Active and Voluntary vs. Passive and Involuntary Control Systems

It is mainly the rise of mechanically situated and embodied approaches to extra-corporal orthotics, prosthetics and robotics that has challenged the conventional wisdom of "active and voluntary" or *enactive and volitional* vs. "passive and involuntary" O&P and robotics control systems. This emergent embodiment is in fact challenging the singularly central issue of a biologically oriented approach to applied physical restoration and rehabilitation science and medicine of and for individuals with desensitized or missing limbs. Therefore, a brief review of "active" vs. "passive" mechanical control and manipulation strategies is in order.

During the 1980s, robotics researchers interested in creating robots to operate in real world environments were finding that getting a machine to process information from sensory transducers into an internal representation of its' surroundings that would provide a suitable basis for action response was a very difficult computational problem. Indeed, some became convinced that, even if it could be done in principle, in practice the process would be unacceptably slow, unreliable, and computationally expensive (by the time the robot knew what was going on, things would have changed). Thus, there was a turn toward "active" (or "animate") techniques in robotic sensory perception. Instead of attempting to build up detailed internal representations of their environment, robots began to be designed to deploy their sensors purposively, to actively seek out just the specific information needed at that particular moment for making an impending behavioral decision (Thomas 2010).

At around the same time, a number of neuroscientists, perceptual psychologists and philosophers began, for diverse reasons, to converge on a similar view of "active" human sensory perception (Ramachandran, 1990; O'Regan, 1992). Ostensibly for the same reasons, biomechanical engineers begin to develop micro processor control systems that would more closely mimic body movement, and hopefully in doing so, provide more accurate and reliable (selective) sensory feedback to the control mechanism as well as kinaesthetic sensory input for the user. However, somewhere along the way the engineering emphasis was switched from a more purposeful acquisition and utilization of sensory perception to contingent augmentation of motor output.

Technological rehabilitation specialist can be viewed as clinical mechanists or those who believe in the doctrine of mechanism. This doctrine holds that natural processes (as in biology) are to be mechanically determined and capable of complete explanation by the laws of physics and chemistry. Ultimately and inevitably (within the context of technological intervention) the fundamental problem or process that needs clarification and influence is the balanced interactivity of neuromuscular and neuropsychological voluntary control mechanisms. All clinical practitioners involved in physical rehabilitation understand and appreciate the anatomical and physiological determinants of voluntary neuromuscular control issues and deal with these determinants and issues to one extent or another on a daily basis. However, some practitioners overlook the neuropsychological determinants of active and voluntary control processes. Simply stated, concomitant neuropsychological determinates and issues can be thought of as the mental construct that comprises the sense impressions, perceptions and ideas about the dynamic organization and content of a single, coherent and egocentric global representation of one's whole and entire body. This construct not only pertains to objects in one's immediate physical environment that are perceived through and with the aid of an orthotics, prosthetics or robotics devices, but also the mechanistic O&P or robotics device itself. In other words, an active and voluntary or *enactive and volitional* mechanistic control device facilitates the optimal balance between what the operator would like to do and what they are capable of doing. Likewise, a passive and involuntary mechanical device does not necessarily facilitate such a balanced interaction.Contemporary thought would have us believe that an active control device is a system that produces power, force and motion, and a passive device just “sits there”. The limitation of this argument is apparent when one considers a manual vs. automatic automobile transmission. One is active and the other passive even though both strategies are capable of producing propulsion to and for the human body that would not otherwise exist.

As with any other nascent hypothesis, this “balancing” idea comes with a series of questions and issues that need resolution, and any insight offered regarding this matter would be greatly appreciated by all individuals interested in this area of physical rehabilitation science. This seemingly controversial issue should be of particular interest to rehabilitation technologists because it is through the working knowledge of biomechanical and neuromechanical function that this balanced interaction can most likely be achieved.

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The Mechanics of Applied Biological Engineering

What measurable mechanical quality clearly differentiates clinical or applied biological mechanical engineering (biomechanics) from clinical or applied kinesiological mechanical engineering? For that matter, what mechanical quality differentiates biomechanical engineering from any other form of applied mechanical engineering? This is an interesting question because it is assumed that applied biomechanics has something to do with biology, but there does not appear to be a commonly held view regarding exactly what that unique mechanical quality is and how it might influence biology or biological systems.

The traditional role of applied biomechanical engineering is much easier to understand when we think in terms of supporting or replacing compromised kinesiological function resulting from illness or injury. We usually prioritize our engineering thinking in terms of kinetic, kinematic and occasionally kinesthetic function. In other words, we are essentially addressing *kinesiological* rather than *biological* issues. Why then do we use the term biomechanics rather than *kinesio*mechanics?

There is an essential biological system or mechanism that is directly influenced by applied mechanical engineering when supporting or replacing desensitized or missing limbs. This mechanism is used in the CNS for the timing of electrical spikes to encode information and rapidly and efficiently solve neural correlation problems. It has been determined that as much as 80% of all energy used by the brain is dedicated to prediction and anticipation, and most of this neural activity pertains to the correlation of sensory perception with imagery skills or sensations. Neuroscientists refer to this specific mode of correlation as kinesthesia, perceptual consciousness and under ideal circumstances conceptualization. Consciousness is very much a crucial biological function (right up there with eating and reproducing), and the applied mechanics that directly influence this crucial biological function are very much biological engineering. Thus, *Biomechanical engineering can be thought of as the science of correlating sensations emanating from the mechanically designed O&P or robotics device with a mental image of wholeness and normality.*

O&P applied technology facilitates this crucial biological function in three separate and distinct areas (it should be noted that this biological function can only be facilitated or influenced through and with O&P technological intervention). The first area is manifest in the mechanical design of the O&P device itself. What is the exact and precise sensory emanation needed from the O&P device? The second area is how this sensory input is mediated and otherwise conveyed to the CNS? The third area is how does the CNS process and utilize this emanated and mediated sensory information for motor control and manipulation of the supportive or replacement mechanism and thus directly influence sequential sensory emanation coming from the O&P or robotics device?

I would like to conclude this brief compendium by suggesting this definition and approach to biomechanics and applied O&P technological intervention represents an entirely new dimension in clinical and technical O&P and this dimension appears limitless.

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