The Effect of Rhythmic Musical Training on Healthy Older Adults’ Gait and Cognitive Function

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Received December 4, 2012; Accepted April 18, 2013

Decision Editor: Rachel Pruchno, PhD

Purpose of the Study: Older adults’ gait is disturbed when a demanding secondary cognitive task is added. Gait training has been shown to improve older adults’ walking performance, but it is not clear how training affects their cognitive performance. This study examined the impact on gait, in terms of cost or benefit to cognitive performance, of training healthy older adults to walk to a rhythmic musical beat. Design and Methods: In a mixed model design, 45 healthy older adults aged more than 65 years (M = 71.7 years) were randomly assigned to 3 groups. One group received a rhythmic musical training and their dual-task (DT) walking and cognitive performances were compared with a group who had music playing in the background but no training, and a third group who heard no music and received no training. Outcomes in single-task (ST) and DT conditions were step-time variability and velocity for gait and correct cognitive responses for the cognitive task. Results: The Musical Training group’s step-time variability improved in both the ST (p < .05) and the DT (p < .05) after training, without adversely affecting their cognitive performance. No change was seen in the control groups. Implications: Rhythmic musical training can improve gait steadiness in healthy older adults with no negative impact on concurrent cognitive functioning. This could potentially enhance “postural reserve” and reduce fall risk.

Key Words: Attention, Dual task, Musical training, Cognition

The ability to carry out two tasks simultaneously is achieved by efficient allocation of attention to both activities. Allocating attention is an executive function carried out within working memory (Baddeley, 1986), the system that oversees aspects of higher level cognitive function (Coolidge & Wynn, 2005). The dual-task (DT) paradigm provides a means of examining the allocation of attention when carrying out two tasks simultaneously, by comparing the impact on the performance of both tasks, when they are carried out concurrently, relative to the performance of both tasks when they are carried out separately (Baddeley & Hitch, 1974). There is almost always a “cost” to at least one of the tasks, known as the dual-task deficit (DTD), of dividing attention between two concurrent tasks, no matter how “simple” they are (Smith & Kosslyn, 2007).

Walking is a well-practiced motor action that involves some element of attention, but with
increasing age, it becomes less automatic and more attention is required (Dubost et al., 2006; Lindenberger, Marsiske, & Baltes, 2000). This is even more pronounced when walking is combined with a second activity such as talking. Decreased ability to allocate attention when carrying out two tasks, such as walking and talking, simultaneously “may be a marker” of cognitive decline (Yogev-Seligmann, Rotem-Galili, et al., 2012). It has been suggested that healthy older adults unconsciously adopt a “posture first” strategy when simultaneously walking and carrying out a cognitively demanding task (Shumway-Cook, Woollacott, Kerns, & Baldwin, 1997). That is, they naturally default to attending more to their gait than to the cognitive task, presumably to ensure their gait (Yogev-Seligmann et al., 2010). As such, reduced ability to effectively allocate attention can be detrimental to posture and balance, increasing the risk of falls (Siu, Chou, Mayr, van Donkelaar, & Woollacott, 2009).

When the cognitive load becomes very demanding, gait stability (which includes a measure of step-to-step variability) suffers (Hausdorff, 2005). This is important because DT situations, such as walking and talking, are common in everyday life. Finding ways to improve older adults’ attention allocation could be beneficial both for ensuring gait stability and enhancing “postural reserve,” which is a factor in an individual’s ability to respond effectively to a postural threat (Yogev-Seligmann, Hausdorff, & Giladi, 2012).

Interventions to improve attention allocation when walking and carrying out a cognitive task have been developed for people with Parkinson’s disease (PD). Some have shown that training older adults with PD to optimize their division of attention when walking and carrying out another activity can benefit their gait (Yogev-Seligmann, Giladi, Brozgol, & Hausdorff, 2012). Others demonstrate that rhythmic movement training increases gait regularity and automaticity, which, in turn, is linked to increased gait safety plus a reduction in fall risk (Bridenbaugh & Kressig, 2011). Auditory cues, sometimes embedded in music, have been particularly successful at training older adults with PD to walk more steadily (Rochester, Burn, Woods, Godwin, & Nieuwboer, 2009; Satoh & Kuzuhara, 2008; Thaut et al., 1996; Trombetti et al., 2011). Matching auditory cues to their preferred walking pace optimizes steady gait in people with PD (Arias & Cudeiro, 2008; de Bruin et al., 2010).

Because walking performance, under ST and DT conditions, naturally declines with age (Dubost et al., 2006; Lindenberger et al., 2000), improving gait steadiness could also benefit healthy older adults who do not currently have a gait or cognitive disorder. Training older adults to walk more steadily by making gait more rhythmic and automatic so that it requires less mental effort could free attentional resources, which potentially could be transferred to carrying out a secondary cognitive task (Luszcz, 2011; Moors & Houwer, 2006; Yogev-Seligmann, Hausdorff, & Giladi, 2008).

**Methods**

**Ethics**

The study was approved by the University of St Andrews Teaching and Research Ethics Committee (UTREC). Participants had the opportunity to raise questions about the study before providing signed consent to participate.

**Participants**

A sample size calculation, using G*Power Version 3.1, showed that 45 participants would be needed in order to have 80% power to detect a large (0.5) effect size. Forty-five participants (28 women and 17 men) aged between 65 and 88 years (mean 71.7 years) were recruited. Inclusion criteria were physically and cognitively healthy adults aged more than 65 years, able to walk unassisted, living independently, and speaking English as a first language. They were assigned to one of the three groups: the first 15 to a Musical Training (MT; \( n = 15 \)) group, the next 15 to a Music Playing (MP; \( n = 15 \)) group, and the final 15 to a No Music (NM; \( n = 15 \)) group.

**Design**

The experiment used a mixed model design. The independent variables were time (pre- vs. post-intervention training) and group (MT vs. MP vs. NM). The dependent variables for gait were velocity and step-time variability in both ST and DT conditions. The dependent variable for cognition was the number of correct cognitive responses (CCR).

**Materials**

A demographic questionnaire was constructed to collect self-reported health, mood, and lifestyle measures. A battery of norm-referenced cognitive
measures was assembled to provide a baseline assessment of participants’ functioning, including memory and executive functions (Table 1).

### Equipment

The “Bigfoot” footswitches and connected software were developed in the School of Psychology at the University of St Andrews. Bluetooth technology, housed in a PC “mouse” in a box attached to the participant’s waist, was used to measure mean step time, velocity, number of steps, and step-time variability via two footswitches, which were fastened to their heels with ‘Velcro’ strips and attached by wires to the box containing the “mouse.” The “Bigfoot” equipment had previously been validated against video-recording equipment and a stopwatch to measure CV and velocity (Maclean & Astell, 2012).

The music chosen for training was the “Bluebell Polka,” which has a 2/4 rhythm (two strong beats to each bar). The preferred walking pace of each of the participants in the MT and the MP groups was matched to the music using the “Amazing Slow Downer” downloaded from www.ronimusic.com. This software allowed the timing of the selected music to be slowed down or quickened from the 100% pace set on the original program. The adjusted music was placed on a “loop” and played continuously. The researcher could then mute and unmute the music at will, depending on the experimental condition.

### Procedure

Participants were asked to attend wearing comfortable, flat shoes. Each participant first completed the demographic questionnaire, cognitive test battery, and BDI. Participants then completed a short balance and mobility battery. They were then asked to walk along a 15-m indoor walkway twice at their self-selected pace. The walkway was a flat corridor marked off at either end with tape indicating the 15-m walk plus 1 m on either side to allow for acceleration and deceleration. The ST time and number of steps were averaged and used to adjust the preselected music to the participant’s preferred walking pace.

The ST cognitive condition was a 1-min seated test in which participants performed a Serial 7s test from a randomly generated three-digit number. They were allowed to practice and only the second score was recorded. The ST test was counterbalanced between the start and end of the experiment, for each group, to minimize possible practice effects during the DT.

In the preintervention, DT participants in all groups walked at their own pace while subtracting

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### Table 1. Description of Baseline Cognitive and Mood Tests

<table>
<thead>
<tr>
<th>Cognitive test</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MMSE (Folstein, Folstein, &amp; McHugh, 1975)</td>
<td>The MMSE provides a brief measure of global cognitive function that is scored out of 30 with norm-referenced adjustments for participants aged &gt;80 years (Spreen &amp; Strauss, 1998)</td>
</tr>
<tr>
<td>TMT A and TMT B: AITB, 1944 (Reitan &amp; Wolfson, 1993)</td>
<td>TMT A and B provide a measure of executive functions assessed through speed in seconds to complete both parts (Delta TMT − [B − A])</td>
</tr>
<tr>
<td>SDMT (Smith, 1982)</td>
<td>SDMT provides a measure of processing speed where participants match as many numbers to symbols as possible in 90 s</td>
</tr>
<tr>
<td>Digit Span Forward and Backward (DS/F and DS/B) (Thorndike, Hagen, &amp; Satle, 1987)</td>
<td>These tasks provide a measure of Working Memory by repeating short strings of numbers both forward and backward. The score is based on the number of items correctly repeated</td>
</tr>
<tr>
<td>Immediate and Delayed Story Recall (Wechsler, 1987)</td>
<td>Story Recall provides a measure of episodic memory by asking participants to recall immediately and after a 30-min delay story as much detail as possible from a story read aloud to them. Scoring comprises total number of ideas correctly recalled immediately out of 25 and the percentage of ideas recalled after the delay</td>
</tr>
<tr>
<td>NART (Nelson &amp; Willison, 1991)</td>
<td>The NART provides a measure of estimated premorbid intelligence through reading a list of progressively difficult and phonetically irregular English words. The total number of errors is converted to a Full Scale IQ equivalent</td>
</tr>
<tr>
<td>BDI (Beck, Steer, &amp; Brown, 1996)</td>
<td>The BDI screens for the presence of clinical depression, where scores above 13 indicate clinically significant problems</td>
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Notes: MMSE = Mini-Mental State Examination; TMT = Trail-Making Test; SDMT = Symbol Digits Modalities Test; NART = National Adult Reading Test; BDI = Beck Depression Index.
7s out loud (DT) from an initial three-digit figure, which was randomly generated for each DT condition. The DT walking conditions were carried out twice so that participants could practice the secondary cognitive task, with data from the second task recorded. The initial ST walking conditions were considered to be practice for the other pre- and postintervention ST walking conditions. All of the cognitive tasks (both ST and DT, practice and recorded) started with different three-digit numbers.

**Musical Training**

The MT group was instructed to walk in time to the adjusted music. Participants were not told that the music had been adjusted to suit their preferred walking pace. Each participant walked up and down the 15 m until they felt that they were walking naturally in time to the music. If clarification was required, they were told to walk in time to the music until they were no longer thinking about the music or the walking. Participants in the MT group walked an average of four times until they felt they were walking comfortably to the music “without having to think about it.” The postintervention conditions consisted of an ST 15-m walk with the adjusted music playing, followed by a DT 15-m walk with the adjusted music playing.

The MP group carried out all the same conditions as the MT group without being trained to walk to the music. This group was told that there would be music playing in the background but were not instructed to walk to the music. The same intervention (4 × 15 m) was used for this group as for the MT group and, like the MT group, these participants were not told that the music had been adjusted to suit their preferred walking pace. The NM group completed all the same conditions as the other two groups, but there was no music playing throughout the experiment.

Each group completed the walking conditions in the same order to ensure everyone experienced the 4 × 15 m walks at the same point in the experiment. The main gait parameters measured more than 15 m were velocity (m/s) and mean step-time variability (ms), expressed as coefficient of variation (CV = SD/M). The main cognitive parameters for each DT were as follows: participants’ correct responses per second (calculated as the total number of responses divided by the time of each walk, multiplied by the proportion of correct answers to the total number of answers, thereby accounting for number of errors made) and number of steps taken.

**Statistical Analyses**

Responses to the questionnaires and standardized cognitive tests were scored and compared between groups using parametric analyses. Descriptive statistics indicated that the gait data were not normally distributed; therefore, nonparametric statistical analyses were used. Kruskal–Wallis was used to test for group effect and Mann–Whitney U (post hoc) to test for differences between pairs of conditions across the groups. Wilcoxon signed ranks test (post hoc) was used to compare results between pairs of conditions within groups. The statistical significance for the experiment was set at .05. Effect sizes were calculated and reported as r values.

**Results**

The 45 older adults were healthy, with the majority reporting only one age-related health condition plus very small numbers of hospital visits in the past 12 months alongside high self-reported general satisfaction with their health (Table 2). Eighteen out of the 45 participants had never smoked, 29/45 reported a moderate level of alcohol intake (less than 7 U of alcohol per week), and 16/45 had a normal body mass index (Table 2). Forty-one out of 45 walked everyday and 43/45 self-reported being cognitively and physically active more than three times a week (Table 2). On the mobility measures, after a short practice walk, 12 out of the 45 healthy older adults, 4 in the MT group, 3 in the MP group, and 5 in the NM group, chose not to attempt the heel-to-toe walk. They were not asked to provide reasons for this; however, declining to perform the heel-to-toe walk has previously been taken as an indicator of a fear of falling (Nakamura, Holm, & Wilson, 1999). Closer inspection of the falls history of these 12 participants did not support this concern. Indeed, 9 of the 12 had experienced no falls in the previous year, 1 had experienced one fall, and 2 had experienced more than one fall. Additionally, another 8 people of the remaining 33 reported one or more falls in the past 12 months, but they did not decline to complete the heel-to-toe walk.

The participants’ self-reported cognitive function was supported by their performance on the battery of cognitive measures (Table 2). All 45 participants were in the normal range of global cognitive function as measured by the Mini-Mental State Examination, and their premorbid IQs suggested that they were an above average sample. None was suffering from depression as measured by the BDI (Table 2).
DT Cognition

At baseline, the three groups performed similarly at counting backward in 7s, both as an ST and when walking and counting concurrently (Table 3). It was anticipated that any impact of the musical training would be reflected in the cognitive performance of MT group, in the form of improvement (training freed up attentional resources from the gait for the cognitive task), reduction (training drew attentional resources away from the cognitive task), or no change (training did not affect attentional resources available for the cognitive task). At postintervention, there was no change in the cognitive performance of the MT group as was the case with both the MP and NM groups.

DT Gait

In the DT condition, all three groups showed a significant DTD in velocity in the pretraining conditions (Table 3; pretraining MT group, $p < .05$, $r = -.52$; MP group, $p < .001$, $r = -.62$; and NM group, $p < .001$, $r = -.62$). In the posttraining conditions, the MP group ($p < .001$, $r = -.61$) and the NM group ($p < .001$, $r = -.59$) had a DTD, but the MT group’s posttraining DT speed (Mdn = 1.08) was not significantly different from the ST posttraining performance (Mdn = 1.09), $p > .05$. That is, after intervention training, the MP and the NM groups’ DT “cost” was that both groups walked more slowly when performing the gait and cognitive tasks together, relative to when they walked without counting, but the MT group, after training, showed no DT deficit in speed, relative to the same ST condition.

Gait stability was examined by looking at CV of step-time variability between groups. At baseline, that is, before training, the MT group and NM groups’ gait did not differ, either in the ST or in the DT. At baseline, the MT group’s CV (Mdn = 0.130) was significantly higher (more unsteady) in both the ST ($U = 53.5$, $p < .05$, $r = -.44$) and DT
Table 3. Group Performance in Gait and Cognition Tasks—Single and Dual Task and Pre- and Postintervention Training

| Parameter                        | Musical Training group (n = 15) | Music Playing group (n = 15) | No Music group (n = 15) |
|                                 | ST | DT | ST | DT | ST | DT | ST | DT | ST | DT | ST | DT | ST | DT |
|                                 | Pre-Trg | Post-Trg | Pre-Trg | Post-Trg | Pre-Trg | Post-Trg | Pre-Trg | Post-Trg | Pre-Trg | Post-Trg | Pre-Trg | Post-Trg | Pre-Trg | Post-Trg |
| Velocity, m/s                   | 1.18 (±.22) | 1.11 (±.25) | .96* (±.32) | 1.07 (±.25) | 1.37 (±.19) | 1.35 (±.16) | 1.1** (±.27) | 1.15** (±.24) | 1.2 (±.24) | 1.25 (±.22) | .96** (±.31) | 1.02** (±.28) |
| Step-time variability (CV), ms   | .18*** (±.17) | .11† (±.16) | .32†† (±.28) | .15‡ (±.14) | .09 (±.09) | .11 (±.10) | .09 (±.07) | .13 (±.19) | .15 (±.14) | .16 (±.16) | .19 (±.23) | .22 (±.18) |
| Number of correct cognitive responses | .36 (±.30) | .32 (±.320) | .29 (±.33) | .41 (±.24) | .37 (±.260) | .31 (±.22) | .34 (±.17) | .35 (±.16) | .23 (±.17) |

Notes: Mean values (±SD) have been shown here for completeness. All statistical analyses were conducted on medians. ST = single task; DL = dual task; CV = coefficient of variation.

*Significant change from ST to DT, p < .05.
*Significant change from ST to DT, p < .001.
**Significant difference between MT group’s ST pretraining CV and MP group’s ST pretraining CV, p < .05.
†Significant change from ST pre to posttraining, p < .05.
††Significant difference between MT group’s DT pretraining CV and MP group’s DT pretraining CV, p < .01.
‡Significant change from DT pre to posttraining, p < .05.
(Mdn = 0.280; U = 49.5, p < .05, r = -.48) conditions than the MP group (Mdn = 0.050) (Table 3). After training, the step-time variability of the MT group (Mdn = 0.130) improved significantly in the ST (Mdn = 0.060; T = 0, p < .05, r = -.62), whereas there was no significant change in CV in either the MP or NM groups’ ST step-time variability after training (Table 3).

The CV of the MT group in the DT condition also improved significantly after training (T = 16.5, p < .05, r = -.41; Table 3), whereas there was no change in either of the other two groups. The improvement in the MT group was such that after training, their gait became steadier in the DT (Mdn = 0.07) than it had been in the ST at baseline (Mdn = 0.13), when the walking task was performed alone. The significant improvement in DT CV was produced at no “cost” to DT cognition, that is, there was no decline in performance on the secondary cognitive task in the DT condition (Table 3).

Attention Allocation

The magnitude of pre- to postintervention change in step-time variability (CV) in the ST and DT conditions was compared between groups (Table 3). This revealed a significant group difference in the DT H (2) = 8.14, p < .05. Post hoc tests revealed that the MT group’s CV improved significantly more from pre to posttraining DT performance than either the MP group (U = 58, p < .05, r = -.34) or the NM group (U = 55, p < .05, r = -.36; Figure 1).

To assess whether musical training freed up attention during the DT, we examined the percentage improvement or decline associated with the MT group’s ST and DT pre- and postintervention training performances to provide a proxy measure of mental effort. The MT group’s gait variability in the ST (pre to posttraining) improved by 38.9% after musical training, whereas it improved by 53.1% in the DT after musical training, with no concurrent detrimental effect to the performance in the cognitive task (Figure 2). If the amount of effort applied to gait is constant across the ST and DT, then the difference between the two conditions, 14.2%, could be seen as a measure of the participants’ mental effort in the DT that went on the secondary cognitive task (Figure 2).

The MT group’s pretraining gait in the DT was 43.7% less steady than in the ST (DTD). After training, it was only 26.7% less steady in the DT.

![Figure 1](https://gerontologist.oxfordjournals.org/)

**Figure 1.** Changes across groups between median DT pre and posttraining step-time variability. Coefficient of variation (CV) = SD/M. *Change significant at p < .050.
than in the ST (DTD). The steadier gait in the DT posttraining suggests that 17% mental effort (the difference between ST–DT pretraining and ST–DT posttraining performances) was “released” by the musical training and redirected back to gait (Figure 2).

**Discussion**

This study investigated the effects of musical training on the gait of healthy older adults living in the community. As predicted, the gait of the MT group became steadier after the intervention training, as demonstrated by a significant improvement in CV between pre and posttraining conditions in both the ST and DT and no DTD in velocity after intervention training. In other words, gait velocity after training did not decline in the DT relative to the ST. These two results for gait cannot be attributed simply to hearing music, as there was no change in the gait of the MP group who had music playing in the background as they walked and counted. The results also cannot be explained as a practice effect as there was no improvement in the gait of the NM group who completed the walking and counting conditions with no music playing. Moreover, the only change in gait between ST and DT, pre to posttraining, across the three groups, was the improvement in the MT group’s DT step-time variability (CV), which became steadier in the DT than in the initial baseline ST. At baseline, the MT group’s gait (CV) in both the ST and DT did not differ from the NM group but it was less steady (CV was higher) in both the ST and DT pretraining stages than the MP group, reflecting the variable nature of gait. This is also seen in the non-normal distribution of scores found in all of the gait conditions, which reflect the variability of gait speed and steadiness between individuals (Hausdorff, 2005).

Taken together, these two gait results suggest that musical intervention training improves gait stability, while having music playing (controlling for the musical rhythm) and simply walking (controlling for the music) as interventions have no effect on steadiness of gait. We anticipated that if musical training improved gait stability by making it more automatic, this would free up controlled attentional processing, which could, in turn, be transferred to performance of the more difficult cognitive task (Schneider & Shiffrin, 1997). Between the pre and posttraining conditions, there was no significant difference in the cognitive performance of the MT group, demonstrating neither decline nor improvement as their gait became steadier.

Finding a way to quantifying the mental effort exerted on either the walking or the secondary cognitive task is a major challenge (Yoge-Seligmann, Rotem-Galili, et al., 2012). It may be possible to examine this by measuring the magnitude of change between pairs of conditions. Looking at the group that showed significant change after training (MT group), we can make two observations about the magnitude of change between pairs of conditions. First, the difference between the ST pre and ST posttraining conditions suggests that the musical training “saves” 38.9% mental effort when
walking. The size of improvement between the DT pre and DT posttraining conditions suggests that 53.1% of mental effort is saved by musical training when walking and counting. The difference between the two “savings” indicates that 14.2% of mental effort was used to count in the DT. Second, the improvement between the ST preintervention (walking only) and the DT preintervention (walking and counting) and ST postintervention (walking to music) and DT postintervention (walking and counting to music) gait variability demonstrates that the MT group had 17% extra mental effort to spare, due to the musical training, which could have been used for the cognitive task but was not. This suggests that the freed-up attention (17%) was not automatically allocated to the cognitive task but possibly, unconsciously, redirected to the primary walking task.

There are two possible explanations for the MT group’s CCR remaining unaffected by the musical training. First, during the DT, the MT group participants had reached their cognitive performance ceiling (Tehan & Mills, 2007) and no amount of freed-up attention could have increased the number of cognitive responses produced by them. We suggest, therefore, that the extra attention freed by the intervention training, for the MT group, was unconsciously allocated back to gait. An alternative suggestion is that the MT group, being cognitively healthy, would naturally adopt a posture first strategy in any situation where gait was threatened. In this case, it is possible that, because the cognitive task was demanding, the threat to gait was maintained in the DT and any extra attention, freed up by the musical training and which might have produced an improvement in CCRs, was, instead, unconsciously allocated to improve gait stability. This added attention to gait could be what was observed in the MT group’s improved DT postintervention CV.

We also anticipated that the cognitive performance of the two groups who did not receive musical training would remain unchanged and this was the case. Because their gait did not become any steadier either, this suggests that they were unaffected by the experimental intervention.

Current understanding of gait suggests that it depends on the integrity of various aspects of cognition, particularly the higher level executive functions of which attention allocation is one (van Iersel, Kessels, Bloem, Verbeek, & Olde Rikkert, 2008). Working memory regulates the attentional flow, which allows gait to be either consciously under control (“effortful”) or unconsciously automatic (“effortless”) (Schneider & Shiffrin, 1997; Stuart-Hamilton, 2012). The MT group’s improved gait performance suggests that rhythmic training may tap into the ability of the working memory to flexibly process demands for attention and allocate it according to a changing situation, for example, when a secondary cognitive task becomes more demanding (Baddeley, 1996; Yogev-Seligmann et al., 2008). Our findings support the suggestion that walking while listening to music may render gait more “automatic” for healthy older adults who would usually unconsciously favor gait in a DT.

The performance outcomes from this group of physically and cognitively healthy older adults have relevance both for other healthy older adults and for those with impairment in gait and/or cognition. In the first case, “postural reserve” is an important factor affecting task prioritization during gait and cognition and that also decreases with age and disease. Improving healthy older adults’ gait by making it more rhythmic through musical training, while maintaining cognitive capability, could result in enhanced postural reserve. Second, if musical training frees up attention, this could be beneficial to older adults with cognitive impairment, who naturally adopt a “posture second” strategy, whereby they allocate attention equally to gait and cognition, thus increasing their risk of falling (Bloem, Grimbergen, van Dijk, & Munneke, 2006). Therefore, musical training to make gait more rhythmic could be a preventative intervention for fall risk for older adults who are adversely affected by “walking when talking” (Lundin-Olsson, Nyberg, & Gustafson, 1997).

This experiment was conducted in a controlled environment over a flat surface, with healthy older adults, but it has the potential to be applicable to in a more ecologically valid and complex environment, such as outdoors or in the home. Further research is required to establish the practical application and therapeutic value to practitioners of these findings.

Funding

This work was supported by a doctoral studentship awarded to the first author as part of grant number ES/G008779/1 from the Economic and Social Research Council held by Arlene J. Astell.

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