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The effects of listening to music or viewing television on human gait

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ABSTRACT

This paper presents a two-part study with walking conditions involving music and television (TV) to investigate their effects on human gait. In the first part, we observed seventeen able-bodied adults as they participated in three 15-minute walking trials: (1) without music, (2) with music and (3) without music again. In the second part, we observed fifteen able-bodied adults as they walked on a treadmill for 15 min while watching (1) TV with sound (2) TV without sound and (3) TV with subtitles but no sound. Gait timing was recorded via bilateral heel sensors and center-of-mass accelerations were measured by tri-axial accelerometers. Measures of statistical persistence, dynamic stability and gait variability were calculated. Our results showed that none of the considered gait measures were statistically different when comparing music with no-music trials. Therefore, walking to music did not appear to affect intrinsic walking dynamics in the able-bodied adult population. However, stride interval variability and stride interval dynamics were significantly greater in the TV with sound walking condition when compared to the TV with subtitles condition. Treadmill walking while watching TV with subtitles alters intrinsic gait dynamics but potentially offers greater gait stability.

1. Introduction

Extraneous interferences during walking such as music and television have become an increasingly integral part of today's culture. People listen to music when they are exercising, walking their dog and going for an evening stroll. Meanwhile, watching television, long thought to be a sedentary activity, has become commonplace at gyms and screens are often attached to treadmills and other exercise machines. In other words, music and television increasingly make up the backdrop of everyday activities, although their effects on gait are not well understood.

Music consists of a beat that may subconsciously alter an individual's intrinsic walking pace, a phenomenon that has been seen when individuals walk to rhythmic auditory stimuli (e.g., [15,26,21,22]). It is well documented that rhythmic auditory stimuli impact variables of human gait (e.g., [15,26]) and in particular the gait patterns for patients with Parkinson's disease (e.g., [26,19]). Similarly, music has been shown to impact gait patterns (e.g., [13,2,23]). Television also contains an auditory component that may affect gait in a similar way. Furthermore, the visual component of television may act as an additional distraction further disrupting natural gait dynamics. Specifically, reading tasks and gaze-stabilization tasks while treadmill walking have been shown to alter human gait [16]; however, the different ways to watch TV (sound vs. subtitles) have not yet been analyzed.

Assessing the stability of human gait under various walking conditions involving music and/or television may have clinical applications in rehabilitation programs. It may also have safety implications in compromised populations such as people with Parkinson's disease, Huntington's disease, frail older adults and people with a history of falling. Specifically, it is important to observe the effect of music and TV on human gait in order to ensure safety of patients with compromised gait patterns and in the creation of gait interventions and rehabilitation programs. We hypothesize that the exposure to both music and television will have negative effects on stride interval dynamics, since the exposure to these additional sources of information will invoke processing from multiple brain centers, activity which may disrupt gait pattern generation. To investigate the effect of these external sources of information, we are going to explore the temporal dynamics of human gait as measured by the fractal scaling exponent (e.g., [5,24]) and the maximum Lyapunov exponent (e.g., [9]).

2. Methodology

2.1. Data collection

The study was divided into two: a music part and a TV part. For each part, participants performed two sessions of three walking trials. Stride interval time series and acceleration time series were

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Table 1
A summary of anthropometric measurements.

Part	Age (years)	Height (cm)	Weight (kg)
Music	25.9 ± 2.76	173 ± 8.16	70.2 ± 12.3
TV	25.4 ± 2.69	173 ± 8.95	69.3 ± 12.2

collected. The protocol was approved by the Research Ethics Board of Holland Bloorview Kids Rehabilitation Hospital (Toronto, Ontario, Canada). All participants provided written consent. Additionally, all participants had normal eye-sight and hearing and did not have any known neurological or musculoskeletal disorders.

Seventeen participants of mean age 25.9 ± 2.76 years (9 male) were involved in the music part (please see Table 1). Participants completed two sessions. Each session involved a sequence of three 15 min trials: over ground walking (OG1), over ground walking while listening to music through standard headphones (OG2) and over ground walking without music once again (OG3). OG3 was used to assess any carry-over effect music has on gait. The participants were instructed to walk at a comfortable pace and were permitted a self-regulated rest period between each trial. The participants walked in a rectangular path along a sparsely populated hallway (of approximate length 85 m and width 2.5 m). Any stumbles or falls were noted by an investigator, who walked slightly behind each participant. Each session was separated by at least 24 h and took place at approximately the same time of day.

The television part of the study involved fifteen young adults (7 male) with a mean age of 25.4 ± 2.69 years (please see Table 1). Again, two sessions were completed by each participant, separated by at least 24 h. Each session involved three 15 min trials performed in a random order: walking on a treadmill while watching television with sound (TV-S), walking on a treadmill while viewing television without sound (TV-NS), and walking on a treadmill while watching television with subtitles without sound (TV-SUB). Participants were instructed to walk at a pace that they considered comfortable. The sessions were conducted as follows: a 5 min warm-up at the self-selected, comfortable speed, a 2 min warm-up under the trial condition, quiet standing for 45 s, and finally, the 15 min trial from standing to the self-selected pace.

2.2. Equipment

An ultra-thin force-sensitive resistor (FSR) (Model 406, Interlink Electronics) was taped beneath the insoles of each of the subject's shoes at the heel. The FSRs measured the heel-strikes of each foot. Voltage changes in FSRs were directly captured by a datalogger (programmable R-Engine – A processor board manufactured by Tern Inc.) which was worn around the participant's waist in a small fanny pack and collected all signals at a frequency of 200 Hz.

A tri-axial accelerometer (Freescale Semiconductor Inc.; model number: MMA7260Q) measured the acceleration of the participants' approximate center of mass in the anterior-posterior (AP), medial-lateral (ML) and vertical (VT) axes. The accelerometer was secured to the small pack over the L3 segment of the lumbar spine and was powered by a small battery carried within the pack. A continuous voltage output of acceleration was also collected and stored by the datalogger.

2.3. Data analysis

2.3.1. Stride intervals

A probabilistic stride interval extraction algorithm from [6] was used to extract the stride intervals. First, the gait signals were trimmed to 15 min in order to exclude the extraneous signals of the participants as they began to walk (i.e. the 2 min warm up and the 45 s quiet standing periods). In order to ensure that the analysis represented participants' 'intrinsic' walking dynamics, atypical strides, identified as stride intervals that fell outside of the 0.01% and 99.99% of a gamma distribution fit, were removed from the time series [11]. A previous study found that removing segments from a signal had no effect on the scaling for positively correlated signals ($\alpha > 0.5$), such as gait signals, even when up to 50% of the points in the signals were removed [7]. Only a small fraction of stride intervals were removed from the time series in the present study.

2.3.2. Statistical persistence

Stride interval dynamics incorporate temporal information into the analysis of the stride interval time series and reveal statistical persistence. Detrended fluctuation analysis (DFA) is used in order to estimate the scaling exponent, α, as described in previous studies (e.g., [5,24,8]). For each signal, $\alpha > 0.5$ indicates the signal is statistically persistent; $\alpha = 0.5$ indicates random, uncorrelated behavior (a.k.a. white Gaussian noise) and $\alpha < 0.5$ means that the signal is anti-persistent [5]. DFA involves fitting a power law across different box sizes, n, of a series' mean fluctuations, $F(n)$, and finds α as the slope of $\log F(n)$ vs. $\log n$ [5,8]. The box size range used for DFA analysis was $[16, N/9]$ as recommended in Damouras et al. [8] where N represents the number of stride intervals. The number of stride intervals included in the analysis ranged from 616 to 965.

2.3.3. Center of mass (COM) acceleration

A procedure outlined in Chang et al. [3] was used to filter the accelerometer data, calibrate the data to within 0.1 g of acceleration due to gravity, calibrate for tilt and calculate the root-mean-square (RMS) of the acceleration variability for each of the three axes. The RMS of the acceleration variability acts as an estimate for COM variability [3].

A non-linear method of demonstrating stability is based on estimating maximum finite-time Lyapunov exponents. It has been previously found that, compared to stride-to-stride variability, average maximum finite-time Lyapunov exponents were able to characterize dynamic stability more precisely and provided additional insight into human gait [9,3]. The maximum Lyapunov exponent quantifies local stability, which is defined as a system's sensitivity to extremely small perturbations [9]. The Lyapunov exponents were calculated using the protocol carried out by Dingwell and Cusumano [9] and Rosenstein et al. [20]. Briefly, the approach involved reconstructing a state-space from the original time series and time-delayed coordinates. This entailed the estimation of the minimum embedding dimension and the time delay. Time delays were estimated by the autocorrelation function [3,20] and the embedding dimension was computed through a global false nearest neighbors analysis [9,3]. The short-term exponents (λ_{ST}) and the long-term exponents (λ_{LT}) were calculated and the reported values represent their means.

2.3.4. Statistics

Mean gait velocity in m/s was calculated for the over ground walking trials (with and without music) using the distance traveled (number of laps completed multiplied by the perimeter of the hallway) and time spent walking. For the treadmill trials, mean gait speed (m/s) was obtained from the treadmill's digital speedometer. The stride interval variability was determined by σ/μ where σ and μ represent the standard deviation and mean of the stride interval time series, respectively. The Kruskal–Wallis one-way analysis of variance, a non-parametric test for equality of group medians, was used to test for statistical differences among the mean values for each gait parameter across the walking