Fractal scaling of visual metronomes affects cortical hemodynamics

Douglas A. Rowen1, Joao R. Vaz1 , Nick Stergiou1,2
1Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
2College of Public Health, University of Nebraska Medical Center, Omaha, NE USA

INTRODUCTION

Walking is one of the most important activities of daily life as it is needed to maintain independence and quality of life. A common rehabilitation approach to improve walking involves using an audio or visual external cue (e.g. metronome) to provide patients with spatial or temporal information on when or where to step. Previous research has shown that individuals are capable of synchronizing their steps with a metronome [1,2] and in pathological populations, improvements to gait characteristics have been shown [3]. More recently, metronomes with different temporal structures that rely on fractal based fluctuations (i.e pink noise) have been shown to more closely resemble natural walking [1,4]. It is unknown however, how walking to a metronome impacts the brain, and if any changes in cortical hemodynamics, blood flow to the brain, occur when walking to a metronome. Thus, the aim of this study is to investigate the changes in blood flow in the brain as a result of walking with different metronomes to determine if fluctuating metronomes produce different responses in blood flow than periodic metronomes. We hypothesize that the pink noise metronome will produce less blood flow in the supplementary motor areas and motor cortex than either a white noise, randomly fluctuating, or periodic metronome.

METHODS

Figure 1: This figure shows the fNIRS probe used for the study and the schematic of the visual metronome used for the study.

3 subjects (age 26.33 ±3.3 yrs.) walked four ten minute trials on the treadmill while wearing a 4x4 fNIRS probe (Hitachi ETG- 4000) to measure brain activity (Figure 1). In addition, footswitches(Noraxon) were worn to determine gait events. They walked to three different visual metronomes: periodic, white noise and pink noise. The periodic metronome was used since it has no fluctuations in inter-beat intervals. The white noise noise was used as it had random fluctuations in inter-beat interval. The pink metronome was used since it mimics the natural stride to stride fluctuations found in health gait. Prior to the three metronome trials, a ten minute trial was recorded to determine the cadence and deviation for the metronomes. The metronome was displayed on a shown on a small HDMI screen that was attached to glasses and shown in the subjects right eye (Figure 2). FNIRS data was recorded and filtered using a low pass filter at .5 Hz. Footswitch data was recorded to accurately identify heel-strike events. Inter-stride intervals were then calculated from heel-strike times. Detrended Fluctuations Analysis [5] was used to calculate the fractal-scaling.

fNIRS SIGNAL

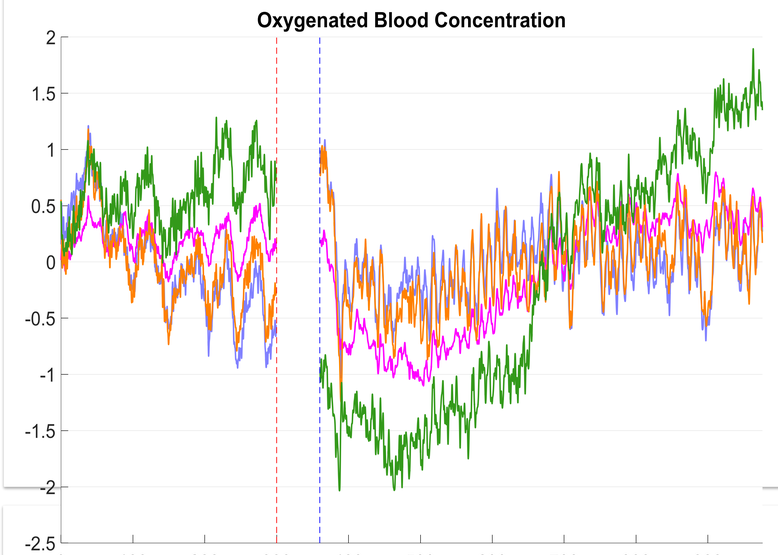

Figure 2: This figure shows an example of the processed fNIRS data for four channels for5 minutes of quiet stand and the ten minute walking trial. The channels shown are from the SMA and the self paced walking condition. The dotted lines represent a one minute period where the subject got ready to start walking.

RESULTS AND DISCUSSION

The results of the present study are in line with the previous literature [1] showing that the fractal scaling of pink-noise metronome (0.89±.14) is similar to the self-paced (0.80±.1) condition, while white-noise (0.50±.06) and periodic (0.36±.1) metronomes exhibit lower values of fractal-scaling (Figure 1). Although this is a preliminary analysis of hemodynamic data, the results of this study do not fully corroborate our hypothesis that pink-noise metronome would exhibited less blood flow in the SMA and MC areas. All three metronomes resulted in an increase of activity in the Prefrontal cortex (PFC) and Supplementary motor areas (SMA). Only the white metronome showed increases in the Motor cortex (MC). The increases in the PFC and SMA were possible due to walking with a metronome may resemble a dual task activity which results in additional brain activity in those regions [6]. The white metronome seemed to result in the largest increase in all regions of the brain. This may be due to the unpredictability of the fluctuation in the white metronome which may cause more attention to the task.

RESULTS AND DISCUSSION

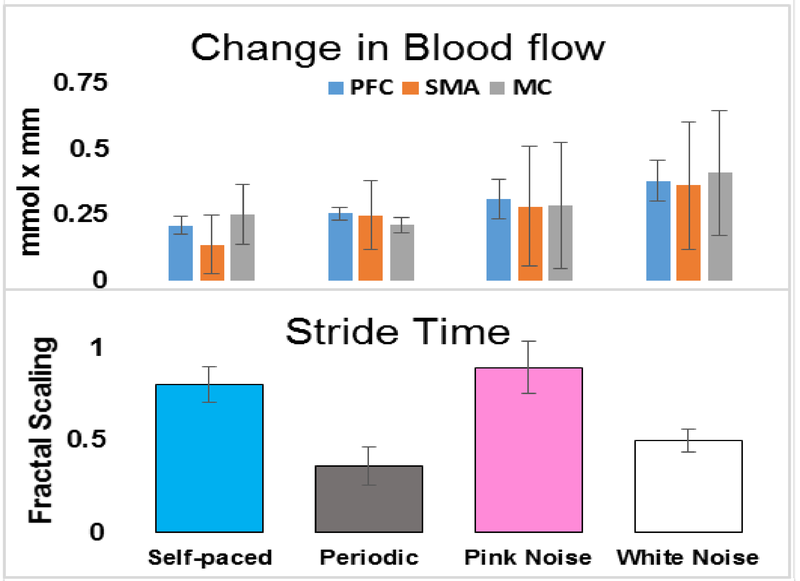

Figure 3: This figure shows the changes in blood flow in the PFC SMA and MC and the stride time fractal scaling for all four conditions

CONCLUSION

Regardless of the temporal structure of the metronomes, the blood flow increased in the PFC and SMA. More subjects need to be collected to understand if the current preliminary findings in terms of largest increase with white-noise metronome are significant and correlates to changes in stride time fractal- scaling values. This may indicate that the temporal structure of the metronome may impose different attentional demands for an individual to remain synchronized with the metronome.

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