To perform with less effort, practice beyond perfection

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Whether you are an athlete, a musician or a stroke patient learning to walk again, practice can make perfect, but more practice may make you more efficient, according to a surprising new University of Colorado Boulder study.

The study, led by CU-Boulder Assistant Professor Alaa Ahmed, looked at how test subjects learned particular arm-reaching movements using a robotic arm. The results showed that even after a reaching task had been learned and the corresponding decrease in muscle activity had reached a stable state, the overall energy costs to the test subjects continued to decrease. By the end of the task, the net metabolic cost as measured by oxygen consumption and carbon dioxide exhalation had decreased by about 20 percent, she said.

"The message from this study is that in order to perform with less effort, keep on practicing, even after it seems as if the task has been learned," said Ahmed of CU-Boulder's integrative physiology department. "We have shown there is an advantage to continued practice beyond any visible changes in performance."

A paper on the subject was published in the Feb. 8 issue of the Journal of Neuroscience. Co-authors on the study include postdoctoral fellow Helen J. Huang and Professor Rodger Kram, both in CU-Boulder's integrative physiology department. The study was funded by the National Institutes of Health.

The study involved 15 right-handed test subjects who used a handle on a robotic arm, similar to a joystick, to control a cursor on a computer screen. The tasks involved starting from a set position to reach for a target on the screen and involved both inward and outward arm movements, Ahmed said.

As part of the study, test subjects had to exert more energy in some reaching movements when the robotic arm created a force field, making subjects "push back" as they steered the cursor toward the target. With repeated practice of moving the robotic arm against the force fields, the subjects learned the task by not only cutting down on errors, but effort as well, according to Ahmed.

The test subjects first performed a series of 200 reaching trials with no force field to push against, then two sets of 250 trials each when pushing back against the force field. The experiment ended with another 200 trials with no force field, said Ahmed. A metronome was used to signal the test subjects to move the robotic arm every two seconds toward the target during the trials.

Each of the test subjects wore a nose clip and breathed through a mouthpiece to chart the rates of oxygen consumption and carbon dioxide production, a measure of metabolism. The research team also collected surface electromyographic data by placing electrodes on the six upper limb muscles used during reaching tasks: the pectoralis major, the posterior deltoid, the biceps brachii, the triceps long head, the triceps lateral head and the brachioradialis.

"What is unique about our study is that we are the first group to measure metabolic cost in addition to muscle activity while performing a physical reaching task," said Huang, who performed most of the research and was first author on the *Journal of Neuroscience* paper. "The results are very surprising and challenge the widely held assumption that muscle activity entirely explains changes in metabolic cost."

The study suggests that efficient movements ultimately involve both efficient biomechanics and efficient neural processing, or thinking. "We suspect that the decrease in metabolic cost may involve more efficient brain activity," Ahmed said. "The brain could be modulating subtle features of arm muscle activity, recruiting other muscles or reducing its own activity to make the movements more efficiently."

The results could be applicable, for example, to stroke patients who have to re-learn to walk, Ahmed said. "The rehabilitation process should not necessarily stop if the patient reaches a plateau in performance," Ahmed said. Continued practice reduces the metabolic cost of the task, an indication the brain still may be learning something," she said.

"Using the robotic system, we can understand the principles underlying the control of human movement and can apply those ideas to design rehabilitation programs that may allow stroke patients to re-learn their movements faster, to retain that learning and to transfer that learning to other tasks as well," she said.

So whether it is playing a musical piece over and over again even after you have the notes and timing down cold, or throwing a ball or swinging a racket after your coach tells you things look great, there appears to still be a benefit to practicing, Ahmed said. "Just because someone can perform the task well doesn't mean there is not added benefit to continued practice."

Provided by University of Colorado at Boulder