A NEW ELECTRIC SYSTEM WITH SIMULTANEOUS ELBOW & HAND CONTROL

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The evolution of electric prosthetic systems has resulted in the widespread transition to digital controllers, i.e., microprocessors. In fact, it may be true that every available electronic controller in the field of prosthetics will soon be a digital controller. In our own experience, the ProControl 2 was introduced seven years ago, which provided digital control of hand and wrist. The last seven years have brought new generations of improved software (the newest version is 5.1.2, so five generations have evolved), as well as development of new sensors. Also, continued evolution of commercial microprocessors has resulted in more powerful controllers, in even smaller sizes than were available previously.

In December of 2002, initial units of the Utah Arm 3 with electric elbow, hand, and wrist functions were prepared, including completely new digital controllers for elbow, hand, and wrist. Five units were placed into field trial usage on every-day wearers of a transhumeral (or higher level) electric arm prosthesis.

The number has been increased as improvements have been implemented, although until January 2005 all were considered "Beta Units," and the early ones upgraded with the improvements to the circuits, or other components.

The goals we have tried to accomplish in the digital Utah Arm 3 include:

- Simultaneous elbow and hand function (when desired)
- Wide variety of input choices:
  single/dual site EMG, harness-mounted force sensor, slider(Linear Potentiometer), touch pads, as well as other manufacturer's sensors.
- Computer Interface for set up of the system and adjustment, also allowing for improvements in training of the patient, and additional options and features.
- Auto calibration of the sensitivity of the hand control, so that the patient can readjust these values at will.
- No sacrifice in the performance relative to the Utah Arm 2, e.g., battery life, controllability, features, configurations, etc.

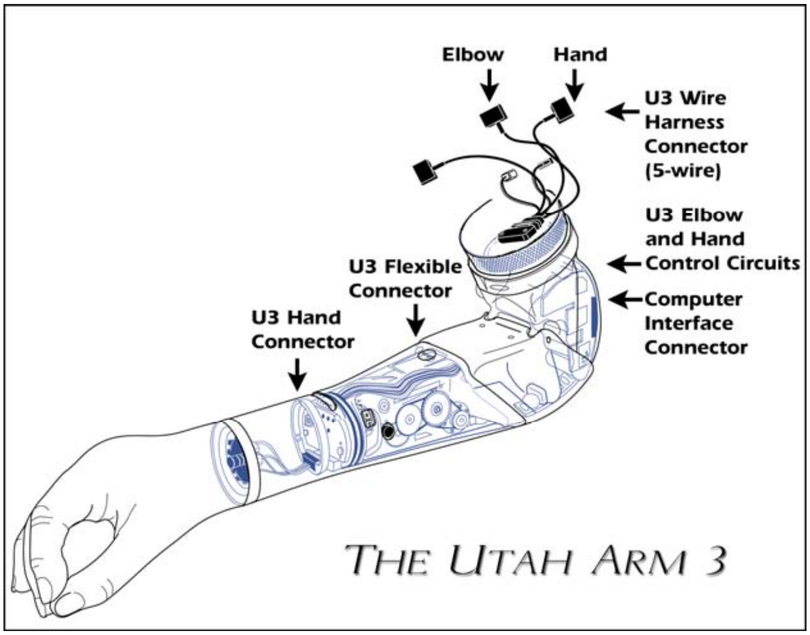


Figure 1: The Utah Arm 3 features entirely new internal electronics, as well as new connector options for separate elbow and hand inputs.

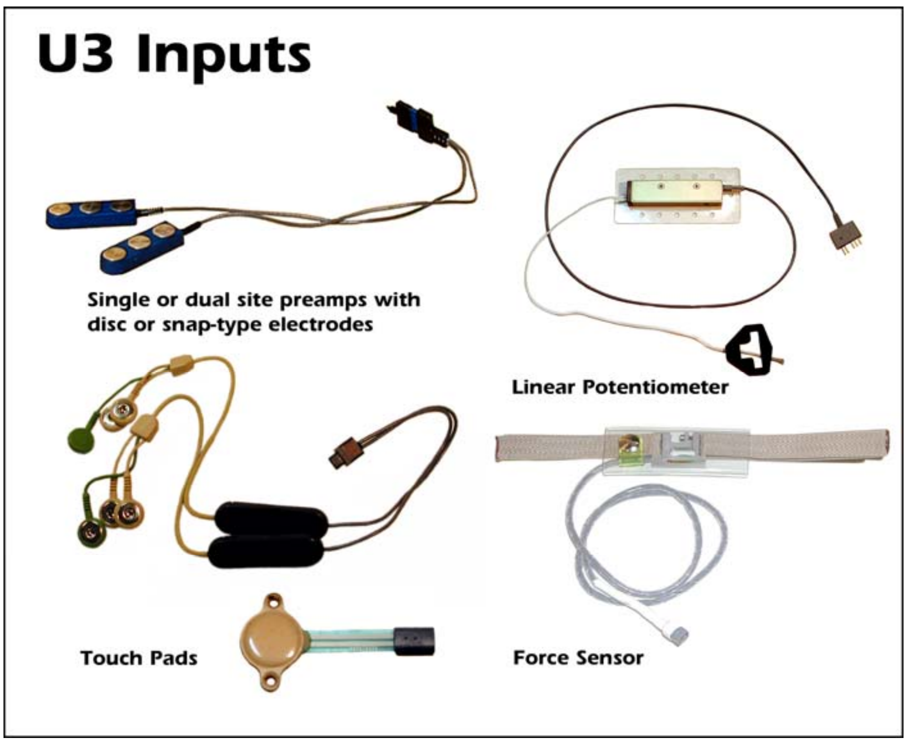


Figure 2: A variety of control inputs allow a wider range of candidates to be considered for electric prosthesis fitting, including EMG (dual or single site), harness-mounted force sensor, linear potentiometer, touch pads, and other manufacturer's sensors in some cases.

Technical issues included the transition from a complex analog controller to a digital-based system, which was not without its challenges. In our "digital world" we might take for granted the sophisticated controls that we find in our automobiles, personal digital assistants, music recorders and players, and many more examples. However, consider the steps involved in making this transition:

- Inputs from a variety of analog sensors must be digitized and signal conditioning must alter the signal for processing in the digital controller.
- Complex processing must be implemented in a digital logic, such as, EMG filtering, thresholds, differencing of signals, transition of elbow states (locking, unlocking, freeswing, etc.)
- Processes previously developed for hand control must be adapted for elbow control, which in some cases requires significant modification.
- Performance of every function must be validated with every small change in the design, e.g., functions of elbow flexion/extension, lock, unlock, freeswing, hand open/close, hand sleep and wake-up, and wrist pronation/supination (7 functions) must be carefully evaluated for each of the 42 control configurations – *with every change in the controller or hardware design.*
- Hardware must be newly designed, to fit into the same spaces in the Arm prosthesis, such as, connectors, circuits, interface with an external computer,
- Battery life must be monitored and evaluated with each change in design. Early versions of the U3 circuits were shown to have unacceptably short battery life, due to the high current draw of the microprocessors. A redesign of the control circuits was required, consuming several months of development time.
- Manufacturing processes must be developed, and refined, to make the new hardware, and software. In this case, these processes will *not replace* the U2 processes, since both versions will continue to be offered, so the same staff must learn to make a second version simultaneously.

Advantages for the patient:

- A more natural combination of elbow and hand function, while still eliminating control cables potentially. The force sensor and linear potentiometer have actually been harnessed to use scapular abduction in most cases (to control elbow flexion), but the force required is very much lower than the forces required for a body-powered control cable.
- The linear potentiometer has been used successfully, usually as the control input for elbow flexion. It seems to provide better proprioception to the wearer, compared to the force sensor.
- In cases where EMG signals are inadequate for dual-site control, single-site control has been conveniently used in some cases. Touch pads are available, but few fittings to date have required touch pad input.
- Although most wearers use simultaneous elbow and hand set up, the battery life has been acceptable- lasting the wearer the entire day.

Advantages for the prosthetist:

- A very wide range of system configurations will be available to the prosthetist, which will allow many patients to utilize as many as three functions, who would not be candidates for this level of function previously.
- The ability to provide two functions simultaneously will allow the prosthetist to overcome what previously could hold back some patients from more natural and rapid use of their prosthesis.
- Training the patient with the system will be much more easily accomplished, using a more visible User Interface program. Adjustments will also be easier, due to the improved visibility and intuitive nature of the adjustments.

Future plans: The Utah Arm 2 will continue to be offered as an alternative, for those not requiring the advanced features of the U3. Other features will continue to be developed, which will be more easily implemented because of the digital control's programmability and its computing power.

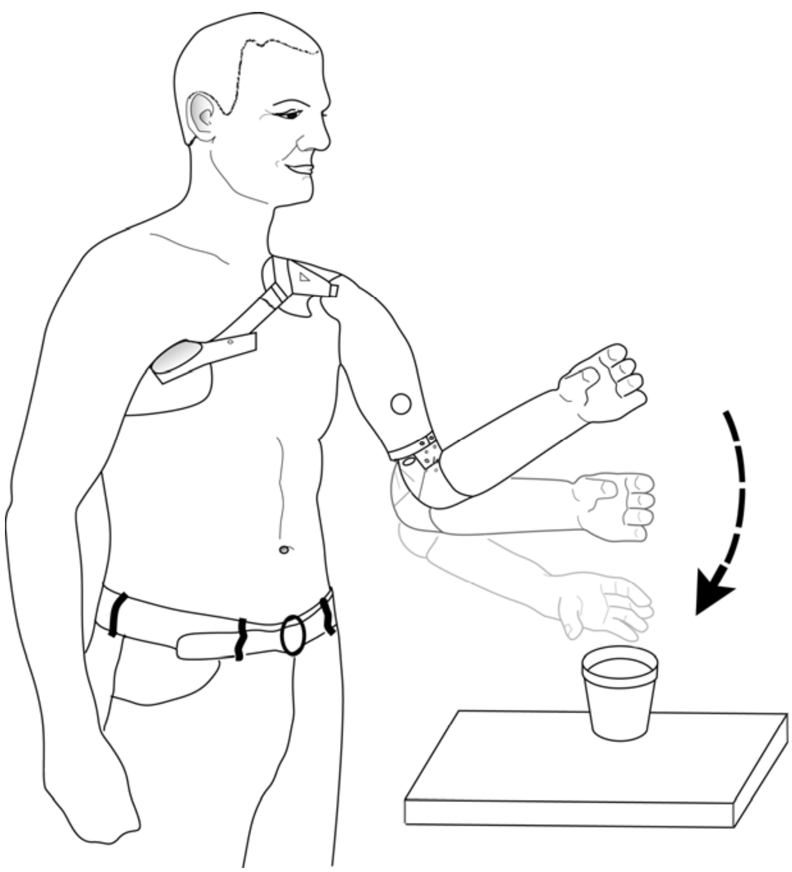
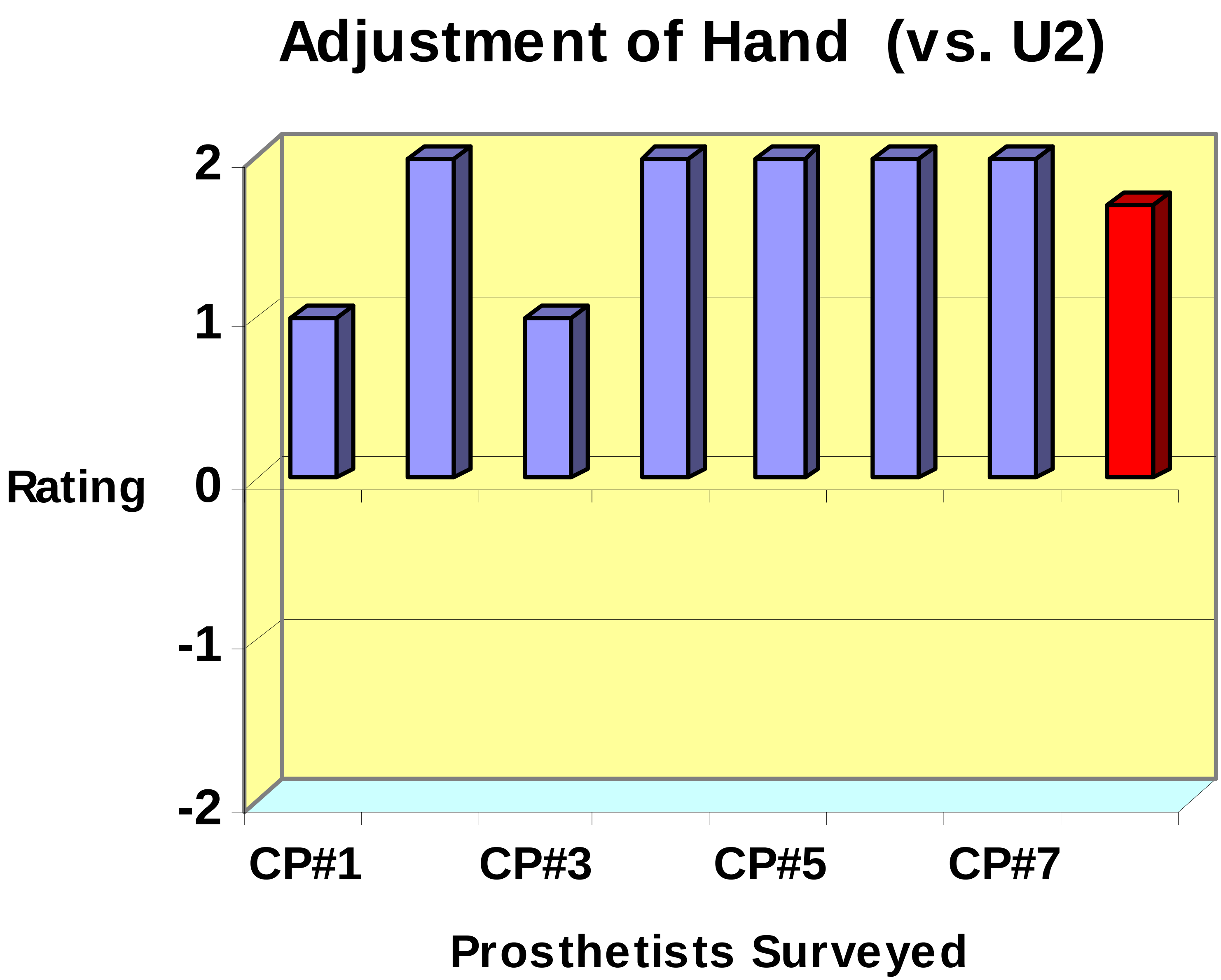


Figure 3: Patient using the U3 Arm learning to perform hand functions without locking the elbow

Results of Clinical Field Trials

A total of seven of the prosthetists involved in the clinical field trials of the Beta units were asked to rate the U3 compared to their previous experience with the U2. Overall, the U3 was rated as much easier to fit and adjust. Survey results follow. (The red bar at the end of each graph represents the average rating).

From “MEC '05 Intergrating Prosthetics and Medicine,” Proceedings of the 2005 MyoElectric Controls/Powered Prosthetics Symposium, held in Fredericton, New Brunswick, Canada, August 17-19, 2005.
A New Electric System with Simultaneous Elbow & Hand Control, Sears et. al.



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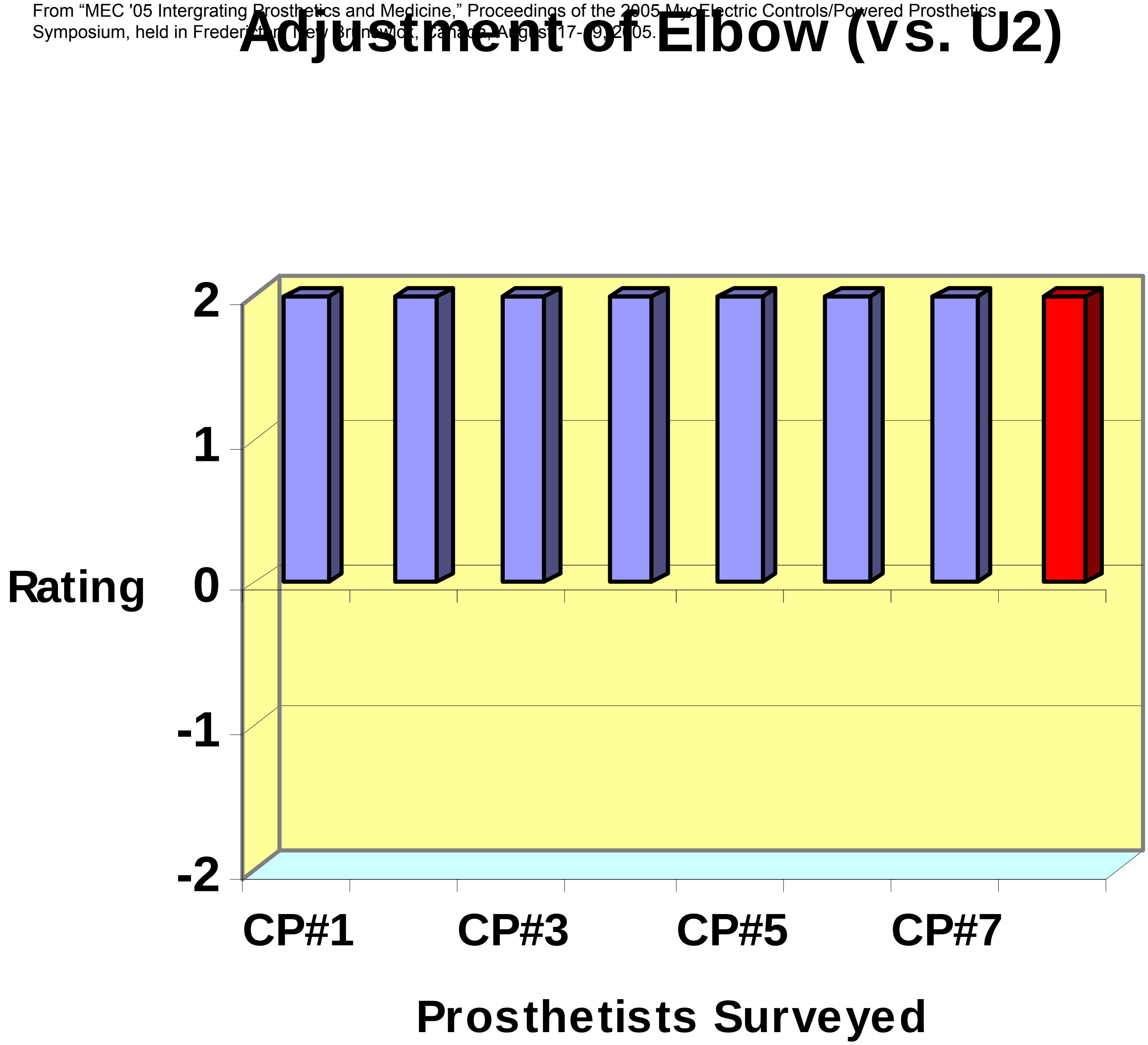

Figures 4 & 5-Adjustment of Hand and Adjustment of Elbow graphs - The U3 arm changes the method of adjustment from physically turning a small potentiometer to adjusting a clearly visible parameter on a computer screen. Both Hand and Elbow adjustments were judged to be "Better (+1) or Much Better (+2), by all surveyed prosthetists.

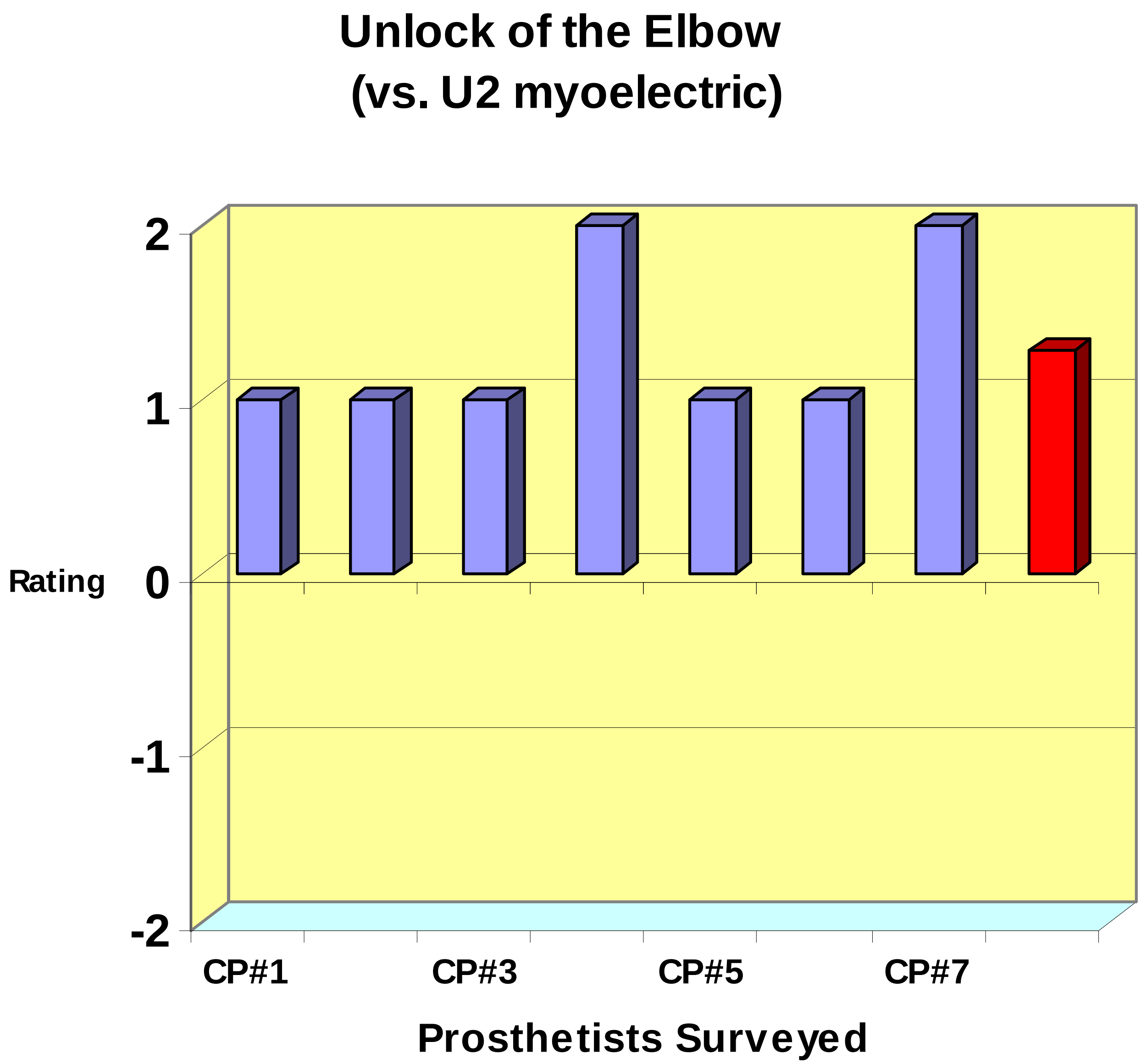

Figure 6- Unlock of the elbow graph - Using simultaneous control, the elbow has nearly always been controlled by a harness-mounted input. This allows unlock of the elbow by a easy-to-learn quick pull on the elbow sensor. This has been judged much easier for the patient to control, compared to muscle co-contraction, formerly the usual method of unlocking.

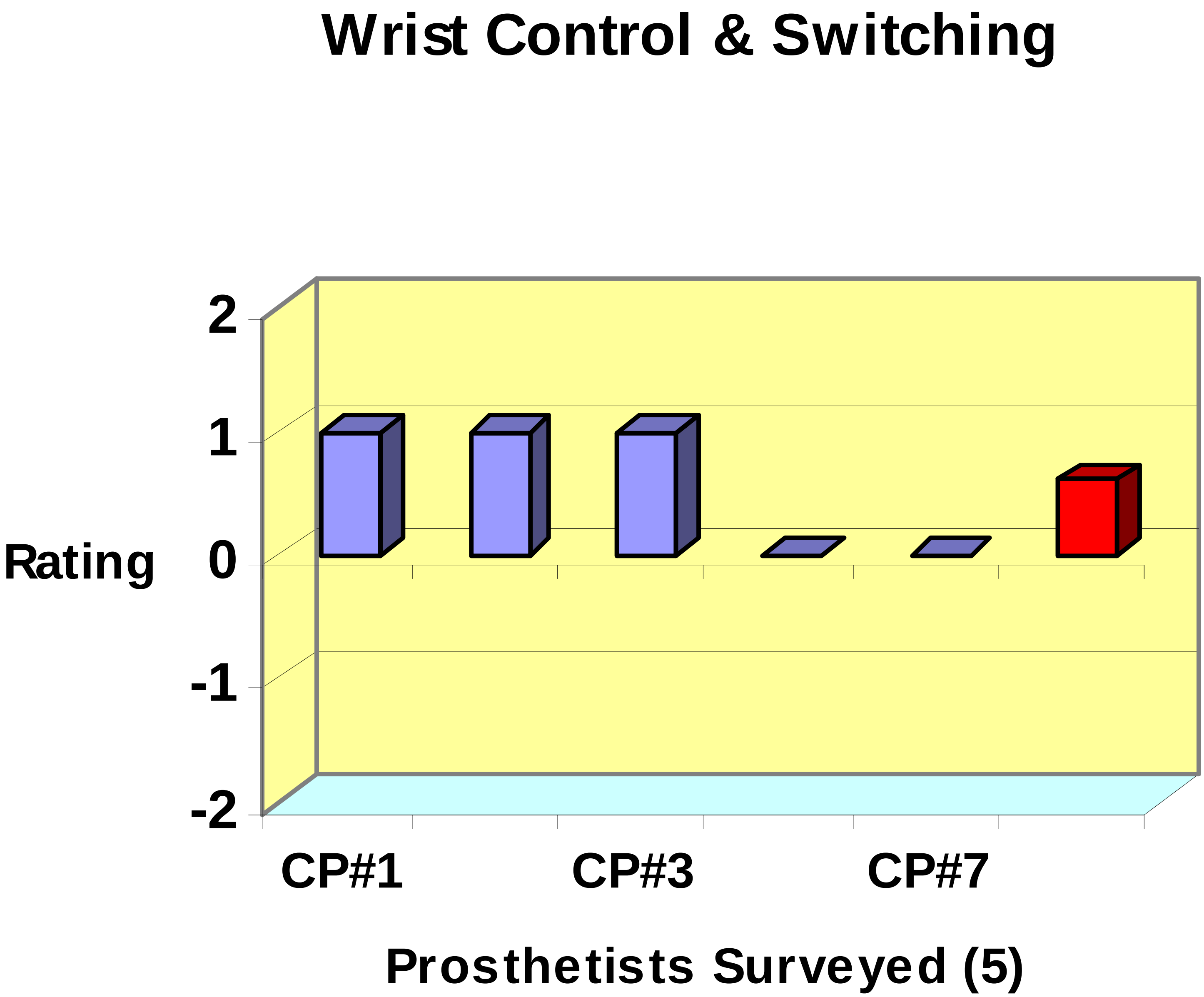

Figure 7 -Wrist Control and Switching - The U3 is capable of providing three powered functions, without requiring any external switches. The push or pull state switch formerly required to transfer control from hand to wrist may be replaced by muscle co-contraction, or Fast Access switching by each individual muscle. At the time not every prosthetist had experience with hand/wrist muscle switching, so the sample size was small.

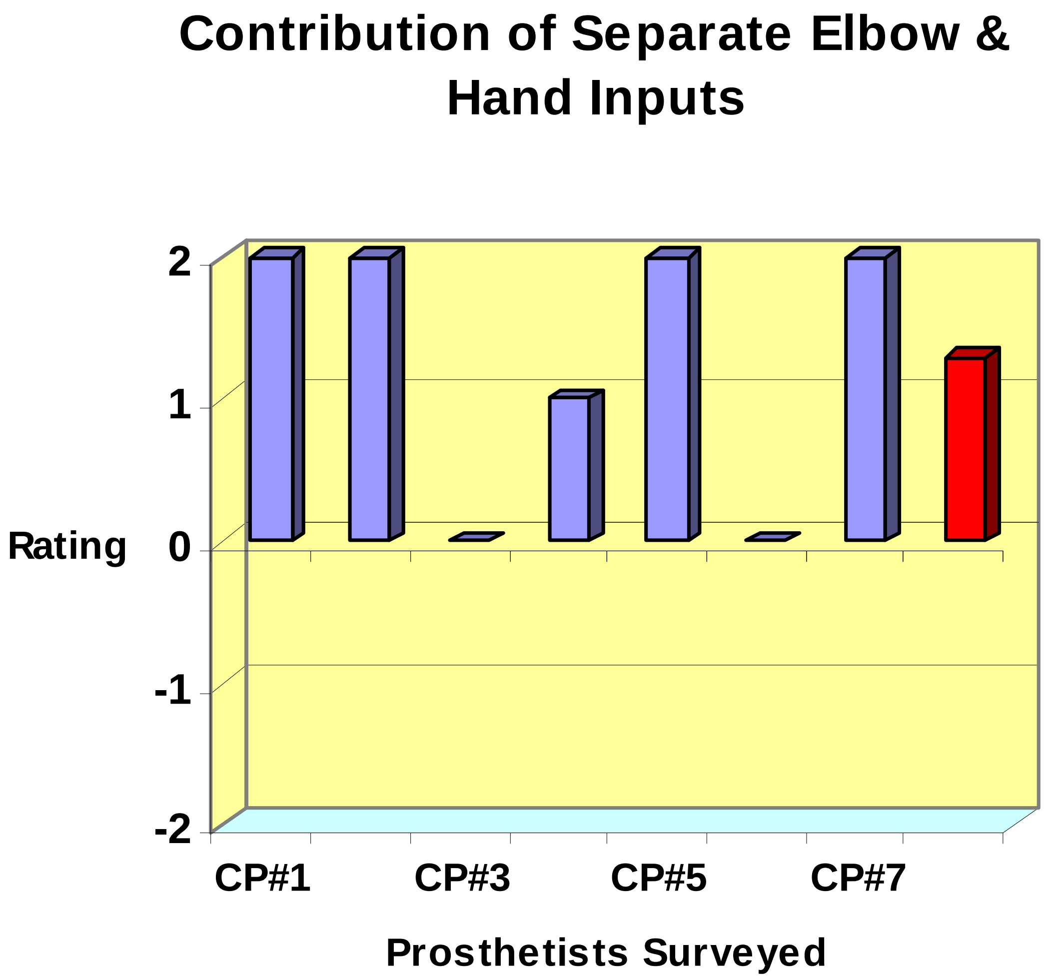

Figure 8. Overall, prosthetists found the contribution of separate Elbow and Hand inputs to be a significant improvement over the Utah Arm 2.