Control of Movement in our Body

Motor control theorists have wrestled with the basic principles underlying purposeful movement and positioning of various body parts. Use of the limbs, for example, in activities such as locomotion, grasping and moving objects, or such skillful behaviors as typing, piano playing, or swinging a golf club, are generally at the top of the list in discussions. But speech motor control theorists are quick to point out that the coordinated movement of phonatory and articulatory gestures in speech and song is as complicated as any limb movement.

Some of the puzzles that are being solved deal with the complexity of the command structure that is needed to execute a given task. It has long been recognized that the human body, being made up of hundreds of connecting members (recall the song about the bones), has too many degrees of freedom to be controlled like a puppet, with multiple strings going to one command level. Instead, the nervous system distributes the command tasks, much like an army of 10,000 men trying to capture a city. There are strategic commands and tactical commands. The general deals with one level of commanding and the platoon leader with quite another.

For example, in the trenches the commanders have to evaluate the terrain, the weather, the number of casualties in their units, the ammunition available, and various other factors, before giving an order to advance or retreat. They rely heavily on sensory information and feedback from direct contact with the ground and the enemy. The general, on the other hand, relies much more on his ability to assess global outcomes. He plays the *if this, then that* chess game. This involves model making, also known as feedforward. Whereas in feedback processes, a correction is made on the basis of what *has* occurred, in feedforward processes a correction is made on the basis of what *is likely* to occur. But, to know what is likely to occur, an accurate model of the cause-effect relations is necessary. We call this wisdom or experience, or in scientific terms, predictability.

Let us now utilize these concepts to understand a bit more about motor control in speech and song. Feedback is provided by our sensory receptors. Most muscles, for example, have small coil-like nerve cells (called muscle spindles) that transmit signals about the length of a muscle. Whenever an antagonist muscle, or a load, stretches a muscle beyond a comfortable physiologic length, the spindle produces a neural output, and the output grows with the amount of stretch. Within a small time delay, the neural signal is received by a control center and a motor command is given to contract the muscle, but only in proportion to the severity of the stretch. In effect, then, the muscle stiffness has increased because a lesser stretch is now associated with the same load or antagonistic muscle pull. This reflexive control of stiffness is often the culprit in tightness in the jaw, tongue, or lips in singing. It is basically a protective mechanism that we have to learn to inhibit.

There are other receptors that respond to speed of movement, touch of a foreign object, increase in temperature, or change in the ambient biochemistry. In analogy with the army, these are all the scouts and surveillance personnel who size up the terrain and the position of the enemy. “One if by land or two if by sea” were the famous Paul Revere signals that conditioned the response of the patriots to protect the cities of Lexington and Concord. The resistance was clearly more effective and could be compared to increased muscle stiffness.

But excessive feedback control can also be a stumbling block. It can ultimately lock up a system to a static condition. If every action is compensated for by an equal and opposite reaction (not in the same sense that Newton described his third law), a system can become immobilized. Even worse, the compensation (feedback) can be exaggerated to the point that repeated overcorrection cause instability, as in the case of someone turning the steering wheel of a car too much to correct for a skid.
Here is where higher level control needs to take over. Long range (strategic) planning of complex systems in motion requires some sacrifice of precision or control at lower levels. The general must be prepared to loose a battle to win the war. The singer must be able to sacrifice a consonants or a specific tone quality to get through a sequence of notes. It is known, for example, that undershoot must occur in rapid speech. None of the vowel and consonant targets are reached exactly, but the speech may still be intelligent because the listener is also a general (he has a model of what is likely to have been said, or better still, what will be said next).

Some movement disorders may be a result of reflexes that get in the way. Spasmodic dysphonia, stuttering, and essential tremor may be of this type, but proof is still lacking. What supports the theory, however, is that gross alterations in speech planning (e.g., at faster or slower rates, at different pitch or loudness levels, or at a different register) may bias the muscles in different regions of operation and thereby avoid the feedback traps.

Singing is also fraught with local traps. It is often necessary to initiate grossly different high level strategies to get the system dislodged. Incremental changes may not do the job. Many singing teachers know this. But unfortunately, some singing teachers become as bound to a few specific dislodging maneuvers as the student is to the lodge itself. Then the benefit of inhibiting excessive reflex activity may be lost.

In conclusion, let me underscore that I am not suggesting that reflexes are the enemy. On the contrary, they are our best friends in protecting us from injury. But like a small paper cut or mosquito bite, they may bring a powerful and complex machine like the human body to a halt unless there is an overriding control power.

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