Code for the bGLS method for parameter estimation of sensorimotor synchronization models: single subject and ensemble synchronization.

Sensorimotor synchronization is the temporal coordination of a rhythmic movement with an external rhythm. This ubiquitous behavior has been studied by measuring the performance of musicians or dancers, or more commonly in the laboratory in the form of finger-tapping experiments, in which subjects are instructed to tap along with simple rhythmic sequences or controlled adaptive stimuli (for a review, see Repp 2005, Repp and Su 2013). There are a number of approaches for modeling sensorimotor synchronization, each focusing on different aspects of this remarkably intricate behavior. One of the leading methods is the class of “linear event-based models”, which attempt to predict the onset of the next response (i.e., the time the finger impacts upon the tapping surface) from the previous onsets of the stimulus and responses using a linear model. Given that their parameters are often linked to psychological processes such as phase correction and period correction, the fit of the parameters to experimental data is an important practical question.

Our recent paper Jacoby, Keller, et al. (2015) points to a specific problem related to the structure of these synchronization models. This problem causes redundancy in parameter space and leads to a high variability error. Because of this problem, standard methods of parameter estimation implemented in standard data analysis software (e.g. MATLAB or R), will not work effectively. This problem has limited the usability of these models. However, introducing a relatively simple and empirically justified constraint specific to synchronization models solves the problem, as demonstrated in Jacoby, Tishby, et al. (2015).

Our method, which we call bGLS, is a variant on the standard generalized least square regression methods (Aitken 1935). The only difference is that within the GLS iteration we enforce an additional constraint: that the motor variance is smaller than the timekeeper variance in the synchronization models.

This free MATLAB package uses bGLS and provides a comprehensive solution to this problem for single and multi-person ensemble of synchronizers. It can be used to solve the single subject model of Vorberg and Wing (1996) and Vorberg and Schulze (2002) and the period correction model of Schulze, Cordes and Vorberg (2005) together with their multi-person generalization. This can be used to estimate parameters of empirical data, such as the string quartet dataset published by Wing, Endo, Bradbury and Vorberg (2014)

If you use the package please cite:

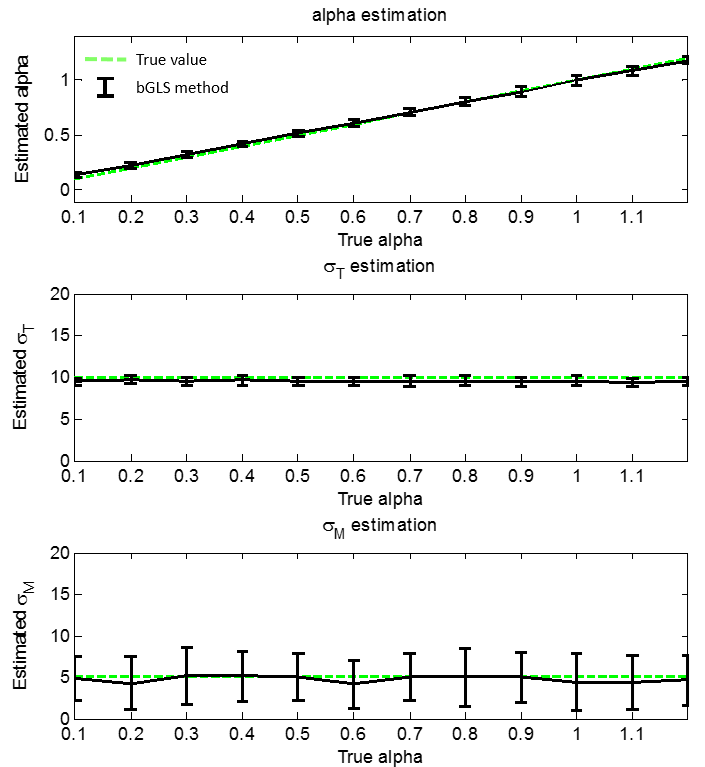
Jacoby, Nori, Peter Keller, Bruno H. Repp, Merav Ahissar and Naftali Tishby. "Parameter Estimation of Linear Sensorimotor Synchronization Models: Phase Correction, Period Correction and Ensemble Synchronization." In review, special issue of *Timing & Time Perception* (RPPW).

For more information on the methodological issues see also:

Jacoby, Nori, Naftali Tishby, Bruno H. Repp, Merav Ahissar, and Peter E. Keller. “Lower Bound on the Accuracy of Parameter Estimation Methods for Linear Sensorimotor Synchronization Models.” In review, special issue of *Timing & Time Perception* (RPPW).

Here are samples of two graphs that use the method. For further details, see Jacoby, Tishby et al. (2015).

**Performance of the bGLS method with a non-isochronous sequence:** ideal performance is marked in dashed line. We simulated 1000 iteration for different alpha values (x-axis) with parameters (σ\_T^2=100 and σ\_M^2=25, nseq=15 N=30). The top, middle, and bottom graphs show the estimates for phase correction, timekeeper variance, and motor variance respectively.



**Simulated string quartet with a setting similar to the data in Wing, Endo et al. (2014);** namely, the same number of synchronizers and the same number of trials and blocks. The top graph shows the phase constants of all four simulated players. The bottom graph shows the different timekeeper standard deviations (σ\_T=10,13,15 and 18 for violin 1, violin 2, viola, and cello, respectively) and motor variances (σ\_M=5,6,7,8). Estimation of 100 iterations of the simulations with nseq=16, and N=40 are depicted. Error bars represents standard deviation of the estimation error.

