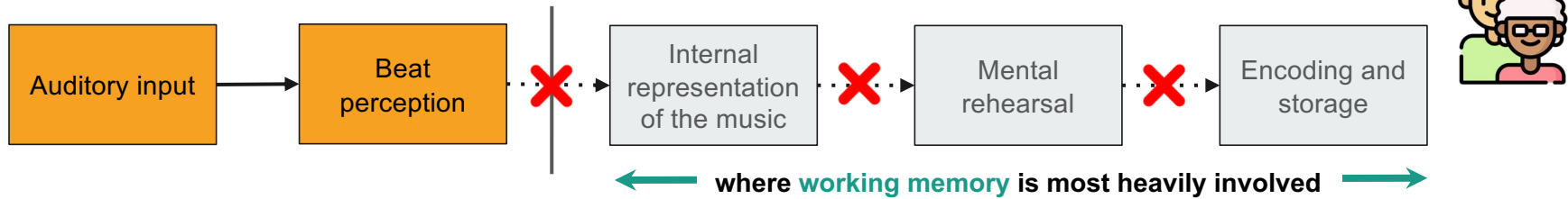
Inherent melodic and rhythmic elements of music stimuli

“Generating vivid auditory images of music is challenging, beating-counting is more preferred”



- Beat-counting method offloading the cognitive demand required in RMMT-AI training
- Contributed by the **early reliance on beat-counting methods for rhythm and movement guidance**
→ tend to use the added numerical labeling instead

Limited Effect on Working Memory



- Previous research show that **only when listening to familiar music** can AI occur
 - During music pauses & anticipation of upcoming tracks (Kraemer, et al., 2005; Leaver, et al., 2009)
- The trainings **used a preselected list of unfamiliar musical pieces** → intentionally impose cognitive demand to the participants
- Over half of the participants (61.9%) relied on mental beat-counting during AI
 - Engages phonological loop for verbal working memory, **instead of motory-auditory integration system**



The preparatory guidance before the rhythm practice may be insufficient to promote music familiarization?

Implication and Future Studies



Training Enhancement

- Pre-training session
 - Introduce **more graded imagery exercises**
- The actual RMMT-AI program
 - **Extend familiarization periods** of each rhythm practice section, with instructor's guidance
 - **Assign music pieces as homework** for listening before next sessions

For Future AI-based Interventions



Over half of the participants reported **difficulties in initiating AI**

Possible lower inherent AI ability and minimal musical experience → hinder their engagement with AI training → compromise training effectiveness

1. Participant recruitment

→ Consider AI ability in inclusion criteria to optimize outcomes

- Screening tool
 - Use auditory-based vividness questionnaires (e.g. Bucknell Auditory Imagery Scale) to assess baseline vividness
- Practical screening
 - Ask the participants clap along to a song to demonstrate beat perceptions

1. Tailored training dosage

- Adjust training intensity based on AI ability and level of musical experience
- Extend to 12 sessions or above

Future Studies

- **Integrate AI strategies** into therapeutic programs for older adults with MCI
- **Validate AI's potential** as a cognitive training tool across diverse clinical settings
- Investigate **long-term effects** and optimal training dosage
- Explore targeted interventions to **address working memory limitations**



References



- Colverson, A., Barsoum, S., Cohen, R., & Williamson, J. (2024). Rhythmic musical activities may strengthen connectivity between brain networks associated with aging-related deficits in timing and executive functions. *Experimental gerontology*, 186, 112354. <https://doi.org/10.1016/j.exger.2023.112354>
- Grahn, J. A., & Brett, M. (2007). Rhythm and beat perception in motor areas of the brain. *Journal of cognitive neuroscience*, 19(5), 893–906. <https://doi.org/10.1162/jocn.2007.19.5.893>
- Grahn, J. A., & Rowe, J. B. (2009). Feeling the beat: premotor and striatal interactions in musicians and nonmusicians during beat perception. *The Journal of neuroscience: The official journal of the Society for Neuroscience*, 29(23), 7540–7548. <https://doi.org/10.1523/JNEUROSCI.2018-08.2009>
- Hubbard T. L. (2010). Auditory imagery: empirical findings. *Psychological bulletin*, 136(2), 302–329. <https://doi.org/10.1037/a0018436>
- Kraemer, D. J., Macrae, C. N., Green, A. E., & Kelley, W. M. (2005). Musical imagery: sound of silence activates auditory cortex. *Nature*, 434(7030), 158. <https://doi.org/10.1038/434158a>
- Leaver, A. M., Van Lare, J., Zielinski, B., Halpern, A. R., & Rauschecker, J. P. (2009). Brain activation during anticipation of sound sequences. *Journal of Neuroscience*, 29, 2477–2485.
- McGuire, P. K., Silbersweig, D. A., Murray, R. M., et al. (1996). Functional anatomy of inner speech and auditory verbal imagery. *Psychological Medicine*, 26(1), 29–38. <https://doi.org/10.1017/S0033291700033699>

References



Pecenka, N., Engel, A., & Keller, P. E. (2013). Neural correlates of auditory temporal predictions during sensorimotor synchronization. *Frontiers in human neuroscience*, 7,380. <https://doi.org/10.3389/fnhum.2013.00380>

Whitton, S. A., Sreenan, B., & Jiang, F. (2024). The contribution of auditory imagery and visual rhythm perception to sensorimotor synchronization with external and imagined rhythm. *Journal of Experimental Psychology: General*, 153(7), 1861-1872. [doi:https://doi.org/10.1037/xge0001601](https://doi.org/10.1037/xge0001601)

Zatorre, R. J., & Halpern, A. R. (2005). Mental concerts: musical imagery and auditory cortex. *Neuron*, 47(1), 9–12.

Multisensory (Audiovisual) Integration in Older Adults

Jones, S. A., & Noppeney, U. (2024). *Older adults preserve audiovisual integration through enhanced cortical activations, not by recruiting new regions*. *PLOS Biology*, 22(2), e3002494. <https://doi.org/10.1371/journal.pbio.3002494>
osot.ubc.ca

Neurotechnological Approaches to Cognitive Rehabilitation in MCI

Gkintoni, E., Vassilopoulos, S. P., Nikolaou, G., & Vantarakis, A. (2025). *Neurotechnological approaches to cognitive rehabilitation in Mild Cognitive Impairment: A systematic review of neuromodulation, EEG, virtual reality, and emerging AI applications*. **Brain Sciences**, 15(6), 582. <https://doi.org/10.3390/brainsci15060582>



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