PERFORMANCE MEASUREMENTS IN DUAL-SITE 9-STATE MYOELECTRIC CONTROL. EFFECT OF TRAINING IN TWO NON-DISABLED VOLUNTEERS

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ABSTRACT.

A microcomputer-based test equipment has been used for measurement of control accuracy and response time in a dual-site 9-state myoelectric control system. In a preliminary trial in two young non-disabled female volunteers it is shown that after a relatively short period of training the system can be managed with a control accuracy of nearly 95% and an average response time less than one second.

The result motivates a larger study to be made, to achieve possible indications whether or not multi-state myoelectric control systems in prosthetic devices may be useful and desirable in the future.

Keywords: Prostheses, upper limb, myoelectric control, multiple function, training effect.

INTRODUCTION.

Increased complexity of myoelectric control systems in prosthetic devices puts a heavier mental load on the user. If the control difficulty is too high or the response accuracy too low, then the prosthetic device will not be used, and the actual advanced constructions are made in vain. It will therefore be of interest to know, concerning the dual-site control systems, how many degrees of freedom can be controlled in an acceptable way.

In order to study this a test was designed. The dual-site multi-state control system described by Philipson (1) was modified to allow the measurement of response times and control accuracy in control systems of varying complexity.

Four groups of ten non-disabled volunteers were then tested on 2, 4, 6 or 8 possible movements respectively, as described by Philipson and Sörbye (2). The conclusion was that 2 and 4 prosthetic movements could be controlled after a very limited amount of training, while more complex schemes demanded more training to be useful.

Preliminary tests of long term training effect concerning dual-site 9-state myoelectric control have now been effectuated in two non-disabled volunteers.

METHOD.

The microcomputer-based control system, the arm model, the screen layouts and the test organization have been described in detail in the two papers mentioned above.

For the 9-state control tests the marker areas on the screen have in principle been arranged as can be seen in Fig.1. An example of a complete test is shown in Fig.2.

EMG activity produced by the biceps muscle is projected along the X-axis, while the triceps muscle gives the activity along the Y-axis. Their interaction is responsible for the activity markings in between.

The position of the marker is determined by the level of the EMG signals 0.1 sec after the marker has left the 0-area.

When the computer reads the marker position of the achieved EMG signals to area 1, this will give a hand closure of the prosthetic arm model. The prosthetic movements corresponding to the other marker areas are shown below (Table 1).

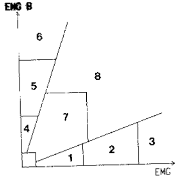

Fig.1. Marker areas for 9-state control

Table 1.

Area	Movement of the prosthetic model
1	Hand closure
2	Humeral inward rotation
3	Elbow flexion
4	Hand opening
5	Humeral outward rotation
6	Elbow extension
7	Hand pronation
8	Hand supination

In the actual tests on dual-site 9-state control two female laboratory technicians have participated as volunteers: M.O. 23 and E.J. 27 years old, both non-disabled and without any previous prosthetic experience.

Each of the volunteers was for the test placed in an armchair, with the dominant forearm strapped to the armrest and surface electrodes carefully positioned over the corresponding biceps and triceps muscles.

After 80 minutes of initial guided training (nominally 10 minutes per prosthetic movement) the first test started. The volunteer performed each one of the actual prosthetic movements 30 times, on commands in pseudo-random order, and the response time and control accuracy were recorded.

This was exactly the same procedure as concerning the 9-state group (group D) of the other volunteers mentioned above. But, in contrast to the previous groups of totally 40 individuals who were trained and tested only once, the two new volunteers were put on long term training and further tests. These tests were effectuated in the same way but without any guided training on beforehand.

The plan was that the two laboratory technicians should give 20 minutes of their daily working hours to the prosthetic control training, the test being repeated every week. However, their work did not allow sufficient free time. This resulted in only 5 respective 4 more tests in a 2-3 months time, with a total of 7.5 respectively 6.5 hours of training. The training was mostly concentrated to 2-3 days previous to and on the very day of the tests.

RESULTS.

The result of the initial test placed the both volunteers within the better half of the group of ten people (group D) previously tested on the 9-state control in the same way and after the same amount of initial guided training. After repeated training, now unguided, the both technicians achieved a great further improvement of their control accuracy as well as of the response times. This can be seen from the following figures (tables 2, 3, 4) :

Table 2. Results from test 1 and 6 (initially and after training) regarding the volunteer M.O., from test 1 and 4 regarding the volunteer E.J., and from the sample of ten single 9-state tests from the previous investigation (group D of the 40 volunteers).

	Grand average response time (sec)	SD (sec)	Grand average hit rate (%)	SD (%)
Group D	1.75	0.56	53.3	15.5
MO no 1	1.31		64.17	
EJ " 1	1.32		62.08	
MO " 6	0.93		94.58	
EJ " 4	0.89		94.17	

Table 3. Test results concerning average response time (sec) for the different possible movements. Volunteers and test numbers as in table 2.

	Areas/movements							
	1	2	3	4	5	6	7	8
Group D	2.13	1.89	1.30	1.73	1.85	1.25	2.03	1.84
MO 1	1.40	1.37	1.10	1.41	1.46	0.93	1.46	
EJ 1	1.70	1.46	0.84	1.16	1.60	0.87	1.50	1.44
MO 6	1.34	0.77	0.59	1.31	0.75	0.72	1.16	0.79
	0.92	0.88	0.72	0.98	0.83	0.74	1.11	0.98

Table 4. Test results concerning average hit rate (%) for the different possible movements. Volunteers and test numbers as in table 2.

	Areas/movements							
	1	2	3	4	5	6	7	8
Group D	66.3	32.0	67.7	63.3	48.7	59.0	39.7	50.0
MO 1	73.3	56.7	93.3	63.3	46.7	33.3	56.7	90.0
EJ 1	70.0	46.7	63.3	70.0	80.0	60.0	30.0	76.7
MO 6	96.7	96.7	100.0	90.0	90.0	96.7	86.7	100.0
EJ 4	100.0	93.3	93.3	100.0	90.0	83.3	96.7	96.7

Occurrence of tests and training occasions, duration of the latter, average hit rates and response times for the both female volunteers are shown in Fig. 3.

DISCUSSION AND CONCLUSION.

The two volunteers had better results on the initial test compared to the majority of the previously tested group under the same conditions. From this point they greatly improved their test results, in spite of only irregular and scanty further training. Distribution of the training over the total period of time would mean less than 6 (5.9 respective 5.7) minutes of training every day. This is obviously less training per day than what an active prosthetic user will normally achieve.

Proper conclusions can not be drawn from a material consisting of only two volunteers. However, we find these preliminary results sufficiently interesting for organizing a stricter trial with an adequate sample of volunteers. Such a trial can perhaps indicate whether or not multi-state myoelectric control systems may be useful and desirable in the future.

REFERENCES.

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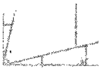
2. **Philipson, L. and Sörbye, R.: Control accuracy and response time in multiple-state myoelectric control of upper-limb prostheses. Initial results in nondisabled volunteers. Med. & Biol. Eng. & Comput., 1987, 25. In print.**



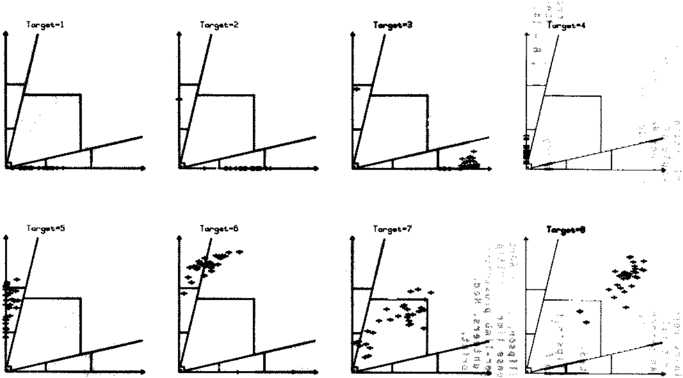


Fig.2 Plots showing the results from a complete test. Movements according to the target areas (= marker areas, see Fig.1 and Table 1) have been requested on short commands. The scatter of marks shows how the tested person has succeeded in selecting the right area/movement.

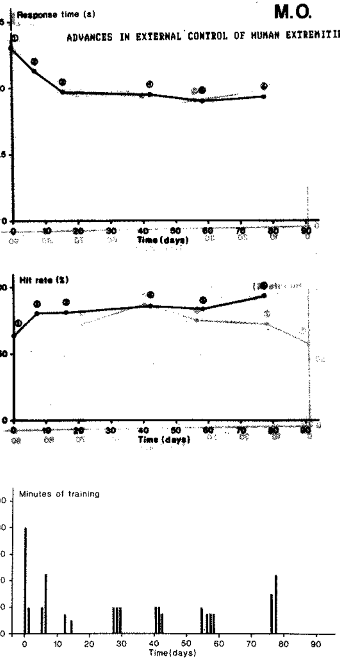


Fig.3A Diagrams showing the developmental course of hit rate and response time for the volunteer M.O.
The amount of training per day is indicated beneath.

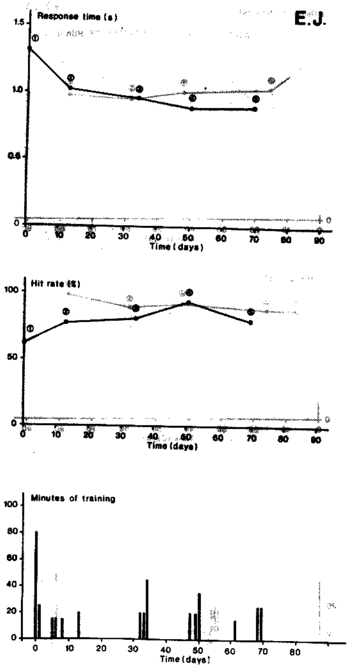


Fig.3B Diagrams showing the developmental course of hit rate and response time for the volunteer E.J.
The amount of training per day is indicated beneath.