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school or college, which was too long before symptom onset to be confused with disease manifestations.

Elucidation of the pathophysiology that might account for these associations would require a prospective study recording the nature (athletic, heavy labor, isometric, aerobic, power, endurance), setting (indoors, outdoors, season), and intensity (frequency, level of competition, caloric expenditure, duration) of the physical activity, as well as environmental/occupational and toxin exposure data, including time between exposure and symptom onset.

Thousands and thousands of slim athletes never develop ALS. Why a tiny few of them do develop ALS is still unknown. There is certainly no justification to avoid athletics in attempts to avoid motor neuron diseases. Moreover, nothing in our data can be construed as evidence that patients with ALS should not exercise or that they should not be as well nourished as possible.

References

Pain and the body schema: Effects of pain severity on mental representations of movement

Abstract—Previous research suggests that response times for imagined movements provide a sensitive measure of the integrity of the motor system. In a group of 12 patients with chronic unilateral arm pain, the authors demonstrate that response times for imagined movements are influenced by the severity of pain. Simulated large-amplitude arm movements were slower for the painful as compared with the unaffected arms before, but not after, effective music therapy entrainment, suggesting that mental representations of movement are influenced by the current state of noxious feedback.

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Several lines of evidence provide support for an online representation of the body in space ("body schema") and its role in the guidance of imagined and actual movements. For example, Parsons argues that the body schema underlies performance on a task that requires participants to judge the Laterality of pictured hands. Response times on this task suggest that participants confirm laterality judgments by imagining their hand moving from its current orientation into the orientation of the pictured hand; response times reflect the disparity between the orientations of stimulus and participant hands as well as biomechanical constraints on movement. For example, just as it takes longer to rotate a hand away from rather than toward the body midline, due to biomechanical constraints, laterality judgment times are longer when they involve imagining a hand rotating away as compared to toward the body midline. We have recently replicated the above findings and demonstrated that performance on the hand laterality task is sensitive to whether movements, if actually executed, would be painful. Patients with chronic unilateral arm pain exhibited significantly slower response times for the painful as compared with the normal arms in conditions that required large-amplitude imagined movements involving both

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distal and proximal joints; response times for judgments concerning left and right hands were not significantly different for controls. Because the task did not require patients to actually move their affected limbs at any time, these findings suggest that the mental representation of movement (body schema) predicts, and is modified by, the same peripheral factors that influence actual movements (e.g., biomechanical constraints and pain). If the body schema is a dynamic representation of the body in space, then we would expect performance on the hand laterality task to reflect changes in the severity of pain as well. The current experiment was designed to test this prediction.

Patients and methods. Patients. Participants included 12 patients with arm pain (10 right, 2 left) of at least 6 months' duration (age: mean 49, SD 9; dominant hand: 9 right, 3 left). All patients had complex regional pain syndrome (CRPS) and were referred from a pain control center where they were undergoing treatment. Testing was approved by the Internal Review Board of Temple University, and participants' consent was obtained according to the declaration of Helsinki.

Stimuli. Digitized pictures of left or right hands were presented on a computer monitor in palm-up and palm-down views at 0° (fingers pointing up), 90° medial (fingers pointing toward patients mid sagittal plane), 90° lateral (fingers pointing away from patients mid sagittal plane), and 180° (fingers pointing down) orientations. Each of the 16 different stimuli were presented to each patient eight times for a total of 128 trials; blocks of trials were administered on the same day before and after treatment.

Design and procedure. Subjects sat with their hands resting palm down on the table in front of them with fingers of the unaffected hand resting on the response keys. On each trial, patients indicated the laterality of a single hand by pressing a left or right key with the index or middle finger. Stimuli were presented until subjects responded. Subjects rated their pain in two ways—by stating a number between 0 (no pain) and 10 (severe pain) and by placing a mark on a 10-cm line anchored by “no pain” and “severe pain.”

Music therapy entrainment was conducted as described by Dileo and involved a collaboration between each patient and the music therapist to create an auditory image of the patient's pain as well as healing sounds in terms of timbre, pitch, texture, rhythm, tempo, and intensity. After playing the sounds associated with the patient's pain, the therapist then gradually progressed the music improvisation to the healing sounds. Two previous studies have demonstrated that music entrainment results in significant pain reduction. Each music entrainment session lasted approximately 30 minutes.

Results. A 2 (limb: affected and unaffected arm) × 2 (view: palm-up and palm-down) × 4 (orientation: 0°, 90° medial, 90° lateral, and 180°) repeated measures analysis of variance (ANOVA) was used to analyze response time (RT) data for the hand laterality pre- and post-test (table). Analyses included RTs for correct responses that were within 2 SD of each participant's grand mean. Separate analyses were conducted to examine differences between the pre- and post-test pain ratings.

Mean pain ratings were lower during the post-test than the pretest for all 12 patients' numbered ratings (pretest mean 7.19, SD 1.91; post-test mean 4.65, SD 2.26), (p < 0.0001, Student's t-test) and 11 of the patients' marked ratings (pretest mean 6.45 cm, SD 2.18 cm; post-test mean 4.17 cm, SD 2.53 cm), (p < 0.0001, Student's t-test), suggesting that patients' pain was less severe after music entrainment.
Figure 2. Mean response times for laterality judgments involving the affected and unaffected limbs of patients for palm-up views during the pre- and post-tests. Closed box = pretest affected; closed triangle = post-test affected; open box = pretest unaffected; open triangle = post-test unaffected.

Consistent with previous findings, hand laterality pretest RT data indicated a main effect of orientation ($p < 0.003$) and an interaction between orientation and view ($p < 0.04$) (figures 1 and 2). The interaction between orientation and limb also approached significance ($p < 0.07$) and appears to be due to slower RTs for the affected relative to the unaffected limb in the 180° condition but not in the conditions requiring smaller amplitude mental rotations. Planned comparisons yielded differences between RTs involving the affected and unaffected limbs for the 180° palm-down condition ($p < 0.05$), but not the 180° palm-up condition ($p < 0.15$), perhaps reflecting the greater involvement of proximal joints for the palm-down condition. There was no significant difference between the mean accuracy scores for the affected (mean 60%) and unaffected (mean 63%) limbs in the 180° palm-down condition, suggesting an absence of speed-accuracy trade-offs.

Analyses of hand laterality post-test data indicated a main effect of orientation ($p < 0.004$), but no interactions ($p > 0.15$) and no significant difference between the affected and unaffected limbs in the 180° palm-down or palm-up conditions. Further, the failure to observe a significant difference between limbs in the 180° palm-down condition appears to be due to selectively faster RTs for responses involving the affected limb; Student’s t-tests revealed that post-test RTs were faster than pretest RTs for the affected limb ($p < 0.006$). There was no significant difference between pre- and post-tests for the unaffected limb or for mean pre- and post-test RTs, suggesting that it is unlikely that practice effects account for the faster RTs for the affected limb after treatment.

**Discussion.** These findings replicate previous demonstrations that a mental representation of movement (body schema) is influenced by the same peripheral factors that constrain actual movements. Furthermore, the findings indicate that the body schema reflects not only chronic or long-standing changes associated with amputation or stroke, but also incorporates moment-to-moment changes in the state of sensory (e.g., nociceptive) feedback. These findings suggest that motor imagery may provide important insights into the on-line mental representation of the body. Consistent with current models of motor control, we suggest that motor imagery might depend on using efference copy information to generate predictions of the movements and sensory consequences associated with motor commands.

Furthermore, the interpretation of subjective ratings of pain for the purposes of legal and therapeutic assessment may be complicated by subject expectancy effects or other psychological factors affecting conscious evaluations of pain. The current findings suggest that motor imagery tasks might provide objective and blind measures of pain without the requirement of any explicit judgment of pain. Thus, such tasks may prove to be useful in the clinical evaluation of pain.

**References**