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Functional effectiveness of a myo-electric prosthesis compared with a functional split-hook prosthesis: A single subject experiment

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Abstract

The functional effectiveness of a myo-electric prosthesis with sensory feedback compared with that of a split-hook is described. Thirty independent observations were made on a single subject with a right below-elbow amputation wearing the myo-electric prosthesis and the split-hook prosthesis. Using a first order autoregressive model for making inferences about the two sets of data, the split-hook was found to be functionally better ($p<0{\cdot}001$) than the myo-electric prosthesis. Functional effectiveness was defined operationally as scores on the Minnesota Rate of Manipulation Placing Test and the Smith Test of Hand Function. No predictions are made regarding the use of either prosthesis for other amputees. However clinical evidence suggested suitability of the myo-electric prosthesis with sensory feedback for some other functional tasks.

Introduction

Traditionally in Australia, upper limb amputees have been fitted with a funcional split-hook operated by a shoulder harness and cable. In addition a passive cosmetic hand may be supplied.

Information regarding the long term follow-up of amputees is sparse and many of the claims regarding the successful use of prostheses have not been substantiated. Yet a recent survey on arm amputees (Department of Veterans' Affairs 1976) has raised questions about the rejection of prostheses as, of some 910 people issued with arm prostheses in Australia, only 240 appeared to be wearing their limbs.

Some researchers (Day et al 1969; Jacobs & Brady 1975) have argued that acceptance of artificial limbs depends on the early fitting of temporary prostheses. Bailey (1970), on the other hand proposed that success depended on intensive training while Friedmann (1978) claimed that the greatest influence on prosthetic acceptance or rejection depended on the psychological effects of amputation.

In recent years work has continued in attempts to produce good functional upper limb devices with acceptable cosmetic appearance. A degree of success has been reported with the use of myo-electric prostheses though quantitative studies on the long-term use by amputees is yet to appear in the literature. Shannon (1975) has argued that the addition of sensory feedback will enhance the acceptability of the prosthesis to the wearer, and as a result of research by Shannon at the University of Queensland, Shannon and Agnew (1979) reported their experience after fitting two subjects with below-elbow myo-electric prostheses which conveyed a sense of touch. Altogether five subjects have been fitted with similar prostheses and Agnew (1979) has described the functional training in the use of the prostheses.

One of the five subjects was found to be a skilled user of the conventional Hosmer-Dorrance split-hook prosthesis. After two years of wearing the Shannon myo-electric prosthesis with sensory feedback, a study was done with the aim of comparing the functional effectiveness of the two prostheses for this subject.

Case report

In 1975, a 34 year old woman lost her hand following a motor car accident. Micro surgery was attempted, but the hand was not viable. A surgical below-elbow amputation was performed following the selection of an ideal stump site.

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The patient was fitted with a below-elbow split-hook prosthesis and had a short uneventful rehabilitation period. She was taught to care for her stump and to use her prosthesis by an occupational therapist. The patient suffered a period of depression for some twelve months after being discharged and did not wear her prosthesis during this time. After twelve months, she became frustrated at her helplessness with one arm and began to use her hook. In 1978, she volunteered as a subject in the myo-electric prosthesis project and was accepted as she met the criteria for selection.

The subject was taught to use the myo-electric prosthesis and had no difficulty operating the myo-electric control system or the sensory feedback. Within a few weeks she had learned to do a variety of tasks with enthusiasm and confidence. She was given rechargeable batteries for continuous use and taught how to care for the apparatus. She was seen once a month for two years during which times new skills were taught, and occasional minor adjustments made to the apparatus. She was referred for a trial work period and now is employed in an office on a part-time basis.

Apparatus

A Hosmer-Dorrance below-elbow prosthesis, myo-electric prosthesis with sensory feedback (Shannon 1979), Minnesota Rate of Manipulation Tests (American Guidance Service 1969), Smith Hand Function Evaluation (Smith 1973) and one stop watch were used.

Design

A single subject experimental design with type of prosthesis as the independent variable, and scores on the Placing Test of the Minnesota Rate of Manipulation Tests and the Unilateral Grasp-Release tasks of Smith Hand Function Evaluation as the dependent variables were used. Thirty independent observations were made with the subject wearing the Hosmer-Dorrance split-hook prosthesis and thirty independent observations were made with the subject wearing the myo-electric prosthesis with sensory feedback (Shannon prosthesis). Scores were measured in seconds with a stop watch.

Possible potential error variables were loss of motivation by the subject and the order of testing both in terms of the two prosthesis and the two tests concerned. To control for loss of motivation as a potential variable, the subject was paid. To control the order of testing as a possible constant experimental error, randomisation of tests and prostheses was used. There was no need to control prosthesis rejection in a psychological sense as a possible error variable as this is considered a part of the inherent characteristic of all prosthesis.

Procedure

The grasp-release tasks of the Smith Hand Function Evaluation (1973) were administered in precisely the same manner as that originally described in the literature (Fig. 1).

For the Placing Test of the Minnesota Rate of Manipulation Test, the procedure followed was that as described in the Examiner's Manual (American Guidance Service 1969) except that only six rows of blocks were used (Fig. 2).

Two testing sessions were held per day for a period of thirty days. There was a fifteen minute interval between each session.

Results and discussion

To analyse the data, Higgins' (1978) autoregressive model for testing means in a single subject experiment was used, as this model guards against the type of gross misinterpretation of data that can occur when independence of observations is incorrectly assumed. The means, standard deviations and autocorrelation of lag 1 were calculated for each of the four sets of data summarized in Tables 1 and 2. If the rho lag 1 would be around 0·5 or less, (Higgins p. 719) the normal approximation to the autocorrelated Z could be regarded as reasonably good for n=30. Inferences for the two means in each case were based on the two sample autocorrelated Z-statistic defined by

$$Z = \frac{(\bar{X}-\bar{Y}-\{\mu_x-\mu_y\})}{(\hat{V}\{\bar{X}-\bar{Y}\})^{1/2}}$$

where the variance of the difference was estimated by using

$$V_2(\bar{X}-\bar{Y}) = V(\bar{X}) + V(\bar{Y}) - 2\operatorname{cov}(\bar{X},\bar{Y})$$

and the covariance was given by

$$\operatorname{cov}(\bar{X},\bar{Y}) = \frac{\sigma^x\sigma^y}{mn}\,\rho\,\frac{(1-\rho^m)}{(1-\rho)}\,\frac{(1-\rho^n)}{(1-\rho)}$$

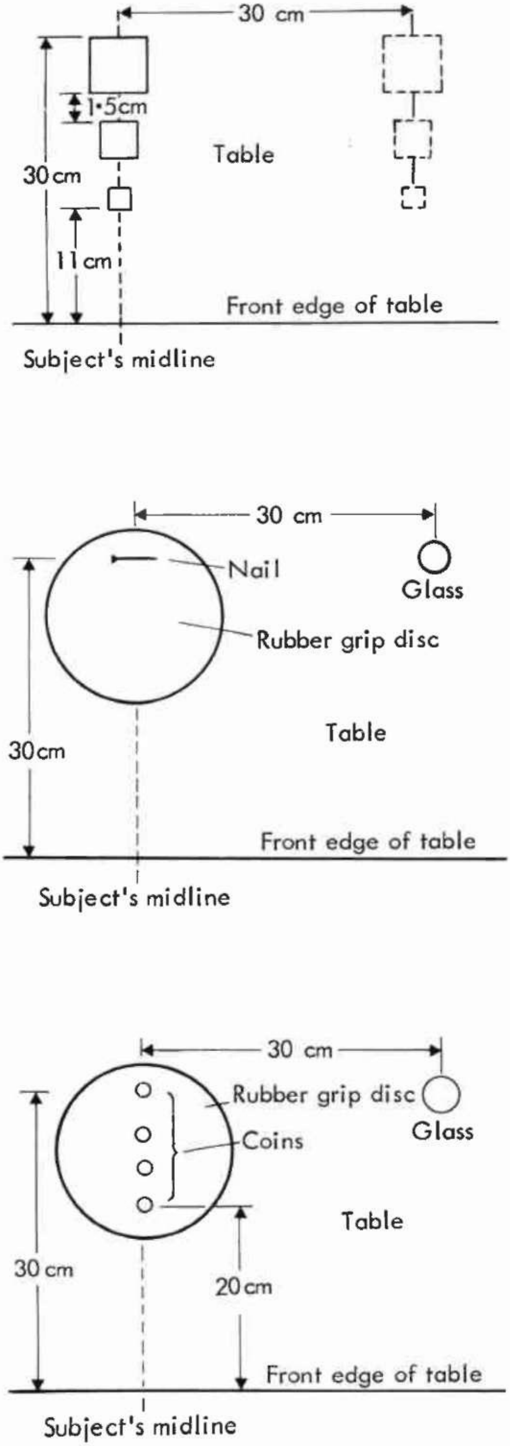

Fig. 1. Top, subject 1—blocks. Centre, subject 2—nail. Bottom, subject 3—coins.

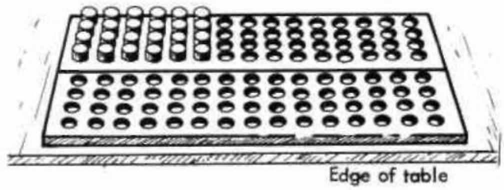

Fig. 2. Blocks set up for Placing Test.

As the sample mean has a normal distribution the approximation of variance was given by

$$V(\bar{X}) \simeq \frac{\sigma^2}{n} \frac{(1+\rho)}{(1-\rho)}$$

Tables 1 and 2 show the rho lag 1 ranging between $-0{\cdot}2$ and $0{\cdot}24$. As these values are much smaller than the critical values of $0{\cdot}5$ as stated previously, it would be safer to make inferences about the means from the autocorrelated Z values obtained.

The hypothesis tested was for equality of means of the myo-electric prosthesis and the split-hook prosthesis scores measured on the Placing Test of the Minnesota Rate of Manipulation Tests and the Smith Hand Evaluation as indicative of hand efficiency. The Z-statistics showed highly significant differences ($p<0{\cdot}001$) between the means of both test scores. As the means for the split-hook prosthesis were lower on both tests for hand function, this clearly indicated the split-hook as functionally better than the myo-electric prosthesis for this subject at that time in terms of two tests of hand function.

Inspection of the Figures 3 and 4 clearly shows no change in trend with time and practice, making an analysis of interaction unnecessary.

Clinical application

The experiment described was used to compare the functional effectiveness of two types of upper limb prostheses. While the results showed the efficiency of the split-hook to be better than that of the myo-electric prosthesis, it is interesting to note that the subject preferred to use the myo-electric prosthesis for certain activities such as handling a baby, folding laundry and when out on social occasions. This supports the views of Agnew and Shannon

Table 1. Means, standard deviation, autocorrelation and Z-statistic for scores on the Placing test of the M.R.M.

	$\overline{X}$	S	Autocorrelation Lag 1	Z-statistic
Myo-electric prosthesis	54·87	3·01	−0·20	21·861*
Split-hook prosthesis	45·03	2·73	0·04	

* $Z \geq 3{\cdot}290$, $p \leq 0{\cdot}001$

Table 2. Means, standard deviation, autocorrelation and Z-statistic for scores of the Smith Hand Function Evaluation

	$\overline{X}$	S	Autocorrelation Lag 1	Z-statistic
Myo-electric prosthesis	15·063	1·61	0·05	9·128*
Split-hook prosthesis	12·273	1·922	0·24	

* $Z \geq 3{\cdot}290$, $p \leq 0{\cdot}001$

(1980) that the myo-electric prosthesis with sensory feedback is of value despite its limitations in efficiency. While the good cosmetic appearance of the myo-electric prosthesis is an important consideration, it should be noted that the subject's choice of prosthesis for various activities could not have been made only on appearance. For example, the fact that the subject chose to wear the myo-electric prosthesis for laundry and kitchen work would indicate a preference for the myo-electric prosthesis for many functional tasks as well as for cosmetic appearance.

No predictions can be made regarding the two types of prostheses for other subjects. The importance in this particular experiment has demonstrated the need for objective study as, from clinical observation of the subject, it was difficult to decide whether there was any appreciable difference in the efficiency of the two types of prostheses. The experiment therefore, has eliminated the possibility of an incorrect and subjective evaluation being made in favour of one prosthesis over the other.

Further research is recommended in two major areas, viz. an objective evaluation of the sensory feedback component of the myo-electric

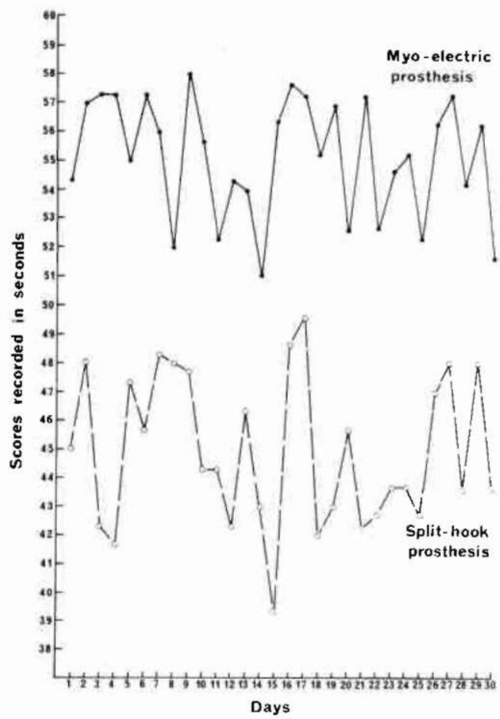

Fig. 3. Scores for Placing Test.

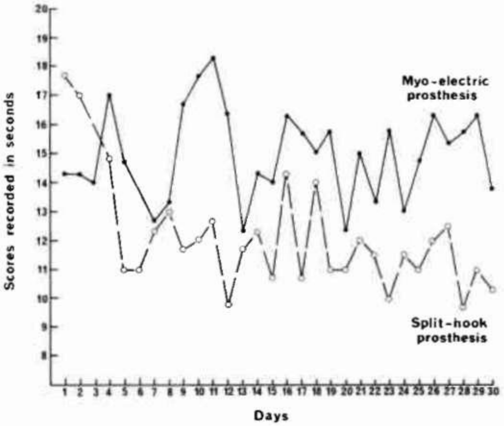

Fig. 4. Scores for Smith Hand Function Evaluation.

prosthesis; and secondly in the availability of multiple control sites for myo-electric prostheses to allow for the control of several degrees of freedom of movement, as it would appear from the literature (Herberts 1969) that there has been little development in myo-electric prostheses with more than one function.

REFERENCES

AGNEW, P. J. (1979). Training for myo-electric prosthesis with sensory feedback. *Occ. Ther.* **42,** 286–288.

AGNEW, P. J. and SHANNON, G. F. (1980). Training programme and testing of a myo-electrically controlled prosthesis with sensory feedback system. *Amer. J. Occ. Ther.*, In press.

AMERICAN GUIDANCE SERVICE. (1969). The Minnesota rate of manipulation tests. American Guidance Service Inc., Circle Pines, Minnesota.

BAILEY, R. B. (1970). An upper extremity prosthetic training arm. *Amer. J. Occ. Ther.*, **24,** 357–359.

DAY, J. W., MADDEN, M. V. & PAYNE, W. W. (1969). A technique for fabricating and fitting a pre-prosthetic training arm. *Amer. J. Occ. Ther.*, **23,** 422–424.

DEPARTMENT OF VETERANS' AFFAIRS. (1976). Arm amputee survey—1975–76. Central Office Research and Statistics Section, Department of Veterans' Affairs, Woden, A.C.T.

FRIEDMANN, L. W. (1978). The Psychological Rehabilitation of the Amputee. Charles C. Thomas, Publisher, Springfield, Illinois, 3–140.

HERBERTS, P. (1969). Myo-electric signals in control of prostheses. *Acta Orthop. Scand. Suppl.*, 124.

HIGGINS, J. J. (1978). A robust model for estimating and testing for means in single subject experiments. *Human Factors,* **20,** 717–724.

JACOBS, R. R. & BRADY, W. M. (1975). Early post-surgical fitting in upper extremity amputations. *J. Trauma,* **15,** 966–968.

SHANNON, G. F. (1975). The case for feedback on upper arm prostheses. *Elec. Trans., I. E. Aust. EEII,* 36–38.

SHANNON, G. F. AGNEW, P. J. (1979). Fitting below-elbow prostheses which convey a sense of touch. *Med. J. Aust.*, **1,** 242–244.

SHANNON, G. F. (1979). A myo-electrically controlled prosthesis with sensory feedback. *Med. & Biol. Eng. & Comput.*, **17,** 73–80.

SMITH H. (1973). Smith hand function evaluation. *Amer. J. Occ. Ther.*, **27,** 244–251.