Chapter 17

A Decision-Analytic Approach to Audiological Rehabilitation

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The approach outlined in the present chapter treats rehabilitation as a programmatic activity based on carefully-designed strategies that comprise diagnostic and therapeutic acts linked by decision rules. Decision analysis is a powerful method that can be applied to the development and evaluation of optimal strategies in the provision of diagnostic and therapeutic rehabilitative services for individuals or client groups. The application of a decision analysis paradigm requires the use of a clear conceptual framework as well as models for both clients' problems and rehabilitation processes. In the present chapter the scheme proposed by the World Health Organization is explained and speculative models of the client predicament and rehabilitation process are presented. The concepts, methods, and data requirements of decision analysis are described. Finally, some issues related to the application of decision analysis to audiological rehabilitation are examined and implications for further research are identified.

INITIAL REMARKS

Adult audiological rehabilitation faces unprecedented sociopolitical and scientific challenges. The response to them will affect the scope and quality of clinical services, as well as the evolution of the audiology profession. Political pressures arise from chronic issues of professional territoriality, but more importantly, they now arise from a remorselessly growing emphasis on accountability and cost control in health services. In this climate of evaluation and rationalization, practices that are not defensible on both effectiveness and cost-efficiency grounds are difficult to fund. In the corridors of health administration and policy-making, the buzzword is *quality,* while the holy grail is cost-containment.

Audiological rehabilitation at large would not fare well under the scrutiny of health services evaluators. There is much variation in practices, clinical goals are fuzzy, there is little professional consensus about what the ideal process should be, and what actually does happen is frequently inconsistent and unstructured. The quality of both the process and the outcome are usually unknown and are governed by the skills and attitudes of individual providers, which vary greatly.

Our scientific challenge is to formulate rehabilitation goals and outcome measures that are explicit and quantitative, and to define care processes that are explicit, structured, and consistent. This should facilitate the provision of more accountable and defensible rehabilitation services.

Challenge is opportunity. To exploit it, some adjustments in training programs, clinical practices, and research directions will be needed. It will be necessary to deal with issues and measures that relate to the client as a functioning whole, rather than to maintain a narrow focus on audiometry and hearing aid prescription. This broader, client-centered approach has many advocates (e.g., Giolas, 1990; Hull, 1992; Riko & Alberti, 1988; Stephens & Hétu, 1991). Not only is it an avenue to improved quality of care, but a strong case can be made on cost and expertise grounds for the audiologist to assume the key role in planning, coordination, and delivery of the required care. This is a crucial professional evolution.

In this chapter, our aim is to outline a viewpoint and an approach that may facilitate some research and development needed to respond to the challenges just outlined. We will also try to identify some of the key research issues that must be addressed. Our starting point is to step back and consider audiological rehabilitation as a health service process. Concepts and procedures that may be useful for this are available in three domains: Health Services Programming, Clinical Decision Analysis, and the World Health Organization (WHO) conceptual framework and terminology related to impairment, disability, and handicap.

Principles of health services program design and evaluation embodied in the management philosophy of Continuous Quality Improvement (CQI) relate closely to the socioeconomic health services environment in which audiological rehabilitation must now evolve. Program Evaluation is a quantitative approach that facilitates Continuous Quality Improvement, and can reveal many of the steps needed to improve program design and implementation. Clinical Decision Analysis is a methodology that offers useful concepts and techniques for program development and evaluation. Lastly, any health service program should be grounded in a conceptual framework that governs goals, structure, and outcome measures. The WHO scheme seems to be the most useful to date. Major points in each area will now be outlined, and the reader is urged to consult the references for further depth and detail.

CONTINUOUS QUALITY IMPROVEMENT

Continuous Quality Improvement (Total Quality Management) is an approach that has produced some dramatic performance gains and economies in the corporate world and is now being espoused widely in health care and other human services areas. Frattali (1991) stressed the importance of accountability and quality improvement issues and tools, at this time of rapid evolution in the audiology profession.

Continuous Quality Improvement stresses sustained efforts to evaluate and improve performance, by everyone involved in service provision, in every facet of the delivery system. It is a constant philosophy, not a one-shot quick fix. It is guided by client-based quality criteria, for service processes and outcomes, and is driven by client expectations, needs, and satisfaction. It adopts a broad definition of quality, embracing clinical outcomes, consumer values, and cost-efficiency measures.

The basic messages are simple: *the goal is the highest possible quality of care; the consumer is the ultimate arbiter of what quality is and how to achieve it; the total process and all the outcomes of care require constant evaluation and improvement.* The most significant implications for audiological rehabilitation arise from the clear focus on care quality; the primacy of the client with respect to the design and evaluation of the individual plan of care, which is a clear departure from technology-driven or authoritarian care models; and the emphasis on explicit evaluation processes as an integral and ongoing part of service programs.

PROGRAM EVALUATION

Program Evaluation is an established body of quantitative methods to examine the implementation and outcomes of many types of program, including those in health care. For an introduction, see Rutman and Mowbray (1983). Applied appropriately, as part of continuous program assessment, the methods of Program Evaluation are an important aid to Continuous Quality Improvement.

Any program can be conceptualized as a goal-directed matrix of component activities or processes, with various objectives, linkages, and outputs, all of which serve the overall program goals. A key feature of the Program Evaluation approach is a highly integrated, macroscopic view of service provision; this programmatic view recognizes the interdependency of many variables and procedures within any program, and the importance of a clear understanding of the care process elements and their conceptual and procedural relationships. The point is that a program is an interconnected organism the function of which is governed by its weakest link; many components of a program can be functioning very well, yet the whole can fail miserably. Some trivial examples of this are: a technically first-class hearing aid fitting to a client exhibiting covert problem denial, or provision of appropriate assistive devices in a residential care setting, without ensuring continuity of relevant supplies and support personnel training.

The programmatic view is vital because it forces consideration of a *complete* process and its context, which may not be obvious. Delivery of truly effective health care requires this larger view, encompassing target population definition, client intake criteria and access, through long-term management, multi-faceted measurement of outcomes, and discharge criteria. One implication is that outcome measurement must reach beyond ordinary clinical criteria, into lifestyle and quality of life areas.

The prime concerns of Program Evaluation are program implementation (processes) and impact (outcomes). The kind of questions addressed are: Are the program objectives clear? How is the program being carried out? Is the implementation as prescribed? Is the target population being reached? What are the outcomes and do they satisfy the objectives? Could the program be delivered more effectively?

Initial steps in Program Evaluation involve complete program description and modelling. This exercise seems simple, but often turns out to be both difficult and revealing. Common deficiencies revealed include:

1. Vague or unrealistic program objectives.
2. Poor definition, requiring elaboration for proper implementation.
3. Failure to adhere to prescribed procedures.

4. Conflict of actual or perceived objectives or priorities between the various component parts of an overall program.
5. Unintended and unwanted side-effects.

The primary themes of Program Evaluation are clarity of definition and validity of measurement, with respect to program objectives, procedures, and outcomes. This is an elaborate way of saying: *know exactly what it is you want to achieve, exactly how you are going about it, and know quantitatively whether you are succeeding.* The significance and implications of this simple message depend on how seriously it is taken.

DECISION ANALYSIS

A useful view of audiological rehabilitation is as a goal-oriented and structured sequence of measurements, decisions, and actions. It is essentially a decision problem. Because of many sources of variation in measurements and in response to therapies, and limited understanding of relationships between audiological, psychological, and behavioral variables, the clinical decisions are usually taken under conditions of uncertainty. Decision analysis is a technique specifically oriented towards clarifying problems of decision-making under uncertainty.

Here, we borrow from a sourcebook by Weinstein and Fineberg (1980). Other useful texts are by Sox, Blatt, Higgins, and Marton (1988), and Sackett, Haynes, Guyatt, and Tugwell (1991). See Hyde, Davidson, and Alberti (1991) and Turner (1991) for an account of basic principles and examples of decision analysis in diagnostic audiology.

Decision analysis is a systematic approach that is explicit, quantitative, and prescriptive. Its usual goal is to prescribe a specific course or strategy of management that has a quantitative, rational basis. It is most often used to identify the best diagnostic or therapeutic strategy within a set of alternatives, especially when the problem is complicated and the best course is not obvious. It can be applied to populations, subgroups, or individuals, and to entire programs or specific components.

The early stages of applying decision analysis to a specific problem are essentially descriptive, involving a careful dissection of procedural options, measures of client state, and reasons for clinical decisions. This examination is usually very useful in itself, because it involves making explicit and quantitative all those facets of client management that may be implicit and qualitative, or even hidden. This process usually reveals important assumptions, areas of confusion, or lack of knowledge, which in turn can be a rich source of hypotheses for clinical research. The process also clarifies thinking about program organization, and helps to break down complicated problems into more manageable subproblems.

Decision analysis can be applied equally well to evaluation of diagnostic or therapeutic strategies. We view audiological rehabilitation as a blend of diagnosis and therapy. Therapeutic outcome can be diagnostic, and the diagnostic process can be therapeutic. Here, we use the term "diagnosis" broadly, defining a diagnostic act as: any act that categorizes the client with respect to choice of therapy or its probable outcome. We also adopt a broad definition of a "test" as: any measurement process giving information that may alter management or outcome probabilities. With this viewpoint, even informal observations or questions to the client can be treated and analyzed as tests. Thus, audiological rehabilitation is a system of interlinked management acts, of one kind or another, all of which are in principle amenable to a decision-analytic approach.

To some, the structured and quantitative nature of the decision-analytic approach is natural, and its results may reflect what already happens, or should happen, at an intuitive level. To others, decision analysis may seem pedestrian or misguided in its dissection of what may be an art. While acknowledging the inherent complexity of rehabilitation, the many idiosyncracies of the individual client, and the immaturity of many of our current concepts and measures, we believe that at least in the context of frontiers of investigation, *it is important and potentially useful to subject audiological rehabilitation to the rigors of decision analysis.* In fact, we believe it is essential to do so, in order to develop rational and consistent clinical protocols that can be evaluated. Note that "consistent" does not mean "invariant"; a protocol can take account of client idiosyncracies yet conform to constant, structural, logical rules.

The Decision-Analytic Method

The approach entails four main stages:

1. *Describe the decision problem.* This includes clear specification of the goal that the decision problem addresses, identification of the alternative actions that may be taken with respect to therapy or to obtaining new information, elucidation of the possible states of the client at any point, and if appropriate, enumerating other aspects such as economic costs.

2. *Structure the decision problem over time.* Definition of a logical structure that connects various events and states, identifying choices and outcomes in their correct temporal sequence. The result of this is a *decision tree,* one of the major tools of decision analysis. A decision tree identifies all pertinent possibilities for action and client state, and is distinguished from a protocol tree, which prescribes a specific strategy. Protocol trees are an important outcome of decision tree analysis.

3. *Quantify uncertainties and valued outcomes.* For each action or client state in (1), the decision maker must understand the factors causing uncertainty, and quantify them as accurately as possible; preferably, numeric probabilities are assigned to the various alternatives identified in the tree. Secondly, the decision maker must assign numeric values to the outcomes at various points in the tree. The outcomes may reflect "diagnostic" measurement values, or possible quantitative responses to therapeutic acts.

4. *Determine a preferred course of action.* This involves pruning the decision tree to eliminate courses of action that are inappropriate or inferior to others.

Often, the process of steps (1) through (3) may suggest the best strategy, but it is customary to invoke an *expected-value* procedure, using a combination of probabilities and outcome values to identify the strategy that has the highest statistically expected value of the desired outcome.

Developing Decision Trees

The decision tree highlights the alternative actions of the decision maker, the measures or situations that precipitate or arise from those actions, and actual states of the client at various stages in the management process. A generic tree diagram is shown in Figure 1. The temporal flow is from left to right. The squares are *decision nodes* or *choice nodes;* they denote points at which choices are made that are under the control of the decision maker, such as to take a measurement or not, or to apply a specific therapy or not. A decision node need not branch, if only one option is clearly indicated. The circles are *chance nodes,*

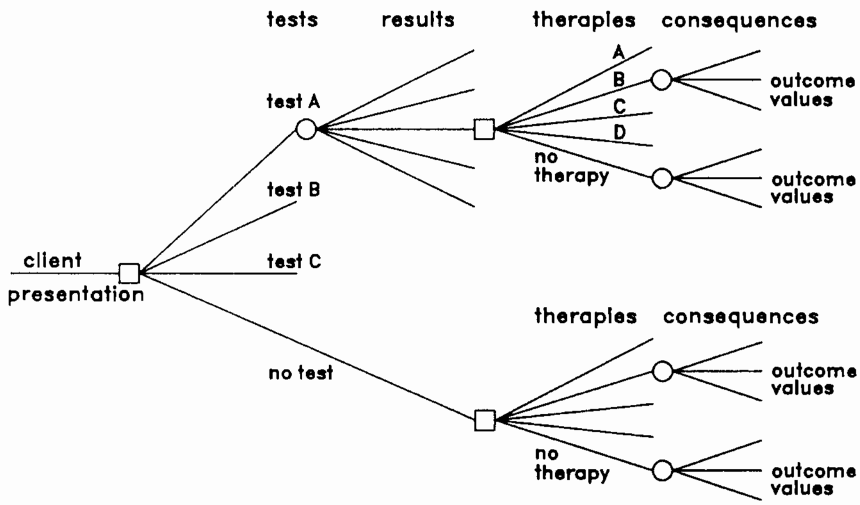

Figure 1. A generic decison tree. The client or group of clients enters at the left. The squares are *decision nodes,* where optional actions under the direct control of the decision-maker (rehabilitationist) occur. The circles are *chance nodes,* where events beyond the control of the decision-maker occur, such as client or group response to tests or to therapies. Audiological rehabilitation strategies (processes) comprise various sequential combinations of tests and therapies (including no test or no therapy, at any point in the sequence). The tree shown is only illustrative, in the sense that in real strategies, therapies may be followed by further tests, followed by further therapies, and so on. In principle at least, the decision tree can express all test-therapy combinations of potential interest. Every combination ultimately terminates on the right in some final consequence of therapy, and some associated value of each possible ultimate outcome. Based on *Clinical Decision Analysis* by M.C. Weinstein and H.V. Fineberg, 1980, Philadelphia: W.B. Saunders Company. Copyright 1980 by W.B. Saunders Company.

denoting points at which various situations that are not under the control of the decision maker are considered. The tree ramifies to the right, ending in terminal chance nodes from which several alternative final outcome states of the client are listed. These states may reflect a single client attribute, such as functional performance in a specific situation, or may incorporate multiple attributes.

There is no limit to tree complexity, but trees often contain repeating structures, which makes them look more complicated than they really are. Special care must be taken regarding the sequence of choice and chance nodes. In particular, the sequence must reflect the actual process that occurs; a common error is to incorporate chance nodes prematurely, detailing outcomes or client states that would not be known at that juncture in the process.

Figure 1 suggests that as well as helping to clarify the decision process by making it explicit, decision trees address two basic questions: is one therapeutic option better than another, and is gathering specific information useful or not? The acts of gathering information and making decisions based upon it can be combined into strategies, and the analysis evaluates the strategic outcomes comparatively.

Analyzing Decision Trees

Formal tree analysis requires assignment of numeric values to the outcomes of all the terminal chance nodes (see Figure 2). In the simplest case, only two outcomes are distinguished, such as correct or incorrect, success or failure. These are assigned arbitrary numeric values, usually 1 and 0; merely to discriminate two outcomes, the actual values do not matter. In more complicated situations with more than two outcomes, non-arbitrary numeric values called *utilities* must be assigned. This can be done by the decision maker, but utilities usually incorporate, or are based on, the preferences of the client for the various outcomes. This reflects the crucial role of the client's priorities and values, which is appropriate in any client-centered scheme.

Utilities can be regarded as numerical ratings of preference, such as might be obtained by asking the client to rate the value of each outcome on a line that has zero and unity as endpoints. Indeed, simple rating scales can be used to yield approximate utilities. However, to function correctly in the tree analysis, utilities are best derived by a procedure that incorporates probability, or risk. Suppose we want to assign utilities to three rehabilitation outcomes: a return to normal hearing function, no effect on pre-therapy function, and some other performance such as "normal function except for speech recognition in noisy surroundings." The first two are assigned utilities of 1.0 and 0.0, respectively. To determine the utility of the third option, a method known as a *standard gamble* is used. The client is given two choices: a guarantee of the condition with unknown utility, and a gamble between "normal" outcome with probability p or the "no effect" outcome with probability $(1 - p)$. The value of p is altered until the client finds the two choices equally desirable (or undesirable); this is the indifference point, and the value of p then equals the unknown utility. For

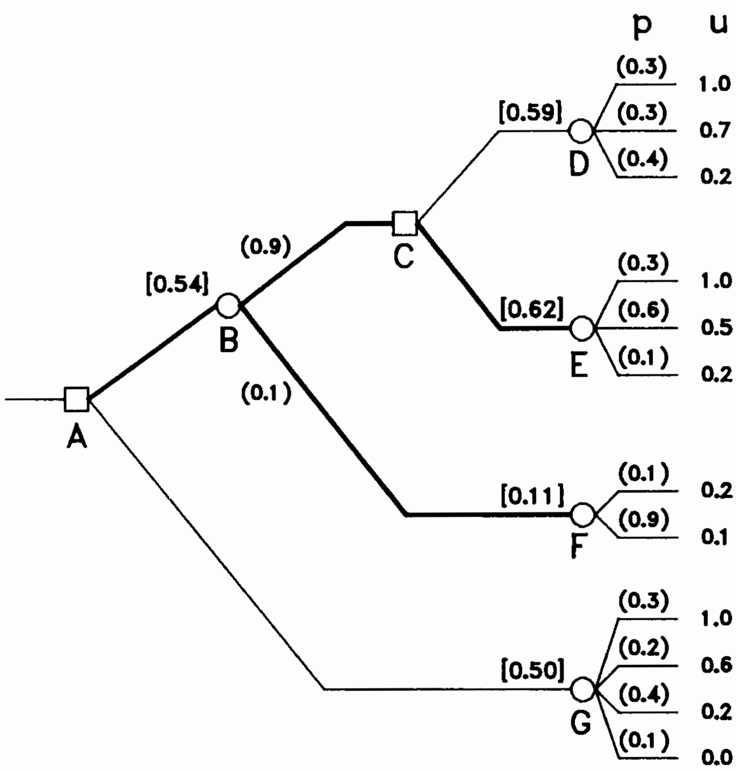

Figure 2. A decision tree example. At decision node A the client (group) may receive some specific therapy (such as a hearing aid and counselling, lower path AG) leading to four possible outcomes at chance node G, each with some associated outcome utility value (u) and probability p (in round brackets). The values chosen are merely illustrative. Alternatively, the client(s) receives a "diagnostic" test (e.g., a screening self-report handicap questionnaire, upper path AB); if the test is "passed," which happens with probability 0.9, say, at decision node C the client goes on to one of two therapies (such as simple hearing aid provision or hearing aid provision combined with formal communication strategies training) leading to chance nodes D and E respectively. "Failing" the test at node B leads to no therapy or deferral of therapy. The figures in square brackets are the *expected utilities* associated with each chance node. Starting at the terminal chance nodes (D, E, F, G), the expected utility for each chance node is the sum of its outcome utilities multiplied by their respective probabilities. Working back to the left, known as *folding back,* leads to a choice of the therapy with the higher expected utility [0.62] at node C. At chance node B, the expected utility for the AB branch is then in turn computed by multiplying path probabilities for BCE and BF by their associated (expected) utilities. Finally, at decision node A, the strategy (bolded) with the highest expected utility is chosen (ABCEF). This illustration indicates that it is better to start with the diagnostic test, defer rehabilitation in those who fail the test, and give the more extensive therapy to those who pass.

an introduction to preference measurement, see Sunnybrook Health Sciences Centre, Toronto (1992); for detailed exposition, see Froberg and Kane (1989a, 1989b).

The other quantity required for tree analysis is the probability of each alternative branch from any chance node. These can be derived from high-quality published reports, if they describe relevant situations and populations. If several such reports are available, meta-analysis is appropriate, to derive more accurate probability estimates. See Hedges and Olkin (1985) for an introduction to meta-analysis. If suitable probability reports are not available, subjective probabilities may be assigned by an expert panel, a client panel, or by the decision maker. A prospective study or retrospective survey may also be useful.

The probabilities associated with every chance node must sum to 1.0. Starting at the terminal chance nodes, the probabilities and utilities of each outcome are combined, yielding an *expected utility* for each node. In the special case of binary outcomes, the probability of each outcome can be used directly as the utility value for that outcome (Sox et al., 1988). In general, expected utility is the sum of utilities weighted by their probabilities; readers with statistical training will recognize this as the mathematical expectation of utility. Expected utility for a terminal chance node can be considered as attached to the path to that node. If a terminal node is preceded by another chance node, the *path utilities* and probabilities for that node, in turn, can be combined to give new expected (path) utilities. This way of working back through the tree, from right to left, is known as *folding back*.

At any decision node, the various path utilities that exit from that node are used to decide among the decision options. Logically, the path with the highest expected utility is selected. This is *pruning,* and the fully-pruned decision tree defines the protocol for the preferred management strategy. This process is illustrated in Figure 2.

Having selected the preferred strategy, it is essential to test whether the conclusions of the analysis hold when path probabilities and outcome utilities are altered. This *sensitivity analysis* is an important technique for determining the stability and generality of decision-analytic inferences. It is also useful for testing the validity of conclusions based on the use of approximate utilities, such as arise from use of simple rating scales (i.e., without standard gambles). In sensitivity analysis, the probabilities and outcome values are treated as variable parameters, and the conclusions redetermined for various parameter combinations. This can be done for only small perturbations of the original base values, or for a wide range of parameter combinations, treating the decision outcome as a categorical regression function of the parameters.

If the choice of optimal strategy is very sensitive to small changes in utilities or probabilities, then its statistical basis is weak. This usually reflects alternative paths having similar expected utilities, in which case factors such as convenience or cost may dominate. If no such factors matter, the strategy with the highest expected utility is the appropriate choice, regardless of how small the differences in expected utilities are.

Many people have at least initial difficulty with either the concepts or the procedures of assigning precise numeric values to probabilities and especially to client outcome states. Sensitivity analysis often reveals that the preferred strategies do not depend on very exact values. *The key point is that clinical management decisions are being made, with or without formal decision analysis. Those decisions are either essentially random, which nobody will admit, or must in fact be based upon implicit probability and utility assignments. No matter how difficult the process may seem, it is in the interests of care quality to replace such covert assignments with explicit values that can be scrutinized scientifically.*

THE WHO SCHEME

Continuous quality improvement, program evaluation, and decision analysis all require a coherent conceptual framework and appropriate terminology, with which to describe both the situation faced by persons with hearing disorders, and the health care processes that are needed. We require a sophisticated model of chronic disease impact and a precise, comprehensive, and widely-accepted terminology. The model and the terminology go hand-in-hand. Terminology is much more than labels; it reflects and affects its underlying constructs, and it provides the vehicle for debate and research. Giolas (1990), Schow and Gatehouse (1990), and Stephens and Hétu (1991) have all stressed the need to adopt clear and generally agreed definitions and terminology.

The WHO (1980) published an analysis of issues in management of chronic disease; a conceptual model; a terminology defining and relating impairment, disability, and handicap; and a generic classification scheme for these variables. This was adapted by Duckworth (1984) and first applied to the area of hearing dysfunction by Davis (1983, 1987).

WHO Conceptual Model and Terminology

The traditional, medical model of disease can be summarized as:

etiology > pathology > manifestations.

This promotes a view of pathology as an entity in isolation from the affected individual as a whole, a view that has limited relevance for chronic, progressive, and irreversible diseases that have a complex set of influences, often subtle yet profound, upon self-image, societal role sustainment, and quality of life. The WHO modification is:

Disease or disorder > Impairment > Disability > Handicap

The usual chain of events is that first, something abnormal occurs in the individual. This is the domain of etiology, pathology, and disease manifestation. Next, someone becomes aware of the occurrence. This is exteriorization of the pathology, in terms of changes in structure or function *at the organ or system* *level,* and is the domain of impairment.

Definition: An impairment is any loss or abnormality of psychological, physiological, or anatomical structure or function.

Impairment is a deviation from a norm. It can exist in the absence of active disease, and may not be perceived by the individual. Because it concerns functions of individual parts of the body, it tends to be an idealized construct. Puretone hearing loss is an impairment measure.

Next, functional performance or behavior may be altered, either directly due to the impairment or mediated cognitively. This is "objectification" of the impairment, and resulting deviations from the norm are disabilities.

Definition: a disability is any restriction or lack (resulting from an impairment) of ability to perform an activity in a manner or within the range considered normal for a human being.

WHO disability relates to *compound or integrated activities expected of the person or body as a whole,* as distinct from the organ or system level. It reflects actual functional limitation in real life, in contrast to the absolute, idealized constructs of the impairment domain. It follows that measures of disability will usually be subjective. Difficulty understanding speech in a noisy environment is an example of a disability.

Next, the awareness of disease or the altered status or performance may place the individual at a disadvantage relative to others: this is "socialization" of the impairment or disability. It includes attitudinal aspects such as stigma. This is the domain of handicap.

Definition: a handicap is a disadvantage for a given individual, resulting from an impairment or a disability, that limits or prevents the fulfillment of a role that is normal (depending on age, sex, and social and cultural factors) for that individual.

Handicap is intrinsically a social phenomenon, relating to *disadvantages experienced through interaction with and adaptation to the environment.* Its key feature is that a negative value is attached to deviation from a structural or functional norm, by the individual or by a peer group. The valuation reflects cultural norms, so time, place, status, and role all contribute. The disadvantage may be experienced in at least three ways: by the affected individual, by significant others (e.g., as a result of another's disabilities), and by the community as a whole. This is a problematic issue for the definition and quantification of handicap, and further research is required.

There is not always a simple progression from impairment to handicap. Impairment may not cause disability, and disability may not cause handicap, if the performance decrement is compensated (e.g., by others) or if it is of no importance to the individual and the peer group. Handicap can arise directly from impairment, without intervening disability (e.g., response to cosmetic disfigurement). Therefore, for any given individual, there can be large differences in the amount of departure from norms for the three types of variable.

Some disabilities promote, retard, or conceal the development of other dis-

Table 1

WHO Classification of Impairments, Disabilities, and Handicaps

A. Major Domains

Impairment (organ/system level)	**Disability** (personal activity level)	**Handicap** (social role level)
1. Intellectual	1. Behavior	1. Orientation
2. Other Psychologic	2. Communication	2. Physical Independence
3. Language	3. Personal Care	3. Mobility
4. Aural	4. Locomotor	4. Occupation
5. Ocular	5. Body Disposition	5. Social Integration
6. Visceral	6. Dexterity	6. Economic Sufficiency
7. Skeletal	7. Situational	
8. Disfiguring	8. Particular Skill	
9. Generalized		

B. Specific Auditory-Related Disability Subdomains[a]

Primary Disabilities	**Secondary Disabilities**
Localization in space and time	Social presentation
for example, self, others, events, objects	Personal safety
Identification	Situation comprehension
for example, persons, events, objects	Situation interpretation
Listening to speech	Situation coping
Listening to nonspeech	Knowledge acquisition
Noise tolerance	Household activities
	Affective relationship (partner)
	Parental role
Ancillary Disabilities	Other family role
Detailed visual tasks	Social cooperation
Lipreading	Motivation to work
Nonverbal cues	Work seeking
	Work routine
	Work performance/output
	Recreation
	Crisis conduct
	Speech comprehension
	Speech production

[a]The labels "primary," "secondary," and "ancillary" are our own.

abilities and handicaps. Also, the causative chain may reverse; for example, a handicap in social interaction may lead to withdrawal and isolation, which in turn may exacerbate a speech recognition disability or lead to collateral social disabilities mediated by emotional states.

WHO Classification Scheme

The WHO scheme has three classification systems for client state description, relating to the domains of impairment, disability, and handicap. Major categories in each domain are shown in Table 1 (Part A); they reflect the conceptual underpinnings, moving from the organ/system level for impairment, through a factoring of everyday composite activities, for disability, to major role areas, for handicap. A detailed list of some of the WHO disabilities that may be caused by hearing impairment is also given in Table 1 (Part B).

In the handicap classification (Table 1, Part A), the WHO designated six basic societal roles, reflecting a transcultural scheme covering a wide range of diseases and not restricted to industrialized societies. However, the six roles actually cover most of what is crucial in daily activity, even in so-called affluent societies. A seventh handicap dimension ("Other") may include specific disadvantages that reduce quality of life.

Severity and Outlook Scaling

The WHO scheme includes a grading system for severity. For disability and handicap, response to intervention and outlook (prognosis) are also incorporated into the classifications. The basic WHO scheme needs refinement, in order to be sensitive and specific enough to quantify audiological rehabilitation outcome properly.

Significance of the WHO Scheme

The scheme includes definitions of terms, concepts about how the components of reaction to disease develop and inter-relate, and specific category labels and severity scales. These all facilitate the precise formulation of rehabilitation program goals, objectives, and outcome measures, and also clarify appropriate directions, approaches, and design elements in research.

The concepts in the WHO disease response model are also useful in developing conceptual models of the client predicament, that is, models that identify specific impairment, disability and handicap elements, their relationships, and their temporal evolution. This in turn clarifies the appropriate problem-solving sequence and the potential contribution of various service program components. The scheme helps to identify the evaluative studies that are required, and offers a more rational basis for study of the determinants and outcomes of health system contact.

The WHO scheme has its critics, but has gained quite wide acceptance, especially in Europe. An obvious difference between WHO terminology and proposals by the American Academy of Otolaryngology (AAO) (1979) and American Speech-Language-Hearing Association (ASHA) (1981) concerns disability, a term that in the U.S. relates exclusively to employment and financial compensation. Along with Stephens and Hétu (1991), we believe much will be gained by adopting the WHO definitions, partaking in a non-parochial scheme that applies to a wide range of chronic diseases. A disparate, specialized terminology obstructs communication between rehabilitation domains. Giolas (1990) indicated a need for refinement of terminology, which we endorse, but we find the

WHO definitions clear, unambiguous, and richer in meaning than the AAO/ASHA concepts. For example, sensorineural hearing loss is not a disorder, but a measure of impairment. AAO/ASHA disability is clearly one, specific component of WHO handicap. Note also that the term "hearing handicap" makes little sense in the WHO scheme (Stephens & Hétu, 1991); we might be more careful, and talk about "social integration handicap" attributable to hearing loss, for example. Refinements in terminology lead to re-evaluation of familiar phrases.

While it is too soon to comment upon the ultimate utility of the WHO scheme, it seems inherently reasonable to distinguish three core domains or planes of disease consequence, namely impairment, disability, and handicap. Some analytic studies support the distinction of these domains (Gatehouse, 1990; Lutman, Brown, & Coles, 1987).

The WHO scheme needs improvement, especially regarding distinction between certain disabilities and handicaps, and the role of disabilities precipitated by other disabilities. Stephens and Hétu (1991) consider handicap to include all "non-auditory" consequences of impairment, but in our view social withdrawal, for example, might be conceptualized better as reflecting a "secondary" disability in relations, probably leading to social integration handicap. Debate of such issues is not necessarily sterile, but can be important for the evolution of better conceptual models of handicap development and management.

A CLIENT PREDICAMENT MODEL

To develop a decision-oriented, structured approach to audiological rehabilitation, a conceptual model of the rehabilitation process is essential. A prerequisite for this is a model of the client "predicament" itself, because the structure of rehabilitation is surely governed by the nature of the client's problems and the mechanisms by which they develop. The term "predicament" is borrowed from clinical epidemiology and refers to the sum of all pertinent aspects of client state and situation, including disorders, impairments, disabilities, handicaps, environments, demands, resources, attitudes, behaviors, and so on.

There are few examples of appropriate predicament models in the audiological rehabilitation literature. Davis (1987) outlined a useful model that is epidemiologically oriented. Hétu, Riverin, Lalande, Getty, and St-Cyr (1988) and Stevens and Hétu (1991) addressed important aspects of client response to hearing impairment. In their development of the Communication Profile for the Hearing Impaired, Demorest and Erdman (1987) identified many facets of predicament variables and issues in measurement. Gatehouse (1990) approached some aspects of predicament modelling through statistical analysis of the determinants of self-reported disability and handicap. Nevertheless, much further research effort here is needed in order to understand fully the nature of the client predicament and its implications for rehabilitation processes.

The WHO scheme offers a foundation for analysis of predicament, and sug-

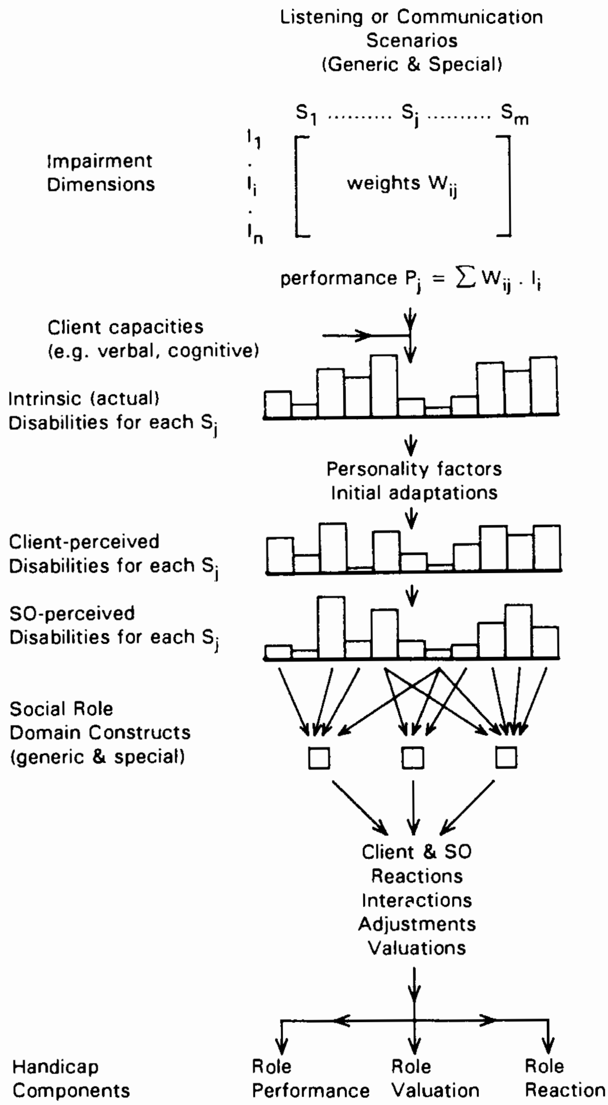

Figure 3. A speculative model for the development of the overall predicament of a client with impaired hearing, based on an adaptation of the World Health Organization model of chronic disease consequence. Various facets of hearing impairment (such as decrease in sensitivity or in frequency, temporal, or spatial resolution) have different importance, reflected as weighting coefficients, in various generic or client-specific real-world scenarios that impose listening or communication demands. Disability is reflected in functional performance in each scenario, normalized as a proportion of normal function, in the range (0-1). It is a weighted sum of impairment effects, modified by internal capacities of the individual. The client and significant other (SO) may have different

perceptions of each and every component of the actual, intrinsic disability array. WHO handicap reflects disadvantages in relation to key social roles of individuals. Roles can be constructed from sets of demand scenarios. The response to perceived deficiencies for various generic and special roles leads to the handicap components.

See text for a more detailed explanation.

gests many facets of an appropriate model. A crude, speculative example of a predicament development model is shown in Figure 3. The Figure shows elements in the impairment, disability, and handicap (I, D, H) domains. These domains are important, dynamic aspects of a client's predicament, that is, their elements can interact and evolve over time, spontaneously or in response to external events and processes. Figure 3 focusses on only a few elements of the early stages of predicament development relating to chronic, progressive sensorineural hearing loss. Perhaps even more important than the I, D, and H elements themselves are the processes that relate them. What exactly are the mechanisms that transform I into D, and D into H? What are reasonable labels for these transformations? Once identified, do the transformations provide clues about desired rehabilitation procedures? The main elements of our highly speculative predicament model are as follows:

1. An individual is routinely faced with real-life situations or scenarios that pose hearing or communication demands. There are many scenarios, some of which are generically important, and the WHO scheme suggests some of these. Other scenarios may be special to any given individual, relating to particular skills or interests.

2. The individual has a progressive disorder, some aspects of which are measured clinically, through common measurements of impairment, such as puretone sensitivity and speech recognition. These are not necessarily the most crucial aspects of auditory function, nor do they reflect unitary or independent phenomena. They are merely the measures that currently we regard as fundamental, rightly or wrongly.

3. Impairments "operate" on scenarios, to generate performance. Various facets of impairment may differ in importance for each scenario; for example, performance in a non-speech detection scenario might depend more on thresholds than on discrimination. The contribution of each impairment facet to each scenario could be expressed as a weighting, and the whole situation can be conceived as a matrix.

4. Performance depends on more than scenarios and impairments; it is affected by several factors that we will call "capacities." Some individuals might have, for example, sensory reserve that is not tapped in the classical impairment measures. Other relevant variables and capacities may include cognitive or verbal skills (see, e.g., Johansson, Ronnberg, & Lyxell, 1991), intellectual function, behaviors, attitudes, experiential base, age, and so on.

In conjunction with impairments, the capacities "produce" performance for each scenario. The performance can be expressed as a disability fraction, relative to a societal performance norm. We call the result of this "actual disability," which may differ (or be zero) for each scenario.

5. At some point, any element of actual disability may be perceived by the individual, leading to a self-perceived disability array. Because communication is usually a two-way affair, others' perceptions are important, and we define another disability array perceived by significant others. The two arrays generally will not correspond element-by-element (Chmiel & Jerger, 1993), nor will either of them necessarily correspond to the intrinsic disability array. Also, there may be a zero-disability percept for any scenario, by any party, for any level of actual disability.

6. The affected individual and significant other may adapt to any perceived disability element. For example, the individual may exert extra effort to sustain acceptable performance for some scenario. The significant other may alter behavior, such as by avoiding some scenarios because of frustration. There may be positive or negative interactions.

7. The scenarios contribute in varying amounts to fulfillment of major social roles, such as those defined by the WHO scheme. Roles can be conceptualized as weighted combinations of scenarios. For each role, the combination of the important expressed disability components leads to a net performance in that role. The perceived lack of role fulfillment precipitates a valuation reaction in the affected individual and the significant others. There may be negative reactions such as deterioration of self-image, depression, withdrawal, or anger, as well as positive reactions, such as adoption of effective compensatory strategies or seeking intervention. The overall results determine the ultimate nature and level of handicap expressed for each role.

The client predicament is not static but evolves dynamically over time, spontaneously and in response to external events. An obvious example of the latter is institutionalization of an individual living independently; any such change in the demand scenarios and support systems may alter many components of disability and handicap. There are few reports that deal explicitly with these temporal aspects of predicament, but those of Cox and Alexander (1992) and Gatehouse (1992) reveal temporal trends in disability percepts following hearing aid provision.

In Figure 4, speculative time-dependency of impairment, disability, and handicap is illustrated. Some impairment dimension increases slowly over time; many dimensions could be displayed and may not start at the same instant or grow at the same rate. Some time later, disability accrues and grows; in principle, various disabilities could start and grow differently; only two are shown, D1 being detection-oriented, and D2 intelligibility-oriented. The disabilities relate nonlinearly to the impairments and may be non-monotonic, such as due to adoption of initial compensatory behaviors. Handicaps then accrue, with the same general caveats. A possible result of intervention is also indicated; a hearing aid and communication strategies training induce differential responses in the disabilities, with delays due to adaptation and learning.

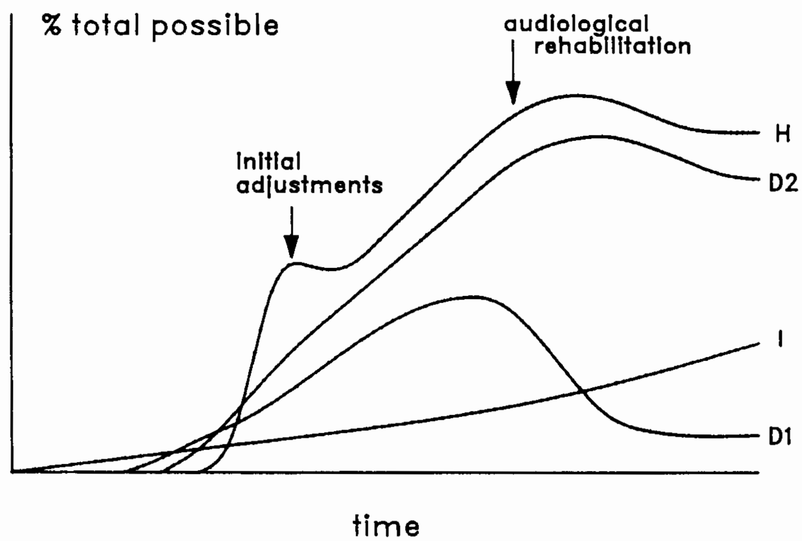

Figure 4. A speculative model of temporally-evolving impairment (I), disabilities (D1 and D2), and handicap (H). For each measure, the y-axis is the fraction or percentage of total possible I, D, or H. The curves are nonlinear. Hearing impairment (I) progresses inexorably over time. Real-life functional disabilities D1 (related to the audibility of non-speech sounds, say) and D2 (related to speech intelligibility, say) arise at different times, may grow in different ways, and may be affected differently by intervention (e.g., provision of a hearing aid). Handicap ((H) arises because of the lifestyle impact of D1 and D2, and may be affected by spontaneous compensatory adjustments as well as by rehabilitation.

In our view, the development of detailed time-series models for the components of client predicament, for the relationships between various elements of impairment, disability, and handicap, and including the seeking of intervention and the response to it, is potentially a very fruitful area for basic and clinical research.

AN AUDIOLOGICAL REHABILITATION PROCESS MODEL

We can now suggest a strategic process model. Again, there are few such models in the literature. The most detailed developments that we know of are given by Alpiner (1993) and by Stephens (1987), and we shall incorporate several features of their approach. See also an interesting predicament/intervention paradigm applied to occupational hearing loss clients by Hétu and Getty (1991). Recall that we are working towards a decision-analytic approach to process evaluation; that approach has diagnostic measurements, therapies, decisions, outcomes, and their linkage rules as its building blocks.

Diagnostic Elements

Many aspects of audiological rehabilitation are actually diagnostic, in the broad sense defined earlier. Measurements having various levels of sophistication are made, and decisions and therapeutic options ensue. Therapeutic outcomes are often expressed in terms of changes in the diagnostic measures.

In audiological rehabilitation, many diagnostic measurements must address psychological or psychosocial variables. An informal probing of client attitude to hearing problems or even to a hearing aid is just as much a diagnostic test as an ABR is in an acoustic tumor workup. Thus, client assessment is essentially a multi-component diagnostic strategy, and standard methodologies such as decision analysis can be used to develop, describe, and evaluate those strategies. The tools include the notions of test variables, decision criteria, false positive and false negative errors, serial and parallel decision rules, likelihood ratios, Bayesian probabilities, and so on (Hyde et al., 1991; Swets, 1988; Turner, 1991).

Many diagnostic elements of the rehabilitation process involve quantifying the client predicament by making measurements of impairment, disability, handicap, the variables that inter-relate them, and a meta-domain: the client's attitude to therapy itself, which can be viewed as part of the predicament.

Therapeutic Elements

The main purpose of diagnostic measurements is to make decisions about therapies. We shall adopt a broad definition of therapy, necessitated by the nature of the chronic disease experience. A therapeutic act is any act that significantly alters the current or future health state of the client. In this context, an act such as "Information Provision," for example, can have a therapeutic effect that is comparable to the provision of an antibiotic for an infection.

A Macroscopic Process Model

At a very macroscopic level, first, the client's predicament must be quantified diagnostically. On that basis, the management plan is formulated and agreed, including specification of goals, specific objectives, and associated outcome variables. The plan is then implemented, and the results are evaluated in terms of the prior objectives, measures, and criteria. The decision criteria for success dictate re-entry into a modified plan, or discharge if satisfied. Three points need emphasis: *assessment of the entire predicament, not just impairment; formulation of specific and verifiable prior objectives; and quantitative evaluation of outcome*. This has many features in common with the "problem-solving model" described by Sanders (1982).

Two more important ingredients influence most stages of our model. First, the process is profoundly client-centered; *the client reveals the predicament, helps to evolve the management plan, and ideally, drives its implementation.* This is the antithesis of the authoritarian approach that has been common in medical-related service delivery. Clients who want to abdicate responsibility may be allowed to do so initially, but every effort is made to empower and involve them, later. Second, *significant others are intimately involved in the process;* rehabilitation in isolation from the client's crucial social unit will rarely be effective and efficient.

A Detailed Process Model

A more detailed, speculative process model is outlined in Figure 5. It reflects some of our notions of service quality, but is not exhaustive; for example, it does not include management of the effects of previous rehabilitation experience. Even so, the process it outlines may seem complicated or impracticable. In fact, however, the experienced rehabilitationist does go through a decision process that is complex, subtle, and multifaceted, and one that leads to complicated flow diagrams. *It is essential to delineate the audiological rehabilitation process explicitly if it is to be understood, evaluated, refined, and disseminated.* The major steps in our suggested process are as follows:

1. Initial exploration of the client's perceived problems and needs. This sets the stage for the client-driven approach.
2. Audiometry to quantify impairment, trigger medical intervention if necessary, and predict (crudely) actual disabilities.
3. Inform client (C) and significant other (SO) about causes, nature, and probable impact of the impairment. This can improve later disability reports, as well as establish therapist credibility.
4. Measure disability, including scenario identification, self-reported disabilities from C and SO, capacities of C, and C/SO adaptations.
5. Integrate impairment and disability data, leading to inference about C's problem awareness and denial.
6. Negotiate and agree with C and SO about expressed disabilities.
7. Measure handicap from C and SO viewpoints, and identify key social roles, role performance, role deficiency valuations, and resultant reactions. Integrate and reconcile these data.
8. Explain the various alternative therapies.
9. Assess denial and counsel to modify denial and motivation, if needed; inform and encourage C/SO, re-evaluate, and defer full rehabilitation in intractable deniers.
10. Formulate a provisional treatment plan, based primarily on C's expressed disabilities and handicaps. Discuss with C and SO the general approach, roles and responsibilities, and expectations about specific therapies.
11. Assess attitudes to rehabilitation, motivation to improve, and degree of buy-in to team problem-solving.
12. Formulate a modified plan, in view of prior discussions and attitude assessment. Negotiate and agree the problem-solving therapy "contract." Agree initial objectives.

13. Start agreed instrumental and adjuvant (non-instrumental) therapies.
14. In the hearing aid process: verify prescription target achievement, measure device management skills, set goals, and make aid/mold modifications as necessary.
15. Communication strategies training and attitude/behavior adjustment therapies (such as taking responsibility, or stress management), and review of related needs and goals.
16. Ancillary services referral, such as for vocational rehabilitation, social work, psychiatric and other medical services. Psychological adjustment counselling belongs here if the audiologist does not have the necessary training.
17. First major followup, 3-6 months after initiating therapies.
18. Review original goals with C and SO, for each area of therapy. Measure disabilities and handicaps by formal subjective report; discuss progress and problems.
19. If initial goals have been achieved, agree further goals. If not, review and adjust the therapeutic plan as necessary.
20. Long-term followup at 1-2 years after starting the therapies. Review original goals and progress with C and SO. If achieved, agree additional goals. If not, review and adjust the therapeutic plan, as needed. Measure satisfaction with process and outcome.

DEVELOPMENT OF THE DECISION-ANALYTIC APPROACH

What has been presented so far helps to define our field of activities in which decision analysis may be applied. Our process model is not a decision tree, but is an example of a process structure from which many decision trees could be built. The overall process model is complicated, and a single, monolithic decision tree covering all important options and outcomes would be unwieldy. However, it is feasible to break down the overall process into subprocesses that can be analyzed individually, if proper account is taken of their inter-relationships. Program components might be defined by grouping subprocesses into thematic clusters, such as "predicament assessment," "attitude management," "goal establishment," "device provision," "supportive counselling," "initial outcome analysis," and so on, and each component may be subjected to decision analysis in order to optimize its design.

Measurement Issues

The suggested process model obviously involves many types of measurement activity. Indeed, measurement lies at the heart of continuous quality improvement, program evaluation, and decision analysis. Quantitative measurement defines program goals and objectives, underlies diagnostic testing, governs decision paths, describes client states, and measurement of outcome is the key to the entire process of optimizing management strategies. Now, we will examine

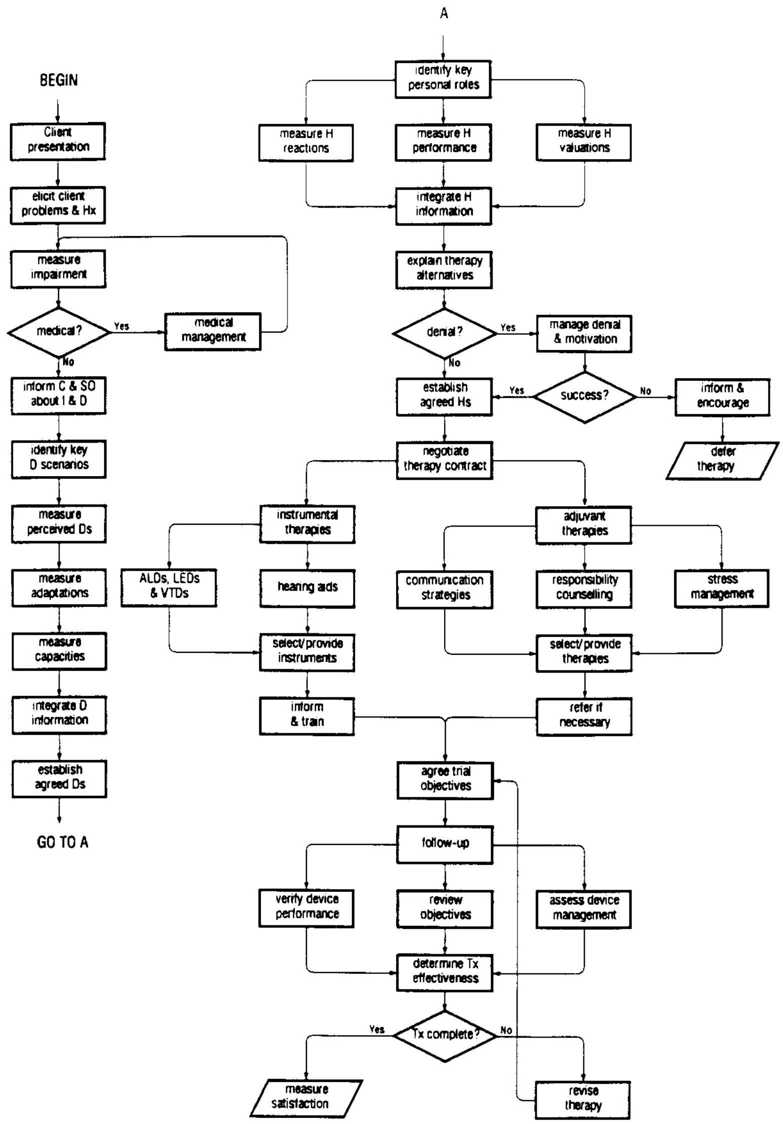

Figure 5. A block diagram of a speculative model for the audiological rehabilitation process, according to our viewpoint. See text for detailed explanation. The process model is illustrative, and not intended to be complete. The term *adjuvant therapies* refers to informational, training, and counselling activities that facilitate or augment response to any instrumental therapies (hearing aid or other devices). This term is more meaningful than "non-instrumental."

briefly some issues in measurement that are relevant to the formulation of decision-analytic approaches.

Implications of the WHO scheme. Most of the measurements needed in audiological rehabilitation relate to impairment, disability, handicap, and the mechanisms that connect them. In the WHO scheme, handicap and disability form the basis for outcome measurement and therefore, for the inseparable process of defining objectives and protocol decision criteria for the overall program or its components. The primacy of handicap and disability means that subjective reports from the client and significant others provide the key information that should guide the process and attest to its effectiveness; this is consistent with the client-centered philosophy of Continuous Quality Improvement. Because WHO handicap reflects many facets of client predicament, such as social roles, values, reactions, attitudes, and physical environment, it follows that a diverse set of measurements is essential, many of which are non-auditory.

The role of impairment measures. Measures of impairment such as conventional puretone and speech perception data are useful as an objective record of manifestations of the disorder, and for making technical inferences about hearing aids and other devices. As tools to quantify or predict disability, such measures have limited value, and to quantify handicap their value may be negligible. The relationships between audiometric measures of impairment and current self-report measures of disability are complex and subject to many sources of variation (see Gatehouse, 1990; Johansson et al., 1991; Lutman et al., 1987; Schow & Gatehouse, 1990). According to the WHO classification, disability reflects performance in scenarios that are psychoacoustically and psychosocially much more complex than ordinary audiometric tasks. Other sources of variation include the multivariate nature of the audiogram, nonlinearity of functional relationships between impairment and disability, and lack of interval-scale strength (Nunnally, 1978) for current self-report disability measures. Furthermore, many factors other than auditory performance affect self-report measures, notably: age, gender, cognitive skills, intellectual and personality variables (Demorest & Walden, 1984; Gatehouse, 1990; Schow, Smedley, & Longhurst, 1990).

Modest correlations reported between audiometric and self-reported disability or handicap measures reflect the fact that they are tapping overlapping but largely different domains, indeed, quite distinct domains in the WHO scheme. Each type of measure contains unique information, and so there are strong logical and practical restrictions on how they may be related, in either research studies or in clinical practice.

Conventional audiometry can be augmented by impairment measures that may relate better to real-life functional performance, such as speech perception in noise, temporal resolution, and localization (Middelweerd, Festen, & Plomp, 1990). Some of the pure performance facets of actual disability might be modelled as composites of these impairment-flavored measures. Other cofactors such as intellectual, cognitive, and personality variables may be tapped by appropriate tests in their respective domains. In this way, some of the mechanisms that transform impairment into disability may be clarified. Much further research is required to develop and refine such models. The relationships between impairment and handicap measures are likely to be even more tenuous, complicated, and nonlinear than those between impairment and disability (Gatehouse, 1990; Lutman et al., 1987; Mulrow et al., 1990; Riko, McShane, Hyde, & Alberti, 1990).

Self-report measures of disability and handicap. Several self-report instruments that address disability and/or handicap (not necessarily of the WHO type) are available (e.g., Schow & Gatehouse, 1990). Few have received adequate scientific evaluation. Psychometric issues were addressed by Demorest and Walden (1984), and several inventories were reviewed critically by Weinstein (1984). General requirements for development of subjective health-related indices are detailed by Kirshner and Guyatt (1985), a comprehensive text on the principles of health measurement scale development is by Streiner and Norman (1989), and a review of many health measurement scales is by McDowell and Newell (1987). An insightful analysis of measurement issues for indices of functional disability was given by Feinstein, Josephy, and Wells (1986). These references reveal stringent requirements of layout, wording, response scaling, reliability and stability, validity, discriminative sensitivity, and responsiveness, that must be addressed in development of any self-report instrument for functional disability and handicap (see also Erdman, 1994: Chapter 4 of the present monograph).

We are unaware of any self-report inventory that is tightly coupled to the specific WHO elements of disability and handicap. Several well-designed inventories are intended primarily to measure functional performance limitations; the items usually reflect psychoacoustical constructs, which is a different approach to the more socially-based themes of WHO disability. In our view, the Communication Profile for the Hearing Impaired (CPHI, Demorest & Erdman, 1986, 1987) comes closest to addressing the broad range of variables and constructs in predicament models based on the WHO scheme.

The CPHI scales address communication performance and importance, the environment, strategies, and many attitudinal and behavioral aspects of personal adjustment. These scales provide a basis for defining some primary components of a comprehensive audiological rehabilitation program, and yield some of the required decision variables and outcome measures (e.g., see: Hallberg, Eriksson-Mangold, & Carlsson, 1992). A recent cross-validation study (Hyde, Malizia, Riko, & Storms, 1992) indicated that the inventory's original domain structure derived mainly in U.S. military male subjects is generalizable to the population at large, and test-retest reliability was excellent. These results attest to the potential usefulness of the CPHI in the general, clinical population, given proper attention to the use of population-specific normative data.

The CPHI may serve as a discriminative index (Kirshner & Guyatt, 1985; Streiner & Norman, 1989), to differentiate clients with respect to their problem levels in many areas. This has implications for candidacy and for optimization of individual rehabilitation programs. The CPHI is also likely to be statistically appropriate as an outcome measurement tool, either in terms of absolute levels of the various factor or scale scores or through change-scores pre- and post-therapy.

Even the CPHI does not cover all the content domains of a complete rehabilitation program. It was not designed specifically to address response to hearing aids, and for that purpose an instrument such as the Hearing Aid Performance Inventory (Walden, Demorest, & Hepler, 1984) or the Profile of Hearing Aid Performance (Cox & Gilmore, 1990) may be more appropriate. It is also possible that to make quantitative sense of self-report data, certain psychological scales (e.g., for neuroticism) may prove useful in a complete rehabilitation program.

Another issue is that of measurements with the significant other (SO), whose perceptions of the client's problems may also be tapped by an instrument such as the CPHI. Concordance of the client and SO reports tends to validate responses, whereas discordance raises questions and the ensuing rationalization can be informative and therapeutic, if it is conducted in a judicious, non-confrontational way. Unless there is clear evidence of denial, neither report is intrinsically more "correct." Because the SO is so intimately involved in both communication and response to therapy, SO report should be given equal importance (for an example of such an approach see Schow & Nerbonne, 1982). The SO and others in close contact with the client may experience considerable secondary handicaps as a result of the client's disabilities (Stephens & Hétu, 1991; WHO, 1980), and an instrument designed specifically to tap these constructs is required.

Disabilities and handicaps may be idiosyncratic, so it is necessary not only to probe standard, specific scenarios and issues using closed-set inventories, but also to augment this with open-ended questioning and structured interviews conducted in such a way that the information obtained can be quantified and recorded. Optimization of the overall measurement approach is an important area for further investigation.

Measurement of client satisfaction. Measurement of satisfaction seems clearly relevant in the context of a client-centered approach to health care quality. There is a substantial literature on satisfaction from other areas of health care, especially health services research; see Cleary and McNeil (1988) for a good critical review of the state of the art. The subject is complex and no standard measurement approach exists yet.

Donabedian (1980) identified three key components of healthcare experience that yield domains for assessment of quality and satisfaction: structure, process, and outcome. Structure refers to the physical and organizational characteristics of the care system (personnel, facilities, etc.), process refers to the chain of events in care provision, and outcome refers to a change in the client's current or future health that can be attributed to the care process and structure. Many now consider outcome to be the crucial domain for care quality assessment. This is a much harder task than the classical approach of process audit.

Attempts to measure satisfaction must take account of interactions between the three facets of care; for example, outcome satisfaction measurements may be biased by client reactions to the structure or process. There are many other sources of bias, particularly if the client is not assessed independently from the care provider(s).

Global measures of overall satisfaction seem simple but can be very difficult to interpret, because of multiple, differential components, even if attention is focussed on outcome. For example, a question about "overall" satisfaction with a hearing aid will confound features of performance, convenience, aid physical characteristics, and stigma. This raises the important issue of whether a univariate, summary measure of satisfaction can ever be useful; perhaps satisfaction is irreduceably multivariate. The literature suggests that satisfaction measures should be specific, differentiated, and multidimensional (Lebow, 1974).

There is a need for higher methodologic standards in satisfaction measurement generally (Cleary & McNeil, 1988). Some difficulties in relation to audiological rehabilitation are revealed by Oja and Schow (1984) and Hutton and Canahl (1985). In addition to this, scientific and clinical advance in the area of satisfaction measurement requires an organizing conceptual framework that relates the various components and determinants of satisfaction. A tentative model of satisfaction determinants is shown in Figure 6. Much further research is needed before satisfaction measurements can be incorporated quantitatively and usefully into evaluations of rehabilitation strategies or outcomes.

Other outcome measurements. Program or component outcomes may be assessed either by absolute values or changes in measures of interest. According to Program Evaluation, it is important to target specific absolute levels of final handicap or of change as the criteria for success, not to adopt fuzzy objectives such as "handicap reduction." In specifying change targets and evaluating individual success, it is important to take account of technical matters that threaten the validity of inferences (see Anderson et al., 1980; Streiner & Norman, 1989).

Change can be measured directly or indirectly. The direct method, using measures that Feinstein et al. (1986) call "transition indices," asks about perceived change explicitly. The Hearing Aid Performance Inventory (Walden et al., 1984) is such an instrument. The indirect method requires repeated measures of absolute problem levels, with the change derived by subtraction. The two methods may not give the same results, and this is an interesting area for research. The advantages of the direct method are efficiency and that it focusses immediately on what many believe is the best index of therapeutic benefit: perceived magnitude of change. A disadvantage is that change may be considerable, but so may absolute final handicap; further therapy is warranted but that need is not apparent from a direct measure of change alone. Also, initial measures of disability or handicap can be useful for tailoring rehabilitation to individual needs. Along with Cox and Gilmore (1990), we prefer the indirect measurement of change. Actual pre- and post-therapy measures are desirable.

With regard to overall rehabilitation outcome, a major issue is whether it is meaningful to combine several variables and domains into a single index of success. Almost certainly, a multivariate approach is needed; it is what is advocated by the WHO, and it has the advantage of taking correlations between measures into account automatically. We are unaware of any reports that take a genuinely multivariate statistical approach to outcome analysis. As in the case of satisfaction, much methodological and clinical research is required in this area.

Outcome evaluation is more straightforward at the program component level, because of the focussed nature of components. For example, a component

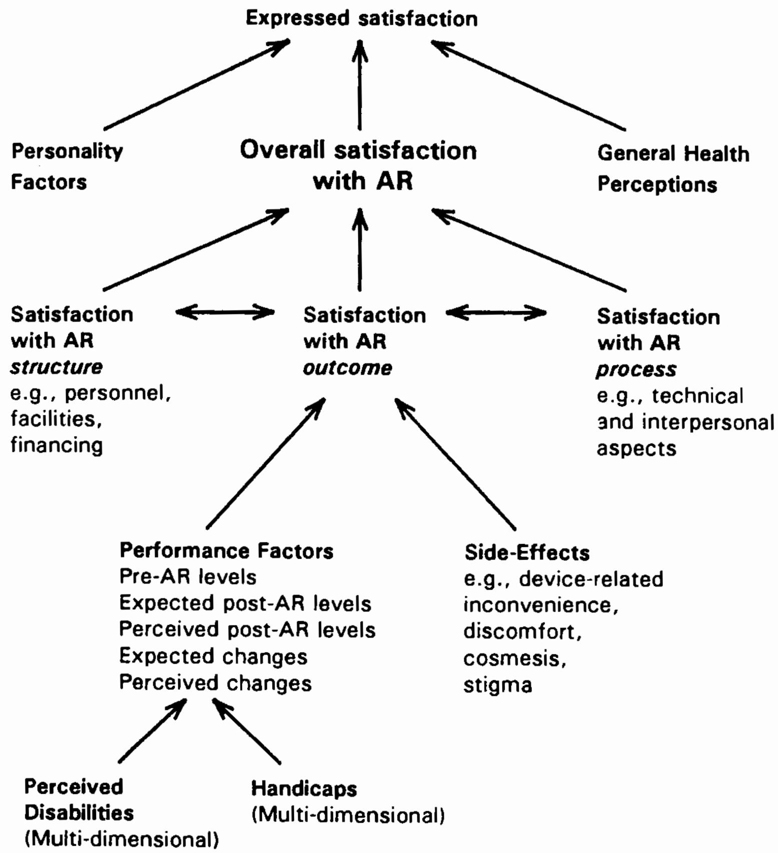

Figure 6. A block diagram of some possible determinants of client satisfaction with audiological rehabilitation, according to our viewpoint. Note that the separation of the *structure, process,* and *outcome* attributes of any health care system (Donabedian, 1980) is a very well-established concept in the discipline of Health Services Research. Personality factors and general health perceptions may influence both the actual level of overall satisfaction and that which is overtly expressed. The most useful measurement approach may be to try and differentiate the structure, process, and outcome components of satisfaction, not to combine them in a global measure that may lack meaning in terms of any attempts to evaluate or improve the health care process or system.

addressing problem awareness or denial might be evaluated in terms of pre-post scores on the pertinent CPHI scales. Using other scales, components such as counselling on communication strategies could be evaluated. Specific prior indices of success, based on absolute or change measures, or some combination of them, must be defined.

Having selected a univariate outcome measure, further difficulties must be faced. Because the metric properties of even well-validated disability scales are not known, the "distance" between scale mean scores of, say, 3.0 and 4.0 on the CPHI Communication Performance scale may not be the same as the distance between 2.0 and 3.0; that is, the scale may not have interval measurement strength. Several techniques are available to explore the underlying metric properties of scales (see, e.g., Nunnally, 1978), but to our knowledge, they have not yet been applied to hearing-related disability or handicap scales. In the interim, we are limited to essentially ordinal (rank) measures.

Another problem is that absolute or change scores relating to, say, functional performance, are not utilities, so they cannot be used directly in decision tree analysis. The actual utility and value structure of the key dimensions of predicament in relation to hearing disorders is virtually unknown. Techniques to develop what are called multi-attribute utility functions and multi-attribute value functions exist (Torrance, 1986), but to our knowledge have not been applied to hearing-related problems. Even for unidimensional outcome variables, we are unaware of any formal utility function development using, for example, the standard gamble method applied to specific disability or handicap scenarios. This is an important area that requires a great deal of research. In the interim, decision trees can be analyzed using dichotomized outcomes, yielding "success" and "failure" probabilities as proxies for utilities.

Performance and effort. A final measurement aspect that may be very important and has not received enough attention is the effort involved in maintaining adequate levels of communication performance. Effort may offset the effects of hearing impairment, leading to acceptable performance at a significant cost to the individual. Thus, an intervention might have negligible effects on measured performance levels, but large effects on the underlying effort required. Therapeutic benefit would be underestimated by performance measurement, with obvious potential to confound decision analyses. The extent to which current inventories that purport to address functional performance are tapping a pure performance construct or a mixture of performance and effort is not clear. Further research is required to disentangle these constructs.

Decision Tree Applications

As outlined earlier, decision analysis seeks to identify the strategic combination of specific diagnostic and therapeutic procedures that yields the greatest outcome utility. What are the diagnostic measures that might provide a sensible basis for decision criteria, and what are the possible candidate therapies? Recall that we have adopted definitions of diagnostic and therapeutic acts that may go beyond conventional boundaries in audiology, but certainly are not unreasonable. In Tables 2 and 3 are listed respectively some diagnostic measures and therapies that might be examined by decision analytic (or other) methods. The table ele-

Table 2

Some Potentially Important Measures That are Diagnostic, Grouped in Domains Governed by our Predicament Model and the WHO Framework

DOMAINS	DIAGNOSTIC MEASURES
Impairment (I)	Puretone sensitivity. Middle ear function. Speech perception (advanced).
Impairment to Disability Transformation	
Scenarios	Perceived importance of generic and special communication/listening scenarios. Key features of the physical and interpersonal environment.
Capacities	Verbal skills. Visual and contextual speech cue utilization. Cognitive function. Visual, dexterity, and locomotor comorbidities.
Disability (D)	
Performance	Subjective scenario performance. I/D concordance. Client/SO concordance.
Adaptation	Subjective effort. Objective effort (e.g., response delay).
Cofactors	Personality variables, for example, neuroticism.
Disability to Handicap Transformation	
Roles	Perceived importance of generic and special social/personal roles.
Adjustments	Communication strategies. Avoidance and control behaviors.
Handicap (H)	
Performance	Perceived generic and special role fulfillment. D/H and client/SO concordance.
Valuation	Importance and impact of perceived role performance limitations.
Reactions	Fatigue. Denial. Anxiety. Anger. Depression.
Attitude to Rehabilitation	
	Reason for client presentation. Motivation to improve D and H levels. Nature and impact of previous audiological rehabilitation. Attitudes to specific therapies or devices (e.g., stigma, cosmesis). Global and therapy-specific expectations.
Therapy-Specific Measures	
	Measures associated with therapeutic technologies, for example, real-ear measures. Device management skills assessment.

Note. Listed are some potentially important measures that are diagnostic according to our broad definition, grouped in domains governed by our predicament model and the WHO framework. Temporal order is NOT implied; for example, it may be appropriate to quantify attitude to rehabilitation or emotional state components of handicap early in the management process. Decision analysis can be applied to evaluate the contribution of any subset and sequence of these measures to optimal rehabilitation strategies. For a few of the measures suggested, valid procedures already exist and are widely used clinically. Some of the other measures are currently used in experimental work and in a few clinical centers, but have not yet achieved widespread clinical adoption, in part due to limited awareness and to time pressures of "productivity." For still other measures, further developmental research into appropriate categorical or rating scales is required.

ments are coupled to the processes and domains within our speculative predicament development model. It is interesting to note that few of the diagnostic or therapeutic procedures identified in these two tables are commonly and explicitly implemented clinically, and yet, at least in our view, many experienced clinicians

Table 3

Some Potentially Important Areas of Therapeutic Intervention, Grouped in Domains Governed by our Predicament Model and the WHO Framework

DOMAINS	THERAPIES
Impairment (I)	Referral to medical assessment and management.
Impairment to Disability Transformation	
Scenarios	Communication/listening function analysis.
Capacities	Speechreading training. Comorbidity management or referral.
Disability (D)	
Performance	Scenario-level problem establishment and priorization. Problem awareness promotion. Client/Significant Other reconciliation.
Adaptation	Effort analysis.
Covariates	Psychological counselling or referral.
Disability to Handicap Transformation	
Roles	Role identification and priorization.
Adjustments	Communication strategies and behaviors training. Assertiveness training.
Handicap (H)	
Performance	Role performance analysis. Client/Significant other reconciliation.
Valuation	Role deficiency impact analysis.
Reactions	Reaction management counselling. Psychological counselling or referral.
Attitude to Rehabilitation	Empowerment. Motivational counselling. Team problem solving techniques. Goal setting. Progress monitoring. Experiential analysis. Device attitude modification. Expectation modification. Support group provision or referral.
Device-Specific Interventions	Hearing Aid/Assistive Listening Device awareness counselling. HA/ALD provision and prescriptive target verification. Device management training. Device utilization counselling.

Note. Listed are some potentially important areas of therapeutic intervention, according to our broad definition, grouped in domains governed by our predicament model and the WHO framework. Temporal order or grouping in practical rehabilitation processes are NOT implied, nor is the list intended to be exhaustive.

Decision analysis can be applied to evaluate the contribution of any subset and sequence of these therapies to optimal management. Note the coupling between therapies and diagnostic measures (Table 2), arising because therapeutic need and outcome are determined by quantitative measures, and because many diagnostic procedures also have a therapeutic role.

As is the case in the diagnostic arena, in some of the suggested areas adequate therapies and protocols already exist, but in others further developmental research is required.

engage (albeit informally) in many of these facets of the rehabilitation process.

Decision trees may be constructed to address the contribution of individual diagnostic decision rules or therapeutic acts, or various combinations of these elements, using the procedures outlined earlier. Note that many of the measurements and therapies identified in Tables 2 and 3 may be applied to both the client (C) and a significant other (SO). The benefits of applying audiological rehabilitation in a highly integrated manner to the C/SO dyad may be substantial, and this problem area can also be formulated as a set of strategies that are evaluatable through decision analysis.

While decision-analytic studies are commonplace in other areas of rehabilitation research in chronic disease states, such as in coronary care or in arthritis management, we know of no application as yet to audiological management. In this chapter, what we are advocating primarily is the decision-analytic *paradigm* itself, that is, a particular conceptual and procedural approach to some of the research that is needed in audiological rehabilitation. A complete decision-analytic treatment of even the simplified and incomplete rehabilitation process model outlined here would be a massive undertaking that would require many years of study. In some areas, such as problem denial or significant-other handicap, the underlying constructs are so unclear and the measurement tools are so lacking in sophistication that proper decision tree formulation must await further developmental research, especially into predicament models. However, in other areas such as hearing aid and other assistive device provision, meaningful decision trees could be constructed immediately.

The fact that many aspects of what we have presented here can be debated or disputed suggests that audiological rehabilitation in general is at an early developmental stage, one in which many of the immediate benefits of decision analysis will arise not from trying to answer specific questions about optimal measurement or treatment options, but from the process of simply trying to construct explicit, rational decision trees that reflect the viewpoints and priorities of both program evaluation and continuous quality improvement.

Recall that decision analysis can be applied to the management of the individual client, using that client's utilities together with probabilities derived from direct experience, published studies, and meta-analysis. It can also be applied to groups of clients. The validity and usefulness of either type of analysis depend on the accuracy of utility and probability assignments, but it is surprising how often the conclusions of decision analysis are found to be robust, through sensitivity analysis.

In our view, clinical audiological rehabilitation is not yet at a stage wherein its processes and measures are sufficiently well understood to make real-time, *clinical* use of decision analysis a practicable proposition. Our emphasis here has been on outlining an approach that may facilitate clinical research. Such research will tend to make use of group data, to address rather broad questions about the strategic value of specific types of measurement or the benefit of specific types of therapy. Note that the application to group data does not mean the analysis is necessarily insensitive to the needs of individual clients. For example, it might be a pre-post therapy functional change in some scenario deemed by the individual to be most important, that forms the basis for an outcome classification. For more than binary outcomes, at least approximate utility values would be required; while the best and worst outcomes can be assigned 1.0 and 0.0 respectively, the precise values for the intermediate outcomes are the issue. Ideally, standard gambles based on various communication performance scenarios would be applied. Use of rating scales would precipitate research into the validity and inter-individual variation of such ratings, relative to gamble-based utilities.

One noteworthy attribute of the decision-analytic approach is that it addresses the performance of diagnostic and therapeutic acts that are conducted not in isolation, but within specific operational contexts, temporal sequences, and client subgroups, as dictated by actual, practical clinical strategies. This is an important distinction of decision analysis from merely a set of disconnected investigations of the same diagnostic or therapeutic acts; the issues are context-specificity of performance, and interactions between various procedures.

In addition to the analysis of expected utility, the decision tree can also be used as a basis for calculations of cost-effectiveness, expressed either in absolute terms of resource cost (equipment, personnel, overhead costs) per successful outcome, or in incremental terms, namely the additional resource cost per additional successful outcome, for one strategy relative to the other. The conclusions of the analysis may change dramatically if the additional dimension of cost factors is introduced. Note that the three questions: (a) what strategy yields the highest utility, (b) what strategy yields the highest utility within cost constraint X, and (c) what strategy yields the highest utility per unit cost, are all quite different questions. However, a decision-analytic approach can be applied to those three questions.

Usually, cost factors are introduced into the equation after a reasonable level of understanding has been achieved about which strategies are likely to be relatively highly effective. In the earlier stages of development, the focus is on expected-utility analysis, for which accurate utilities and probabilities are the crucial ingredients (along with valid outcome measures). Note that probabilities are proportions, and confidence intervals for probability estimates from experimental studies can be derived from statistical tables of binomial proportions. These reveal that sample sizes of typically over 100 clients are needed, to yield usefully accurate (90% confidence interval less than 0.1, say) estimates of them. To explore even a very simple decision tree experimentally, with useful precision and population coverage, might require a sample of several hundred clients. The implication is that serious, decision-analytic studies with an experimental base will tend to be multi-center in nature, and may be expensive. One alternative is to try and integrate piecemeal results of smaller studies, partly through meta-analysis. For this purpose the consistency and complementarity between studies that would arise from widespread use of a consistent conceptual framework, terminology, and models, such as those outlined here, would be very advantageous.

SUMMARY OF RESEARCH IMPLICATIONS

Trends in health services research and healthcare resource allocation make it almost inevitable that audiological rehabilitation services must become more explicit, accountable, and client-centered. This will require: formulation and explicit description of rehabilitation strategies and protocols, a shift in emphasis towards subjective measures of client state, a broadening of professional training programs and clinical services to address psychological and psychosocial problems, and unprecedented focussing of effort upon measures of service effectiveness.

From our perspective of health services research and decision analysis, particularly important areas for research are summarized below. Many of them can be addressed in parallel, making use of tentative models and crude measurement tools until more refined versions become available. Currently, however, there is a low level of consensus in many areas of measurement in our field. Changes in experimental design and data analytic methodology that may improve the situation dramatically include: much greater emphasis on the use of multivariate dependent variables, routine assumption of nonlinearities in relationships between variables (in contrast to assumptions of linearity), and much more explicit attention to interactions between independent variables, such as in multifactorial experimental designs or in multiple regression analyses of client state or rehabilitation outcome.

1. *Client Predicament Modelling.* Efforts should be intensified to develop a valid, detailed, and comprehensive conceptual model of client predicament. The model proposed earlier is only a crude, illustrative example. A predicament model is the prerequisite for all other modelling efforts, such as for rehabilitation process and outcome. Such a model should address impairment, disability, and handicap as multidimensional state variables, as well as their interconversion processes and important covariates. It should also include time-series aspects, both for spontaneous evolution and for client response to intervention. The WHO conceptual framework is a useful starting point for a predicament model.

2. *Definitions and Terminology.* Closely linked to conceptual modelling is the acute need to adopt a conceptually sophisticated, unambiguous definition of terms. This will facilitate communication within and between the clinical and research communities, and promote a more integrated, comparable, and consistent body of investigation and reporting. There is no room for terminological parochialism. The North American definitions can be modified and incorporated within the richer and more generalizable international scheme.

3. *Rehabilitation Process Modelling.* A process model that is tightly coupled to the predicament model is needed. The model should not only identify relevant domains of assessment and therapy, but also specific, quantitative objectives,

pertinent measurement tools, temporal linkages, decision criteria, meaningful therapeutic options, outcome alternatives, and outcome evaluations. Several levels of modelling detail are required, from the macroscopic to the microscopic. The model should take into account both probabilistic, population-based optimal strategies, and the idiosyncracies and values of the individual client. The model will require a more generalized view than is currently widespread of what constitutes a diagnostic test in the rehabilitation context, and also of what constitutes a therapeutic act.

4. *Rehabilitation Outcome Modelling*. The ultimate goal is to develop a valid and complete conceptual model of client satisfaction and all of its determinants. This could be built up from absolute post-intervention levels of communication performance or pre-post therapy changes, through multidimensional measures of benefit, and through satisfaction with rehabilitation outcome, as well as the process and structure. Research into outcome measurement methods is of the highest priority, because outcome measures underlie so many other activities, not only in clinical practise, but also in research and in technical development.

Self-report measures that address disability and handicap, applicable to both the client and the significant others, have a crucial role in outcome modelling, as well as in program evaluation. Many currently available inventories do not satisfy basic design principles or have not been evaluated with sufficient rigor. Those that do satisfy these requirements can be used at least as a basis for interim measures, until more sophisticated and comprehensive instruments are developed. Critical comparative evaluation of well-validated inventories will be a rich source of hypotheses for refinement of predicament models and measurement techniques. Validation of a multi-scale inventory is usually a painstaking, cumulative process of hypothesis generation and testing, in relation to many possible underlying relations within the multifactorial data. A related vital area is the determination of quantitative relationships among objective and subjective measures of therapeutic benefit.

Special research effort is needed to clarify the many areas of ignorance that relate to client preferences, values, and utilities. Multi-attribute value and utility functions are the crucial measures that underlie determination of program effectiveness and comprehensive strategic optimization through decision analysis. The measurement methodology is available from other areas of health research, but has not been applied extensively in the audiological field. An understanding of exactly which predicament dimensions matter generally and for the specific client, and development of interval-strength subjective measurement scales to quantify absolute value levels and changes due to intervention, are the non-technologic keys that will transform the stature of audiological rehabilitation.

ACKNOWLEDGEMENTS

We wish to acknowledge the support of Mount Sinai Hospital, The Toronto Hospital, and the Ontario Ministry of Health; the assistance of Dana Storms, Kathy Malizia, and other members of the Otologic Function Unit and the Hearing Health Care Research Unit; scholarly critiques by Marilyn Demorest and Remond Hétu; and the courtesy of the editors.

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