Motor Skills

Temporal processing (or the timing of neural oscillations/transmissions) plays a critical role in coordinated motor movement. In this paper published in Science, the authors distinguish between "continuous" motor tasks, which involves moving steadily and smoothly at a certain pace, versus "discontinuous" motor tasks, which involve a succession of stops and starts as a person accomplishes each step of an overall goal (i.e., picking up a plate, walking it over to the table, and setting it down). They discuss the role of the cerebellum in each of these types of motor tasks and how the timing control for each differs in terms of the brain structures used, arguing that the cerebellum is involved only early on in setting the timing goal for continuous, smooth movements, but that the cerebellum is involved throughout the movement when it is discontinuous or involves several starts and stops by setting several, successive timing goals. Timing in the brain may be disrupted due to developmental disorder, trauma, or illness resulting in uncoordinated movement and/or cognitive impairment. The Interactive Metronome is a treatment program that measures and improves temporal processing, or timing in the brain, that is critical for movement and thinking.

Spencer, R.M.C., Zelaznik, H.N., Diedrichsen, J., and Ivry, R.B. (2003). Disrupted timing of discontinuous but not continuous movements by cerebellar lesions. Science, 300(5624), 1437-1442.

Here is a fascinating study in Cortex that looked at the brain under fMRI while listening to rhythmic auditory sounds. Bengtsson et al (2009) found that areas of the brain involved in motor planning and sequencing (or preparing motor sequences) were activated while listening to rhythmic sound. Interactive Metronome (IM) training improves motor planning and sequencing (and thus motor coordination) through a series of progressive exercises that are synchronized to a steady auditory rhythm. As the person performs each distinct movement, audio and/or visual feedback is provided in milliseconds to improve "temporal processing" for fine and gross motor coordination.

Bengtsson, S.L., Ullen, F., Ehrsson, H.H., Hashimoto, T., Kito, T., Naito, E., Forssberg, H., and Sadato, N. (2009). Listening to rhythms activates motor and premotor cortices. Cortex, 45, 62-71.

Most of the motor movements involving our arms and hands are bilateral, meaning they involve using both limbs together in a coordinated fashion. Examples given in this paper are: typing, using a fork and knife, and buttoning a shirt. In this article by Ivry et al (2004), the authors go into significant detail about how the two sides of the brain work together to make this possible. They discuss timing in the brain and show how thinking and movement work in tandem for coordinated motor movement. Interactive Metronome is a unique training tool that challenges thinking and movement simultaneously as the individual synchronizes movements with a steady

auditory rhythm. Feedback regarding how close to or how far away from the beat is provided following each individual movement to help the individual refine his/her motor skills. Research has shown that listening to rhythmic sound activates the centers of the brain involved in coordinated motor planning and sequencing.

Ivry, R., Diedrichsen, J., Spencer, R., Hazeltine, E., and Semien, A. (2004). A cognitive neuroscience perspectivce on bimanual coordination and interference. In S.P. Swinnen & J. Duysens (Eds.), Neuro-Behavioral Determinants of Interlimb Coordination: A Multidisciplinary Approach (Chapter 9). New York: Springer Publishing.

In this study by Jantzen et al. (2007), the authors identified that timing in the brain for motor coordination relies upon a "network of brain areas engaged to meet the specific sensory, motor and cognitive demands of the associated coordination behavior." While looking at the brain under fMRI during synchronous movement they were able to tease out regions of the brain involved in interval timing for motor activity and to show that information about timing from the environment (or context) influences internal timing for coordinated movement. Interactive Metronome training promotes synchronization within this neural network for more coordinated movement through a series of progressive exercises that are performed to a steady beat. Millisecond feedback for mental/interval timing is provided following each movement to help refine timing skills and coordination.

Jantzen, K.J., Oullier, O., Marshall, M., Steinberg, F.L., and Kelso, J.A.Ss. (2007). A parametric fMRI investigation of context effects on sensorimotor timing and coordination. Neuropsychologia, 45, 673-684.

Movement requires precise timing, especially that of athletes, musicians, and skilled workers. This article by Larue (2005) delves into the timing mechanisms within the brain that govern movement. What I particularly like about this paper is its readability as I am not a neuroscientist but am keenly interested in timing in the brain and the interplay between temporal processing, cognition, and coordinated movement. The author discusses unique versus multiple timing mechanisms, learning timing, the contribution of movement-related feedback to timing, the contribution of attention in the learning of timing, and other important topics relating to how timing in the brain determines the quality of movement. This article should be of particular interest to anyone who is familiar with or uses the Interactive Metronome in the habilitation or rehabilitation of motor skills. Timing & rhythm are essential to movement.

Larue, J. (2005). Initial learning of timing in combined serial movements and a no-movement situation. Music Perception, 22(3), 509-530.

This study by Lewis et al. (2004) shows that our brain learns then retains the

temporal (or timing) information about particular movement sequences. Once the movement is over-learned (or repeated to the extent we can do it without thinking) we can continue the movement on “autopilot” so to speak. The relevance of the paper here is to point out, once again, that movement is governed by timing in the brain and that the brain can learn the temporal information necessary for coordinated movement. Interactive Metronome can be easily integrated into habilitation/rehabilitation programs to provide this learning opportunity through exercises requiring synchronization of movement with auditory rhythm (and of course, feedback for timing!).

Lewis, P.A., Wing, A.M., Pope, P.A. Praamstra, P., and Miall, R.C. (2004). Brain activity correlates differentially with increasing temporal complexity of rhythms during initialization, synchronization, and continuation phases of paced finger tapping. Neuropsychologia, 42(10), 1301-1312.