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Actual and imagined music-cued gait training for people with multiple sclerosis: a multicentre qualitative study

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ABSTRACT

Objectives To explore the experiences and acceptability of music-cued motor imagery (MCMI), music-cued gait training (MCGT), and combined MCMI and MCGT (MCMI-MCGT) in people with multiple sclerosis (pwMS). We also aimed to explore participants' self-rated health status postintervention and gather recommendations for further programme development.

Design Qualitative study alongside the double-blind randomised controlled real and imagined gait training with music-cueing (RIGMUC) multicentre trial of MCMI, MCGT and MCMI-MCGT.

Setting PwMS recruited for the RIGMUC trial from Departments of Neurology at Medical Universities of Innsbruck and Graz and Clinic for Rehabilitation Muenster, Austria.

Participants All 132 pwMS with mild to moderate disability randomised into the trial were included in the analysis.

Methods Participants practised home-based MCMI, MCGT or MCMI-MCGT for 30 min, 4×/week, for 4 weeks. Three trained researchers conducted weekly semistructured telephone interviews during the intervention period, supporting adherence, addressing problems, sharing experiences and assessing intervention acceptability. Follow-up interviews at 4-week postintervention aimed to understand participants' self-rated changes in walking, fatigue and overall health compared with their prestudy condition. Investigator triangulation was employed among the researchers to enhance trustworthiness and credibility.

Results Using thematic analysis, we identified five themes: (1) empowerment, (2) remaining in sync, (3) interconnection between imagined and actual walking, (4) sustaining focus and (5) real-world transfer. Participants appreciated and found the imagined and actual MCGT innovative. Problems included concentration issues, early fatigue in advanced disability and difficulty synchronising with music cues. Positive changes in walking, fatigue and overall health postinterventions were reported offering valuable insights for programme development.

Conclusions A participatory study to codevelop a music-cued exercise programme for pwMS seems appropriate as participants appreciated the innovation and effectiveness of both imagined and actual MCGT. Future studies should also investigate pwMS' potential and limitations in enhancing their MCMI abilities with intensive therapist-supported practice.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Conducted alongside a randomised controlled trial, this qualitative research drew on insights from prior studies and the involvement of people with multiple sclerosis (MS).
⇒ We created a semistructured interview guide and conducted telephone interviews to gather detailed insights on the experiences and acceptability of an actual and imagined music-cued gait training, as well as their combination, in people with MS.
⇒ Reflexive thematic analysis was used, and investigator triangulation was employed to enhance trustworthiness and credibility.
⇒ The data collection involved multiple interviewers with varying levels of experience in qualitative interviewing, and despite all receiving training, the potential influence of these differences on the gathered information cannot be dismissed.
⇒ The lack of member checking and the absence of self-rated health status evaluation at the start of the study represent further limitations.

Trial registration number DRKS00023978.

INTRODUCTION

Multiple sclerosis (MS) is a chronic, inflammatory demyelinating disease of the central nervous system, affecting approximately 2.3 million people globally.[1] It presents as deficiencies in motor, sensory, visual and other bodily functions and often leads to progressive disability.[2] Walking impairment and fatigue are notable concerns for people with MS (pwMS), detrimentally influencing their quality of life (QoL).[3 4] Reductions in walking speed and distance impact daily activities and participation and can serve as indicators for levels of independence in self-care, functional mobility and domestic life.[5]

Motor imagery (MI) involves mentally simulating movement without physical execution to enhance motor performance.[6] Two modes of MI exist: a visual mode (visualising oneself

moving) and a kinaesthetic mode (perceiving one's body moving).[6] The kinaesthetic mode that was used for the current study relies on existing motor representations and acquired motor skills,[7] making walking ability essential for effective MI of walking. Originally developed for enhancing athletic performance,[7 8] MI has been explored in rehabilitation settings,[9] showing promise as an alternative method to stimulate movement in people with various conditions including MS.[10] It shares temporal characteristics and activates brain areas involved in actual motor actions.[6 7]

External rhythmic cues have been shown to improve MI timing and ability in pwMS.[11] Consequently, we integrated MI with rhythmic cueing in our earlier research.[12 13] Rhythmic-auditory cueing involves metronomes, musical beats and rhythmic-verbal cues to assist cyclical movements, particularly walking.[12–15] This approach has proven effective in enhancing walking and gait parameters in people with neurological conditions including MS.[16 17] It operates by facilitating rhythmic entrainment, aligning neural rhythms with external auditory cues.[14] Our prior randomised controlled trials (RCTs) indicated the efficacy of combined MI and rhythmic-auditory cueing on walking, fatigue and QoL in pwMS.[12 13] Our real and imagined gait training with music-cueing (RIGMUC) trial indicated improvements in walking, fatigue and QoL after music-cued MI (MCMI), music-cued gait training (MCGT) and combined MCMI and MCGT (MCMI-MCGT) in pwMS, with no significant between-group differences observed.[18]

A comprehensive assessment is essential for the successful integration of these interventions into clinical practice. Gathering detailed qualitative feedback complements quantitative evaluations, providing deeper insights into individuals' experiences with actual and imagined MCGT.[19 20] So far, no qualitative studies have explored the experiences of pwMS regarding actual or imagined MCGT. The aim of this study, therefore, was to gain insight into the experiences and acceptability of an actual MCGT, an imagined MCGT and a combination of actual and imagined MCGT in pwMS. Additionally, the study aimed to explore participants' self-rated health status including perceived changes in walking and fatigue after the intervention and gather their recommendations for developing the programme further.

METHODS

Design and setting

This qualitative study employed a design centred on reflexive thematic analysis (TA) within a constructionist epistemological framework.[21] Interviews were performed in parallel to the multicentre double-blind 'RIGMUC' RCT investigating the effects of home-based MCMI, MCGT and MCMI-MCGT on walking, fatigue, cognitive and emotional functioning, and health-related QoL in pwMS.[18 22] The Consolidated criteria for Reporting Qualitative research[23] was followed to enhance rigour and trustworthiness (online supplemental file 1). The study was conducted at the Clinical Department of Neurology, Medical Universities of Innsbruck (centre 1) and Graz (centre 3) and Clinic for Rehabilitation Muenster (centre 2), Austria.

Participant selection

Every participant enrolled on the RIGMUC trial (n=132) was interviewed as part of this qualitative study. Primary inclusion criteria encompassed people aged ≥18 years, diagnosed with MS based on McDonald criteria,[24] with an Expanded Disability Status Scale (EDSS) score of 2.0–5.0[25] and stable disease. Key exclusion criteria included cognitive impairment (Montreal Cognitive Assessment (MoCA) score <26/30[26]); anxiety or depression (Hospital Anxiety and Depression (HADS) subscales score ≥11/21 points[27]) or suicidality (narrative screening); relapse within the past 3 months; initiation or modification of medication (including corticosteroids, disease-modifying treatment and symptomatic treatment that impacts walking) and physiotherapy in the preceding 3 months or during the study.[22]

Information brochures and study participation invitations were displayed at study centres, and clinical staff informed pwMS about the research. Furthermore, the study was advertised on the Austrian MS Society website. Sample size determination was guided by the parallel RCT rather than saturation, as our aim was to acquire in-depth understanding of the experiences and to gather suggestions for improvement from each participant undergoing the MCGT intervention.

Data collection

Demographic and clinical data, encompassing age, gender, education, EDSS, MS phenotype, and disease duration, global cognitive impairment (MoCA), anxiety and depression (HADS), and suicidality (narrative screening) were assessed.[22]

Individual, semistructured telephone interviews were carried out weekly and on participants' requests by trained researchers (BS, BH and IH; online supplemental file 2) throughout the 4-week home-based intervention period to support adherence, address problems, share experiences and assess acceptability of the intervention. Recording of home-based training and incidents of falls was performed. Follow-up interviews were conducted by the same trained researchers 4 weeks postintervention to understand participants' self-rated changes in walking, fatigue and overall health status compared with their condition before the study. The interviews followed an interview guide (online supplemental file 3) created based on the literature and researchers' clinical expertise. The interview guide development incorporated primary open-ended questions grounded in a constructionist theoretical framework,[21] supplemented by follow-up probing questions for interviewers to use during the interview.[28] The guide was pilot tested with three pwMS. Interviews were audio recorded and transcribed, and field

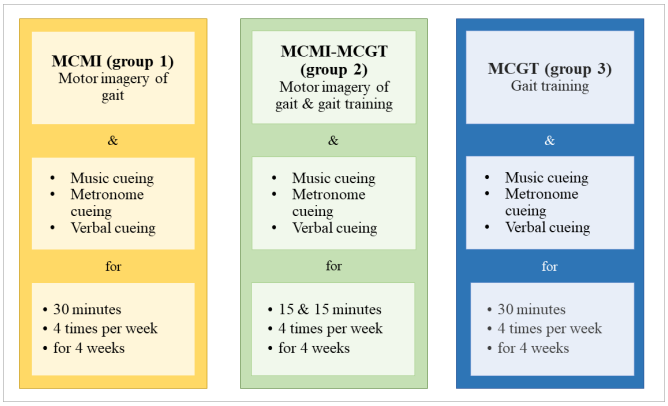

Figure 1 Central elements of the intervention across the three groups. MCGT, music-cued gait training; MCMI, music-cued motor imagery.

notes were taken. An open-ended interactive, responsive and flexible interview format was chosen to explore unexpected perspectives and capture the most significant details for each participant.[29] Building a connection with interviewees involved introducing the researcher's professional background, personal goals, interests in the research topic and study purpose. Participants, on giving written consent for telephone interviews to be transcribed (online supplemental file 4), were explicitly informed of their right to withdraw at any point, and that all transcripts would be anonymised. Clarifying questions were included in all interviews to ensure an accurate understanding of participants' narratives. Interview duration ranged from 20 to 46 min.

Intervention

Three intervention groups practised home-based kinaesthetic MI and/or gait training with music, metronome and verbal cues 4×/week, for 4 weeks. Participants practised 30 min of MCMI (group 1), 15 min each of MCMI-MCGT (group 2) or 30 min of MCGT (group 3). Figure 1 presents the key elements of the intervention.

Rhythmic-auditory cueing of the audio mix comprised three components:

1. For music-cueing, motivational instrumental music featuring a regular beat in a 2/4 or 4/4 m and strong ON and OFF beat patterns was used.[14 30 31] Rhythmic music sequences at 80–120 beats/min were used as the predominant cueing component.
2. Metronome cues were integrated into the music sequences, emphasising the music beat and tempo, aiming to support gait synchronisation.
3. Rhythmic-verbal cues were also integrated into the music-metronome sequences, served as reminders for task practice and helped participants' focus on specific respective body parts such as the feet. Rhythmic-verbal cues intermittently accentuated the cueing, employing phrases like 'step-step' or 'toe-off'[32] with various walking tasks.

An audio mix containing the three cueing components was specifically created for this study using Audacity, V.3.0.0).[33] Additionally, verbal instructions on MI or gait training were incorporated. The audio mix was modified weekly to progressively increase the tempo and prevent disengagement, encouraging adherence. It was made available for download on participants' electronic devices for all groups or as study CDs for MCMI group.

Participants were individually familiarised with MCMI and MCGT following established recommendations[10 34]: For enhancing MI ability, the PETTLEP approach to MI was applied, involving the components of 'Physical, Environmental, Task, Timing, Learning, Emotional and Perspective'.[8] Detailed information on the intervention was outlined in the published study protocol.[22] Participants in all groups received weekly telephone support for their MCMI and MCGT practice throughout the 4-week intervention period. These calls served a dual purpose: they were both a component of the intervention and a part of the data collection process. Participants recorded practice frequency and duration in a diary.

Data analysis

Descriptive statistics were employed to summarise information on demographic and disease-specific data (IBM SPSS software, release V.28.0, IBM). Recordings were transcribed verbatim using f4transcript adhering to Dresing and Pehl's semantic-content transcription rules.[35] Transcripts were cross-checked with recordings while member checking was omitted due to the exploratory nature of this research and complexity of findings. f4 software (Dresing & Pehl, Germany) was used for TA, defined as a 'method for identifying, analysing and reporting patterns or themes within data'.[36] BS coded all data, with IH coding 50% of the data. Investigator triangulation was employed among the data analysts to enhance trustworthiness and credibility, and emergent findings were discussed within the wider research team (n=8; online supplemental file 2). We identified semantic and latent themes relevant to the research question. These themes were summarised and interpreted[36] involving coding, segmentation and data extraction. Developed themes were reviewed and refined reflexively and iteratively, and data recoded as appropriate.[37] Themes were assessed for internal homogeneity and external heterogeneity.[38]

Patient and public involvement

The study intervention was formulated by integrating insights from previous research findings[12 13 15 39] and patient involvement including an MS advisory group. Based on the feedback from an MS advisory group, we chose motivating music with a pleasant melody, along with metronome cues featuring varying tone pitches. Furthermore, the selection of the intervention duration and frequency was endorsed by an advisory group.

Table 1 Participants' baseline characteristics

	MCMI group (n=44)	MCMI-MCGT group (n=44)	MCGT group (n=44)
Age*	49.2 (11.3)	47.4 (9.8)	49.9 (11.5)
Gender			
Female†	31 (23.5)	32 (24.2)	33 (25.0)
Male†	13 (9.8)	12 (9.1)	10 (7.6)
Diverse†	0 (0.0)	0 (0.0)	1 (0.8)
Years of education*	13.5 (3.1)	14.3 (3.0)	14.2 (3.7)
Disease duration*	16.4 (8.8)	16.8 (9.7)	18.9 (10.7)
Multiple sclerosis phenotype‡			
Relapsing-remitting†	30 (22.7)	34 (25.8)	28 (21.2)
Primary progressive†	7 (5.3)	0 (0.0)	5 (3.8)
Secondary progressive†	6 (4.5)	10 (7.6)	9 (6.8)
Secondary progressive active disease†	1 (0.8)	0 (0.0)	2 (1.5)
EDSS score§	2.5 (2.0–4.0)	3.0 (2.5–4.0)	3.0 (2.0–4.0)
HADS anxiety§	5.0 (4.0–7.0)	6.0 (5.0–7.0)	5.0 (4.0–7.0)
HADS depression§	5.0 (4.0–7.0)	4.0 (4.0–6.0)	5.0 (4.0–7.0)
HADS total§	11.0 (9.0–13)	10.0 (9.0–13.0)	10.0 (9.0–13.0)
MoCA§	28.0 (27.0–29.0)	28.0 (28.0–30.0)	28.0 (28.0–29.0)

Higher EDSS scores reflect more severe disability caused by multiple sclerosis.
*Data are mean (SD).
†Number (%).
‡The multiple sclerosis phenotype was determined based on the criteria outlined in the Lublin classification.[64]
§Median (IQR).
EDSS, Expanded Disability Status Scale; HADS, Hospital Anxiety and Depression Scale; MCGT, music-cued gait training; MCMI, music-cued motor imagery; MoCA, Montreal Cognitive Assessment.

RESULTS

Participant characteristics

Between 9 February 2021 and 15 November 2022, 132 participants were randomly assigned to MCMI (n=44), MCMI-MCGT (n=44) or MCGT (n=44). Five participants did not complete the intervention (online supplemental file 5). Overall, we performed 718 interviews, including 593 support interviews (mean 24 min (18–46)) and 125 follow-up interviews (mean 31 min (18–44)). Mean age of all participants was 48.9 years (SD 10.9), and 96 (72.7%) were women, 35 (26.5%) were men and 1 (0.8%) reported diverse gender. The median EDSS score was 3.0 (IQR 2.0–4.0) (table 1).

Overview of themes

We identified five themes through TA: (1) empowerment, (2) remaining in sync, (3) interconnection between imagined and actual walking, (4) sustaining focus and (5) real-world transfer. Themes 2 and 3 as well as themes 3 and 4 were related to each other and were drivers of themes 1 and 5 but also stood alone so were not considered subthemes. Theme 5 was a driver of theme 1 and also stood alone (figure 2). See online supplemental table 1 for additional quotes.

Empowerment

Incorporating both physical and emotional aspects through exercise, participants viewed the MCGT approaches as innovative and positive, not only towards exercise but also in coping with MS. They associated the training and instructions with positive reinforcement, fostering a sense of personal empowerment. Participants expressed that life with MS can still be fulfilling and

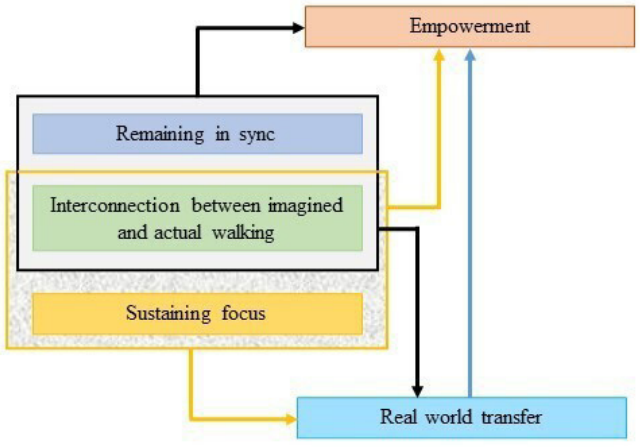

Figure 2 Thematic map presenting the main five themes and their key relationships.

beautiful, emphasising the idea that despite challenges, one can find value and purpose. Participants voiced feeling motivated to actively manage their health, make decisions aligning with their values and lifestyles, ultimately fostering a greater sense of autonomy and control in their healthcare journey. They emphasised the interconnected nature of motivation and empowerment, describing them as mutually reinforcing qualities. Motivation was seen as laying the foundation for empowerment, while empowerment, in return, bolstered motivation by nurturing feelings of empowerment, confidence and effectiveness. Participants described that the music's rhythm helping them shift their focus away from effort and worries. Moreover, they described that the programme educated them on reconnecting with their bodies. Nearly all participants conveyed their liking for the music, noting it assisted both their walking and balance. Music-cueing effectuated a sort of automation in walking, thereby facilitating a smoother and more effortless gait.

> The music motivates me significantly! Walking takes on a different rhythm with the music, influencing my gait and adding a unique dimension to the experience. (ID65/MCGT)*

*Participant's ID/group name.

Participants indicated that engaging in gait training would enhance their motivation to walk, driven by increased self-confidence and self-efficacy. They derived pleasure from the walking training due to their perception of its effectiveness.

> I appreciate gait training as it enhances my motivation to walk regularly. The consistent practice fosters greater self-confidence, making me realise what I can achieve and pushing my boundaries. (ID90/MCGT)

Participants valued the novelty of the music-supported exercises, recognising that this combination increased their motivation to walk, inspired them to be active and participate in new activities and expanded their belief in what they could accomplish. The weekly changes to the audio mix further heightened motivation.

> The walking exercises are innovative and fantastic because the music not only motivates me but also helps me accomplish more than I would under normal circumstances! (ID29/MCGT)

Music-cued walking training held value, especially for those with more pronounced walking impairments as it introduced novel movement patterns.

> With this walking training, you engage in certain movements that you might not attempt otherwise. (ID118/MCMI-MCGT)

Participants reported experiencing both physical and psychological advantages through music-cued (imagined) gait training. These benefits were intertwined, influencing their perspective on living with MS. Participants associated the training and instructions with positive reinforcement, fostering acceptance of MS and promoting a sense of personal empowerment.

> The music-supported exercise approach and instructional style contribute to my increased acceptance of my MS condition, demonstrating that life with MS can be beautiful. It reinforces the idea that one can make life worthwhile despite the challenges. (ID119/MCMI)

Many participants recommended integrating these music-cued walking exercises for pwMS, highlighting the potential to be physically active and gain new insights into exercise routines.

> I highly recommend these exercises to fellow pwMS. They are quite innovative, not only instilling a newfound desire in me to walk more but also making the training thoroughly enjoyable. (ID37/MCMI-MCGT)

Remaining in sync

Participants expressed feeling a subconscious connection to the music's rhythm, noting a transformation in their walking that resembles a meditative experience. Achieving synchronised walking with the beat was viewed as a source of increased motivation. They expressed that the music served as a catalyst for their movement, infusing walking with a sense of enjoyment. Participants found that music also facilitated an automatic response in their walking, making their gait smoother and more effortless. This would reduce the need to concentrate during walking, lessening external distractions and resulting in extended distances walked.

> Having the music or rhythm in my ear while walking really helps; you get into the flow if you just keep going with it. (ID60/MCMI-MCGT)

Participants shared that the walking training remained enjoyable even when the music tempo was quite fast, presenting a challenging aspect. Combining slow rhythms and large steps posed initial difficulties in maintaining balance. They acknowledged that with consistent practice, they were able to successfully complete the tasks, enhancing their awareness of movement.

> Gait training is super fun! At the start of each new week, it's challenging to get in sync again, but it gets better. (ID37/MCMI-MCGT)

Music appeared to deeply engage participants' emotions. Those who favoured the selected genres, noted melodies and rhythms to resonate with their feelings and personal experiences, establishing a profound emotional connection and eliciting considerable pleasure.

> I'm increasingly connecting with the music beat, and it's translating into my physical movements. (ID50/MCGT)

Participants in both the MCMI and MCMI-MCGT groups faced comparable difficulties in coordinating

their imagined walking with the music beat, especially in initial training stages.

> At the moment, it is not yet possible for me to remain with my imagined walking on the rhythm and beat for a whole song. (ID1/MCMI-MCGT)

Early difficulties were mainly noted in kinaesthetic MI, but practice led to noticeable improvements.

> I find the MI training quite pleasurable now; even though with some faster songs, it's still a little challenging to maintain the pace, I can already better 'feel' my body walking. (ID109/MCMI)

Participants perceived a resonance with the rhythm during MCMI, leading to a positive sensation after practice.

Certain participants considered the walking programme quite strenuous. Among the challenges reported, some found keeping in time and taking slow steps to be the most difficult exercise while others struggled with taking large steps.

> Big steps are still somewhat difficult because of my balance issues. With slow walking, keeping balance is also challenging, and this exercise is unfamiliar to me. (ID122/MCMI-MCGT)

Participants with severe walking impairment found certain exercises challenging, requiring extra recovery time post-training. Fatigue further exacerbated the effort required during walking.

> If the music tempo is fast, I tire quickly. (91/MCGT)

Participants who were proficient walkers did not encounter significant challenges with walking itself, but they still faced issues related to endurance.

> Keeping up the pace works well, but I notice that I lack stamina. (ID67/MCGT)

As participants progressed through the exercises, they found them to become more manageable, indicating improvement. Several participants mentioned sensing the music's influence on their gait, providing support and reducing the perceived physical exertion.

> I find it interesting that when I exercise with the music, it feels easier, and I don't feel the effort as much. (ID47/MCGT)

Participants held varied views on different types of cues. Many found both music and metronome beneficial in aiding orientation and maintaining a consistent walking pace.

> The music tracks and the metronome both serve as effective guides for keeping my orientation while walking. (61/MCMI-MCGT)

Participants appreciated verbal cues as helpful reminders, but some felt they interfered with their ability to focus on walking.

> The verbal cues tend to interfere because if they're 'left—right,' I may just step with the other foot. But otherwise, the verbal cueing is good because it reminds me of the task. (ID42/MCMI-MCGT)

One participant in the MCGT group expressed feeling overwhelmed by the various stimuli.

> I feel overwhelmed when faced with all the information simultaneously. (ID74/MCGT)

Some participants felt that the metronome beat was somewhat too loud or even irritating while others found it particularly helpful, preferring it over the music cues.

> Honestly, I find the metronome annoying. (ID84/MCMI)

> Finding the beat at first is a bit difficult—the metronome helps with this. (ID4/MCGT)

Interconnection between imagined and actual walking

The ease or difficulty to perform walking exercises was reported to be influenced by an individual's current physical, cognitive and emotional state. Patients often noted that MI can enhance their walking abilities even when their overall health is inferior. Imagining oneself walking appeared to be less demanding than physically executing the movement, although imagining more challenging movements, especially those involving impaired body parts, could pose difficulties. Participants in MCMI and MCMI-MCGT groups reported heightened awareness of the connection between real and imagined walking, especially regarding the level of exertion.

> I've discovered that what comes easily in real walking is similarly effortless in my imagination. (ID102/MCMI)

Participants facing challenges in foot lifting, narrow walking, large steps and gait speed observed these difficulties persisting during MI. Simulating walking on the more impaired side was notably more challenging than the side with better motor functioning.

> Visualising the movement of my left foot is more difficult, likely because my gait issues are more pronounced on that side. (ID113/MCMI)

Changes in tempo appeared to present challenges in both actual and imagined walking. Successfully managing the task led to a temporary improvement in walking.

> I often struggle with MI, especially with small and quick steps. Such movements are typically challenging for me, making it hard to visualise. However, if it works, it tends to inspire me to walk, and I manage to take a few steps quite nicely! (ID18/MCMI)

Coordinating the movement of arms and legs in sync with the beat seemed nearly impossible for most participants, both in real and imagined walking.

It's challenging for me to envision my hands moving along during imagined walking because I haven't been able to do that in real walking for a long time. (ID131/MCMI)

For certain participants, engaging in MI seemed to trigger autonomous changes akin to those experienced during real walking, such as sweating.

During MI, I tend to perspire similarly to when I engage in proper walking. (ID119/MCMI)

Some felt that their muscles were inclined to contract or actually contracted, even when they were sitting in a relaxed position on a chair.

I even feel my muscles contracting during imagery, creating an enjoyable sensation. (ID53/MCMI-MCGT)

Participants facing challenges in MI were advised by study therapists to experiment with strategies like physically performing the movement before transitioning into MI, a successful approach in some cases.

With MI, I initially had to actively execute the foot lift to be able to visualise the movement effectively. (ID15/MCMI-MCGT)

After practising several weeks of MCMI, some participants observed improvements in their motor function.

I've observed that imagining movements positively impacts the way I actually do them. (ID131/MCMI)

Sustaining focus

The majority of participants viewed MI as a stimulating and novel experience, with successful imagery evoking feelings of happiness and satisfaction. Overall, engaging in MI was described as pleasurable, calming and uplifting, often accompanied by a sense of warmth in the body during the practice. Initially, certain participants struggled with MI, but over time, many found it enjoyable. However, concentrating on MI could be challenging due to distractions from other thoughts or external factors. Some faced ongoing concentration issues, especially those prone to fatigue. Introducing a pause was identified as a beneficial strategy. Participants acknowledged that regular practice was crucial for effective MI.

Engaging oneself in movement imagery is initially quite demanding. However, once immersed, I get into a certain flow with it. (ID83/MCMI-MCGT).

Effort specifically pertained to the cognitive load.

Imagining myself walking is more mentally taxing than I anticipated. (ID101/MCMI-MCGT)

As MI duration increased, some initially experienced a decline in concentration. However, concentration on MI improved over weeks of practice.

With MI, the first 15 minutes are always harder than the second 15 minutes. The second week I was much better at imagining (…). (119/MCMI)

Although the study intervention focused on kinaesthetic MI and participants were instructed to perform kinaesthetic MI, some found visual MI to be easier. This distinction persisted for certain participants while for others, continuous practice led to an improvement in feeling their body moving during MI.

I can imagine moving my limbs quite well already, but 'feeling' my body walking is a bit more difficult than 'seeing' it. (ID109/MCMI)

Participants observed that MI not only enhanced their walking but also positively impacted other body systems. Improved sensory responses, enhanced body perception and mood were reported. For pwMS with impairments in bodily perception, imagining strong movements like taking large steps was found beneficial. Participants also found it helpful to imagine walking in familiar contexts and appreciated the positive influence of particular songs on their MI experience.

This programme is so innovative! Personally, envisioning myself walking proves beneficial for my psyche. (ID53/MCMI-MCGT)

Participants described a sensation of their body warming up or their heartbeat quickening during MI practice.

… my body warms up while practicing [MI]! (ID52/MCMI)

When MI posed challenges, certain participants found it advantageous to relate its content to their immediate surroundings. 'The motor imagery part is difficult, and therefore I imagine myself walking in certain familiar contexts such as a path along the river close by, which helps.' (28/MCMI-MCGT)

Real-world transfer

Many participants aimed for integrative use of the training content in daily life. Most participants welcomed the intervention for its diverse approach, incorporating weekly changes in audio mix, exercises and music, along with walking on different surfaces. Some emphasised the personalised aspect, like using walking sticks outdoors during fast melodies and walking without sticks indoors with a slower beat. They found guidance and instructions to the programme helpful, boosting adherence.

The training provides a refreshing change from the usual therapies. (ID 8/MCMI-MCGT)

Several participants conveyed a preference for an even greater variety in the exercises.

In my opinion, even more variety would be desirable, such as taking side steps and not just walking straight ahead, stair climbing, and standing still for a moment. (ID127/MCGT)

Participants emphasised the importance of structuring their MI considering the time of day and their fatigue level. Applying to both actual gait training and MI, the

choice of timing depended on individual work and care responsibilities.

> Structuring my walking imagery training is important, considering the time of day and fatigue. I find it best to practice first thing in the morning! (ID20/MCMI)

Certain participants were unsure if their MI or walking aligned with the intended approach. They desired a supervising physiotherapist for instructions, corrections and video guidance.

> I feel uncertain about whether I'm doing it right, so it would be helpful for me to show the various walking tasks to a supervising physiotherapist and ask for confirmation. /… could potentially be combined with video guidance in advance. (ID128/MCMI-MCGT)

Many participants wanted personalised MCGT, desiring customisation in both walking exercises and music selection. Those with distinct music preferences, such as hard rock or jazz, expressed a desire for the option to choose the music genre in future applications.

> I'd appreciate different musical genres to choose from. (ID82/MCMI-MCGT)

Participants appreciated the no-cost access to the exercise programme, highlighting its convenience as it required no special equipment, allowing easy engagement whenever needed.

> There's no need for special equipment; you can always engage in the walking training. (ID132/MCGT)

Some participants saw the training as beneficial not only for pwMS but also for those with other neurological disorders. They acknowledged the detailed instructions and helpful tips, recognising the broader applicability of the training.

> I believe this programme can be used as is, with guidance for information, by all individuals who could benefit from it, not just those with MS. (ID66/MCMI-MCGT)

Some participants emphasised the need for progressive difficulty and a broader range of exercises to maintain engagement. Recommendations included incorporating exercises for pwMS post-relapse and presenting training elements through videos for clearer instructions.

> I propose a further development that integrates short videos for individuals with MS to visually observe the different steps and movements. (ID103/MCMI)

Participants valued the flexibility of integrating gait training into different situations and drew motivation from its usage. Some suggested using this training as a group activity.

> I believe this kind of training would be fascinating as a group activity. It could be even more enjoyable, with people motivating each other. (ID101/MCMI-MCGT)

Most participants reported improvements in walking, fatigue, overall health status and body perception.

> The walking exercises inspire a more active approach and encourage better awareness of your body; this is truly a new experience for me. (ID7/MCGT)
>
> I am eager to continue gait training as it not only provides mental fortitude but also positively impacts the body and overall health. It feels like training the entire movement process. (44/MCMI)

Participants expressed feeling more secure on stairs and an enhanced sense of upright posture during daily sitting and walking.

> I feel great because I can navigate stairs more easily now, and I no longer feel as insecure. (ID36/MCMI-MCGT)

Following MCMI, some participants noted that the skills acquired through MI had successfully transferred to their real-life walking.

> It's easier to walk in everyday life if I apply what I've learned through MI. (ID63/MCMI)

Accessibility was considered crucial, with recommendations for the programme to be widely available due to its practicality and potential benefits for those with walking difficulties. Participants proposed a collaboratively developed comprehensive music-cued exercise programme extending beyond gait training, incorporating daily activities and various motor tasks. Suggestions included integrating walking sticks into MI, involving arm and hand tasks, applying MI to household activities and combining walking and breathing exercises.

> For future exercise programmes, I'd like a comprehensive plan with music that includes various tasks, potentially incorporating daily life activities. (ID63/MCMI)

DISCUSSION

This study aimed to gain insight into the experiences and acceptability of an actual and imagined MCGT versus their combination in pwMS. Furthermore, the study aimed to explore participants' self-rated overall health status including perceived changes in walking and fatigue after the intervention and gather their recommendations for the further development of the programme. Five themes were identified through TA: (1) empowerment, (2) remaining in sync, (3) interconnection between imagined and actual walking, (4) sustaining focus and (5) real-world transfer.

Theme 1 encapsulates participants' reflections on personal empowerment, increased motivation and the perceived possibility of leading a more active life while living with MS. This theme also details the physical and psychological advantages derived from both real and imagined gait training, shaped by positive reinforcement and music-supported exercises. Our results are partially consistent with those of a qualitative study involving pwMS with moderate disability.[40] The participants in that study reported enhanced bodily confidence, greater autonomy in daily tasks and increased involvement following core stability and balance exercise training.[40] Similar to our study, participants in the referenced study found the exercises to be novel, engaging and demanding in terms of physical capabilities and focus. However, a distinction between the two studies is that their account did not extend beyond the improvements in functional abilities, omitting enhanced personal empowerment and the perceived potential for leading a more active life with MS. Consistent with our results, another qualitative study characterised exercise as a vital therapeutic approach for MS management. Participants in that study viewed exercise as a means to assert control over MS, rather than letting MS control them.[41]

Theme 2 illustrates participants' perceptions of synchronising their walking to the music beat, which was described as a rewarding challenge, improving concentration and providing a sense of flow. Our findings align with research suggesting that music can evoke biologically grounded emotions crucial for human experience.[42] Studies exploring the connection between music and meaning have identified mechanisms influencing emotions, using diverse information to shape future behaviour.[43 44] These mechanisms are linked to mental representations.[45 46] Our results may be explained by various mechanisms engaging distinct modes of mental representation, as outlined in the BRECVEMA framework.[47] BRECVEMA comprehensively addresses emotional responses to music through psychological mechanisms such as brain stem reflex, rhythmic entrainment, evaluative conditioning, contagion, visual imagery, episodic memory, musical expectancy and aesthetic judgement.[47 48] In our study, each of these elements constituted the intervention, contributing to the observed findings. While one participant in the MCGT group expressed feeling overwhelmed by various stimuli, no other mentions of feeling overstimulated were reported. Conversely, participants largely valued the music cueing, with some individuals finding the metronome or verbal cues particularly beneficial. This contrasts with prior studies highlighting sensory processing challenges,[49] especially concerning multisensory information processing.[50] The differences observed might be linked to the intervention context, considering that previous cross-sectional studies solely conducted distinct tests, while our study involved a comprehensive intervention facilitated by physiotherapists through phone support. Further investigation is warranted to delve deeper into this topic.

Theme 3 highlights MCMI and MCMI-MCGT group participants' perspectives regarding the strong connections between real and imagined walking. These findings align with prior studies indicating the interconnection of imagined, perceived and executed actions.[51 52] Imagining specific movements activates a representation linked to the sensory outcomes and motor output of the same movement.[51 52]

Theme 4 highlights participants' initial challenges with MI, though many reported gradual improvement and increased enjoyment. Despite the study team's intention to solely use kinaesthetic MI, visual MI was easier for some, persisting throughout the 4-week period while continuous practice improved kinaesthetic MI for others. These findings align with common observations of impaired MI ability in pwMS, particularly when cognitive impairment is present.[53] Some of our participants reported that the effort involved in MI was indeed linked to cognitive load, noting that MI was more mentally demanding than expected. While our eligibility criteria excluded pwMS with cognitive impairment, this decision could explain why participants did not report additional challenges concerning cognitive limitations. Limited evidence exists on improving MI ability through repeated rhythmic-cued practice in pwMS.[53] Previous studies suggest methods like PETTLEP and external cueing can enhance MI abilities in pwMS,[11 13 54] both were incorporated in our study. A study reported differences between internal and external MI perspectives, indicating that patients with higher levels of physical proficiency tended to use internal MI.[55] Other research demonstrated that employing kinaesthetic MI improves mental synchrony between imagined and actual movements, particularly compared with visual MI in a sedentary population.[56] Some of our participants with varying degrees of motor impairment initially struggled with kinaesthetic MI, but improvements were observed over time. The reasons for this are currently unknown and warrant further investigation in future studies. These findings further emphasise the importance of exploring methods to facilitate kinaesthetic MI in pwMS.

Theme 5 embraces a diverse approach of MCMI, MCGT and MCMI-MCGT, including the programme's weekly variations in audio mix, exercises and music and highlighting personalisation. Some participants suggested expanding the programme, introducing greater variety, progression in difficulty, physiotherapeutic supervision and video instructions. Our findings are consistent with a systematic review[57] that highlighted key components in successful motor training programmes for pwMS, including a great variety of exercise components, high intensity and variability in training, task-focused exercises, progressive difficulty levels, context-specific training and a client-centred approach.[57] Participants' positive response to the diverse training content, finding it enjoyable and challenging, resonated with findings from a recent qualitative study on multimodal agility-based exercise training in fatigued

pwMS.[58] Additionally, our participants expressed desire for diverse exercise options aligns with a study demonstrating that increased variety in exercises can promote well-being, motivation and adherence.[59] The positive outcomes and the transfer of MI skills to real-life walking reported by our participants corroborate findings from systematic reviews outlining effective MI training characteristics across different populations[10] and a recent study in healthy individuals showing transfer effects to motor skill performance from MI practice.[60] Our participants valued personalisation, information accessibility and individualised support from physiotherapists, aligning with a qualitative meta-synthesis indicating that positive professional guidance, exercise-related information and tailored adjustments were crucial factors highlighted by individuals with MS to enhance their exercise motivation.[61] These aspects highlighted by our participants mirrored several exercise training principles from a systematic review of exercise training in pwMS. These principles include high specificity, sufficient intensity, progression in difficulty/intensity, greater potential with low baseline values and maintaining training for sustained improvements.[62] Furthermore, reflecting our complex intervention, a network meta-analysis of RCTs demonstrated that although a variety of exercise types improved functional balance and walking in pwMS, the most effective were more complex interventions including yoga, aquatic exercise training and virtual reality training.[63]

Implications for further development of the MCMI and MCGT programmes include ensuring the integration of training content into daily life, maintaining a diverse intervention approach, incorporating weekly changes in audio mixes, exercises and music and walking on different surfaces. Specific instructions, individualised guidance and free access to the exercise programme are also essential. Additionally, expanding the range of exercises, introducing progressive difficulty levels, providing supervisory physiotherapy support, offering video guidance and personalising training with customisable walking exercises and music selections are recommended. Group activities should be included, and the exercise programme should potentially be extended beyond MS to other neurological disorders, aligning with the desire of pwMS for a comprehensive and varied approach beyond traditional gait training.

While our study possesses notable strengths, it is important to acknowledge its limitations. First, the data collection involved multiple interviewers, each with varying levels of experience in qualitative interviewing. While all interviewers underwent training, the potential influence of these differences on the gathered information cannot be dismissed. We are confident that the substantial sample size helped mitigate this disadvantage. Second, the lack of member checking represents a limitation of our study. Third, self-rated health status was only evaluated after the intervention and not at the start, which represents a further study limitation. Finally, our study generated a considerable volume of qualitative data, necessitating a comprehensive and in-depth analysis. Recognising the challenges associated with such an analysis, we made a concerted effort to uphold the depth and richness of our data. We recognise that due to their regularity, the weekly interviews with participants might have been an essential part of the intervention rather than just an evaluation tool. The interviews not only monitored progress and offered tailored support for MCMI and MCGT but also potentially bolstered engagement, communication, accountability and relationships between participants and therapists.

In conclusion, participants valued both the imagined and actual MCGT approaches, acknowledging them as innovative. They reported positive changes in their self-rated walking, fatigue and overall health status following the study interventions. They offered valuable recommendations for the further development of the programme, extending beyond gait training, incorporating daily activities and various motor tasks. Therefore, proceeding to a participatory study aiming to collaboratively develop a music-cued exercise training programme with and for pwMS seems appropriate. Future studies should also focus on exploring the potential and limitations of pwMS in enhancing their MCMI abilities through intensive therapist-supported MI practice.

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