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Neurophysiological evidence of the dynamic and adaptive pain-motor interaction

Stephen A. Coombes, Wei-en Wang, Arnab Roy and Rachel L. M. Ho
Laboratory for Rehabilitation Neuroscience, Department of Applied Physiology and Kinesiology, University of Florida, Gainesville, Florida

Email: scoombes@ufl.edu

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Neige et al. provide new evidence of how the anticipation of movement-related pain alters corticospinal tract excitability during motor preparation (Neige, Mavromatis, Gagné, Bouyer, & Mercier, 2018). They recorded motor evoked potentials from the biceps brachii immediately preceding the execution of elbow flexion and extension movements. Different groups of subjects were conditioned to expect a pain-eliciting stimulus to the lateral epicondyle during flexion movements or during extension movements. The elegance in the design was that the same muscle was targeted using TMS but that its role as agonist and antagonist varied as a function of movement direction. The key finding was that the anticipation of pain during movement increased corticospinal tract excitability before extension movements when the biceps brachii was preparing to function as an antagonist, as compared to flexion movements when the same muscle was preparing to function as an agonist. Neurophysiological evidence of this protective motor strategy is important for bridging the gap between behavioral studies of pain and motor processing and their corresponding neurophysiological basis.

Understanding how the brain plans and controls movement in the context of pain will lead to fundamental advances in rehabilitation and human motor performance. The paper by Neige et al. moves the field forward in an important way by demonstrating that the expectation of pain during an upcoming movement leads to objective and measurable changes in excitability of the corticospinal tract. The key point is that changes in excitability were task specific and were assayed during movement preparation rather than movement execution. The comparison between predicted sensory feedback and actual sensory feedback is key to how we adapt voluntary movements, and the paper by Neige et al. extends this principle by directly manipulating the expectation of pain during a specific movement. Together, their neurophysiological and behavioral data highlight the complex and dynamic interaction between the prediction of pain and the planning and control of motor function. These exciting new findings highlight two important issues. First, the relative timing between when pain is expected, when pain is experienced, when movements are executed, and when neurophysiological data are collected is critical. Second, the study focused on the primary motor cortex and the corticospinal tract, but converging evidence from other studies in both humans and animals suggest that regions beyond the primary motor cortex are also involved in how movements are adapted in the context of pain.

Our group and others have shown that during ongoing acute pain states, voluntary movements are initiated more quickly, and a pain-related priming of movement is associated with a decrease in beta power over premotor cortex (Misra, Ofori, Chung, & Coombes, 2017), and an increase in functional activity in midcingulate cortex. In contrast, Neige et al., reported a slowing of reaction time when pain-eliciting stimuli were delivered after movement onset, irrespective of movement direction. Delivery of the pain-eliciting stimulus occurred when elbow angle rotation exceeded 5 degrees relative to its starting position. Hence, onset of the pain-eliciting stimulus followed rather than preceded the movement. Delaying the onset of the movement therefore delayed the onset of pain. However, following the onset of the pain eliciting stimulus, peak velocity of flexion movements was greater suggesting that the experience of pain facilitated rather than inhibited movement velocity. Together, these findings suggest that manipulating the relative onset times of acute experimental pain and voluntary movement can lead to opposite patterns in motor function. These findings also point to the rapid and dynamic nature of the pain-motor interaction such that the neurophysiological state that reflects a protective strategy during movement planning may not predict movement adaptations following the onset of the pain-eliciting stimulus.

The midcingulate cortex and cerebellum are anatomically and functionally connected with the motor cortex and have been associated with motor adaptation. Converging evidence suggests that the midcingulate cortex may integrate pain, affect, and cognitive control to shape motor function (Shackman *et al.* 2011). Our group has demonstrated that the blood-oxygenation-level-dependent signal is increased in the same region of midcingulate cortex during both pain and motor processing (Misra & Coombes, 2015), and studies in rodents show that manipulating activity in the midcingulate cortex has a profound influence on motor behavior. In addition to the midcingulate cortex, emerging evidence also points to a role for the cerebellum in how pain leads to adaptations in motor control. Error based learning has been consistently associated with cerebellar function, and recent studies have demonstrated that sensorimotor integration regions of the cerebellum, including lobule VI and VIIb, are engaged during both pain and motor processes (Coombes & Misra, 2016). The dynamic and adaptive nature of the pain-motor interaction suggests that regions beyond the primary motor cortex play a critical role in how the prediction and experience of pain shape motor behavior. Novel experimental paradigms that measure and manipulate brain function in regions including the primary motor cortex, the midcingulate cortex, and cerebellum will build on the exciting new findings of Neige et al. to unlock the dynamic neurophysiological basis for how pain and motor processes interact. Such progress will drive new approaches in rehabilitation and human performance.

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Additional information

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