EVALUATION OF EMG-CONTROLLED HAND PROSTHESES

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Introduction

EMG controlled hand prostheses have now been used for several years in various countries. This prosthesis with its "natural" control using normal controlling muscles and its close similarity to the normal hand would appear to be a new step in functional replacement. In Sweden eighteen months ago it was considered necessary to carry out some evaluation of their value for functional replacement.

Previous Work

Previous work on prosthetic evaluation has emphasized the technical nature of the prosthesis and has been supplemented with clinical trials on convenient patients. The problem has always been realistic criteria against which to judge the prosthesis.

The importance of recognizing critical factors in acceptance of a technical aid has been heavily stressed in rehabilitation literature for many years.

Much of this work has been treated from a conceptual rather than a practical standpoint. One exception to this are the NYU studies [1] in 1958 which described many experiments carried out to assess cosmetic and functional factors of prostheses. Many have tried to find factors of importance for successful rehabilitation and often used key words are "strive for independency", "future-orientation", "cooperative attitude towards clinic's staff", "intellectual and emotional considerations", etc. With regard to amputee-rehabilitation especially, many writers are aware of the impedance of the fact of "acceptance of loss" [2], [3], [4].

This is thought to be fundamental and before an amputee is able to cope with prosthetic substitutes in a realistic and goal-directed way he must accept his loss. The variable "acceptance of loss" is probably multidimensional. Little is known about the correlates of and sources to acceptance (e. g. what personality traits are associated with acceptance), and research is needed. There is a lack of methods especially for verification and measurement of this variable, as is the ease for many phenomena in rehabilitation. Cowen [5] puts these questions in a fairly challenging form when he asked:

Are we at present able to do something so fundamentally as to describe the different stages in a rehabilitation-process? Before we have established a methodology for this we can only except to be thwarted. We do not even know what we do mean by "successful" and "efficient" rehabilitation. The only fruitful and, in the long run, economic way to find the solutions of these problems is by research.

Present Investigation

This paper describes work carried out on a small number of patients in an attempt to make a realistic and controlled investigation into the problems of acceptance and functional value of EMG controlled hand prostheses.

The experimental method used in this work has been described in detail earlier (Dundee 1969). Basically the plan was to fit six persons (five men and one woman) with two kinds of electric hands (Italian Myodin and Austrian Myomot) for periods of six weeks, one after the other. During these periods thorough checks were made on the use of the hands and in any changing attitude toward them.

The subjects were selected to include most of the main variables that were considered important in acceptance. Tests were carried out to measure psychological variables such as intelligence rigidity-flexibility, attitude toward disabled people, and temperament. Social factors regarding background, amputation, attitudes, and expectations were also noted. They were also assessed with regard to the present degree of function and general physiological condition. With most of these factors the variation between the subjects was considerable. Age for example varied from 20 to 70 years, and time since amputation from 3 to 25 years.

The training for each person was aimed at producing maximum function as quickly as possible. This involved training the controlling muscles to provide maximum signal and good discrimination, use of the hand in all areas around the body, and coordination with the other hand. This was followed by a testing procedure which was mainly concerned with functional activities using the EMG hand (or old prosthesis). The tests were constructed on the following criteria:

1) Tasks involving all normal activities around the body.
2) All basic grasping patterns that are normally used in daily living.
3) Bimanual activities.
4) Activities relevant to the subjects daily life.

The activities consisted of 23 tasks mostly of ADL-type and were carried out in their homes with the old prosthesis and with the EMG hand immediately after fitting and six weeks after the fitting. The performance in the test was assessed on the basis of the

degree of use of the prosthesis, naturalness, number of mistakes including slippages etc. and the time taken to perform the task.

Another type of test employed was a wall test, developed from the Beograd Hand Evaluation. This consisted of a matrix of shelves with objects which should be moved horizontally and vertically by the subject standing at various distances from the front of the shelves. This indicated the subjects ability to control the hand in different position in front of the body.

At the time of the visit to the home a final assessment was made of the result of the hand application. Many factors were taken into consideration regarding the use of the hand, reactions to the hand and the attitudes produced by the environment.

Technical Description

The Italian Myodin hand is operated by a screw jack giving automatic locking in both opening and closing movements. The jack drives two metal fingers in opposition to a thumb to give a "three-jaw" prehension grip. The motor and fingers are covered with a thick PVC glove which is also itself covered with a thin PVC skin glove having a close resemblance to the normal hand. Motor operation is effected by the output from two relays supplying 14 volts. The amplifier is of a differential, two-stage type which amplifies the myo-signals to operate the relays.

The Austrian Myomot hand is operated by four-stage spur wheel system with an automatic locking device to prevent opening when the motor is not energised. Motor operation is effected by the output (14 V) from output transistors of the main amplifier. The amplifier is of a differential, two stage type which amplifies the myo-signals to control the current to the motors.

Technical Results

Technical evalution	Italian Myodin	Austrian Myomot
Opening	67 mm	57 mm
Time to max. opening	2.0 sec	1.65 sec
Time to closing	1.8 sec	1.75 sec
Maximum 100 c/s	39 μV	74 μV
Sensitivity 1000 c/s	13 μV	43 μV
5000 c/s	44 μV	89 μV
Max. pinch	4.5 kg	6.5 kg
After pulsing	7.5 kg	11.5 kg
Weight — Hand	470 gram	433 gram
Battery and amp.	502 gram	508 gram
Current		
Consumption — no load	100 mA	40—60 mA
stalled	1000 mA	400 mA
standing	15 mA	15 mA
Power source	10 Ni. Ca. cells 450 mill. amp. hr. at 14 V	10 Ni. Ca. cells 450 mill. amp. hr. at 14 V

Functional Evaluation

In appearance and functional operation both hands are similar. The grasping patterns are very alike although the grasping force is different. As will be seen later even this did not appear subjectively to be very different. Control is effected by myo-signals from the extensor and flexor muscles of the wrist for opening and closing. Where there are absent other muscles associated with the action of grasping or releasing may be used. The signals are sensed by two electrodes over each of these muscles.

Both hands, having only one grasp, a simple three-finger pinch grip, lack many possibilities to pick up small or flat objects. In addition the hand surfaces of the finger tips give poor stability to any object grasped with the pinch grip.

With this type of grasp it is often difficult to position the hand in the absence of wrist flexion without gross body compensation. When pronation and supination are present grasp and coordination are much increased but manipulation of objects as a phone or eating utensils around the face tre not provided for fully.

With both hands the third and fourth finger rely on the shape and material of the inner glove. Vhilst sometimes these fingers act as a support in grasping objects (the third and fourth fingers remaining more flexed than the first and second), at other times they can prevent the grasping of large diameter tall objects such as a glass.

Certain features of a technical nature had a certain relevance for the EMG-hand's acceptability.

There were a few characteristics that brought about negative attitudes unanimously. One of these negative factors was the noise, generated by the hand when in use. The noise caused, in almost all cases, irritation and embarrassment, sometimes leading to non-use in social settings. The "clicking" sound in the Italian reinforcer caused irritation too, mostly because it was not possible to stop it. (The noise in the motor in the hand was of course under control as far as it was heard only when the hand was used. This was not the case with the other "clicking" sound).

The equipment was felt to be very awkward and clumsy (the Austrian with battery and reinforcer in one box and the Italian *separate* reinforcer and battery). In some cases it was not so much the box in itself but the cables from it to the electrodes and hand, that were felt as quite an obstacle in that it hindered normal movements.

The glove's tendency to get dirty also brought negative responses. Printing ink and other materials were extremely hard to remove. In almost all other aspects, the EMG-hand's other more or less technical features brought about very different reactions.

The size of the grip (distance between thumb and indexfinger) was felt by some to be quite the proper size; others thought it was

quite too small; and others thought it was too large so that looked artificial.

The two outer fingers (small and ring-fingers or 3rd and 4th fingers) are passive in the EMG-hand and they do not follow the actual grip-movement. This was strongly disliked by some because they had to take those passive fingers away when grasping a bottle and such, and the same condition was appreciated by others who thought it looked natural, and it was heard natural because, when placing the hand on a table, it gave no artificial sound as the old, passive and stiff hand did.

The weight of the prosthessi did provoke rather negative feeling in the beginning by some patients (the ones with the shortest stumps) but they seemed to get used to it rather soon.

The color of the cosmetic glove was in some cases felt to be too pinky, in other cases it was appreciated very much and one thought it was too yellow. The relative softness of the hand itself (excl. the gripfingers that are hard) were partly disliked, partly liked. The ones who liked it did so because of cosmetic considerations (it "felt" natural and looked natural when the hand gave way); the ones who did not like it thought it was impractical and awkward when using the hand.

The friction of the PVC-glove was in some cases felt to be too harsh, making it difficult to take the hand in and out of a pocket. Others thought the harsheness was an asset when holding papers and other things.

A small lag in the grip was present in all EMG-hands and there were quite a few persons who noticed it. Those who did thought it was a drawback. The fact that the hands turned up to be sensitive to electric current interferences in some cases gave rise to much irritation and many complaints. In some cases this could be improved by better ground connections but it was extremely hard to eliminate completely. The Austrian hand had to be given continuous muscles impulses to be maintained open at maximum width, otherwise the glove caused closing of the grip.

Factors Affecting Acceptance of the EMG-Hands

The outcome of the experiment could be described in the often used terms of acceptance-rejection. In that case three persons did definitely accept the hand-prosthesis as such, 2 rejected it and one is very doubtful. It is felt however that the dichotomy is highly artificial because it was found that acceptance-rejection was a continuum and the EMG-hand played very different roles in the persons lives, and different roles at different occasions for the same individual.

Unfortunately it is not possible to describe all findings here, especially not about the individual EMG-hand application results, although these are very fruitful to penetrate.

A general conclusion could be drawn that the EMG-hand is not the best prosthesis, as it was found that prosthetic replacement is a most individualistic problem, dealing with individual needs and requirements. (Certainly it can be said that there exists no such thing as the best prosthesis). The introduction of the EMG-hand seemed to create in some cases fairly profound changes in the persons activities performed (quantity and quality), attitude to prostheses, perception of oneself, and perceived needs.

Occupation and sparetime activities had a certain importance. Very heavy work seemed to create resistance to use the hand though in most cases of hard work it was not even tried. Active sparetime activities, "office" work, many social activities, and stimulation from family and others seemed to promote frequent use of the hand.

It was an interesting finding that Attitude to Disabled People (measured in a test) had a 1/1 relationship to acceptance of the hand, so that the ones with the most positive attitude to the disabled were the ones that accepted the hand the most, whilst the ones with very negative and stereotyped attitudes did not accept the hand.

Time since amputation had in this small group a clear relationship to acceptance of hand so that the oldest since amputation did reject the hand, and the youngest since amputation were the ones the most accepting it. (Time since amputation had no relation to chronological age.)

There was no indication that kind of earlier prosthesis (passive or active, hook or hand) had any significance in the outcome, nor did attitude to earlier prosthesis. This last point is interesting because it turned out that the EMG-hand after some time did awaken certain needs in several of the persons; need for function and for cosmesis of which they were not aware at the beginning. Typical for this trend was the man who was quite satisfied with his present prosthesis and very negative to the EMG-hand before he had tried it at home and at work. After some weeks he felt quite dependent on the EMG-hand and quite handicapped without it. This change in attitude and perceived needs was present in several cases.

It turned out clearly that good technical function with the hand was not necessarily an indication of acceptance.

It did also turn out that absence of criticism of the hand did not mean acceptance of it but rather the opposite. Only careful follow-ups made it possible to evaluate the actual use of and attitude toward the hand.

Regarding stump conditions the two with the shortest and softest stumps (just below the elbow) in the long run became the two who accepted the hand the most.

It became clear that the hand's technical reliability was very important for its acceptance. Unreliability was very destructive for the hand's acceptance and if this drawback shall be overcome the person must still find the advantages unusually great to be able to accept it.

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