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Introduction to Interpersonal Synchronization

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The first example of synchronization in mechanical systems was reported in 1665 by Christiaan Huygens, who noticed that two clocks that were ticking on their own cycles eventually ticked in unison. The communication between clocks occurred because vibrations were transferred between them through a wooden beam. William Strutt opened investigations into the structure of sound waves in 1879, including those that appear synchronized. He observed that two organ pipes generating the same pitch and timbre would negate each other's sound if they were placed too close together. Thus two oscillators could exhibit an inverse synchronization relationship that he called *oscillation quelching* (Pikovsky, Rosenblum, & Kurths, 2001).

Based on the following century of advancements in the study of oscillating phenomena, Pikovsky et al. defined synchronization as "an adjustment of the rhythms of oscillating objects due to their weak interaction" (p. 8). The oscillators must be independent, however; each one must be able to continue oscillating on its own when the others in the system are absent. Strogatz (2003) concisely described the minimum requirements for synchronization as two coupled oscillators, a feedback loop between them, and a control parameter that speeds up the oscillating process. When the control parameter speeds the oscillating process fast enough, the system exhibits *phase lock*.

In phase lock, the contributing oscillations all start and end at the same time, with start and end times varying only over a small and rigidly bounded range. If we imagine that the time series of observations produced by a pure oscillator is a sine wave and that its phase-space diagram is a circle, the positions of two or more synchronized oscillators are clustered together as they move around the circle at the same time. Phase synchronization is actually a matter of degree that depends on other matters of degree, such as the tightness or looseness of the coupling produced by the feedback, whether the feedback is unidirectional or bidirectional (or omnidirectional in the case of systems of multiple oscillators), and whether delays in feedback are prominent.

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A phase lock is different from a phase shift, although nothing prevents the two from occurring together. A phase lock occurs when biological or behavioral events from two or more sources adopt the same rhythm of output. A phase *shift* is the event associated with some self-organizing and emergent phenomena and catastrophe models when a qualitative change in the system state occurs suddenly.

Is synchronization the same as coordination? The strength of the similarity varies depending, in last part, on whether one is studying neuromuscular phenomena, biometrics such as EEGs or electrodermal responses, or behavioral choices such as those described in game theory. Some of the author teams in this special issue address the possible connections between synchronization and coordination.

Although it may be convenient to think of the oscillators that are synchronizing as pure oscillators, one does not need to assume purity. Oscillators can be forced, aperiodic, or chaotic processes. In fact, three coupled oscillators are sufficient to produce chaos (Newhouse, Ruelle, & Takens, 1978); this principle has been exploited in other ways (Guastello, Peressini, & Bond 2011). Chaos can also be controlled by imposing a strong oscillator on the system (Ott, Grebogi, & Yorke, 1994). Two or more chaotic simplexes from synchronizing with each other further (Stefánski, 2009), as some of the contributions in this special issue illustrate. Nervous systems are composed of many oscillating and chaotic subassemblies; some activate each other while others are inhibitory (Whittle, 2010). Thus one would anticipate that the products of the nervous system – movements, autonomic arousal, speech and cognition patterns – are also fundamentally chaotic, and that pure oscillators are more often the exception than the rule.

The contributions in this special issue are organized from those that focus on dyadic relationships (Ramseyer & Tschacher, Orsucci et al.; Gipson, Gorman, & Hessler) to those that encompass teams of four (Guastello et al.) or six people (Stevens & Galloway), and finally the *N*-agent case (Sulis). The researchers ask questions such as who synchronizes to whom, in what way, and to what extent? What conditions affect the synchronization of movements, autonomic arousal, speech patterns, and brain waves?

The contributions also address pragmatic questions: How does synchronization promote more successful therapy sessions and more effective work teams? Are there conditions where synchronization is not in the best interest of the dyad or team? Here one might anticipate that the principle of optimum variability (Guastello et al., 2013; Navarro & Rueff-Lopes, 2015; Schuldberg, 2015) would rule eventually. If synchronization at the nonverbal level contributes to desirable decisions and actions at a more explicit level, it can also facilitate irrationality, particularly if stressful conditions are involved (Adamatzky, 2005).

Eventually the growing knowledge base of synchronization effects could result in a coherent theory that connects individual and group arousal levels, EEG patterns, speech patterns, and effective collective behaviors (Salas et al., 2015). The agenda as it is imagined today would not fully develop overnight, especially in light of the many opportunities for nuances and surprises in self-organized systems. Meanwhile, the *NDPLS* Editorial Board strongly encourages new research on synchronization topics, and expects to see more contributions on synchronization phenomena in the pages of *NDPLS* soon.

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