Center for Lifespan Psychology

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The project continued its major focus on analyzing electroencephalographic (EEG) data of skilled musicians playing music together (see Figure 16). In our initial study with guitar duets, we discovered that interpersonally co-ordinated actions are preceded and accompanied by within-brain synchrony and between-brain oscillatory couplings (Lindenberger, Li, Gruber, & Müller, 2009). We replicated and extended these original findings in a series of follow-up studies. In analyses of hyper-brain networks based on EEG data from a guitar quartet, we found that within-brain connections tend to operate at higher frequencies (e.g., beta, gamma) than between-brain connections (e.g., delta, theta)—in line with Lindenberger, U., Li, S.-C., Gruber, W., & Müller, V. (2009). Brains swinging in concert: Cortical phase synchronization while playing guitar. *BMC Neuroscience, 10*: 22. doi:10.1186/1471-2202-10-22


![Figure 15. A forward model of interpersonal action coordination. Drawing on the work of Steven M. Boker, Wolfgang Prinz, Daniel Wolpert, and others, our model assumes that interpersonal action coordination is based on a set of linked representational layers. The single-person layer is shaded in gray. Individuals acting together attempt to synchronize their forward model regarding their own actions with their forward model regarding the other person’s actions. Highly skilled individuals, such as dancers or musicians, may represent jointly performed activities as a unified suprapersonal action with a joint forward model and partially joint sensory feedbacks. The various representational layers of the actors are intertwined by sensorimotor feedback loops (see also Sänger, Lindenberger, & Müller, 2011).](image-url)
In a methodologically oriented reanalysis of standard single-person EEG data during rest and auditory oddball performance (Müller et al., 2016), we showed that cross-frequency couplings (CFC), in addition to within-frequency couplings (WFC), help to characterize the topology of hyper-frequency networks, including condition differences in graph-theoretical parameters, such as strength, clustering coefficient, characteristic path length, as well as local and global efficiency.

We explored the utility of hyper-frequency, hyper-brain networks in a data set of couples engaged in romantic kissing (Müller & Lindenberger, 2014). Oscillations in the alpha band played a central role in binding the two brains together. Also, network strengths were higher and characteristic path lengths were shorter when individuals were kissing each other than when they were kissing their own hand. Between-brain strengths of theta oscillations (around 5 Hz) were reliably associated with reported partner-oriented kissing satisfaction, especially over frontal and central electrodes.

Given our earlier observations of fronto-central between-brain synchronization in guitar players, we suggest that these couplings reflect cell assemblies representing movement coordination among interacting partners. During the reporting period, we also went back to cardiac, respiratory, and vocalizing data from 11 singers and 1 conductor engaged in choir singing (Müller & Lindenberger, 2011). Ongoing analyses reveal that cardiac, respiratory, and voice production subsystems interact among each other both within and across singers as a function of whether a canon is sung in unison or in different voices. The conductor’s hand movements are synchronized with each of the three subsystems.

In a second line of work, the project has sought to devise new EEG paradigms that are suited to delineate the behavioral function of inter-brain synchrony (Dissertation Caroline Szymanski). In one of these studies (Szymanski et al., 2017), participants were asked to perform a visual search task either alone or with a partner. Local phase synchronization and between-brain phase synchronization were generally higher when partners attended to a visual search task jointly than when they attended to the same task individually. Also, between-team differences in behavioral performance gain during the joint condition were associated with between-team differences in local and inter-brain phase synchronization. These results suggest that phase synchronization constitutes a neural correlate of social facilitation and may help to explain why some teams perform better than others. A second study tests the hypothesis that same-frequency, same-phase transcranial alternating-current stimulation (tACS) is associated with greater behavioral synchrony in a dyadic drumming task than no stimulation or stimulation that differs in phase and frequency. The collected data are currently being analyzed.
Figure 17. Coupling strengths and connectivity brain maps while playing guitar in a quartet. (a) Guitar traces in the four guitarists and the four time windows represented by the brain maps. (b) Time course of within- and between-brain out-strengths in the four guitarists. (c) Brain maps of within-brain connectivity in the four guitarists across the four time windows shown in (a). (d) Brain maps of between-brain connectivity in the four guitarists across the same four time windows. Note that color in (a)–(d) corresponds to the different guitarists as depicted in (a). During the first time window, when guitarist D (shown in yellow) is playing alone, strong within- and between-brain connectivity is evident. (e) Modularity structures of hyper-brain networks across the same time windows. Modules are coded by color. Note that most are hyper-brain modules sharing nodes from two, three, or even four brains.

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