Neural Encoding of Auditory and Motor Rhythms in Production Tasks

Ella Sahlas, Rebecca Scheurich, Caroline Palmer
Department of Psychology, McGill University, Canada

Sequence Production Lab

Introduction

How do individuals achieve temporal precision in rhythmic tapping and melody production?

- We compare behavioural and neural responses in rhythmic tapping with and without musical sound

Hypotheses

- Tapping rates may differ in the presence and the absence of sound
- Auditory feedback is expected to facilitate error correction during rhythmic tapping *(Repp, 2002)*
- EEG power spectra are predicted to show peak amplitude at each individuals' tapping frequency

Spontaneous Production Rate (SPR)

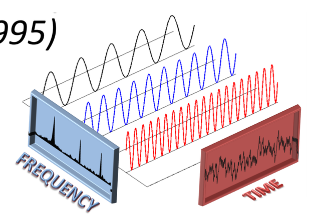
- Rate of tapping a melody *with* auditory feedback
- Reflects biases toward a particular performance frequency *(Palmer et al., 2019; Scheurich et al., 2018; Zamm et al., 2016)*

Spontaneous Motor Tempo (SMT)

- Rate of self-paced regular tapping *without* auditory feedback *(McAuley et al., 2006)*

EEG Power Spectrum

- The square of the amplitude of neural oscillations at each frequency *(Kaplan and Glass, 1995)*
- The spectrum captures neural power at stimulus frequencies in perception and performance



(Nozaradan, 2014) *groups.csail.mit.edu/netmit/sFFT/*

Power Spectral Density (PSD)

- Amplitude of the neural response at the beat period of a stimulus event *(Nozaradan et al., 2015)*
- EEG recordings reveal PSD peaks at musicians' performance frequencies *(Zamm et al., 2019)*

Method

Participants

6 adults, aged 19-27 (M = 22.8, SD = 3.1), ranged in musical training 0-14 years (M = 4.8, SD = 6.2)

- Familiar with *Twinkle, Twinkle, Little Star*
- Hearing thresholds < 30 dB HL for 250-1000 Hz
- Edinburgh laterality quotient: M = 71.7 (47-100)

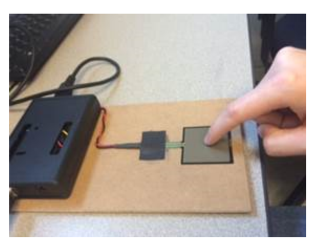
Spontaneous Motor Tempo (SMT) task

- 44 taps at a steady rate on a force-sensitive pad
- Analyzed middle 32 taps

Spontaneous Production Rate (SPR) task

- 3.5 melody repetitions at a steady rate
- Analyzed middle 84 taps (repetitions 2 and 3)

Within-Subjects Design



Independent variables

- Task (SPR, SMT); trial (1, 2, and 3)

Dependent variables

- **Behaviour**:

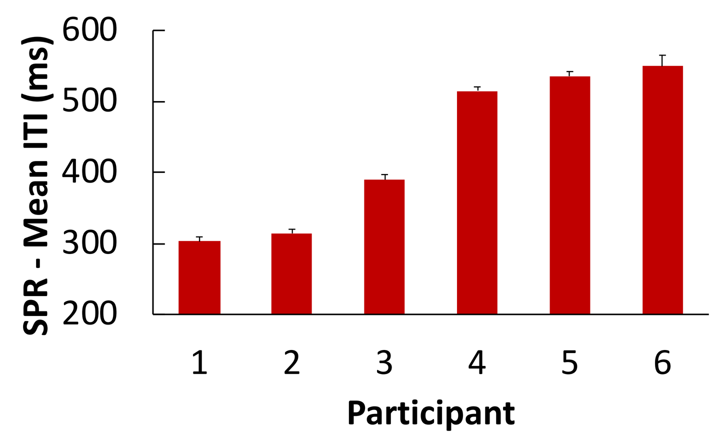
- Mean tapping inter-tap interval (ITI)
- Coefficient of variation (CV) = SD / mean ITI

- **EEG**: power spectral density (PSD) at tapping rate

EEG: 64-channel BioSemi Active-Two system 512 Hz sampling rate; data referenced to the common average reference, artefact correction performed with independent component analysis, channels with poor signal quality interpolated Force sensor and EEG signals were synchronized

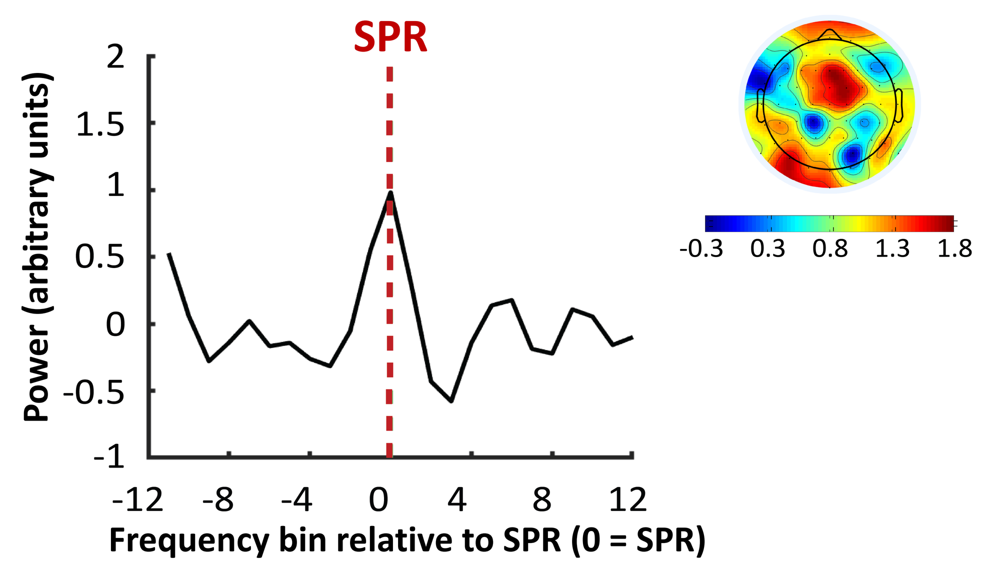
Spontaneous Production Rate

Mean Tapping Rates (smallest to largest)



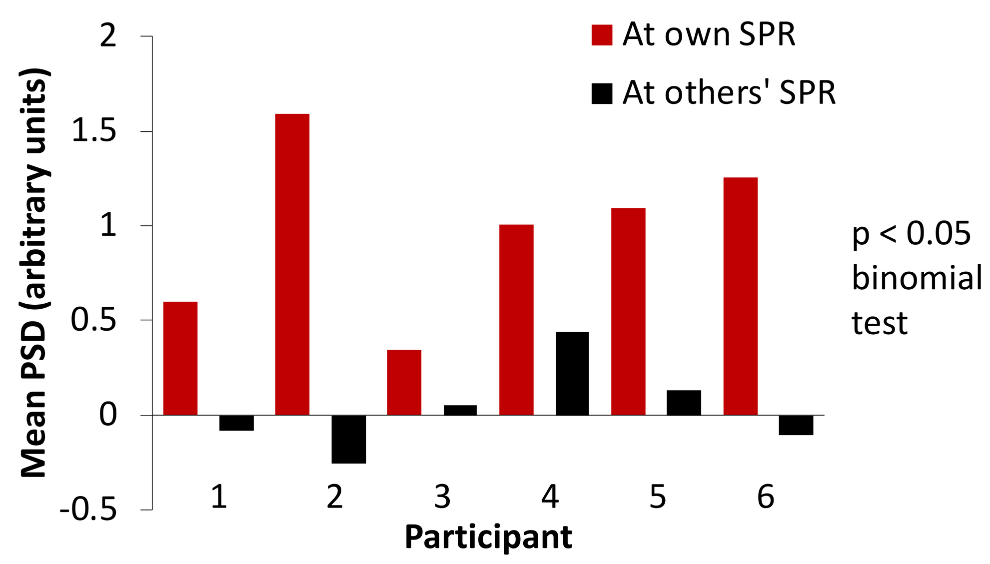
Power Spectral Density at SPR

Grand average across 64 electrodes



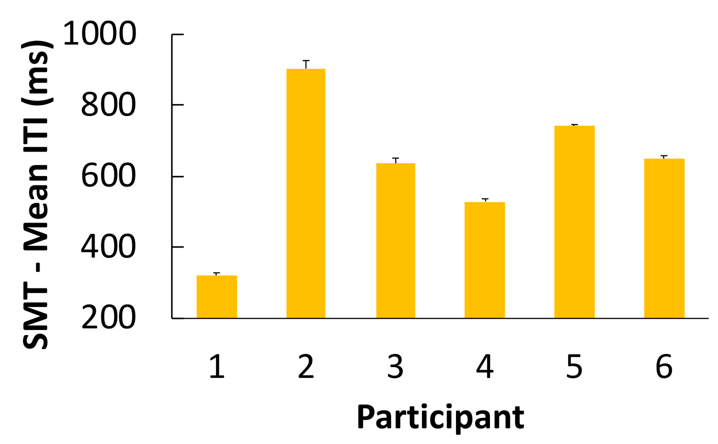
Person-specificity of EEG Power (SPR)

PSD at participants' SPR > PSD at others' SPR



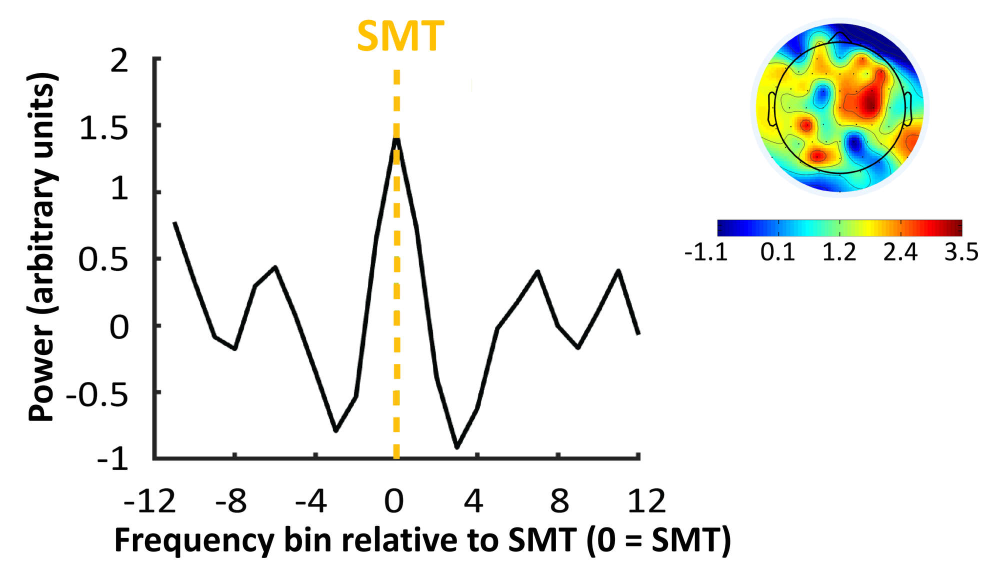
Spontaneous Motor Tempo

Mean Tapping Rates (ordered by SPR values)



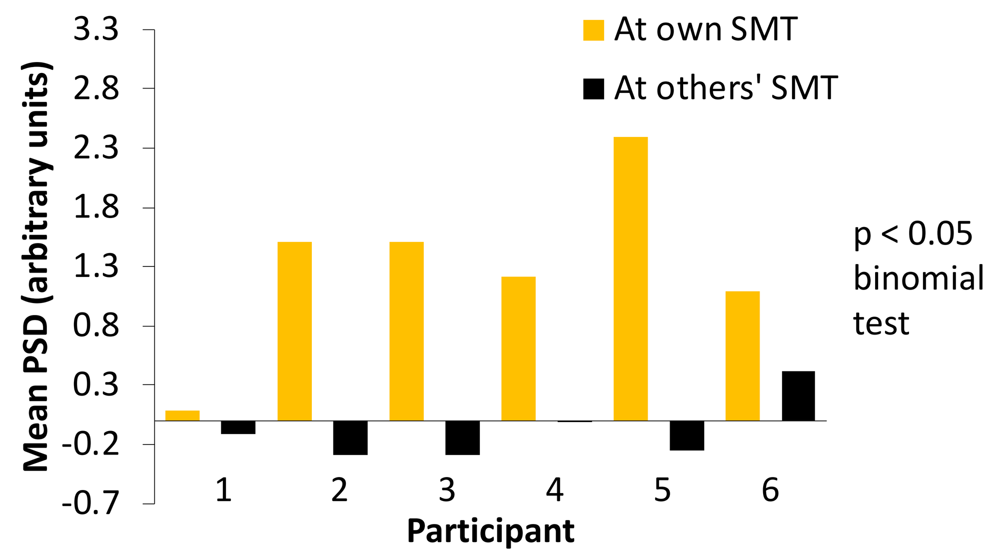
Power Spectral Density at SPR

Grand average across 64 electrodes

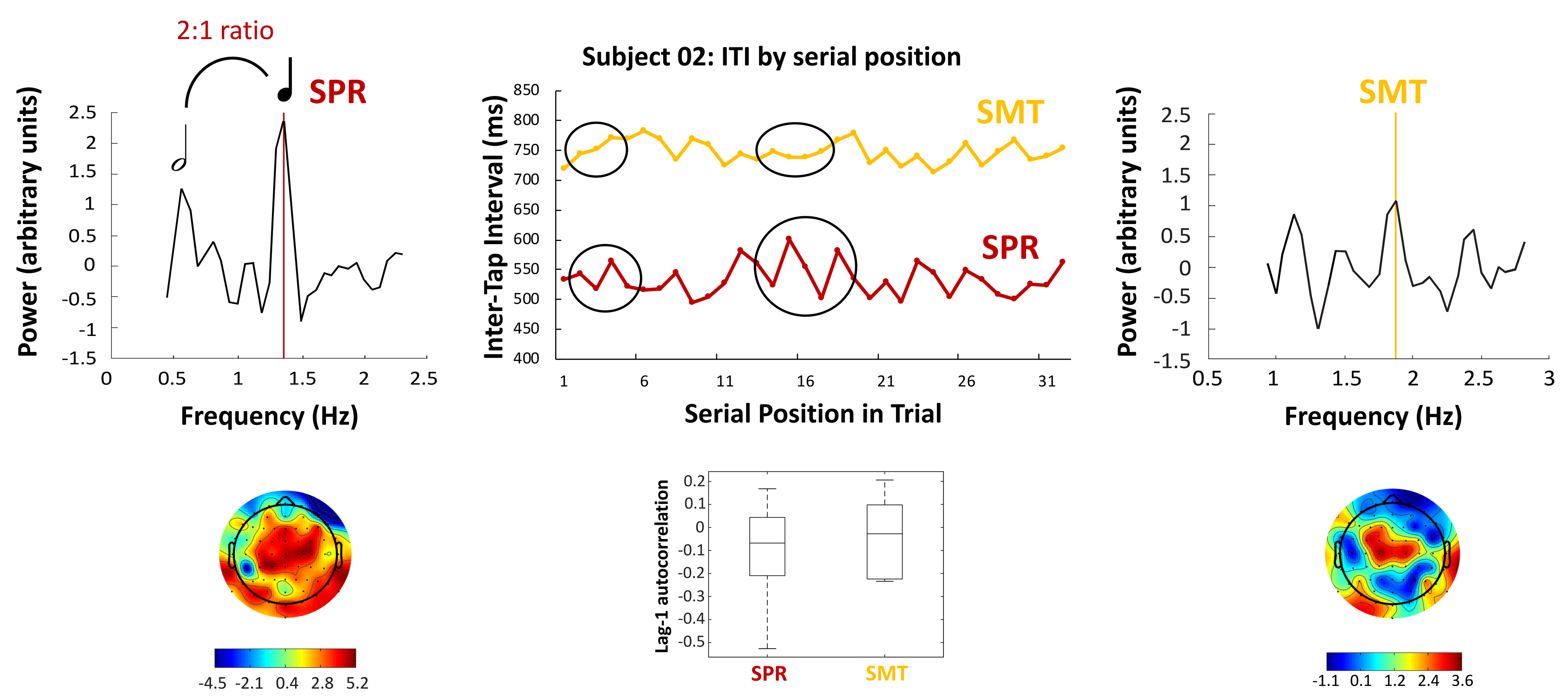


Person-specificity of EEG Power (SMT)

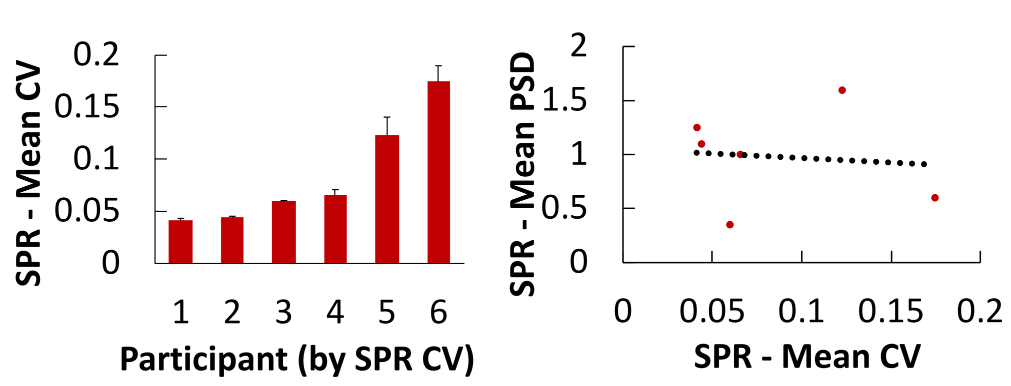
PSD at participants' SMT > PSD at others' SMT



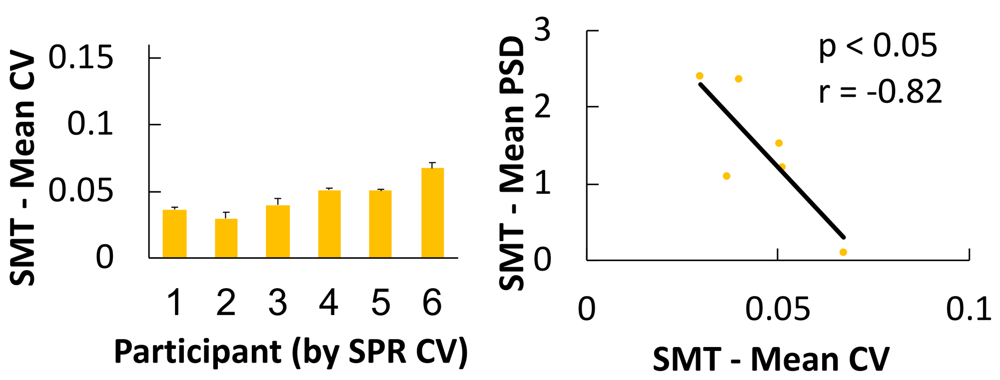
Does Sound (SPR) Induce More Error Correction?



Brain-Behaviour Correlations



Brain-Behaviour Correlations



Discussion

Tapping rates differ with and without sound

- Participants' tapping rates were uncorrelated across SPR (auditory-motor) and SMT (motor) tasks

EEG power peaks at tapping frequency

- Power spectral density: peak amplitude at the produced beat frequency in each task (with and without auditory feedback)
- Peaks at simple ratio frequencies (2:1) in the presence of sound (SPR)

Person-specificity of EEG power

- Chance estimate of PSD computed for each participant: mean of their neural power at the tapping rate of each other subject
- PSD was greater at each participant's production rate than at others' rates in SPR and SMT tasks

Auditory feedback facilitates error correction

- Lag-1 autocorrelations suggested more error correction in the presence of auditory feedback (SPR) than in the absence of sound (SMT)

Brain-behaviour correlations

- PSD at performance frequency was negatively correlated with variability in SMT but not in SPR
- Auditory feedback seems to affect error correction in SPR measures of variability

Future Directions

- Topographic SMT maps suggest right-lateralized activity; potential explanations include:
  - Wide range of participants' laterality quotients
  - PSD measures of area M1 power reflecting interhemispheric crosstalk *(Bestmann et al., 2015; Paek et al., 2014; Seeber et al., 2016)*
- We might consider other data cleaning methods
- Recurrence quantification analysis (RQA) will help capture hierarchical relations between frequencies

References

Bestmann, S., & Krakauer, J. W. (2015). The uses and interpretations of the motor-evoked potential for understanding behaviour. *Experimental brain research, 233*(3), 679-689.

Kaplan, D., & Glass, L. (1995). *Understanding nonlinear dynamics.* Springer Science & Business Media.

McAuley, J. D., Jones, M. R., Holub, S., Johnston, H. M., & Miller, N. S. (2006). The time of our lives: life span development of timing and event tracking. *Journal of Experimental Psychology: General, 135*(3), 348.

Nozaradan, S. (2014). Exploring how musical rhythm entrains brain activity with electroencephalogram frequency-tagging. *Philosophical Transactions of the Royal Society B: Biological Sciences, 369*(1658), 20130393.

Nozaradan, S., Zerouali, Y., Peretz, I., & Mouraux, A. (2015). Capturing with EEG the neural entrainment and coupling underlying sensorimotor synchronization to the beat. *Cerebral Cortex, 25*(3), 736-747.

Paek, A. Y., Agashe, H., & Contreras-Vidal, J. L. (2014). Decoding repetitive finger movements with brain activity acquired via non-invasive electroencephalography. *Frontiers in neuroengineering, 7*, 3.

Repp, B. H. (2002). Phase correction in sensorimotor synchronization: Nonlinearities in voluntary and involuntary responses to perturbations. *Human Movement Science, 21*(1), 1-37.

Scheurich, R., Zamm, A., & Palmer, C. (2018). Tapping into rate flexibility: musical training facilitates synchronization around spontaneous production rates. *Frontiers in Psychology, 9*, 458.

Seeber, M., Scherer, R., & Müller-Putz, G. R. (2016). EEG oscillations are modulated in different behavior-related networks during rhythmic finger movements. *Journal of Neuroscience, 36*(46), 11671-11681.

Zamm, A., Palmer, C., Bauer, A. K. R., Bleichner, M. G., Demos, A. P., & Debener, S. (2019). Synchronizing MIDI and wireless EEG measurements during natural piano performance. *Brain Research, 1716*, 27-38.

Acknowledgments

We thank Luke Zhang for his assistance with this project.

Chaires de recherche du Canada / Canada Research Chairs
Canada
NSERC CRSNG