Studies of the Upper-Extremity Amputee

VIII. Research Implications

SIDNEY FISHMAN, Ph.D.[1]

AT WAS the purpose of the NYU Field Studies to explore the matter of the upper-extremity amputee in a broad and comprehensive way. To this end there was devised a research program consisting of three phases—survey studies, clinical studies, and evaluation studies. The first of these consisted of the single examination of each of 1630 upper-extremity amputees for the purpose of developing normative, descriptive data concerning the status of the upper-extremity-amputee population at the beginning of the research program. Through the vehicle of an organized program of prosthetic management, 769 of the 1630 amputees surveyed were provided in the clinical studies with what at the time was a new type of upper-extremity prosthesis, the purpose being to study the varieties of prostheses provided, the prescription procedures used, the preprosthetic treatment employed, the adequacy of prosthetic fabrication and fitting, the effects of training, and the results of initial and final checkouts. Finally, in the evaluation studies, the prior status, mental and physical, of 359 individuals selected from the clinical study was compared with their corresponding status after participation and treatment. The procedures used in each of these studies, and the objectives sought in the work, have all been discussed in detail in Section I of this series (ARTIFICIAL LIMBS, Spring 1958, p. 4).

While the variety, scope, and degree of completeness of the resulting data all increased as work progressed from the survey studies through the clinical studies and on to the evaluation studies, the size of the experimental sample decreased. The survey studies were limited to the normative data that could reasonably be gathered by means of a one-time interview and examination of the largest possible sample of upper-extremity amputees. The clinical studies supplemented the normative data with observational information concerning 769 amputees receiving prosthetic treatment. The evaluation studies included normative, observational, and research procedures. Only in the last series of studies did control of any research variables become possible. The major focus of the evaluation studies was, then, to obtain information on possible changes in the individual resulting from the application of new and experimental procedures in the management of the upper-extremity amputee.

The types of information sought in each of the three phases fell into one or more of five broad categories:

1. *The physical and personal characteristics of the amputees.* Included identifying data (age, height, weight, residence, marital status); educational level; vocational, avocational, and recreational pursuits; amputation etiology; amputation type; and the strength, ranges of motion, and general characteristics of the stump.

2. *The prosthetic components and fabrication techniques utilized.* Included information concerning the functional and mechanical characteristics as well as the advantages and disadvantages of each component of the artificial arm.

[1] Director, Prosthetic Devices Study, Research Division, College of Engineering, New York University; Director, Prosthetics Education, NYU Post-Graduate Medical School; Adjunct Professor of Psychology, Fairleigh-Dickinson University, Rutherford, N. J.; member, Committee on Prosthetics Research and Development and Committee on Child Prosthetics Problems, PRB, NRC.

3. *The treatment factors.* Included data concerning the frequency of prescription of various components, prosthetic therapy, prosthetic training, and checkout.

4. *Amputee performance.* Concerned with testing the individual's proficiency in accomplishing the basic activities of prehension, positioning, and release of objects from grasp and with amputee reports concerning the usefulness and importance of the prosthesis in various practical activities of daily living.

5. *Psychological considerations.* Involved an assessment of amputee attitudes and personality factors as they affect reactions to prosthetic restoration as well as the social consequences of living with a disability.

While data within these five areas of interest were gathered in all three phases of the investigation, the comprehensiveness and sophistication of the measurement techniques varied from phase to phase. In view of the wide range of matters investigated, it is clear that the problems involved in their accurate measurement were considerable. Some factors *(e.g.,* mechanical characteristics of prosthetic components, results of checkout, certain personal identifying data, etc.) lent themselves rather conveniently to so-called "objective measurement," while in the light of presently available techniques other factors could be appraised only through subjective observation and rating by trained observers *(e.g.,* amputee performance, quality of prosthetic training, quality of prosthetic fabrication, etc.). Still other factors *(e.g.,* attitudes, personality factors, opinions concerning prosthetic components and treatment methods, etc.) could only be inferred from the verbal reports of the amputees themselves. As a consequence, the resulting data are of three kinds—objective measurements, observations and ratings, and amputee verbalizations. It should, however, be pointed out that no relationship necessarily exists between the significance and value of various data and their objectivity. Quite often the most objective data are the easiest to obtain but are also the least revealing. Yet certain data obviously subjective and barely capable of meeting any standards of precision provide the greatest insights and understanding.

With several relatively minor exceptions, all five subject areas have individually been the topic for separate analyses and discussions and have culminated in five corresponding articles (Sections II, III, V, VI, and VII) in this series. Section II (ARTIFICIAL LIMBS, Spring 1958, p. 57) dealt with the descriptive characteristics of the sample. Section III (ARTIFICIAL LIMBS, Spring 1958, p. 73) was concerned with the evaluation of the treatment process. Section V (page 4) reviews the specific components and fabrication techniques that go to make up a prosthesis. Section VI (page 31) describes the performance or functional capabilities of the amputee subjects, while Section VII (page 88) analyzes the psychological attributes of the amputee group.

STUDIES COMPLETED

THE SAMPLE (Section II)

The initial point of interest is that there were in the nationwide, somewhat urban sample almost as many above-elbow as there were below-elbow amputees (41 percent as compared with 51 percent). The remaining cases consisted of shoulder-disarticulation amputees (5 percent) and bilateral arm cases (3 percent). Within each of these four basic amputee types, a further detailed breakdown is presented. For example, the below-elbow cases are classified and discussed as very short, short, medium, and long, and as wrist disarticulations. A similar breakdown is offered for the above-elbow and shoulder-disarticulation groups.

It is important to emphasize that 73 percent of the participating subjects were veterans of military service who had lost limbs in World War II, a matter having a strong influence on the characteristics of the sample—on age, height, weight, educational level, and vocational status as well as on other physical characteristics.

Although certain amputees continued to pursue agricultural and mechanically oriented occupations, amputation generally resulted in a shift away from agricultural, manual, and mechanical occupations toward clerical, sales, and managerial activities, and there was in addition a very significant increase in the extent of unemployment (from 1 percent to 19 percent). Such a finding raises the question whether these shifts are caused chiefly by the physical inability to perform and compete in certain activities or primarily by socioeconomic factors.

An overwhelming majority of the subjects were found to have in their residual anatomy sufficient strength and sufficient range of motion to use an upper-extremity prosthesis. Despite this physical potential, 25 percent of the below-elbow, 39 percent of the above-elbow, and 65 percent of the shoulder-disarticulation amputees were not wearing arm prostheses at the time of the survey studies. Typically, those who did wear prostheses used Dorrance hooks, Miracle or APRL hands, and friction-type wrist units. The below-elbow prostheses typically consisted of a leather socket, rigid metal elbow hinges, and a figure-eight harness. The above-elbow and shoulder-disarticulation prostheses had in general plastic or leather sockets, manually operated or harness-controlled elbows (in about equal proportions), and chest-strap harnesses with shoulder saddles.

THE TREATMENT PROCESS (Section III)

Before the advent of the Upper-Extremity Field Studies, only some 17 percent of the group had had arms prescribed for them by a clinic team consisting of a physician, a therapist, and a prosthetist. In the NYU program, where prescriptions were written and filled in this manner routinely, all the professional groups concerned and 94 percent of the amputee subjects heartily approved of the multidisciplinary, clinical approach.

With respect to prosthetic components utilized there were several very significant shifts, such as the tendency toward the use of the APRL hook (from 12 percent to 61 percent of the sample) and toward the APRL hand (from 11 percent to 80 percent of the sample). There was also a marked increase in the use of positive-locking wrist units as compared with friction types, a strong shift toward the use of flexible hinges instead of rigid hinges for the below-elbow amputees, and an increase from 46 percent to 100 percent in the proportion of above-elbow amputees wearing harness-operated elbows. Plastic laminates were used exclusively for fabrication of the nonoperating parts of the prostheses, and the harness patterns tended to be of the figure-eight type. In point of fact, it may be said that the whole pattern of prosthetic prescription for the upper-extremity amputee was revolutionized in the course of the Upper-Extremity Field Studies.

Introduction of the checkout procedures met with considerable success. Clinic personnel considered checkout a valuable management tool, and more than 90 percent of the amputees thought it useful. Whether initial checkout or final checkout, almost 70 percent of the arms passed on the first trial. The remaining cases required two or more visits to resolve all problems, the major deficiencies uncovered being in the areas of socket fit, harnessing, and alignment of control systems.

Application of the training procedures was not nearly so successful. Some 40 percent of the group thought that the results of training could be improved by extending the instruction over a longer period and by including more and varied practice in the regimen. The finding that during the training period 54 percent of the sample needed adjustments or corrections in the prosthesis suggests the great value of supervised training—that is, of training in a situation so controlled that specific difficulties can be uncovered and resolved with a minimum of difficulty. Although the length of the training period was greater for bilateral cases than for shoulder disarticulations, greater for shoulder disarticulations than for above-elbow amputees, and so on, the time allotted for shoulder disarticulations and for above-elbow cases over that allowed below-elbow cases did not seem to be in keeping with the increase in operating difficulty known to accompany loss of the natural elbow.

All in all, the system of amputee management introduced as part of the Field Study was accorded a high degree of acceptance both by the amputees and by the professional personnel charged with their care. Perhaps the strongest recommendation for the management procedures lies in the fact that, with appropriate revisions and variations, they are now in widespread use in amputee clinics throughout the country.

THE ARMAMENTARIUM (Section V)

The data concerning the prosthetic armamentarium tend to be encyclopedic and

documentary. Each component of the upper-extremity prosthesis has been considered in terms of appearance, usefulness, ease of operation, and weight, and this information has been supplemented by data on the ranges within which the components functioned and on the magnitudes of the activating and resulting forces. The adequacy of the fabrication techniques utilized in making the upper-extremity prosthesis was also reviewed. These data provide the biomechanical basis upon which to revise a number of the checkout standards.

Lastly, the new components that go to make up the present armamentarium (terminal devices, wrist units, elbow hinges for below-elbow arms, elbow joints for above-elbow arms, control systems, and harnessing equipment) have been compared with corresponding components in the prior art. Amputee reactions toward the conventional preprogram arms have been compared with the reactions toward the new program prostheses. The amputees felt that the program prostheses are characterized by:

1. Higher, better-fitting, and better-appearing sockets.
2. More useful and easier-operating elbows.
3. Improved efficiency of force transmission reflecting better cable alignment and more stable materials.
4. Lighter, freer, and more comfortable harnessing.
5. A marked increase in terminal devices offering improved control of grasp force.

Of the 290 amputees who had an opportunity to wear both types of arms, 261 preferred the new, 25 the old, while 4 expressed no preference.

AMPUTEE PERFORMANCE (Section VI)

Section VI has been concerned with the functional value of arm prostheses, the uses to which they are put, and the skill and efficiency with which arm amputees can utilize them. From interrogation of the subjects, it became apparent that the usefulness of an arm prosthesis varied considerably from activity to activity in the five broad areas of daily living (work, home, recreation, dressing, and eating). In the numerous activities that go to make up work, recreation, and home life, prostheses tended to have wide applicability and to be most helpful to the wearer. As a matter of fact, use of the prosthesis in a variety of jobs and hobbies was much more extensive than is usually recognized, and we must therefore conclude that the functional potential of the upper-extremity amputee is also a good deal greater than commonly thought. But in the activities of dressing and eating, which for the most part involve a limited number of relatively difficult operations performed close to the body, prostheses tended to be considerably less useful. An interesting note is that, as regards the performance of any one given task, prosthetic usage tends to be on an all-or-none basis. Either the amputee uses his prosthesis every time he is confronted with a given task, or else he never uses it for that task. "Sometimes" usage is reported infrequently.

To shed further light on the comparative values of below-elbow, above-elbow, and shoulder-disarticulation prostheses, 20 selected bimanual activities, considered both by the examiners and by the amputees to be significant in terms of frequency of occurrence and of importance, were used in an attempt to determine how widely prostheses were used. In summary, the results showed that:

Over 50 percent of the below-elbow amputees always used their prostheses for 19 of the 20 tasks.
Over 50 percent of the above-elbow amputees always used their prostheses for 13 of the 20 tasks.
Over 50 percent of the shoulder-disarticulation subjects always used their prostheses for 8 of the 20 tasks.
Over 50 percent of the bilateral arm amputees always used their prostheses to accomplish 15 of 18 tasks (two tasks not applicable).

These and other data show clearly that the higher the level of amputation for which an arm prosthesis is intended the less the utility of the prosthesis. The sharp distinction between the usefulness of prostheses for below-elbow amputees and that of prostheses for above-elbow and shoulder-disarticulation amputees can be explained readily in terms of the limited function to be had from the mechanical elbow and the concomitant need for a comparatively high order of skill in order to use it properly. The difference in

apparent usefulness is clearly due to the loss of the normal anatomical elbow. This circumstance re-emphasizes the need for more practically oriented and more extended training for above-elbow and shoulder-disarticulation amputees.

While contemporary below-elbow prostheses appear to be more useful than are the corresponding prostheses for above-elbow amputations and for shoulder disarticulations, arms for the higher levels of limb loss still offer a significant measure of utility. It should also be noted that not all amputees of a given type use their prostheses to the same extent or for the same activities. Obviously, then, the prosthesis varies in value and convenience for the individual wearer, and this factor also helps to determine the amount of use made of the limb by the individual wearer.

Through a series of tests of abstract function (prehension and positioning viewed as ends in themselves) and of the performance of practical activities of daily living, a systematic, observational method of rating amputee performance was developed. Although the tests are not as precise as might be desired, an initial step in the measurement of amputee function has been taken. One direct result has been the establishment, for the upper extremity, of a set of norms which may be used as a point of comparison in evaluating amputee performance and in setting reasonable goals for prosthetic training.

The data from these tests clearly indicate that, in general, more could be accomplished with the new arms than with the old and that more skillful and more natural performance with the new prostheses was usually obtained without any increase in performance time.

The advantages of the experimental arms over the older, conventional arms were most noticeable in above-elbow and shoulder-disarticulation prostheses, less so in below-elbow prostheses. In the below-elbow case, apparently, prosthetic function is very much less dependent upon the quality or precision of arm fabrication, or on the specific components included in the prostheses, or both.

While in general the results point up the inadequacies of even our most advanced devices and techniques and thus emphasize the continued existence of much room for improvement, they also show that present-day upper-extremity prostheses are quite useful devices despite the inadequacies, especially for those types of amputees heretofore thought incapable of deriving much benefit from any prosthesis. Since we seem now to have exploited the existing concepts of upper-extremity prosthetics, there would seem to be little more to be gained by continued redesign of current prosthetic equipment. Instead, there is now a need for dramatic, if not drastic, new concepts in approaching the problem of rehabilitating the upper-extremity amputee.

AMPUTEE ATTITUDES AND REACTIONS (Section VII)

Section VII attacked the problem of prosthetic restoration from the point of view of the psychological characteristics of the amputee and tried to evaluate the subjects on the basis of nine personality variables, to explore a number of factors influencing prosthetic wear and function in social situations, and to study the amputees' attitudes toward prosthetic wear before and aftei fitting with a prosthesis The predominant finding as regards the personality functioning of the amputees was that, no matter which aspect was studied, the subjects appeared to try consistently to maintain feelings of bodily integrity and adequacy by denying many of the personal, vocational, and social consequences of amputation. They consistently de-emphasized their physical difficulty, rejected notions of abnormality, and set their cosmetic and functional desires in line with those of normal people. Superimposed on this general positive tone of the amputees' statements concerning adjustment was the additional positive effect of the treatment program on many of the personality variables, as evidenced by consistent indications of some decrease in expressed feelings of sensitivity and frustration, increased feelings of functional and social adequacy, and greater acceptance of their disability.

One problem associated with this aspect of the study was that, because of the limitations of the experimental design, the data

were based entirely upon the voluntary expressions of the subjects themselves, who consistently tended to color their responses by hiding any attitudes which might be viewed as "negative." Aware of this difficulty in the measurement of the social and functional factors affecting prosthetic wear, the experimenters attempted a somewhat more indirect approach in the form of cartoons depicting a series of ambiguous, potentially sensitive, situations. The amputees were asked to respond to these situations, the expectation being that they would "project" their attitudes in a less inhibited form. Probably the major finding of this line of inquiry developed from the answers given when the amputees were requested to react to the cartoons as prosthesis wearers and then as nonwearers. The data show consistently positive attitudes toward prosthetic wear, the feeling being expressed that the prosthesis makes the amputee more effective and independent functionally, more self-reliant, more secure, more self-accepting, less shy, less easily embarrassed, and more adaptable. One may, of course, ask whether the amputees held these attitudes fundamentally or whether they were merely expounding an expected "cultural norm." On the basis of the available data it is not possible to answer the question.

In a comparison of the preprosthetic expectations of amputees with the actual degree to which these expectations were fulfilled after fitting, it was concluded that:

1. Normally, little prosthetic information is available to the new amputee, and this deficiency encourages the development of unrealistic expectations concerning prosthetic wear.
2. Anticipations which tended to be overly optimistic were in most cases modified downward (with considerable personal disappointment and regret) after the individual had an opportunity to wear a prosthesis.

The last question studied had to do with whether or not the postfitting behavior of the amputee toward his prosthesis is related to, and whether or not it can be predicted on the basis of, his prefitting attitudes, a matter that would seem to have significant practical implications. Should preprosthetic attitudes turn out to exercise a determining or controlling influence over later prosthetic acceptance, performance, and use, it would be desirable to attempt to influence early attitudes so as to obtain the best possible rehabilitation results. Investigation did indeed show that those amputees holding favorable attitudes before ever having had a prosthesis tended to maintain favorable attitudes after wear and use; those at first negatively disposed continued to react negatively after receiving a prosthesis.

FUTURE STUDIES

Although the amputees in the NYU Field Study have thus far been assessed rather thoroughly in terms of five broad areas (physical and personal characteristics, prosthetic components and fabrication techniques, treatment procedures, prosthetic performance, and psychological orientation), little has yet been done toward exploring the relationships that may exist either within or between the several categories of data. As a matter of fact, the data reported and discussed here constitute a phenomenological picture of observed events and are therefore basically descriptive in nature. While data of this type are valuable in that they focus attention on significant occurrences and reveal what is taking place and what is changing during the period of observation, the reasons why the events occur, and the nature of the causal train producing them, can be learned only by more detailed and more definitive study.

The only studies of this more detailed variety which have been performed thus far are as follows:

1. A substantial segment of the findings concerning the unilateral amputees have been analyzed and presented in terms of the three basic amputee types—below-elbow, above-elbow, and shoulder-disarticulation amputees. But there is still a need for further analyses of this variety using finer categories in the amputee-type classification system (such as wrist disarticulation, long below-elbow, medium below-elbow, short below-elbow, very short below-elbow, etc.).
2. A number of attitudes toward prosthetic wear held by the amputees prior to prosthetic fitting have been studied and presented in relation to postfitting attitudes and psychological adjustment.

Whatever cross-correlations are attempted,

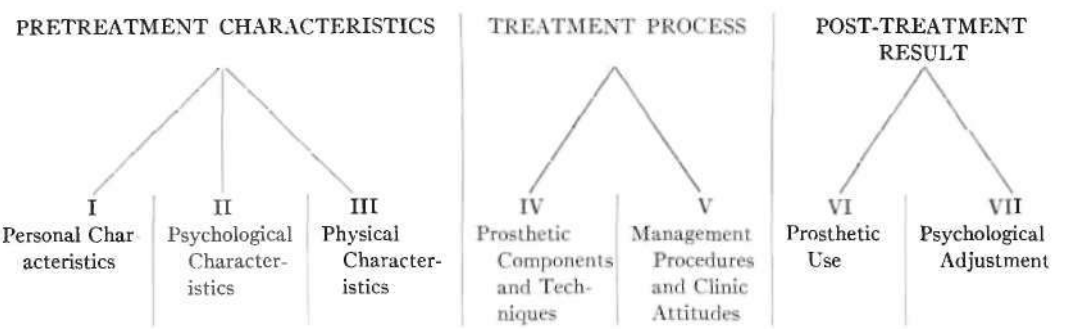
however, it must be remembered that the subject matter deals with the complex interactions between a human being, the patient, and an involved environmental process, the treatment procedure. Man is not composed of a series of discrete traits and attributes, nor does he represent the simple sum of such features Taken as a whole, the configuration is more exponential that additive. Similarly, the treatment procedures at any given level of observation may represent a series of obvious events simply measured and simply described, or they may be seen more subtly as sets of behavior of professional people—physicians, prosthetists, therapists, others—directed toward another individual, the amputee. In this light, distinctions and comparisons drawn between the patient, the treatment process, and the restorative result are unavoidably arbitrary to the extent that they tend to be abstractions from the intricate network of human behavior. Since in practice, however, analyses must be performed at some level not fully reflecting the human interactions at work, attempts at further study require some kind of conceptual framework within which to consider the data.

A CONCEPTUAL FRAMEWORK

When the mass of available data is reviewed,[2] the individual elements fall naturally into two groups—those which describe the factors contributing to the over-all result of prosthetic restoration and those which describe the result itself. The data in the first category, those dealing with the causal factors, seem in turn to constitute two separate subcategories—the individual characteristics, which the patient brings to the restoration regimen, and the treatment process, which describes the management procedures applied. Together the interaction of these two contributing factors (variables) produces the over-all result of prosthetic restoration. Thus:

Amputee Characteristics + Treatment Process = Over-All Result of Prosthetic Restoration

But each of these three broad factors consists, again in turn, of a number of more specific considerations that were the subject of investigation in the NYU Field Studies. It is therefore possible to recast the formula into somewhat more specific terms, whereupon the three factors in the original relationship are found to consist of seven different types of data. Thus:



[2] Almost all of the data developed during the NYU Field Studies have been codified and punched on IBM (International Business Machines Corp.) cards, and all of the major analyses presented in this (Vol. 5, No. 2) and the preceding (Vol. 5, No. 1) issue of ARTIFICIAL LIMBS have been performed through the use of IBM electromechanical data-sorting techniques. Any future analyses may be accomplished conveniently through the same means.

Further expansion of such a breakdown leads to Table 1, which reflects in greater detail the kinds of information available. All told there are some 60 variables on which data have been collected.

The data having been thus classified, it is now necessary to find the means with which to develop whatever significant interrelationships may exist within and between the various categories. Analyses may be performed at any of the three levels of complexity, but those best undertaken first would tend to consider the segmented types of data listed in the lower portion of Table 1. Contrary to first impression, they are in reality by far the simplest to investigate. To study the earlier, more general, and apparently less complex relationships shown in the first two formulae will require the development of suitable means for consolidating individual sets of data in some meaningful way to describe the composite concepts utilized. Accordingly, analyses of the data will vary in complexity depending on whether we wish to study the relationships between discrete variables or those between increasingly composite, and therefore complex, conceptualizations. As the chosen formulation becomes clinically more meaningful, the complexity of the statistical analysis increases. Conversely, the simple selection of a pair of variables and the study of their interrelationship is easiest to effect statistically.

TWO-VARIABLE ANALYSES

When the available data are considered, the area of primary interest that comes at once to mind concerns the question of what factors in the amputee and/or in the treatment process tend to influence the over-all restoration result in a significant way, positively or negatively. Since the final level of prosthetic restoration is a composite measure made up of two different types of data, we can study various individual factors, one at a time, as they influence one segment of the rehabilitation result (use of the prosthesis by the amputee) or the other segment (the amputee's postfitting patterns of psychological adjustment). In the study of these relationships, the data concerning prosthetic performance (or those concerning amputee adjustment, one or the other) are organized and then compared systematically with data describing a variety of possible causal factors.

Since any of some 40 individual factors may influence either segment of the final result of prosthetic restoration, it becomes a matter of judgment as to which of the many possible relationships are worth checking. On the basis of previous experience, the prefitting considerations which seem to have the greatest potential significance, and which would seem to be most worth while exploring in relation to each part of the prosthetic restoration result, are as follows:

I. Personal characteristics: age, residence, education, marital status, vocation, hobbies, recreational activities.

II. Psychological characteristics: acceptance of loss, identification with the disabled, functional adequacy, independence, sensitivity, acceptance by others, sociability, frustration, optimism, security, prosthetic expectations.

III. Physical characteristics: etiology, dominant or subdominant loss, amputation level, stump strength, stump motion.

IV. Prosthetic-component characteristics: voluntary-opening *vs.* voluntary-closing terminal devices, canted *vs.* lyre-shaped fingers, range of pinch forces, friction *vs.* locking-type wrist units, step-up *vs.* nonstep-up elbow hinges, single-axis *vs.* polycentric hinges, figure-eight *vs.* shoulder-saddle harnesses, quality of prosthetic fabrication (as revealed by checkout).

V. Management procedures: extent of training, time lapse before training, extent of preprosthetic therapy, behavior and attitudes of clinic personnel (physician, therapist, prosthetist).

In this analysis, the factors included under headings I through V may be considered "predictor" variables, while the data listed under headings VI and VII may be looked upon as "criterion" information. If firm relationships can be established between the data in the first group of categories (I-V) and those in the second group (VI-VII), the former information may be used as a basis for predicting the outcomes of the prosthetic restoration process. The choice of predictor variables to be studied depends, of course, upon the segment of the prosthetic restorative result (prosthetic use or psychological adjustment) selected for study. It is, for example, quite enlightening to relate stump factors to prostehtic usage, but there would be less

CLASSIFICATION OF TYPES OF DATA ACCUMULATED IN THE NYU FIELD STUDIES[a]

PRETREATMENT CHARACTERISTICS			TREATMENT PROCESS		POST-TREATMENT RESULT	
I Personal Characteristics	II Psychological Characteristics	III Physical Characteristics	IV Prosthetic Components and Techniques	V Management Procedures and Clinic Attitudes	VI Prosthetic Use	VII Psychological Adjustment
Age	Acceptance of loss	Weight	Terminal devices	Extent of training	Prehension tests	Acceptance of loss
Education	Identification with disabled	Height	Wrists	Quality of training	Positioning tests	Identification with disabled
Residence	Functional adequacy	Amputation level and etiology	Elbows or hinges	Attitudes of clinic personnel (MD, therapist, prosthetist)	Practical-activity tests	Functional adequacy
Marital status	Independence	Dominant or subdominant loss	Control systems	Preprosthetic therapy	Reported use of prosthesis in: dressing, eating, work, home, social life, selected activities of bilaterals	Independence
Vocation	Sensitivity	Stump strength	Harnesses			Sensitivity
Hobbies	Acceptance by others	Stump motion	Quality of fabrication			Acceptance by others
Recreational activities	Sociability					Sociability
	Frustration					Frustration
	Optimism					Optimism
	Security					Security
	Prosthetic expectations					Prosthetic expectations
						Opinions of management procedures

[a] *The instruments used to elicit the types of data here classified are reproduced as appendices IA through IIIH on pages 21 through 56 of the issue of* ARTIFICIAL LIMBS *for Spring* 1958 (Vol. 5, No. 1).

reason to select stump factors when we are interested in predicting psychological adjustment. Whatever variables are ultimately selected for study, however, the basic analytic approach remains unchanged.

A second important type of two-variable analysis can very well involve a study of what relationships exist between the two aspects of the post-treatment result itself (prosthetic use *vs.* psychological adjustment). Is there, for example, any relationship between an amputee's sense of independence and the extent to which he uses his prosthesis? Is the quality of prosthetic performance related to the individual's social sensitivity? Any number of relationships of this variety could be the subject of study, and the results would contribute to the solution of one of the problems of amputee rehabilitation. Does extensive prosthetic usage of high quality imply good general adjustment, or does good adjustment give rise to efficient prosthetic use? Or is there in fact no significant relationship between these two important aspects of successful amputee rehabilitation?

A third variety of two-variable analysis stems from the fact that even within the individual areas of prosthetic usage and of amputee behavior there are important relations to be studied. How, for example, does the amputee's performance with a prosthesis relate to the importance which he attributes to a given activity? What is the relationship between the efficiency of prosthetic use as reflected by tests (actual usage) and the efficiency as reported verbally by amputees (reported usage)? In the psychological area, what is the relationship between an amputee's feelings of sensitivity and his sense of identification with the disabled? To what extent do feelings of frustration affect the amputee's sense of functional adequacy? All these are examples of significant relationships which may exist within the given segments of the prosthetic restoration result and which may very well be amenable to study.

In addition to all these possibilities, there remains a fourth type of two-variable analysis, one concerned with the relationships between the various amputee characteristics and data concerning the treatment process. Do amputees with similar occupations, hobbies, and/or recreational pursuits receive similar prosthetic prescriptions, or is the prescribed prosthesis unrelated to these matters and more dependent upon the personal attitudes of the clinic personnel? Are the variations in prescription, training, and checkout procedures based on geographic factors, age of patient, etc.? Relationships such as these are also worth exploring.

There is no question but that a considerable amount of knowledge is to be gained from the segmented type of analytic approach described. But a major limitation and a fundamental weakness is inherent in these techniques. When correlations are limited to no more than two factors at a time, the variables concerned are unavoidably isolated out of the large complex of continuously interacting forces known to exercise control over the final result of prosthetic restoration in any given case. In separating, out of the entire data, pairs of variables that may happen to interest us, we ignore the well-known clinical observation that the whole result of prosthetic rehabilitation is the consequence of a number of simultaneous, interdependent influences. In effect the other factors are treated as "constants" at any given time, an expedient admittedly not in keeping with the facts. Were the data made up of a large number of independent variables (factors independent of other influences in a situation), the difficulty would be less critical. But we find in fact that only comparatively few of the items are truly independent of one another.

Although this limited analytical approach will not provide the ultimate in understanding of the prosthetic restoration process, it will provide information concerning the more salient relationships existing within the data. The technique of two-variable analysis can be carried one last step by combining selected distributions of data in order to develop indices of more general factors in the prosthetic-restoration complex. Data concerning performance on prehension tests, positioning tests, practical-activity tests, and reported use of the prosthesis may, for example, be combined to provide a composite measure of amputee performance. This combination factor

may then be studied in relation to other discrete variables or other composite factors. But before one goes very far along this path he comes face to face with the desirability of attempting a "global analysis."

GLOBAL ANALYSIS

In view of the weaknesses in the two-variable approach, it would seem desirable to be able to explore the interaction of all the various factors, each with the others. That is to say, it would be helpful to be able to gauge the extent to which each factor in the prosthetic-restoration complex affects the others and to determine to what extent the total pattern of interdependence affects the final result. In any such study of interactions of variables, we are of necessity drawn to relatively sophisticated methods in statistics, such as multiple correlation, analysis of variance, and possibly factorial analysis. That analysis by these methods would be completely fruitful is by no means assured. For unless the relationships within the data are reasonably clear-cut, the statistical procedure may not be discriminating enough to bring them to light. Deficiencies in the sampling, weaknesses in the measuring instruments, and other technical shortcomings would also tend to obscure the results.

This known risk notwithstanding, such an effort is clearly worth while and will be undertaken in view of the *possibility* of approximating the significance to be afforded various considerations involved in the prosthetic-restoration potential of an individual. Success in this more ambitious approach would shed light on the relative influence that various factors, within the amputee and within the treatment process, have on the final result. Although it is well understood clinically that not all patient characteristics or all treatment methods influence the final outcome equally, no scientifically validated picture of the relative significance of the causal factors exists to date. From further studies, one might hope to learn what combinations of amputee characteristics and treatment procedures make for the best prosthetic-restoration results and, by the same token, what combinations dictate poor results. An understanding of these matters would permit reasonable predictions as to the probable success of the restorative effort, suggest modifications of the treatment process the better to fit the needs of the individual patient, and make it possible to identify and to grade "optimum" restoration results in any given case.

CONCLUSION

It is clear then that this presentation constitutes an overview of the information evolving from the NYU Field Studies and suggests that a considerable amount of additional data analysis will be required before the available material will have made its final contribution to the field of upper-extremity prosthetics. Many of the remaining analyses are already in process, and it is planned to publish these results as the work is completed. It must, however, be recalled that the NYU Field Study was essentially research "in breadth" and that this approach should not be expected to answer all questions relating to the upper-extremity amputee. For many of the issues needing resolution, research embracing the study of individual cases "in depth" will be required. Meantime, it is in order to express appreciation for the singular opportunity of studying such a large group of upper-extremity amputees. Because of the nature of the disability associated with arm loss, it usually is very difficult to gather large numbers of arm amputees in any one location, and it is almost impossible to be able to subject such a group to a systematic pattern of treatment. Although it would be gratifying if it could be said that the most had been made of the unusual opportunity afforded, afterthought and hindsight tell otherwise. Unfortunately the problems of research into the unknown do not cast their shadows before, and the path to discovery remains exceedingly narrow. Until better methods of dealing with the complicated manifestations of the human being become available, we must be content with studies and analyses that can shed even small light on the challenging problems of prosthetic restoration.

Staff Participation

IN THE planning, operation, and reporting of the NYU Upper-Extremity Field Studies (1953-56), a number of members of the professional staff of the Prosthetic Devices Study fulfilled certain specific supervisory responsibilities, although they participated, on one occasion or another, in all phases of the program. Listed with their particular areas of major interest, they were:

SIDNEY FISHMAN, Project Direction
EDWARD R. FORD, Technical Coordination
NORMAN BERGER, Instrument Development
HECTOR W. KAY, Data Collection
EDWARD PEIZER, Data Collection
EARL A. LEWIS, Data Reduction

The following additional members of the staff participated in the development of instruments, collection of research data, analysis of data, or preparation of reports:

HAROLD BERKOWITZ
GAVIN CARTER
BARBARA DUNSKY
WALTER GOODMAN
MARSHALL A. GRAHAM
MORRIS KRANSDORF
SIMON LEVIN
BERTRAM D. LITT
THEODORE MARTON
SANFORD SHER
ADELE SHUCHATOWITZ
JEROME SILLER
SYDELLE SILVERMAN
WARREN P. SPRINGER
SIDNEY TOABE
PIERRE VENTUR
BRENNAN C. WOOD

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