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Music and metronome cues produce different effects on gait spatiotemporal measures but not gait variability in healthy older adults

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ABSTRACT

Rhythmic auditory cues including music and metronome beats have been used, sometimes interchangeably, to improve disordered gait arising from a range of clinical conditions. There has been limited investigation into whether there are optimal cue types. Different cue types have produced inconsistent effects across groups which differed in both age and clinical condition. The possible effect of normal ageing on response to different cue types has not been reported for gait. The aim of this study was to determine the effects of both rhythmic music and metronome cues on gait spatiotemporal measures (including variability) in healthy older people. Twelve women and seven men (>65 years) walked on an instrumented walkway at comfortable pace and then in time to each of rhythmic music and metronome cues at comfortable pace stepping frequency. Music but not metronome cues produced a significant increase in group mean gait velocity of 4.6 cm/s, due mostly to a significant increase in group mean stride length of 3.1 cm. Both cue types produced a significant but small increase in cadence of 1 step/min. Mean spatio-temporal variability was low at baseline and did not increase with either cue type suggesting cues did not disrupt gait timing. Study findings suggest music and metronome cues may not be used interchangeably and cue type as well as frequency should be considered when evaluating effects of rhythmic auditory cueing on gait. Further work is required to determine whether optimal cue types and frequencies to improve walking in different clinical groups can be identified.

1. Introduction

Sound and human movement are closely linked due to extensive connections between auditory and motor brain regions [1]. This is typified in the spontaneous synchronisation of rhythmic body movements such as foot tapping or head nodding to rhythmic music. This connection has been exploited in studies using rhythmic music or simple beats to cue rhythmic movements such as gait, which have become slowed and irregular due to a variety of clinical conditions [2]. In people with Parkinson's disease (PD) there is now sufficient evidence of the effectiveness of cueing gait with rhythmic auditory sounds for it to be recommended practice for improving spatio-temporal features of gait [3].

Whilst the specific neural pathways for auditory-motor synchronisation are not fully understood, early studies identified that sound could facilitate muscle activation via the reticulo-spinal system [4]. More recent studies have shown the posterior superior temporal gyrus and premotor cortex to be key structures for entrainment of motor responses with auditory cues [5]. Other brain regions implicated in rhythm synchronisation include supplementary and pre-supplementary motor areas, cerebellum and basal ganglia [1,5]. The ability of rhythmic auditory cueing to be effective across a range of different clinical conditions affecting different brain structures suggests cues are able to access a still-functional auditory-premotor circuit [5].

Rhythmic auditory cues (RACs) range in type from a simple rhythmic beat such as a metronome to specifically composed complex rhythmic music with accentuated beats. Despite some evidence that different cue types may produce different effects on movement [6], there has been limited systematic investigation to determine whether there are optimal cue types for gait and how they might operate. A group of healthy young adults walked faster in time to music than metronome cues at a range of tempi suggesting that the extra auditory elements in the music may have enhanced their motor performance more than simple beat cues [7]. In contrast, metronome but not music cues produced an increase in gait speed in a group with Huntington's disease (HD) and this difference was more pronounced with increased disease severity [8]. The authors

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suggested that participants' cognitive deficits may have impaired their ability to discern the beat from the more complex music structure [8]. Whilst differences in cognitive function may be the main reason for the difference in results between these two studies, another possibility not previously discounted is that age-associated changes in motor and sensory function affected responses to different cues in the older HD group.

In addition to its effects on spatio-temporal gait measures, rhythmic auditory cueing may also affect the variability or stride to stride fluctuation of walking. Gait variability has been identified as a marker of gait stability with increased variability associated with increased risk of falling [9]. An evaluation of a potential treatment approach such as rhythmic auditory cueing should therefore include not only its effects on measures of gait but also on their variability. It seems intuitive that synchronising movement to a rhythmic beat may reduce its temporal variability however the process of synchronising may increase executive function load which may have the opposite and undesirable effect of increasing gait variability [10]. Furthermore, different types of RAC may affect variability differently due to differences in the amount and complexity of information conveyed.

The effects of single types of RAC on gait variability have been reported however effects of different types of RAC on gait variability of the same participants have not been investigated. A study using a less complex rhythmic motor activity (finger tapping), found music cues produced less response variability than metronome cues at a cue frequency of 1 Hz [6]. The authors suggested that the extra timing information between the main beats in the music allowed participants to more accurately synchronise their finger movements [6].

Results from studies evaluating effects of single types of RAC on gait variability have been inconsistent. In healthy groups metronome cues delivered at 90% [11], 100% and 110% [12] of comfortable speed cadence resulted in an increase in gait temporal variability. Increased temporal variability of walking was also recorded in groups with PD at metronome cue frequencies of both 80% [13] and 110% [12] potentially supporting the proposal that RACs increase cognitive load. In contrast, however, two other studies of groups with PD found that metronome cue frequencies at both 90% [11] and 100% [14] of comfortable speed cadence decreased gait temporal variability. The only study to report the effect of rhythmic *music* cues on gait spatio-temporal variability also reported decreased timing variability in a group with stroke [15]. As well as the effects of different populations and cue frequencies in these studies, conflicting findings may also be due to the variety of gait parameters, testing protocols and analysis methods used.

We aimed to investigate the effects of music and metronome cues on spatio-temporal gait measures of healthy older people with normal cognition. We hypothesised that whilst normal ageing may result in some deterioration in neural and musculoskeletal function, responses of cognitively healthy older people to different RACs would be similar to those previously reported for healthy young adults [7]. Therefore older people with normal cognition would increase speed with music cues but not metronome cues. We also aimed to assess any changes with music and metronome cues in measures of gait variability using published recommendations for testing, analysis and reporting [16,17]. As our cognitively healthy older participants were likely to have low baseline spatio-temporal variability which would be unlikely to significantly decrease with cueing, the study was designed to detect potential increases in variability, important as a marker of decreased stability. We hypothesised that, similar to previous results for healthy groups [11,12], variability of cued gait would increase at comfortable speed tempo.

2. Methods

2.1. Participants

Nineteen healthy older adults (>65 years, mean age = 79.0 ± 7.8 years, 12 female, 7 male) were screened using a questionnaire designed to detect musculoskeletal, neurological and other problems which would affect walking including uncorrected visual disorders or pain. Other inclusion criteria were intact cognition (Mini-mental state examination (MMSE) score ≥26), adequate hearing and lower limb strength and range of movement within normal limits. The University Ethics Committee approved the study and participants provided written consent.

2.2. Apparatus

Spatio-temporal gait measures were recorded using a GAITRite® electronic walkway (CIR Systems, Inc., Havertown, PA 19083, USA). The walkway was 830 cm long and 89 cm wide with an active sensor area of 732 cm long and 61 cm wide. Data were sampled at a rate of 80 Hz. The system has been shown to provide valid and reliable measures of gait in older people [18]. The RACs were MIDI files of a musical piece (Pomp and Circumstance March No. 1 in D – Elgar. Available from: http://www.fordham.edu/halsall/mod/rulebritannia.asp#Rule%20Britannia) and a metronome beat. Each was played using commercial software (PowerTracks Pro Audio® PG Music Inc., Victoria BC V8Z 1T3, Canada) installed on a laptop computer connected to bookshelf speakers positioned adjacent to the walkway, with sound volume set at an "easily audible" level for each participant.

2.3. Procedure

Participants wore their own comfortable low-heeled shoes and walked firstly at self-selected comfortable speed eight times on the walkway (baseline). The first two walks were used for familiarisation and mean cadence for each participant was calculated from the last six. Sixteen further walks were then undertaken, eight (including two familiarisation walks for each condition) in time to each of music and metronome cues which were both set at a tempo matched to individual mean baseline cadence. The order of RACs was decided by coin toss and participants rested between each condition.

Prior to each cued walk the auditory cue was played and the participant was instructed to walk on the spot in time to the beat. Once gait cadence appeared to be synchronised an instruction was given to continue walking in time to the beat of the cue along the walkway. Walks started and finished two metres beyond each end of the walkway to ensure constant speed walking was recorded.

2.4. Data analysis

In order to select gait measures which adequately characterise walking we chose measures from five gait domains identified in a recent factor analysis [19] (Table 1). We also report swing time variability as it has been shown to be independent of gait speed so may be used to indicate steadiness where there is potential for speed to be a confounder [20], and cadence as an indicator of how closely participants matched their stepping tempo with cue frequency.

All usable walks (up to six per condition) for each participant were processed using the application software. Walks where the participant was recorded as having talked or become distracted were removed. According to typical practice for gait analysis studies we had planned to combine data from individual walks for each condition for each participant. Inspection of mean velocity values for individual walks however, revealed that whilst they were similar under each condition for most participants, there were a small number of larger differences between fastest and slowest velocity values in a single condition (e.g. 20 cm/s for one participant). As overground gait velocity is related to variability of most gait measures in older adults [21] we wished to minimise its potential to confound the comparison of measures of gait variability. We therefore removed the fastest and slowest walk under each condition for each participant and combined strides from the remaining walks. This resulted in a mean difference in velocity between fastest and slowest walks for the group under all conditions of 3.5 ± 2.2 cm/s (which is below a reported minimum clinically significant change value of 4.15 cm/s [22]). As the RAC tempo for each participant had been calculated during their testing session from the mean cadence of all usable baseline walks, we then compared the mean cadence of baseline

Table 1
Gait measures selected in five domains[a] of gait performance.

Gait performance domain	Gait measures
Rhythm	Swing time, stride time
Pace	Velocity, stride length
Phase	Double support percentage
Base of support	Stride width
Variability	Stride length variability, stride time variability

[a] Accounted for 83.3% of the variance in gait performance in adults aged >70 years [19].