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Familiarity with music increases walking speed in rhythmic auditory cuing

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Rhythmic auditory stimulation (RAS) is a gait rehabilitation method in which patients synchronize footsteps to a metronome or musical beats. Although RAS with music can ameliorate gait abnormalities, outcomes vary, possibly because music properties, such as groove or familiarity, differ across interventions. To optimize future interventions, we assessed how initially familiar and unfamiliar low-groove and high-groove music affected synchronization accuracy and gait in healthy individuals. We also experimentally increased music familiarity using repeated exposure to initially unfamiliar songs. Overall, familiar music elicited faster stride velocity and less variable strides, as well as better synchronization performance (matching of step tempo to beat tempo). High-groove music, as reported previously, led to faster stride velocity than low-groove music. We propose two mechanisms for familiarity's effects. First, familiarity with the beat structure reduces cognitive demands of synchronizing, leading to better synchronization performance and faster, less variable gait. Second, familiarity might have elicited faster gait by increasing enjoyment of the music, as enjoyment was higher after repeated exposure to initially low-enjoyment songs. Future studies are necessary to dissociate the contribution of these mechanisms to the observed RAS effects of familiar music on gait.

Keywords: familiarity; groove; rhythm; rhythmic auditory stimulation; gait rehabilitation

Introduction

In gait rehabilitation, synchronization of movements to a metronome or to musical beats can partially ameliorate gait abnormalities in Parkinson's disease and stroke patients.[1–4] This method of gait rehabilitation is commonly termed rhythmic auditory stimulation (RAS). RAS outcomes vary across individuals and across studies, perhaps in part because rehabilitation protocols use musical cues with varying properties, which are rarely adapted to individual differences (for reviews, see Refs. 5–7). Previous work has indicated that groove, or how much the music makes an individual "want to move," is one important property.[8–10] Another important property may be familiarity of the music, which might influence gait in two ways, detailed below.

First, familiarity with music increases familiarity with the beat structure.[11–14] Removing the need to extract beat locations as the music unfolds likely reduces the cognitive demands of synchronizing movements to the beat. Other work has shown that strides are faster and less variable when cognitive demands are low.[15] Thus, familiarity may result in faster and less variable gait by reducing the cognitive demands of synchronization.

Second, familiarity with music might lead to greater enjoyment of RAS by modulating reward mechanisms necessary for the experience of pleasure.[16] Repeated exposure to unfamiliar music increases music-induced pleasure or reward.[17,18] Reward increases movement "vigor" as people make faster movements in the context of reward.[19] Music-induced rewards have been linked to more vigorous movements.[20–23] Thus, the reward induced by highly familiar music might elicit faster strides than that for unfamiliar music.

In this study, we examined how familiarity with music affected synchronization performance and spatiotemporal gait parameters when walking to music. Participants synchronized to (1) music that

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they rated as low or high familiarity and (2) music that was initially unfamiliar but for which familiarity was increased via repeated exposure during the experiment. We predicted that greater familiarity with music would elicit better synchronization performance and faster, less variable strides. Faster strides (i.e., greater stride velocity) can be achieved via longer stride length and/or briefer stride times. As groove is known to modulate synchronization performance and gait,[24] we also included low- and high-groove conditions to determine whether the effects of familiarity were additive or interacted with the effects of groove. Although this study did not explicitly manipulate musical enjoyment, we also examined whether enjoyment ratings increased with repeated exposure to the music.

Methods

Participants

Seventeen volunteers from the University of Western Ontario participated, receiving $5/h for their time. The University of Western Ontario Human Research Ethics Committee approved the study. Data from two participants were excluded because language barriers led to difficulty understanding the task instructions, and data from four participants were excluded because their ratings of the stimuli did not fulfill the criteria for creating the different levels of familiarity and groove needed for the experimental conditions (i.e., familiarity or groove ratings were always close to 50 in a 1–100 point rating scale). For the remaining 11 students, the mean age was 22 years (six female), and mean years of musical experience was 5.09 ($SD = 6.02$).

Procedure

Baseline walking. First, each participant's baseline step rate (steps per minute) was measured while he or she walked eight lengths of a 16-foot Zeno pressure sensor walkway (sampling rate 120 Hz). To obtain reliable measurements of steady-state gait, walks started and finished at lines marked 1.78 m beyond the walkway, and participants continued stepping to the beat while turning at the line.[25]

Stimulus preparation and selection. Prior to the experiment, we created a set of 26 music clips (for details of selection and a stimulus list, see Supporting Information). Metronome sequences were created using 50-ms 1-kHz sine tones. Beat onsets and tempo of the music clips were estimated using BeatRoot, a beat-tracking software program that uses spectral flux to estimate beat onsets.[26] Two musically trained lab members independently verified BeatRoot's accuracy. Prior to cued walking, music tempo was adjusted to be 15% faster than the participant's preferred step rate,[27] and participants always walked to these faster versions of the clips. Audacity was used to change tempo (http://audacity.sourceforge.net) without altering pitch[28] and to normalize all clips to the same relative volume.

Ratings task (single exposure). Each participant rated the 26 music clips (prior to tempo adjustments) on familiarity, groove, enjoyment, and beat salience using a 100-point Likert scale. Clips were presented in random order and played for 30 seconds. Rating scale items appeared as follows: (1) familiarity: How familiar are you with this piece of music? 1 = never heard it before, 25 = may have heard it before, 50 = know the song and certain that you have heard it before, 75 = heard it several times before, 100 = know this song so well that I can predict what happens next in the song; (2) groove: How much does this piece of music make you want to move to it? 1 = would definitely not move to this, 25 = do not think I would move to this, 50 = indifferent about moving to this, 75 = think I would move to this, 100 = would definitely move to this; (3) enjoyment: How much do you enjoy listening to this piece of music? 1 = I strongly dislike this song, 25 = I dislike this song, 50 = I feel neutral towards this song, 75 = I enjoy this song, 100 = I strongly enjoy this song; and (4) beat salience: How strong is the beat in this piece of music? 1 = very weak, 50 = neutral, 100 = very strong.

Clips were classified as low familiarity or low groove if the rating was lower than the participant's mean familiarity or groove rating across clips, respectively, and classified as high familiarity or high groove if the rating was higher than the participant's mean familiarity or groove rating across clips, respectively. Two clips were selected for each participant, for each of the following conditions: low familiarity, low groove; low familiarity, high groove; high familiarity, low groove; and high familiarity, high groove.

Cued walking (run 1). Participants completed 10 walking trials (each trial = eight lengths of the walkway) under the four music cue conditions (two trials per condition): low familiarity, low groove; low familiarity, high groove; high familiarity, low groove; and high familiarity, high groove. We also included two metronome trials as control stimuli to examine participants' ability to synchronize to unambiguous beat cues. Trials were presented in random order. Participants were instructed to synchronize their footsteps to the beat and were allowed as much time as needed to find the beat before initiating walks.

Repeated exposure task: increasing familiarity. Participants were next exposed to two repetitions of 1-min clips of the songs selected for the first walking task. During each repetition, they rated the songs on the following: (1) pleasantness: How pleasant is this song? 1 = very unpleasant, 50 = neutral, and 100 = very pleasant; (2) enjoyment: How much do you enjoy listening to this piece of music? 1 = strongly dislike this song, 25 = dislike this song, 50 = neutral, 75 = enjoy this song, 100 = strongly enjoy this song; (3) arousal: How relaxing or stimulating do you find this music? 1 = very relaxing, 51 = neutral, 100 = very stimulating; and (4) familiarity: How familiar are you with this piece of music? 1 = never heard it before, 25 = may have heard it before, 50 = know the song and certain that you heard it before, 75 = heard it several times before, 100 = I know the song so well that I can predict what happens next.

Cued walking (run 2). The participants then completed another 10 walking trials (two trials per condition) with the same stimuli as in run 1, in random order.

Data analysis

Synchronization performance

Tempo-matching performance. Ability to match step tempo to the stimulus tempo (i.e., period-matching accuracy) was assessed with the interbeat interval deviation (IBI deviation—see Eq. (1),[29,30] calculated as follows for each trial. First, the first contact time of each step was matched to the nearest beat. Beat onset times at the lowest (fastest) metrical level were objectively estimated with the validated beat-finding software BeatRoot[26] and verified by two musically trained lab members. Interbeat intervals were calculated by subtracting beat onset times of consecutive beats. Then, interstep intervals were calculated by subtracting the first contact times of consecutive steps. The IBI deviation was calculated by taking the absolute difference bet–ween each interstep interval and its corresponding interbeat interval and averaging the resulting absolute differences. The average difference was divided by the average IBI to normalize to the interbeat interval and thus control for differences in cue tempo.

Variability of tempo-matching was estimated by the standard deviation of the IBI deviation.

$$\text{IBI deviation} = \frac{\text{mean}\left|\text{interstep interval} - \text{interbeat interval}\right|}{\text{mean interbeat interval}} \tag{1}$$

Spatiotemporal gait parameters

Analyses focused on gait speed and gait variability. Gait speed was determined from (1) stride velocity (distance covered per unit time (cm/s) for every two consecutive steps); (2) stride length (distance (cm) from the first contact of one step to the first contact of the next step from the same foot); and (3) stride time (time interval between the first contact of one step to the following first contact of the next step from the same foot). Stride velocity is the ratio of stride length and stride time, and thus changes in stride velocity can result from changes in stride time and/or stride length. Gait variability was determined from the coefficient of variations of stride velocity, stride length, and stride time. The coefficient of variation is the standard deviation of gait parameter normalized to the mean gait parameter. Owing to space constraints, other gait parameters (e.g., percentage double support time) that were not reliably modulated by our manipulations are not reported here. We were interested in how gait changes in cued conditions compared to baseline uncued walking. Hence, we calculated change scores of each gait parameter for each cue condition by subtracting the average baseline gait parameter from the average gait parameter in that cue condition (see Eq. (2).[31] Then, to minimize the effect of individual differences (e.g., effect of leg length) on gait, we normalized these change scores to baseline gait parameters.

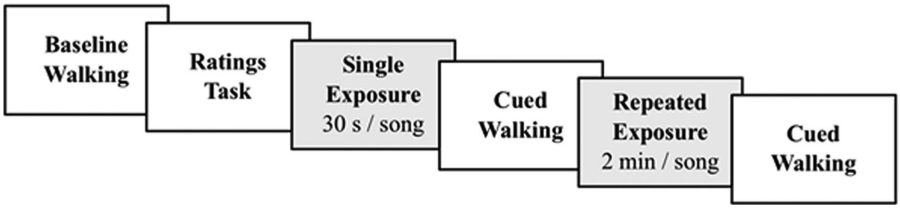

Figure 1. Study protocol. Songs were presented in a random order for each block. Each test session lasted approximately 110 minutes.

$$\text{normalized change score} = \frac{(\text{gait parameter} - \text{baseline gait parameter})}{\text{baseline gait parameter}} \quad (2)$$

Statistical analyses

We first examined how ratings of familiarity and enjoyment changed with repeated exposure. Participants rated the stimuli on familiarity and enjoyment three times: first during stimulus selection (rating 1) and then twice more during the repeated exposure task (rating 2, rating 3). Exposure might differentially affect songs initially rated as low enjoyment versus high enjoyment. To examine this, we calculated mean enjoyment ratings for songs initially rated as low enjoyment (those rated less enjoyable than that subject's mean enjoyment ratings for all songs at rating 1) and for songs initially rated as high enjoyment (those rated more enjoyable than that subject's mean enjoyment rating for all songs at rating 1) and then conducted an initial enjoyment (low enjoyment, high enjoyment) × rating (rating 1, rating 2, rating 3) analysis of variance (ANOVA) on enjoyment ratings.

Next, we evaluated how repeated exposure and familiarity with the music affected tempo-matching performance and spatiotemporal gait parameters. Three-way repeated-measures ANOVAs with within-subject factors run (run 1, run 2), familiarity (low familiarity, high familiarity), and groove (low groove, high groove) were conducted on measures of tempo-matching and normalized change scores of gait parameters. ANOVA results were followed up with *t*-tests to identify significant differences between conditions. Phase matching was not analyzed because it is not clear exactly what point of the footstep (e.g., initial heel strike, or toe-off time) that participants intend to synchronize to the beat, or indeed whether the synchronized point of the footstep is consistent across participants or across conditions.

Results

Familiarity and enjoyment ratings

Familiarity ratings increased significantly from rating 1 to rating 2 ($M_1 = 52.26$, $SD_1 = 11.88$, $M_2 = 71.94$, $SD_2 = 20.71$; $t(10) = 4.79$, $P = 0.001$) and marginally significantly from rating 2 to rating 3 ($M_2 = 71.94 \pm 20.71$, $M_3 = 78.09$, $SD_3 = 30.86$, $t(10) = 2.10$, $P = 0.06$). An initial enjoyment (low enjoyment, high enjoyment) × rating (rating 1, rating 2, rating 3) ANOVA showed a significant initial enjoyment × rating interaction ($F(1.16,11.7) = 4.52$, $P = 0.02$): enjoyment increased significantly from rating 1 to rating 2 for low initial-enjoyment songs (rating 1: $M_1 = 44.79$, $SD_1 = 19.68$, rating 2: $M_2 = 58.89$, $SD = 24.63$, $t(10) = 2.44$, $P = 0.035$) but not for high initial-enjoyment songs (rating 1: $M_1 = 81.54$, $SD_1 = 13.21$; rating 2: $M_2 = 77.44$, $SD_2 = 12.50$, $t(10) = 1.73$, $P = 0.11$). For low initial-enjoyment songs, there was a trend for changes in enjoyment from rating 1 to rating 2 to correlate with changes in familiarity from rating 1 to rating 2 ($r = 0.58$, $P = 0.06$, two-tailed). For rating 2 to rating 3, enjoyment ratings did not change significantly for low initial-enjoyment songs ($M_2 = 58.89$, $SD_2 = 24.64$; $M_3 = 55.81$, $SD_3 = 31.38$, $t(10) = 0.84$, $P = 0.42$) and high initial-enjoyment songs ($M_2 = 77.44$, $SD_2 = 12.50$; $M_3 = 77.50$, $SD_3 = 13.19$, $t(10) = 0.71$, $P = 0.95$).

Synchronization performance

Tempo-matching accuracy. Figure 2 (left panel) shows interbeat interval deviations—smaller values indicate more accurate tempo matching. Familiar music elicited better tempo-matching accuracy overall (familiarity main effect: $F(1,10) = 11.03$,

Table 1. Means and standard deviations of gait parameters for the different cuing conditions for run 1 and run 2, averaged across all participants

		Stride velocity (cm/s)	Stride time (s)	Stride length (cm)	Stride velocity variability (CV)	Stride time variability (CV)	Stride length variability (CV)
Baseline		121.50 (19.63)	1.11 (0.16)	132.51 (10.54)	0.05 (0.02)	0.03 (0.01)	0.03 (0.01)
Run 1							
Low groove	Low familiarity	122.90 (21.15)	1.09 (0.22)	129.65 (11.69)	0.08* (0.05)	0.06 (0.06)	0.05* (0.02)
	High familiarity	123.37 (17.39)	1.06 (0.19)	127.88 (14.21)	0.07 (0.04)	0.05 (0.03)	0.05* (0.01)
High groove	Low familiarity	137.61* (18.62)	0.99* (0.13)	134.19 (13.33)	0.05 (0.02)	0.03 (0.03)	0.04* (0.02)
	High familiarity	139.28* (20.80)	0.98* (0.12)	134.18 (14.72)	0.05 (0.02)	0.04 (0.02)	0.05* (0.02)
Metronome		137.88* (17.46)	0.98* (0.12)	134.14 (14.92)	0.06 (0.04)	0.03 (0.01)	0.05* (0.03)
Run 2							
Low groove	Low familiarity	126.93 (18.97)	1.05 (0.16)	130.57 (14.38)	0.06 (0.03)	0.04 (0.02)	0.05 (0.02)
	High familiarity	130.43 (17.55)	1.01 (0.15)	130.29 (12.93)	0.05 (0.02)	0.03 (0.01)	0.04* (0.01)
High groove	Low familiarity	141.87* (20.02)	0.97* (0.13)	135.77 (15.17)	0.04 (0.02)	0.04 (0.03)	0.04 (0.02)
	High familiarity	143.85* (20.25)	0.97* (0.13)	137.39 (15.06)	0.04 (0.01)	0.03 (0.03)	0.04 (0.02)
Metronome		140.65* (18.19)	0.98* (0.12)	136.24 (16.36)	0.04 (0.01)	0.03 (0.02)	0.04 (0.02)

NOTE: Asterisks indicate that the gait parameter was significantly different from baseline. All cues were presented at 15% faster than the baseline preferred step tempo.

$P = 0.008$, $\eta_p 2 = 0.53$). Familiarity increased tempo-matching accuracy more for run 2 than run 1 (run main effect: $F(1,10) = 4.56$, $P = 0.06$, $\eta_p 2 = 0.31$; run × familiarity interaction $F(1,10) = 7.96$, $P = 0.018$, $\eta_p 2 = 0.44$). High-groove music showed a trend toward eliciting better tempo matching than low-groove music (groove main effect: $F(1,10) = 4.41$, $P = 0.06$, $\eta_p 2 = 0.31$). Groove did not interact significantly with any other factors.

Tempo-matching variability. Figure 2 (right panel) shows standard deviations of interbeat interval deviations. Smaller values indicate less variable tempo matching. Familiarity with music did not significantly affect tempo-matching variability (main effect of familiarity, $F(1,10) = 1.17$, $P = 0.31$, $\eta_p 2 = 0.10$), and familiarity did not interact with any other factor. Repeated exposure to the music reduced tempo-matching variability (Fig. 2, bottom panel), as shown by a significant main effect of run ($F(1,10) = 6.19$, $P = 0.03$, $\eta_p 2 = 0.38$), and a run × familiarity interaction ($F(1,10) = 5.62$, $P = 0.039$, $\eta_p 2 = 0.36$). The effect of groove was not significant ($F(1,10) = 2.20$, $P = 0.17$, $\eta_p 2 = 0.27$) and did not interact with any other factors.

Gait parameters

Descriptive statistics of gait parameters for the different cue conditions for runs 1 and 2 are shown in Table 1.

Effects of familiarity

Gait speed. Figure 3 shows that high-familiarity music elicited briefer stride times and faster stride velocity, as shown by the significant main effect of familiarity on stride time ($F(1,10) = 10.54$, $P = 0.009$, $\eta_p 2 = 0.51$) and a trend toward significance on stride velocity ($F(1,10) = 4.61$, $P = 0.06$, $\eta_p 2 = 0.32$), with no significant interactions. Stride length, however, was not significantly affected by familiarity (familiarity main effect: $F(1,10) = 0.40$, $P = 0.85$, $\eta_p 2 = 0.004$, no significant interactions).

Gait variability. For stride velocity variability, stride time variability, and stride length variability, there were no significant main effects of or interactions with familiarity.

Effects of repeated exposure (run)

Gait speed. Repeated exposure to the music tended to result in faster and briefer strides, as there were marginally significant main effects of run for stride velocity ($F(1,10) = 4.00$, $P = 0.07$, $\eta_p 2 = 0.29$) and stride time ($F(1,10) = 4.90$, $P = 0.051$, $\eta_p 2 = 0.33$), with no significant interactions.

Gait variability. Repeated exposure also resulted in less variable gait, as shown by significant main effects of run for stride velocity variability ($F(1,10) = 12.23$, $P = 0.006$, $\eta_p 2 = 0.55$) and marginally significant main effects for stride time variability ($F(1,10) = 3.86$, $P = 0.078$, $\eta_p 2 = 0.28$), with no

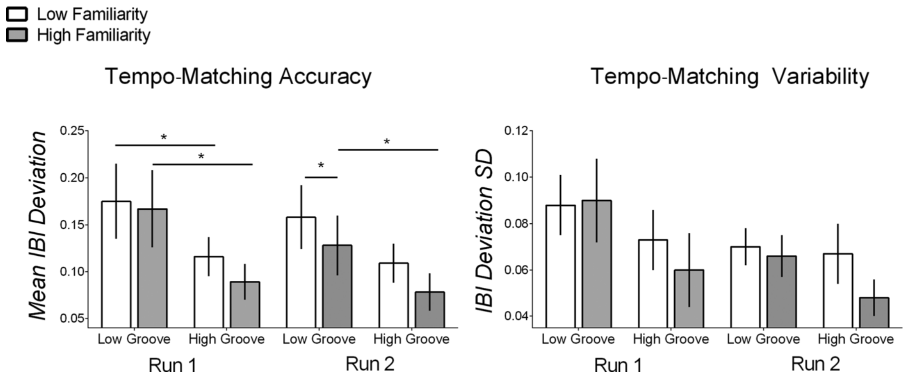

Figure 2. Tempo-matching accuracy (left panel), as shown by interbeat interval deviation. Lower scores show better performance. Tempo-matching variability (right panel), as shown by standard deviation of interbeat interval deviation. Lower scores show less variable performance. Asterisks indicate significant differences between conditions. Comparisons between conditions are not significant unless otherwise indicated. Error bars represent standard error of the mean.

significant interactions. The main effect of run was not significant for stride length variability ($F(1,10) = 3.26$, $P = 0.10$, $\eta_p2 = 0.25$), and there were no significant interactions.

Effects of groove

Gait speed. High-groove music elicited faster, briefer, and longer strides than low-groove music, as shown by significant main effects of groove for stride velocity ($F(1,10) = 14.82$, $P = 0.003$, $\eta_p2 = 0.60$), stride time ($F(1,10) = 8.90$, $P = 0.014$, $\eta_p2 = 0.47$), and stride length ($F(1,10) = 5.55$, $P = 0.04$, $\eta_p2 = 0.36$). Groove did not interact significantly with any factors.

Gait variability. For stride velocity variability, the main effect of groove neared significance ($F(1,10) = 4.61$, $P = 0.06$, $\eta_p2 = 0.3$) with no interactions. For stride time variability and stride length variability, there were no significant main effects or interactions with groove.

Effects of repeating the synchronization task

Spatiotemporal gait parameters can change as a result of greater familiarity with the music from repeated exposure or as a result of practice effects from repeating the synchronization task. To assess whether task repetition improved tempo-matching performance and altered gait parameters, we compared gait during the metronome conditions in runs 1 and 2. Unlike for the music cues, metronome cues were not repeatedly played to participants during the exposure period between run 1 and run 2.

Task repetition did not significantly improve tempo matching, as paired *t*-tests showed that both tempo-matching accuracy ($t(10) = 0.02$, $P = 0.82$) and tempo-matching variability ($t(10) = 0.09$, $P = 0.93$) with metronome cues did not differ between run 1 and run 2.

Task repetition also did not significantly affect gait speed when walking to metronome cues, as no significant differences between run 1 and run 2 were observed for stride velocity ($t(10) = 1.30$, $P = 0.23$), stride time ($t(10) = 0.63$, $P = 0.54$), or stride length ($t(10) = 1.13$, $P = 0.28$). Task repetition also did not significantly alter gait variability, which did not differ significantly between run 1 and run 2 (stride velocity variability $t(10) = 1.96$, $P = 0.08$; stride time variability $t(10) = 0.49$, $P = 0.64$). Stride length variability decreased from run 1 to run 2, but significance was marginal ($t(10) = 2.06$, $P = 0.07$).

Discussion

The current findings show that during synchronization of footsteps to the musical beat, high-familiarity and high-groove music elicit more accurate tempo matching and faster and less variable strides than low-familiarity, low-groove music. These findings demonstrate that music familiarity and groove may be manipulated to maximize effects of music in gait rehabilitation.

Greater familiarity with the music elicited more accurate tempo matching, suggesting that familiar music is easier to synchronize to. Familiarity with the beat structure of a song precludes the need to predict beat onsets as they unfold, reducing the

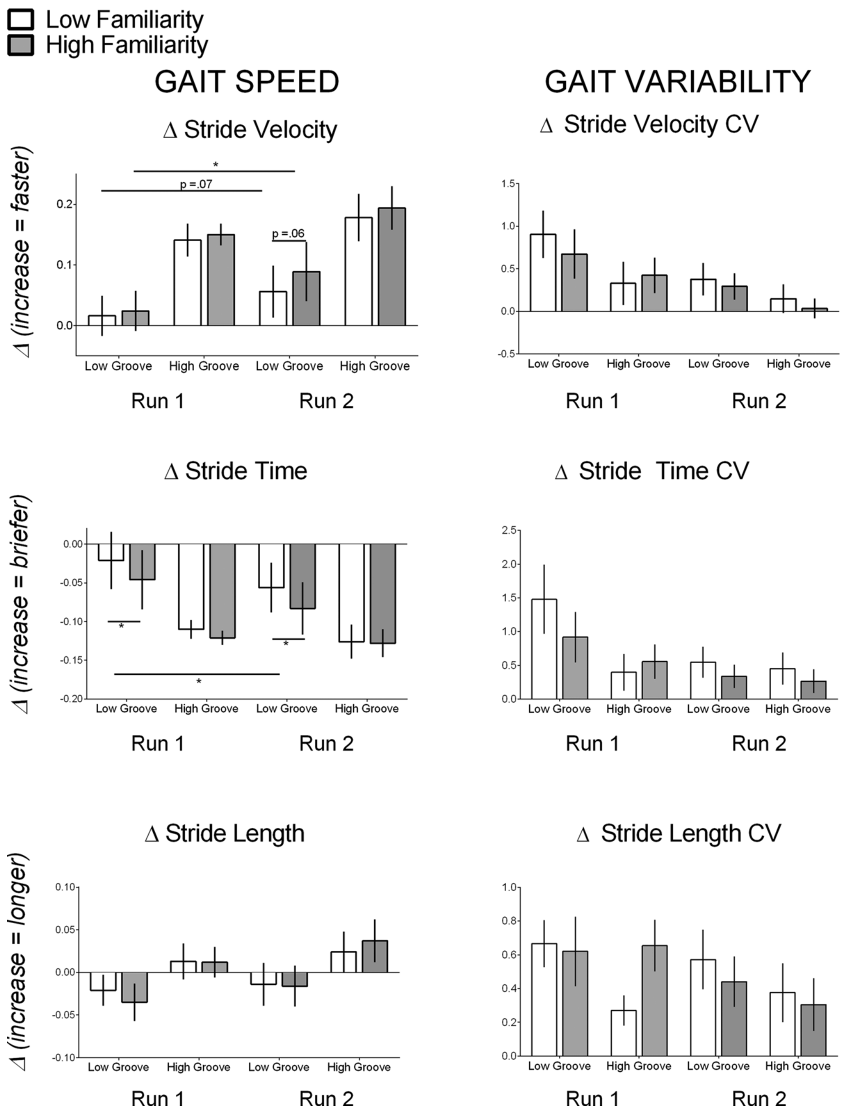

Figure 3. Normalized change scores for gait speed parameters (stride velocity, stride time, and stride length) (top panel). Normalized change scores for gait variability measures (stride velocity CV, stride time CV, and stride length CV) (middle panel). All values are a proportion of the baseline gait parameter, with zero representing no change from baseline. Asterisks indicate significant differences between low familiarity and high familiarity and between run 1 and run 2. Significant differences between low groove and high groove are presented in Supporting Information.

cognitive demands of synchronizing to the beat, and synchronization performance is improved. The reduction in cognitive demands may have led, as in other work, to strides that had faster velocity and were less variable.[15]

In addition to potentially reducing the cognitive demands of synchronization, familiarity can make music more enjoyable.[17,18] Here, repeated exposure increased enjoyment of initially low-enjoyment songs. Music-induced enjoyment elicits dopamine release,[16] which in turn is associated with greater movement vigor (faster movements).[19,32] Enjoyment might therefore have contributed to the faster strides observed in this study. However, as this study did not independently manipulate enjoyment, future studies are necessary to systematically examine how enjoyment affects gait in RAS.

It is noteworthy that groove was at least as effective as familiarity at eliciting faster strides. Effect sizes for groove were larger than those for familiarity for stride velocity and comparable for stride time. Effect sizes for groove were larger than for repeated exposure. However, none of the factors interacted, indicating that both groove and familiarity (either preexisting familiarity or experimentally induced familiarity via exposure) can maximize gait speed in RAS protocols. Finally, movements to the metronome did not significantly differ from movements to high-familiarity, high-groove music. On the one hand, this suggests that metronomes are also effective at changing gait parameters and that music need not be used. On the other hand, because listening to music is generally more pleasant than listening to metronomes, it is encouraging that music can elicit equally beneficial effects on gait, as music may have the added benefit of improving patient enjoyment of and adherence to RAS protocols.

Practice improves synchronization of movements to the beat,[33] and practice alone might have reduced the cognitive demands of synchronization, facilitating faster, less variable strides. One might therefore question whether the effects of familiarity resulted from practice effects—participants might have learned to synchronize with the beat more accurately by run 2 through practice, not because of exposure-induced increases in familiarity with the music between run 1 and run 2. However, two lines of evidence suggest that the effects cannot be explained by practice. First, high-familiarity music elicited faster strides than low-familiarity music at first exposure to the task in run 1. Second, for the metronome condition, neither synchronization accuracy nor gait parameters differed between run 1 and run 2.

Conclusions and implications

In conclusion, we find that music that is high in familiarity and high in groove during RAS elicits more accurate tempo matching and faster strides. We infer that high familiarity may have elicited these effects by reducing the attentional demands of synchronizing movements to the beat and/or increasing enjoyment of the music. We also replicated previous results[24] showing that high-groove music elicits faster strides than low-groove music. The current findings in young adults are consistent with previous findings of faster strides in RAS studies employing familiar music[4] and repeated exposure[2,34–36] in patients with Parkinson's disease. Overall, familiarity and groove of music are important to consider in future RAS implementations.

Acknowledgments

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Conflicts of interest

The authors declare no conflicts of interest.

Supporting Information

Additional supporting information may be found in the online version of this article.

Table S1. List of stimuli used

Table S2. Results of *t*-tests for the low-groove versus high-groove comparisons

Table S3. Results of *t*-tests for comparing high-groove conditions with metronome cues

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