1 Introduction

Auditory events can be considered to have spectral energy at both short and long timescales. In the context of music, energy at short timescales determines the psychological phenomena of pitch, timbre, and sound-source localization, whereas long timescales give rise to the perception of pulse. Within the field of music cognition, there has been recent interest in neural oscillations and entrainment [1], whereby populations of neurons synchronize their firing with external stimuli, such as auditory events. Through this synchronization, it is thought that one is able to track periodic stimuli like tones and rhythms. Neural synchronization at both timescales can be measured using electroencephalography (EEG), and it has been found that the spectrum of the EEG signal closely matches that of the stimulus. Recent research has revealed that musicians, who in their daily lives are exposed to subtle differences in pitch and pulse, show better subcortical synchronization with energy at short timescales, as indexed by a larger peak at the fundamental frequency (f0) of stimuli [2]; a similar test for long timescales has not been investigated. In the current study, EEG was measured from musicians and nonmusicians while they listened to an isochronous sequence of tones. It was predicted that similar to subcortical synchronization at short timescales, the strength of cortical synchronization at long timescales would also increase with musicianship. Additionally, it was hypothesized that neural synchronization at multiple timescales would successfully predict measures of musical experience in a regression analysis.

2 Methods

Participants (musicians, amateur musicians, and nonmusicians) were seated in a soundproof booth and fitted with foam insert earphones for the duration of the experiment. Participants first completed behavioural tasks assessing pitch discrimination and pulse perception before being fitted with an EEG electrode cap. Participants listened to an isochronous sequence containing periodicities at short timescales (fundamental frequency of each tone) as well as long timescales (the rate of presentation of tones). Each tone had a fundamental frequency of 220 Hz and energy at the first 5 harmonics (440, 660, 880, 1100, and 1320 Hz). Tones were presented at a rate of 2.5 Hz (period of 400 ms) with an intensity accent on the first tone of every group of 4 (0.625 Hz). Afterwards participants completed questionnaires assessing their history of playing music, listening habits, and current musical activities.

Subcortical and cortical activity were recorded on separate systems and at different sampling rates to accommodate for the different timescales present in the stimulus. Subcortical activity was recorded at 20000 Hz using earlobe electrodes and a forehead ground. Data were bandpass filtered between 100 and 1500 Hz, the response to each tone was extracted as a separate trial, and trials exceeding 35 µV were discarded as artifacts [3]. Trials were averaged together and a fast-Fourier transform (FFT) of the resulting waveform was calculated with a bin size of 5 Hz. The spectrum of a pre-stimulus baseline period was subtracted to correct for the noise floor [4].

Cortical activity was recorded at 512 Hz with a 64-channel electrode cap. Data were highpass filtered at 0.1 Hz and subjected to an independent components analysis (ICA) to identify the presence of eyeblink and other artifacts. The contribution of artifactual components was removed from the timeseries data. Data were segmented into epochs containing 64 tones (approximately 25 seconds) and an FFT with a bin size of 0.0312 Hz was calculated for each electrode [1]. The contribution of the noise floor was removed by subtracting, from each frequency bin, the average of two bins on either side lying two bins away from the current bin [1]. The resulting spectra were averaged across all electrodes.

3 Results

Average spectra for subcortical synchronization to tones can be found in Figure 1. Musicians showed greater synchronization strength to the fundamental frequency of the tone, but this difference was only marginally significant ($t(8)=2.010$, $p=0.079$).

![Figure 1: Spectrum of subcortical response to the 220 Hz tones.](image-url)

Synchronization strength at the fundamental frequency is larger for musicians as compared to nonmusicians.
Average spectra for cortical synchronization to the pulse can be found in Figure 2. Musicians showed greater synchronization strength to the pulse frequency, but this difference did not reach significance ($t(8)=0.884$, $p=0.402$).

![Figure 2: Spectrum of cortical response to the 2.5 Hz pulse rate. Synchronization strength at the fundamental frequency is larger for musicians as compared to nonmusicians.](image)

The extent of synchronization to both timescales did not correlate with years of musical experience, however they did correlate with measures of current musical engagement. Specifically, subcortical synchronization to the fundamental frequency of tones significantly correlated with the number of hours spent playing music ($r=0.55$, $p=0.021$), and cortical synchronization to the pulse frequency was marginally correlated with the number of hours spent listening to music ($r=0.46$, $p=0.067$).

A regression analysis (Figure 3) on the total number of hours spent playing or listening to music, using neural synchronization strength to the fundamental frequency of the tone and pulse frequency, explained approximately 31% of the variance and was marginally significant ($R^2=0.314$, $p=0.071$).

![Figure 3: Plot of regression analysis. The size of subcortical frequency-following response (FFR) peaks to tones and the size of cortical steady-state evoked potential (SSEP) peaks together may predict the number of hours an individual is engaged with music.](image)

4 Discussion

The current study investigated differences in neural synchronization between musicians and nonmusicians. It was found that while musicians yielded larger spectral peaks than nonmusicians at the frequency of the stimulus at both short and long timescales, these differences were only marginally significant. Although the strength of peaks did not correlate with years of musical experience as predicted, they did correlate with the number of hours per week spent playing or listening to music. Previous research indicates that musical experience relates to the strength of subcortical synchronization [2, 3], but the current study suggests a more nuanced explanation. The amount of time currently spent engaged with music might be a better predictor of neural synchronization. Additionally, the strength of neural synchronization at short and long timescales together can predict the amount of time an individual spends engaged in musical activities. This kind of coherence in synchronization across timescales and levels of musicianship is a novel finding and suggests that synchronization abilities in different parts of the brain may be improved concurrently with musical engagement. Since music typically contains nested periodicities, it makes sense that an ability to faithfully represent these periodicities neurally would be necessary for listening or playing.

5 Conclusion

These findings indicate that the experience-dependent plasticity observed in musicians manifests itself at multiple cortical levels corresponding to oscillations at different timescales present in music.

References