Motor Learning Made Possible Using a Tool of Applied Psychophysiology: Quantitative Surface Electromyography

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Motor learning is achieved when the subject learns to associate “if movement A, then event B occurs.” Before using surface electromyography to promote motor learning, one must establish that the subject is capable of the cause and effect described above otherwise, the failure to learn may be assumed to be due to a failure in the modality used. In this case SEMG. If the subject is truly incapable of motor learning then no treatment approach is going to be successful. In this case study, quantitative surface electromyography is used to help a 7-year-old child with autistic-like behaviors learn to sit with an upright posture on a bench. The child has never shown any capacity to learn by association, that is, if one does behavior A, then B will occur. Not only did she learn, but the learning generalized outside of the treatment area such that she found and maintained an upright sitting posture at home and school without cueing. Having mastered the sitting goal, new goals were established for her treatment. The new goals began 4 weeks after she demonstrated mastery of sitting and there was no indication that her sitting posture had deteriorated in any way. Sitting with a severe back curvature for prolonged periods at this age poses problems for later development of the spine and negatively affects the ability to maintain good breath support for speech therapy.

The whole neural organism, it will be remembered, is, physiologically considered, but a machine for converting stimuli into reactions.
—James, 1892, p. 370

Introduction
There are many events that can interfere with the success of psychophysiology based treatments. Poor site preparation, operator error, equipment malfunction, patient resistance to treatment, and lack of knowledge of applicable body systems by the clinician are a few. Often ignored is the capacity for the patient to learn. It is entirely possible for a patient to be unable to appreciate contingent learning where “contingent” is defined as the ability to link two events in time. Hume (1739) writes that there are three necessary conditions of causation for contingency learning to occur. They are: (a) cause and effect must be contiguous in time and space, (b) cause must occur prior to effect, and (c) there must be a constant connection between cause and effect.

The contingencies that surround biofeedback treatment, be it temperature, skin conductance, heart rate variability, EMG, or EEG-based, can have a profound influence on the treatment outcome. Contingencies are defined as those events that surround the treatment session. For example, in classical conditioning the conditioned stimulus takes on valence, or meaning, by the pairing in time with an unconditioned stimulus. The classic example of this in animal learning is the ringing of a bell moments before the presentation of food. In classical conditioning, the response is said to be “emitted.” In operant conditioning, the response is said to be “elicited,” as when a rat uses its paw to press a bar to receive a food tablet (Schwartz, 1978). In all cases, there are multiple cues that surround the learning situation, some of which are obvious and some not. For example, in the rat learning environment mentioned above, in addition to the physical presence of the bar to press there is the texture of the floor of the cage, odors present in the room, sounds that could become part of the learning environment, and assorted visual stimuli. Classical conditioning depends on developing associations between events; operant conditioning involves learning from the consequences of our behavior (Schwartz, 1978). The earliest proponent of operant conditioning was Edward Thorndike with his Law of Effect. This law states that actions that take place prior to a “satisfying state of affairs” are more likely to be repeated, while responses prior to an unpleasant state of affairs are
more likely not to be repeated (Thorndike, 1932). From a learning theory perspective, the approach used in this paper follows operant conditioning principles. Behaviors followed by a reward tend to increase, while those followed by an unpleasant event tend to decrease. The desired behavior must be shaped by rewarding successive approximations of the desired behavior. A motor skill can be defined as a skill that requires voluntary body and/or limb movement to achieve a goal (Magill, 1998).

Motor Control Restoration is a program created by the author that utilizes the concept of QSEMG, or quantitative surface electromyography. During QSEMG the patient does not seek to control discrete muscles but rather a patterned response based on the constellation of muscles involved in the movement otherwise known as the myotatic unit (Bolek, 2012). In this case, the myotatic (functional) unit consisted of bilateral lower paraspinal muscles (erector spinae) and the lower trapezius. The lower paraspinals are the main trunk movers and stabilizers; the lower trapezius stabilizes the scapulae (Simons, Travell, & Simons, 1998). These muscles were chosen to correct the patient’s usual bench sitting posture of a collapsed pelvis and rounded upper back. To perform a given movement, muscles must act in concert, with some becoming more active (agonist), others counteracting the action of the agonist (antagonist), and others enhancing the activity of the agonists/antagonists (synergists). The covering by a sheath or fascia of the interconnecting muscles of the body is the basis for the myotatic unit. It is the myotatic unit, typically consisting of four or more muscles, that is the gateway to mastering function, not just one or two muscles. For example, teaching drinking from a cup involves training the myotactic unit for postural support, such as bilateral gluteus maximus and gluteus medius, because without a firm base of support the muscles of the back cannot support the shoulder as the arm moves toward the mouth. Postural adjustments of the back must compensate for the cantilever-like effect of the arm in motion. In most people, this occurs effortlessly and unconsciously; in those with an injury it must be relearned. Once the lumbar support is addressed, the myotatic unit of the shoulder, arm, and hand involved in drinking must be taught to perform in a fluid, controlled motion. Sites that comprise this myotatic unit may include the (bilateral) biceps, triceps, wrist extensors and flexors, pronator teres, and brachioradialis. Therefore, to teach hand-to-mouth movement may require as many as eight electrode sites.

This program has produced the only published literature using multiple (four to eight) sites in motor re-education. It is not possible to effectively treat a motor control problem without attending to the biomechanics of movement. Attending to the biomechanics of movement requires including the myotatic unit during treatment (Bolek, 2013).

Before any training can be done, thought must be given to the following: cause and effect awareness, motivation, motor planning capability, and sensorium intactness. Sensorium intactness refers to the ability to use the senses (hearing, tactile, vision) to interact with the environment. If tactile awareness is compromised, modification of devices will be needed (e.g., changing a switch surface from smooth plastic to sandpaper). A certain level of intellect is needed to perceive cause and effect. In those with developmental disabilities, this may or may not be intact. Obstacles to motivation may range from the desire to carry on the sick role with adults to young patients that require frequent changes in the reward to stay motivated. Lastly, the patient may have cause and effect, with an intact sensorium and high motivation, but if the ability to motor plan is compromised, success will be limited. At face value, the above appears obvious, but in a clinical setting it is very easy to jump to the conclusion that the inability to perform a purposeful act on command is due to a physiological insult such as CNS damage or muscle or nerve damage. The author has witnessed many instances of a child with a hemiparesis due to a stroke, who was seemingly unable to generate any purposeful movement, suddenly respond when the reward obtained had value to the child.

**History**

Mary was a 7-year-old wheelchair bound child with autistic-like features. She had no firm medical diagnosis. She had a three-word vocabulary. She communicated mostly by grunts and facial expression and had a G tube for feeding. An underlying seizure disorder had been difficult to control despite multiple antiepileptic medications. A genetic workup was in progress through the National Institute of Health. She had never shown the ability to stand, and was receiving physical and speech therapy. In physical therapy she was working on “tall kneeling,” or kneeling with the femur and tibia at ninety degrees. Her motor skills were limited to making eye contact and show emotion by facial expression and grunts. At no time had she consistently displayed cause and effect. If provided with a switch toy, she never consistently struck the switch with an apparent attempt to activate the toy despite numerous training sessions over several months. Her sitting posture was with her back severely rounded with a collapsed pelvis. As she continued to grow there was a concern about how this posture would affect the boney structure of her back, especially her spine. An additional challenge in this case was that Mary was tactile defensive so contact with her skin, whether touching or hugging, was perceived as unpleasant. By necessity, the number and location of electrode sites was consequently limited. In cases...
involving a stable base of support such as this inclusion of the gluteus maximus would normally be required.

**Treatment**
The treatment scenario with Mary was as follows: A video monitor at a height of 12 in. (30.48 cm) was placed 3 ft (91.44 cm) in front of the child and a bench at 14 in. (35.56 cm) was used for sitting. The equipment used was a Biograph® Infiniti system (Thought Technology, Montreal West, QC, Canada) with screens and channel sets developed by the author. Electrodes were disposable pregelled electrodes (available from Bio-Medical Instruments, Inc.; http://bio-medical.com/). The program was set to activate the onset of a video (reward) if all QSEMG muscle sites remained above a threshold. Onset and offset of the video varied depending on the progress toward attaining the reward. Initially, onset was set at 0.10 second, then gradually lengthened to 1 second over the course of several sessions, (i.e., immediate onset to delayed). Likewise, offset was initially set at 1 second, then changed to 0.10 second (delayed to immediate). These parameters are critical, especially in the early stages of treatment. After some trial and error, the thresholds were set (all four sites above threshold) by a therapist-defined approximation of spine to the legs in a sitting posture at 90 degrees. In all cases, in the early stages (treatment sessions 1 through 3), the ratio of success to failure was never allowed to go below 80%. In other words, Mary received the reward at least 80% of the time of the session, which usually lasted for 50 minutes.

**Results**
Figure 1 shows the result of treatment across 11 consecutive 1-hour sessions per week. Figures 2 and 3 show before and after treatment bench sitting. She began with a success of 33% and achieved 90% success at session 11. Success is defined as sitting erect on the bench with minimal back curvature, such that an approximate 90-degree angle is formed from the bottom of the bench in relation to the back. The progress was not linear. There are dips at weeks three and six, not unusual for a child this age. A high level of success (≥74%) was achieved from session 7 and beyond. After treatment week seven, she began to sit upright at home and at school without prompting. A most interesting finding is that shortly after she mastered proper sitting form via QSEMG, she began using a “button” switch for the first time. She began to reach with her hand to touch the switch with enough pressure to activate a toy. This skill could not be demonstrated prior to the QSEMG intervention despite numerous training sessions.

**Discussion**
The end goal in this case, independent sitting, may first have to follow the sequence of assisted sitting followed by diminishing support. Success via a tangible reward (video onset) must graduate to the linking of success with a verbal prompt (“show me good sitting”), otherwise the skill is not likely to generalize. Individual tailoring of patient treatment plans using these and other principles of conditioning produces maximum effectiveness.

Typically, a child with these handicaps would not be considered a candidate for treatment. She did not show any propensity to learn. Her communication skills were very limited so she could not easily express her needs or what she enjoyed or disliked so an appropriate reward could be used. She did not like to be touched so the placing and removal of sensors posed a problem. This child was exposed to multiple...
learning environments in physical, occupational, and speech therapy. She never displayed consistent choices when presented with a “choice” task, be it academic, play, or preference. For example, although she appeared to know her colors, she never would consistently point to the correct color when said to her. When presented with a picture preference (“do we eat candy or a ball?”) again, she gave no consistent correct response. As a result, there was no way to ascertain her intellectual level.

Of interest is that the graph of success did not really take off until session 4; by the session 7, she clearly had established correct sitting. There may have been a delay in her demonstrating what she had learned; her mother had noticed that often she would respond some minutes after the first prompt, as if there was a delay in processing. It may be that using QSEMG provided her early feedback of the correct behavior. One advantage of surface electromyography is that it provides the patient with information on muscle activity before a movement is visible. This may have helped her to link using the target muscles with the outcome, video activation. At about session 7, placing her on the bench in preparation for electrode placement caused her to sit upright without any prompt. For all practical purposes, the equipment was redundant after session 7, as she automatically self-corrected her posture.

One technique used to check on whether motor learning has truly occurred is to ask the patient to deliberately not turn on the video using their muscle activity. This assures that coincidental activation of the video at the time of muscle activity is not counted as true learning. This was not possible to do with Mary, as she did not consistently respond to verbal commands. Nevertheless, there was the substantial positive outcome of being able to promote motor learning with this child. It is possible that the work done using QSEMG to promote good sitting posture generalized such that she was then able to make the connection between pressing a button switch and toy activation.

The results of a case study cannot claim to have been the source of this new behavior. However, successful use of a cause and effect switch was not a skill she could be taught prior to the QSEMG intervention, despite numerous attempts. These results also suggest that the usual procedure for determining if a patient is a candidate for motor control work using surface electromyography (presenting the patient with a simple cause and effect design, such as pressing a button switch) may disqualify some patients that could benefit from treatment using QSEMG. More robust experimental designs will need to be conducted to further explore this finding.

References