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ARTICLE

The effect of patient-initiated rhythmic auditory stimulation on gait speed status post stroke

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ABSTRACT

Rhythmic auditory stimulation (RAS) has been found to be an effective, low-cost, and easily applied intervention for improving gait speed post-stroke. Music-based RAS, the use of auditory rhythmic cues in the form of metrically accentuated music, can result in improved temporal abilities of gait through rhythmic practice. No study has observed the effect of patient-initiated auditory cueing, in conjunction with music-based RAS, on gait speed. Therefore, this study aimed to determine if having the patient initiate an external audible cue, by controlling the timing of their foot adorned with a shoe bell contacting the ground, coordinated with music-based RAS during gait training, will produce further improvement in gait speed. A single-centre randomised pilot study was conducted, consisting of 20 patients with a stroke diagnosis randomised into two groups. The control group (n = 7) received music-based RAS using *only music* during gait training, whereas the intervention group (n = 13) received music-based RAS using both a *shoe bell and music* during gait training. The 10-m walk test was conducted to determine each participant's pre- and post-intervention preferred and fast gait speed. Preferred speed was the comfortable, naturally chosen speed by the participant, and fast speed was the patient's maximum speed. The t-test showed that there were no statistically significant differences between groups. Paired t-test showed that there were significant improvements in gait speed between pre- and post-test within groups. The inclusion of a shoe bell, in conjunction with music-based RAS during gait training, resulted in a slightly larger improvement in preferred gait speed, whereas music alone during gait training results in a slightly larger improvement in fast gait speed.

KEYWORDS

stroke,
gait speed,
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INTRODUCTION

Following a stroke, patients may lose their ability to walk normally due to weakness and spasticity affecting the involved side of the body, which is often termed hemiplegic gait (American Stroke Association, 2022). As a result of these physical deficits, stroke leads to a significant decline in gait speed. Gait speed is significantly correlated with disability in patients post-stroke (Tilson et al., 2010). The most frequently stated goal for patients after a stroke is the recovery of gait ability. When stroke patients improve gait speed, they report improved function and reduced disability.

Selecting the optimal approach to enhance gait performance is often a confounding issue for patients and clinicians, since there are so many different interventions for physical deficits post-stroke (Dickstein, 2008). Interventions for improving gait speed post-stroke should be considered in relation to convenience, patient preference, mode of application, and cost. Rhythmic Auditory Stimulation (RAS) is an intervention in which movement is coordinated to sound and has been commonly used in gait rehabilitation for movement disorders (Ghai & Ghai, 2019). This method has been found to be an effective, low-cost, and easily applied intervention for improving gait speed. For instance, research has shown that RAS has medium to large standardised effects to enhance spatiotemporal gait parameters such as gait speed. Ko et al. (2016) have demonstrated increases in gait speed, stride length, step length, and cadence for hemiplegic stroke patients training with various RAS tempos, with greater changes occurring with faster tempos. Specifically with gait, Thaut and Rice (2014) summarises evidence of more attentive and consistent muscle activity during push-off, resulting in faster gait speeds, when RAS is present.

Additionally, for stroke rehabilitation, it is considered best practice that interventions be individually tailored, salient, task-specific, and involve adequate repetition and intensity to induce recovery (Ghai & Ghai, 2019). Training with music-based RAS has the potential to meet these guidelines for post-stroke gait rehabilitation. Music therapy has been found to be a common, as well as salient, adjunct to treatment for patients during rehabilitation. Music-based RAS, a formalised technique used in Neurologic Music Therapy, can result in improved temporal abilities of gait through rhythmic practice. Music-based RAS consists of a specific protocol aligned with neurological principles and uses auditory rhythmic cues in the form of metrically accentuated music with or without a metronome (Gonzalez-Hoelling et al., 2024).

In healthy older adults, music has been shown to improve gait parameters when compared to a metronome cue (Schaefer, 2014). This finding may be due to the emotional response of music which can motivate continuous rhythmic movement and positively impact gait speed, more so than the production of a precise motor prediction to sound. Music can be easily suited to the patient based on their preference and adjusted throughout gait training with music-based RAS to meet adequate intensity at minimal to no cost.

RAS involves synchronisation processes that are both conscious and unconscious (Schaefer, 2014). Patients tend to react foreseeably to auditory cues once the temporal pattern is mentally 'set up'. Adjustments to the beat pattern occur through conscious effort, which helps fine-tune tempo changes that may occur in the mental representation. In the scenario that music is used during gait training to encourage the mental representation of the gait tempo, the use of an auditory cue on the patient's foot using a shoe bell could help in maintaining the gait speed as the patient would have to adjust their cadence to fine-tune any deviation heard by the shoe bell in comparison to the music. Simply stated, if the patient is still not able to take or maintain a fast enough step with the music over time, the auditory cue of the shoe bell may assist in adjusting their gait speed to maintain the desired tempo, or gait speed.

There is a paucity of research investigating the effect of the patient playing an active role in initiating an auditory cue in conjunction with music-based RAS on gait speed. In prior studies, music played by the music therapist, was the only stimulation used and adjusted to facilitate a change in gait parameters, such as speed. Therefore, this randomised prospective pilot study from a single centre aimed to determine if having the patient initiate an external audible cue, by controlling the timing of their foot adorned with a shoe bell contacting the ground, in sync with music-based RAS during gait training would produce further improvement in gait speed. This intervention differs from prior studies in that the patient is producing an additional external auditory cue to match the tempo change in music to achieve a change in gait parameters. It was hypothesised that patients would demonstrate a more consistent volitional reaction to their own production of sound with each step taken in concurrence with the tempo of the music and, therefore, show a further increase in gait speed.

MATERIAL AND METHODS

Participants

This study was approved by Memorial Healthcare System's Internal Review Board (IRB #MHS.2022.047). Informed consent was obtained from all participants prior to enrolment and initial assessment, as required for the protection of human participants. Consent forms included details on the purpose of the study, benefits and risks of participation, voluntary right to participate and withdraw, and confidentiality of records and data sharing. Authorisation to release protected health information was also requested as part of the informed consent.

Design

A pilot randomised prospective study was conducted to determine if music-based RAS with music and shoe bell during gait training impacted preferred, or comfortable gait speed, and fast, or maximum, gait speeds. Primary eligibility criteria for the study included: stroke diagnosis, age 18 years or older, adequate hearing, intact capacity to follow simple commands, and the ability to ambulate 10 meters on initial assessment. Initially, a sample size of 30 was chosen based on the number of strokes admitted to the study facility per year and likelihood of ability to ambulate the minimal 10 meters on admission. However, due to staffing changes and time constraints, only 20 patients were enrolled and completed the study. Using a computer-generated randomisation schedule, a total of 20 patients with a stroke diagnosis were randomly assigned to the control or intervention group. Based on the computer-generated randomisation, seven patients were placed in the control group and thirteen patients were placed in the intervention group by the end of subject recruitment. The control group received music-based RAS using *only music* during gait training, whereas the intervention group received music-based RAS using both *a shoe bell and music* during gait training.

Procedures

Prior to the interventions, the research investigator, who was masked to the randomisation, conducted a 10-m walk test to determine each participant's baseline gait speeds. The 10-m walk test was used to assess gait speed in meters per second over a 10-m distance (Shirly Ryan Ability Lab, 2014). The participant walks without assistance for 10 meters, with the time measured for the middle six meters to allow for acceleration and deceleration. Either preferred gait speed or fast gait speed can be tested (Shirly Ryan Ability Lab, 2014). Preferred gait speed is the participant's comfortable, natural walking speed, while fast gait speed is the maximum walking speed of the participant. For preferred gait speed, the participants were asked to walk the 10-m distance at their comfortable, natural pace. When assessing fast gait speed, participants were asked to walk as fast, but safely, as they could for the 10-m distance. An average of two trials was computed to measure preferred and maximum gait speed. Assistive devices may or may not be used but must be kept consistent and documented for each measure of performance. For the stroke population, the 10-m walk test has excellent test-retest reliability (ICC = 0.95 to 0.99) and strong correlation with dependence in instrumental activities of daily living (r = .76; Shirly Ryan Ability Lab, 2014).

During each session, music-based RAS was conducted with music set at the recommended one to three beats per second above the patient's baseline gait speed (Ghai & Ghai, 2019). Music consisted of played guitar chords synced to a metronome monitored and adjusted by the Neurologic Music Therapist providing treatment. Chords played were based on the song and genre preference of each patient. For patients in the intervention group, a shoe bell was strapped around the patient's foot of the involved lower limb as shown in Figure 1. The intervention lasted a total of 20-minutes per session, not including seated rest breaks. A total of six treatment sessions were provided during the patient's rehabilitation stay (three times per week for two weeks). Following the sixth session, the 10-m walk test was repeated to determine the patient's post-intervention preferred and fast gait speeds. The collection of all data was conducted by a separate recorder that was not involved in the intervention, randomisation of subjects, or assessment of the outcome measures.

STATISTICAL ANALYSIS

Descriptive statistics were calculated for all demographic variables. Fisher's Exact Test was used to examine categorical variables with results presented as counts and proportions. Welch's *t*-test was used to assess continuous variables for between group differences (i.e., control vs. intervention group mean differences). To assess the study's outcome measure of within group mean difference in gait speeds, pre- and post-intervention, a paired sample *t*-test was used. Results of continuous variables are presented as mean and standard deviation (SD), as well as range. Results were considered statistically significant at a significance level of $p < .05$. All analyses were conducted using Stata/SE 15.1.

Figure 1: Shoe bell donned to the foot of the involved limb

RESULTS

A total of 20 patients met the study's inclusion criteria, of whom 65% (n = 13) were randomised to the intervention group. Age ranges for each group included minimum to maximum values. The average age among the control group (music only) was approximately 59 years old, while the average age among the intervention group (music with shoe bell) was almost 65 years old. There were no statistically significant differences in demographic characteristics between the control and intervention group, as shown in Table 1.[1] All participants were patients admitted into inpatient rehabilitation in the early subacute phase, which is an average of seven to ninety days post their initial onset of stroke.

In the assessment of between-group mean differences for preferred gait and fast gait speeds, there were no statistically significant differences between the control and intervention groups as demonstrated in Table 2. However, in the assessment of within group pre-to-post mean differences, there were statistically significant increases in preferred and fast gait speeds, pre-to-post interventions for both the control and intervention groups. Although both groups had significant increases in preferred and fast gait speeds, on average, the intervention group had a slightly larger increase in preferred gait speed compared to the control group (0.5 vs. 0.4 m/s) and the control group had a slightly larger increase in fast gait speed compared to the intervention group (0.7 vs. 0.6 m/s) as demonstrated in Table 3.

[1] Note for Tables 1, 2 and 3: Boldface font indicates statistical significance at $p < .05$. Note: Rounding errors may be present.

	Music only (%)	Music with shoe bell (%)	*p*-Value
N (%)	7 (35.0)	13 (65.0)	-
Age in years			
Mean ± SD	59.3 ± 6.0	64.9 ± 15.7	.266
Range	52 - 68	26 - 91	-
Gender			1.000
Male	4 (57.1)	7 (53.8)	
Female	3 (42.9)	6 (46.2)	
Race/Ethnicity			.718
NH White	2 (28.6)	4 (30.8)	
NH Black	3 (42.9)	6 (46.2)	
NH Other	1 (14.3)	0 (0.0)	
Hispanic	1 (14.3)	3 (23.1)	

Table 1: Participant demographics, by intervention type

Abbreviations: SD, Standard Deviation; NH, Non-Hispanic

	Music only, Mean ± SD	Music with shoe bell, Mean ± SD	Absolute mean difference	*p*-Value [a]
Preferred Gait (m/s)				
Pre-Intervention	0.4 ± 0.3	0.4 ± 0.2	0.0	.814
Post-Intervention	0.8 ± 0.4	0.9 ± 0.4	0.0	.835
Fast Gait (m/s)				
Pre-Intervention	0.6 ± 0.4	0.7 ± 0.3	0.1	.570
Post-Intervention	1.3 ± 0.6	1.2 ± 0.4	0.0	.912

Table 2: Gait speed between group absolute mean differences

[a] p-Values indicate statistical significance of mean differences *between* the control (music only) and intervention (music with shoe bell)

	Music only, N= 7				Music with shoe bell, N=13			
Gait Speed (m/s)	**Pre Mean**	**Post Mean**	**Absolute Mean Difference**	***p*-Value [a]**	**Pre Mean**	**Post Mean**	**Absolute Mean Difference**	***p*-Value [a]**
Preferred Gait	0.4	0.8	0.4	0.004	0.4	0.9	0.5	<0.001
Fast Gait	0.6	1.3	0.7	0.002	0.7	1.2	0.6	<0.001

Table 3: Gait speed within group pre- and post-intervention mean differences

[a] p-Values indicate statistical significance of differences between the pre and post periods *within* each group

DISCUSSION

Overall, there was no statistically significant difference between the control and intervention groups. Within each group, there was a significant difference in the improvement of preferred and fast gait speed. Specifically, the control group, which had only music, had a slightly *larger* improvement in *fast* gait speed. This result could be due to the control group having no cognitive loading factor, or need to dual task synchronising the sound of shoe bell with music. However, the intervention group with music and shoe bell had a slightly *larger* improvement in *preferred* gait speed. In other words, a slightly larger change in preferred, natural gait speed occurred in participants in the intervention group. Based on this finding within the intervention group, a question arises of whether or not there was an internal neuroplastic adjustment of the patients' physiological and spatial settings for preferred gait speed.

There are multiple studies that provide evidence of the ability of RAS to induce neural entrainment of auditory, sensorimotor, and motor pathways of the brain resulting in significant functional and structural brain changes, especially in motor regions (Braun Janzen et al., 2022; Ghai & Ghai, 2019). Hutchinson et al. (2020) showed that an immediate change in preferred and fast walking speeds occurred after only a single bout of training, with additional increases following three days of training. Also, positive benefits of training with RAS have been shown to persist after six months of intervention in community-dwelling older adults (Shirly Ryan Ability Lab, 2014). However, more research is needed on retention of gains once training is stopped.

Numerous factors contribute to our preferred gait speed including the aforementioned neurological control, joint range of motion, limb strength, sensory function, cognitive status, and energy level (Chui et al., 2020). Collimore et al. (2023) observed a reduction in the energy cost of walking following RAS with gait training in post-stroke patients. The mechanism by which the shoe bell could have specifically affected these individual factors will need further investigation. Regarding joint range of motion and limb strength, a question arises of whether the shoe bell may have facilitated more intentional ankle movement and muscle force of the limb by the patient to produce a synchronised bell ring with the music. As far as sensory function, additional questions arise pertaining to whether or not the bell may give feedback of foot placement for patients who lack sensory information of the affected limb. In other words, did the sound of the bell enhance coordination, timing, and initiation of the affected limb to increase speed? Although cognitive loading likely contributed to the fast gait speed being slightly lower within the intervention group compared to the control group, could the attention required to synchronise the bell sound with music increase the attention to initiate a step more quickly during the slower preferred gait speeds? Shaefer (2014) reviews that tasks performed with auditory rhythmic cues lessen the requirement of motivational and attentional efforts directed towards timing and motor control, with an enhancement in emotional engagement. With these contributing factors being enhanced, gait spatiotemporal parameters such as cadence and stride length, and ultimately velocity, will also improve and lead to a more efficient gait pattern which plays a significant role in our selected preferred gait speed (Chui et al., 2020).

Last, is fast or preferred gait speed more important to monitor during the recovery of stroke patients? Based on past study results, preferred gait speed should be considered for predicting physical function and chronic diseases, while fast gait speed helps in estimating subjective general health and muscle mass gains (Kim et al., 2016). Therefore, fast gait speed is a stronger predictor of disability onset, while preferred gait speed is a highly reliable indicator of health and functional ability in older adults (Mehmet et al., 2020). Moreover, during post-acute stroke, fast gait speed would be considered favourable to monitor for the severity of disability caused, whereas in the subacute to chronic stage, preferred gait speed is essential in determining maintenance of function versus decline from a possible regression due to progression of initial stroke or reoccurring stroke. All the factors discussed could guide the choice of whether to use a shoe bell in addition to music during RAS training versus music alone. For example, if a patient is within the subacute stage post-stroke and exhibits sensory deficits, decreased motivation and/or attention, and has minimal cognitive deficits, utilising music-based RAS in conjunction with a shoe bell may slightly improve their preferred walking speed while also engaging the patient and allowing insight into their current physical function and health.

CONCLUSION

Music-based RAS with only music and music-based RAS with music and shoe bell resulted in statistically significant improvement of both preferred and fast gait speeds, when comparing pre-post intervention. There were no statistically significant differences between the two groups; however, a slightly larger improvement in preferred gait speed was observed in the music-based RAS with music and shoe bell group. Therefore, using a shoe bell in addition to music versus music alone during music-based RAS may show a slightly larger improvement in preferred gait speed across time for individual patients. Contrary to the hypothesis of the shoe bell resulting in globally faster gait speeds when compared to music alone, gait training with music only was shown to result in a slightly larger improvement in fast gait speed across time for individual patients.

The results of this study are limited due to the small sample size and further research is needed to confirm findings. Other potential topics for future studies may include how a shoe bell impacts the factors that determine preferred gait speed along with the impact a shoe bell has on attention to limb advancement during preferred gait speed. Cognitive loading limitation should be considered when assessing fast gait speed, particularly for patients with cognitive deficits. Choosing whether to use a shoe bell in conjunction with music versus music alone, should be guided by the patient's stage of recovery post-stroke and cognitive ability.

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Ελληνική περίληψη | Greek abstract

Η επίδραση της ρυθμικής ακουστικής διέγερσης με πρωτοβουλία του ασθενούς στην ταχύτητα βάδισης μετά από εγκεφαλικό επεισόδιο

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ΠΕΡΙΛΗΨΗ

Η ρυθμική ακουστική διέγερση (rhythmic auditory stimulation, RAS) έχει αποδειχτεί ότι είναι μία αποτελεσματική, χαμηλού κόστους και εύκολα εφαρμόσιμη παρέμβαση για τη βελτίωση της ταχύτητας βάδισης μετά από εγκεφαλικό επεισόδιο. Η βασισμένη-στη-μουσική RAS, δηλαδή η χρήση ακουστικών ρυθμικών σημάτων με τη μορφή μετρικά τονισμένης μουσικής, μπορεί να οδηγήσει σε βελτιωμένες χρονικές ικανότητες βάδισης μέσω ρυθμικής εξάσκησης. Σε καμία έρευνα δεν έχει μελετηθεί η επίδραση των ακουστικών σημάτων με πρωτοβουλία του ασθενούς, σε συνδυασμό με τη βασισμένη-στη-μουσική RAS, στην ταχύτητα της βάδισης. Ως εκ τούτου, η παρούσα μελέτη είχε στόχο να προσδιορίσει αν η παροχή ενός εξωτερικού ακουστικού σήματος από τον ασθενή, ο οποίος ελέγχει τον χρονισμό επαφής του ποδιού του με το έδαφος, καθώς φοράει παπούτσι με κουδούνι, συντονισμένα με βασισμένη-στη-μουσική RAS κατά τη διάρκεια εξάσκησης της βάδισης, μπορεί να επιφέρει περαιτέρω βελτίωση στην ταχύτητα της βάδισης. Πραγματοποιήθηκε μία μονοκεντρική τυχαιοποιημένη πιλοτική μελέτη, με 20 ασθενείς με διάγνωση εγκεφαλικού επεισοδίου οι οποίοι τυχαιοποιήθηκαν σε δύο ομάδες. Η ομάδα ελέγχου (n=7) έλαβε βασισμένη-στη-μουσική RAS μόνο με χρήση μουσικής κατά την εξάσκηση της βάδισης, ενώ η ομάδα παρέμβασης (n=13) έλαβε βασισμένη-στη-μουσική RAS με χρήση παπουτσιού με κουδούνι και μουσική κατά την εξάσκηση της βάδισης. Διεξήχθη η δοκιμασία βάδισης των 10 μέτρων για να προσδιοριστούν η προτιμώμενη ταχύτητα και η γρήγορη ταχύτητα βάδισης κάθε ασθενούς πριν και μετά την παρέμβαση. Κατά την αξιολόγηση των μέσων διαφορών μεταξύ των δύο ομάδων για την προτιμώμενη ταχύτητα και τη γρήγορη ταχύτητα βάδισης, δεν βρέθηκαν στατιστικά σημαντικές διαφορές μεταξύ των ομάδων ελέγχου και παρέμβασης. Κατά την αξιολόγηση των μέσων διαφορών εντός των ομάδων πριν και μετά την παρέμβαση, υπήρξε στατιστικά σημαντική αύξηση ως προς τις προτιμώμενες ταχύτητες και τις γρήγορες ταχύτητες βάδισης, πριν και μετά την παρέμβαση. Η προσθήκη ενός κουδουνιού στο παπούτσι, σε συνδυασμό με τη βασισμένη-στη-μουσική RAS κατά τη διάρκεια της εξάσκησης της βάδισης, είχε ως αποτέλεσμα μία ελαφρώς μεγαλύτερη βελτίωση στην προτιμώμενη ταχύτητα βάδισης, ενώ μόνο η μουσική κατά την διάρκεια της εξάσκησης της βάδισης οδήγησε σε ελαφρώς μεγαλύτερη βελτίωση στην γρήγορη ταχύτητα βάδισης.

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εγκεφαλικό επεισόδιο, ταχύτητα βάδισης, μουσικοθεραπεία