Standardization

INTERNATIONAL PROGRESS ON WHEELCHAIR STANDARDS, THE NORTH AMERICAN CONTRIBUTION

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Background

Standards writing is an effort to bring some uniformity of understanding to the diverse points of view of the manufacturer, the researcher, and the user of a product. The potential benefits include: (i) improvement in quality and reduction in cost, (ii) avoidance of duplication in testing, and (iii) improvement in communication and problem-solving.

In this country, the Veterans Administration has played a major role in developing a uniform approach to the specification and selection of rehabilitation devices. In 1968, the VA finished development and published a set of standard test methods to be used in selection of manually propelled wheelchairs. For several years thereafter, other agencies and individuals concerned with the purchase of wheelchairs looked to the VA standard for guidance in making their selections. The VA has recently completed a draft standard for electrically powered wheelchairs which will probably serve also as a model document for other agencies.

In 1974, the American Society for Testing and Materials (ASTM) formed the Committee on External Prosthetics, Orthotics and Mobility Aids (designated Code F–19). The ASTM is an internationally recognized organization which manages the development and publication of voluntary consensus standards. Recognizing the need for a consensus format relating to wheelchair standards, ASTM F–19 elected to begin a process of standards development which could be offered to the Food and Drug Administration for consideration.

In September of 1978, ASTM F–19 assembled a group of persons with broad-ranging knowledge and experience to conduct in-depth review of the 1968 VA standard on manual wheelchairs. The purpose of that review was to determine the general applicability of the VA standard toward the perceived needs of the non-veteran population. A report of that meeting was submitted voluntarily to the VA (1). Then in December of 1979, the ASTM group reconvened at the Wheelchair II conference (2), to discuss a plan of action for the development of more generally applicable standards for all forms of wheelchairs used in the public arena. That group recommended the following three-pronged approach to standards development—

1. Design a **classification system** for wheelchair products according to use pattern and user size.
2. Conduct an objective **site visit** to the facilities of American wheelchair manufacturers to observe the methods currently being employed for product quality assurance and response to service problems.
3. Collect **service data** from recognized wheelchair service facilities across the country to determine the most frequent forms of wheelchair and wheelchair component breakdown.

Early in 1980, the Canadian Standards Association (CSA) recognized the efforts of ASTM and invited a joint meeting to pool the Canadian and American efforts toward wheelchair standards development. At a meeting in Toronto in June of 1980, the two organizations agreed to cooperate and share resources for wheelchair standards development and to send delegates to a subcommittee meeting of the International Standards Organization (ISO) which was working to develop international wheelchair standards. In early October of 1980, Subcommittee (SC) 8 (Wheelchairs) of Technical Committee (TC) 136 (Hospital Furniture) met in West Berlin and was joined by the official Canadian representative and two official visitors from the United States.

International Standards Organization

ISO is an international body based in Geneva, whose representation is made up of the official standards-setting agency of each of the member countries (3). In the United States, that organization is the American National Standards Institute (ANSI). ANSI assigns its expert representation for each area of specialization to a Technical Advisory Group (TAG). The designated TAG in this country, for TC136, had no interest in standards activity relating to wheelchairs. Consequently, ANSI authorized two representatives to attend the ISO meeting as non-voting observers: Sam McFarland, the author, representing ASTM; and Keith Rodaway, Everest and Jennings, representing manufacturing interests in the United States.

The meeting of TC136/SC8 was held at the German Standards Institute (DIN) in West Berlin on October 2–3, 1980. Designated representatives to the sub-committee are listed in Table 1. Representation on TC173/SC1 will continue to be the same as on the former TC136/SC8. There were two key business items. First were the reports from the Working Groups (WG) and action on their recommendations. Second, and equally as important, was the vote to transfer the activities related to wheelchair standards from TC136 to TC173, Technical Systems and Aids for Disabled or Handicapped Persons, which had been formed in late 1979. It was announced at this meeting that future efforts toward wheelchair standards development would be conducted under Subcommittee 1 of TC173, and that the directorate for the subcommittee would continue to be Sweden (SIS). The chairman of former TC136/SC8, now TC173/SC1, Mr. S. Holmstedt from Sweden's Handikappinstitutet, was re-elected to another 3-year term of office.

All of the ISO work in drafting and revising drafts of wheelchair standards documents is carried on in specific working groups. Three working groups reported to the subcommittee their activities of the year.

1. **WG 1—Test Methods for Wheelchairs** is chaired by the

TABLE 1
Representation to ISO/TC136/SC8[1], Berlin, West Germany, October 2–3, 1980.

Country	Agency	Membership[2]
Sweden	Swedish Standards Institute (SIS)	P
France	Association Francaise de Normalization (AFNOR)	P
Denmark	Dansk Standardiseringsvaad (DS)	P
Netherlands	Nederlands Normalisatie-instituut (NNI)	P
United Kingdom	British Standards Institute (BSI)	P
Germany, F.R.	Deutsches Institut für Normung (DIN)	P
Canada	Canadian Standards Association (CSA)	P
United States	American National Standards Institute (ANSI)	O
Japan	Japanese Industrial Standards Committee (JISC)	O

[1]The same representation will continue on ISO/TC173/SC1.
[2]P—Participating (voting)
O—Observing (non-voting)

representative from the United Kingdom Department of Health and Social Services (DHSS), Mr. Eric Burnett. Much of the work under consideration by this group was drawn from extensive test methods developed by the British DHSS. However, significant contributions toward testing procedures were offered by the German and French delegations, each of which has its own functioning test methods.

2. **WG 2—Type Classification of Wheelchairs** is chaired by Ake Hansson, Swedish vendor. Not unlike the American model proposed by ASTM, the Swedish delegation has fostered a classification scheme based on a combination of chair size, user size, and use pattern. A significant contribution has been made to this effort by a member of the Dutch delegation (GMB) (4) which has, like the Veterans Administration in this country, a standards development and purchasing specification authority under the government of the Netherlands.

3. **WG 4—Dimensions for Transport and Storage** is chaired by Dr. C. P. Dubbelman from the Netherlands and has been responsible for determining the important measurements needed to describe a folded transportable wheelchair. Of course this dimensioning becomes a significant part of the other standards development for classification and test methods. WG 4 has completed its work and the draft standard for dimensioning will be submitted to an exhaustive series of voting procedures designed to achieve ultimately an official document.

Since the October meeting of ISO/TC136/SC8, the Health Industries Manufacturing Association (HIMA) has been assigned as the administrator of the USA TAG to TC173/SC1. The administrator provides a focal point for national effort. The next annual meeting of TC173/SC1 will be November 5–6, 1981, in Zeist, The Netherlands, immediately following meetings of the working groups. The working groups also have met from time to time throughout the year to continue development and preparation of draft standards documents to be submitted to the subcommittee for official debate and revision.

HIMA will be represented by a large delegation at the working group meetings and at the ISO/TC173/SC1 meeting in the Netherlands. In addition to providing direct representation by manufacturers, consumers, and general interest factions, the U.S. delegation will invite the Secretariat to schedule the 1982 meeting in the U.S.

TABLE 2
European Wheelchair Manufacturers

Company	Country
Carters	**United Kingdom**
Everest & Jennings, Ltd.	
Newton Aids, Ltd.	
Rehab Invacare, Ltd.	
Remploy, Ltd.	
Vessa, Ltd.	
Zimmer Orthopaedic, Ltd.	
Deutsche Orthopädische Werke (DOW)	**Germany, F.R.**
Orthopaedia	
Wilhelm Meyer (Meyra)	
Poirier, S.A.	**France**
Annastolen	**Netherlands**
Oostwond	
R. T. C.	
Vermeiren	
Saab (Permobil)	**Sweden**

Resource: Basisboek Voorzieningen
Gemeenschappelijke Medische Dienst
Bos en Lommerplantsoen 1
Postbus 8071
1005 AB Amsterdam

European Wheelchairs

Table 2 is a listing of major wheelchair brands manufactured and sold in Western Europe. European wheelchairs are not unlike those known to Americans except that use patterns in Europe demand certain characteristic variations. Many wheelchairs, for example, have placed the large drive wheels at the front and casters at the rear because of the need for better indoor and small space maneuverability. Dynamic hand brakes on manual wheelchairs are frequently seen in response to the hilly environment of many European cities. Electric wheelchairs tend to be more elaborate, more expensive vehicles capable of use on village streets and in limited competition with automobile traffic. In keeping with the European love of

bicycles and motorcycles, electric wheelchairs tend to be larger, more powerful, and include such vehicle trappings as headlights, turn indicators and horn. The vast majority of wheelchairs purchased in Europe are provided by government health programs. Thus, government agencies tend to be very active in developing standards and quality assurance tests.

Domestic Standards (Recent Developments)

Now that HIMA has been selected by ANSI to administer the TAG for TC173/SC1, there will be an official focal point for comments and developments on wheelchair standards. Several groups have expressed their interest in the subject and have been officially acknowledged by HIMA. Each group represents a unique point of view, which helps assure that all persons who may be affected by the development of standards will have an opportunity to contribute to that development process.

U.S. Veterans Administration Rehabilitation Engineering Center (VAREC)—Responsible for evaluation and approval of wheelchairs supplied to individual disabled veterans by the VA, VAREC evaluates products available for purchase, sets minimum criteria of performance, writes test methods, performs compliance tests, and maintains an up-to-date perspective on quality assurance measures.

U.S. Food and Drug Administration, Bureau of Medical Devices (FDA)—Mandated by the Medical Devices Amendment of 1976, FDA assembled a panel of experts to classify a vast list of medical devices according to the perceived need for regulatory activity. According to that panel, wheelchairs for chronic users were appropriate candidates for standards development. Whenever possible, FDA will monitor consensus standards development rather than undertake to write its own.

Health Industries Manufacturers Association (HIMA)—Composed of members who manufacture a vast variety of products for medical and home care markets, HIMA represents the capabilities and concerns of the wheelchair manufacturers. In its role as the administrator of the ISO/TC173/SC1 TAG, however, it is constrained by ANSI to operate within strict procedural guidelines which insure a balance of participating viewpoints.

American Society for Testing and Materials, Subcommittee F–19.40 on Mobility Aids (ASTM)—Internationally recognized as an enabler, manager, and publisher of developing standards, ASTM offers an unbiased forum for assuring full consensus input to the standards development process.

Paralyzed Veterans of America, Incorporated (PVA)—The largest single coalition of chronic wheelchair users, PVA is active in its advocacy for assurance and development of improved products and services for disabled consumers.

Rehabilitation Engineering Society of North America (RESNA)—Organized in 1979 to create a forum for rehabilitation professionals who deal with technology, engineering, and assistive devices, RESNA includes wheelchair designers, prescribers, manufacturers, vendors, testers, and users among its members.

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CURRENT TRENDS IN AURAL REHABILITATION IN AUSTRALIA

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The following is a report on a study visit to Australia during the summer of 1980. The study visit was concerned primarily with the system of hearing-aid delivery and supporting audiological services, personnel preparation and research in Australia. The study was supported by a fellowship from the World Rehabilitation Fund under a grant from the Research Services Administration, U.S. Department of Health, Education, and Welfare.

While this account does not focus explicitly on the subject of "Standards" as the subject is usually meant by the heading of this department of BPR, any such thorough description of an advanced nation's manner of dealing with a universal problem makes implicit comparisons with the details of other nations' efforts to do (presumably) as good a job of it. And value judgements based on comparisons are, clearly, the necessary first step in the process that ultimately produces formal, practical standards. Editor.

Background

The National Acoustic Laboratories (NAL) is the major provider of hearing aids and audiological services in Australia. Almost half of the total Australian population is covered by the services offered by NAL. Services provided outside of the NAL framework are heavily influenced by NAL procedures, and in most cases are designed to supplement the services offered by NAL. In order to review current trends in aural rehabilitation it is first necessary to understand relevant aspects of the geographic, demographic, and governmental structure of Australia and how the National Acoustic Laboratories operate.

Australia occupies a land area of just under 3 million square miles with a population of roughly 15 million. The

population density is thus quite low (5 persons per square mile on the average; the corresponding figure for the United States is more than 13 times as large, approximately 66 persons per square mile). More than 80 percent of the Australian population is concentrated in urban areas, most of these being located on the southeastern seaboard. The two major population centers are Sydney in the State of New South Wales (population approximately 3 million), and Melbourne in the state of Victoria (population approximately 2.5 million). Other major cities are Brisbane (Queensland), Adelaide (South Australia), and Perth (Western Australia), each of which has a population approaching 1 million. With the exception of Perth, all of the above cities are within about 600 miles of Canberra, the capital of Australia. Perth is situated on the western coast and is over 2,000 miles away from the other major population centers. Two other major cities are Hobart, the capital of Tasmania (population approximately 200,000) and Darwin, capital of the Northern Territory (population approximately 50,000).

The government has a federal structure. The country is divided into seven states (New South Wales, Northern Territory, Queensland, South Australia, Tasmania, Victoria, and Western Australia). Each state elects its own government which is responsible for internal state affairs; these include education, social services, and certain health services.

The federal government is concerned with national affairs, such as defense, foreign policy, taxes, and various federal authorities such as the Commonwealth Department of Health. The distribution of power between the federal and state governments is similar to that of the United States; services provided by the federal government are often supplemented by state-supported services. The seat of the federal government is Canberra which, like Washington, D.C., is not subject to the jurisdiction of any one state but occupies a small self-governing area, the Australian Capital Territory (ACT).

Despite the vast distances involved, the uneven distribution of population, and the complex interplay between state and federal areas of jurisdiction, the delivery of audiological services in Australia is remarkably good and is reasonably consistent between states. The backbone of this system is the national hearing-aid delivery system developed and operated by the National Acoustic Laboratories (NAL).

The National Acoustic Laboratories is a branch of the Commonwealth Department of Health. Previously known as the Commonwealth Acoustic Laboratories, it was formed immediately after World War II to look after children born following the maternal rubella epidemic in the early 1940's as well as war veterans with hearing impairments. The Commonwealth Acoustic Laboratories developed its own hearing aids and methods of prescribing these aids. A network of hearing centers was established, beginning with a regional center in each state capital and a main research center in Sydney. The centers were staffed initially by psychologists who were then given additional training in audiology. In due course, an audiology training program was established at the University of Melbourne. That program is now the major program of its type in Australia.

The Commonwealth Acoustic Laboratories (which became the National Acoustic Laboratories in 1975) increased steadily in size and scope over the years. A major expansion came in 1968, when pensioners and their dependents were included among those Australians eligible to receive hearing aids and supporting audiological services.

The primary functions of National Acoustic Laboratories (NAL) are—

1. To undertake in hearing, acoustic amplification for the hearing-impaired, and the effects of noise on man;
2. To provide hearing aids and supporting audiological services to eligible Australians; and
3. To provide consultative service to other federal authorities, particularly to the armed services, on noise-related problems.

In order to achieve these objectives, a network of hearing centers has been established throughout the country. In addition, a large central research and engineering laboratory has been established in Sydney. At this center research is conducted on hearing, on acoustic amplification for the hearing-impaired, and on the effects of noise on man. In addition, these researchers work closely with the engineering staff in designing and developing new hearing aids. And as already noted, the research and engineering center also provides consultative services to other government authorities.

The NAL Hearing-Aid Delivery System

The audiological and hearing-aid services provided by the National Acoustic Laboratories are available to all Australians under 21 years of age, to eligible pensioners and their dependents, and to members of the armed services and veterans with service-related hearing impairments. Almost half of the Australian population is eligible for these benefits. Persons not covered are typically working adults between 21 and 65 years of age, who obtain their hearing aids commercially either by direct purchase or through an employee benefit program. Adults not eligible for hearing aids under the NAL system and who are in financial need receive hearing aids under state-supported social welfare programs.

The hearing-aid service provided by NAL includes the initial audiological assessment, prescription and fitting of the hearing aid, followup to monitor effective usage, servicing of the hearing aid and, finally, replacement of the instrument with a technologically more advanced aid after several years (typically, after about 5 years of service). The National Acoustic Laboratories also design and develop their own hearing aids and supervise their production by industry. Two commercial hearing-aid types are used for special cases in which there is a low demand.

The audiological assessment, hearing-aid prescription and fitting, follow-up evaluation, and maintenance of the hearing aids are all performed at hearing centers operated by NAL. There are 27 such centers located in major towns and cities throughout Australia. Since over 80 percent of the population is located in urban areas, these centers are easily accessible to the large majority of the population. A visiting service is provided for persons living in remote areas.

The Four-Appointment System

The method of hearing-aid prescription differs between adults and children. For adults, the process begins with a referral for an evaluation at a NAL hearing center. A four-appointment system is used at present.

The first appointment involves a 45-minute assessment in which basic audiological measurements are obtained, e.g., air and bone-conduction thresholds. From these data a decision is made as to whether a hearing aid would be helpful and if so, which type of aid is likely to be most effective in terms of amplification characteristics and whether the aid(s) should be fitted monaurally, binaurally or CROS. About 95 percent of the prescribed aids are post-auricular and about 1 percent are in-the-ear aids. The balance are body aids. Binaural hearing aids are more likely to be prescribed for children than for adults. Depending on which type of aid is selected, appropriate earmold impressions are made.

The frequency response and maximum power output of the prescribed aid are determined using the method developed by Byrne and Tonisson (1976). Basically, the method is designed to place the spectrum of the amplified speech signal at a comfortable level at all frequencies. Research is currently in progress on refining and extending this procedure.

The second appointment lasts about an hour, during which the hearing aid is fitted and several basic aided measurements are obtained (e.g., aided thresholds). Additional measurements may be obtained if these aided measurements are unusual in any way.

The third session consists of a followup in which the fitted hearing aid is checked. This session is usually fairly brief (½ hour) if no problems are identified. Basic performance measures are used as a check (e.g., aided speech discrimination) but additional tests will be administered if performance is poorer than expected.

The fourth and last appointment takes the form of a group orientation session lasting about 1¼ hours. The group typically consists of six newly-fitted hearing-aid users who describe their experiences with the aid and, with guidance from the audiologist, discuss tactics for measuring the effectiveness of their aids.

A five-appointment schedule is currently being considered (Upfold and Smither, 1981). The major difference between the existing system and the possible new system is that more detailed performance measures (primarily speech tests) will be obtained, coupled with more intense counselling and followup procedures. For example, a questionnaire on how well the hearing-aid user functions at home is being developed. Similarly, methods for training and testing the new hearing-aid user in manipulating the controls of the aid are being considered.

The services provided to children are more extensive than those provided to adults. The basic approach, however, is the same. After a child with a possible hearing problem has been identified (e.g., by an infant screening program), a more detailed audiological assessment is provided in which air and bone conduction thresholds and other basic measurements are obtained using techniques appropriate for the child's age (e.g., play audiometry, conditioned-response methods). From this information a hearing aid is selected, using either the Byrne and Tonisson (1976) approach or the Byrne (1978) method for severely hearing-impaired children.

The followup procedures for children depend on the age of the child. They are most extensive for very young children. Typically children under 11 years of age are seen 1 month after the initial fitting and then at 6-month intervals. The NAL center also provides counseling to the parents and some habilitative training to the children.

The number of hearing aids fitted each year by the National Acoustic Laboratories is substantial. During the year ending June 30, 1980, some 28,000 Australians were fitted with hearing aids. Of these, roughly 9,000 were binaural fittings requiring two instruments. The total number of hearing aids provided by the National Acoustics Laboratories is thus roughly 37,000 instruments per year. Of these, approximately 6,000 are fitted to children (primarily binaural fittings), 25,000 to pensioners, and 6,000 to veterans. In addition, a small number of hearing aids (about 200) are fitted to federal employees. A more detailed breakdown of the number of hearing aids fitted during the period July 1979 to June 1980 is shown in Table 1. The upper half of the table shows the number of new cases examined, the lower half shows the number of hearing aids fitted. The columns show the breakdown by state; the rows show the breakdown by user group. The majority of new cases are young children of whom roughly 800 are fitted with hearing aids. The average age of fitting for children is 7 years. Most children with losses greater than 90 dB are fitted by 2 years of age. For the pensioners and veterans there are fewer new cases, but more hearing aids are prescribed. This is because many of the fittings are for replacement hearing aids. (As noted earlier, hearing aids are replaced after about 5 years of service.)

By far the largest number of hearing aids are fitted in New South Wales, which is the most populous state. Victoria and Queensland are the second and third most populous states, respectively. The number of hearing aids fitted in Victoria exceeds that for Queensland by a corresponding amount. In contrast, more children are seen by the National Acoustic Laboratories in Queensland than in Victoria. This difference reflects the greater role played by the state of Victoria in providing state-supported services for the early detection and diagnosis of hearing impairment.

The cost to the National Acoustic Laboratories of fitting a hearing aid is A $167.00[a]. This includes both the cost of the instrument (approximately A $65) and the cost of testing and prescribing the hearing aid. These costs are relatively low compared to those in the United States. The low cost is due in large measure to the size and efficiency of the Australian system. Because of the large number of hearing aids fitted, the National Acoustic Laboratories designs and manufactures its own hearing aids. The engineers responsible for the design of the hearing aids work in close co-operation with researchers involved in basic research on acoustic amplification and methods of prescribing hearing aids. Consequently, the cost of the intrument is low, and the prescriptive fitting procedures are relatively efficient. Typically, a staff member fits about 7 hearing aids per week.

Another positive aspect of this close co-operation between the research, design, manufacture, and prescriptive fitting of hearing aids is that the hearing aids appear to be of high quality, particularly with respect to those qualities which are of importance for effective communication. (Most hearing aids produced commercially place considerable

[a]These figures apply to mid 1980. At the time, A $1.00 was roughly equivalent to US $1.15.

emphasis on cosmetic considerations.) Further, the hearing aids have been designed to facilitate the prescriptive fitting procedure that will be used, with the result that they are relatively flexible in terms of shaping frequency response and controlling maximum power output.

The National Acoustic Laboratories, among its other activities, also maintains detailed statistical records on the incidence of hearing impairment and the fitting of hearing aids. Table 2 shows a typical set of statistics for the State of Queensland. The table shows the number of children under 17 years of age who have been fitted with hearing aids in the state of Queensland as of March 31st, 1980. The rows of the table show year of birth. The columns show, for each year, the number of live births in the state, the age at which the hearing aid was fitted, the total number of children fitted, the rate of fittings per 1,000 live births, the number of cases attributable to maternal rubella, the degree of hearing loss, and the number of children fitted in the 12-month period ending March 31, 1980.

Regular record keeping of the type described provides a valuable quantitative overview of current trends, the effectiveness of prevention programs, and the impact of specific events such as the rubella epidemic of 1963. Thus, for example, the data show a systematic downward trend in the incidence of hearing impairment, particularly with respect to impairments due to rubella. An analysis of the data also shows that the proportion of children fitted with hearing aids during the first 2 years of life has increased steadily over the years, from less than 10 percent in 1963 to over 30 percent from 1973 on. These figures reflect the impact of a well organized national program of hearing-aid prescription and associated audiological assessment procedures. For additional information on the distribution and use of hearing aids in Australia, see Upfold and Wilson (1980).

State-Supported Services

The hearing-aid delivery and audiological services provided by the National Acoustic Laboratories are supplemented by state-supported programs. These typically involve educational and social services. Thus, the provision of schools and training programs for the hearing impaired vary between the states, as do hospital-based audiology services and state-wide screening procedures for the early detection of hearing impairments.

State-supported services for the hearing impaired vary widely between the states. A good idea of the extent of this variation, and how the states supplement the services offered by the National Acoustic Laboratories, can be obtained by comparing supplementary services provided by the states of Victoria and Queensland, respectively. These two states have been chosen for this comparison since Victoria probably provides the most extensive supplementary services—whereas Queensland provides the least.

Victoria vs. Queensland: a comparison—the state of Victoria, for example, provides hospital-based audiological services, community health centers which provide audiological screening as well as full audiological assessments, and infant welfare centers which provide audiological screening, among other services. Children who

TABLE 1.
New Cases Examined and Hearing Aids Fitted by NAL for 1979/80

NEW CASES EXAMINED		NSW & ACT	VIC	QLD	S.A. & N.T.	W.A.	TAS	AUST.
Persons under 21 yrs	(a)	9,257	4,989	5,392	1,881	1,482	1,153	24,154
Pensioners	(b)	5,804	3,749	2,677	1,708	1,102	638	15,678
Veteran's Affairs	(c)	1,194	926	556	477	428	222	3,803
Others		728	311	849	291	151	130	2,460
TOTAL		16,983	9,975	9,474	4,357	3,163	2,143	46,095
HEARING AIDS FITTED								
Persons under 21 yrs	(a)	2,143	1,560	964	632	426	166	5,891
Pensioners	(b)	10,783	5,574	3,744	2,251	1,563	739	24,654
Veteran's Affairs	(c)	2,410	1,362	808	602	712	235	6,129
Others		82	48	26	18	26	2	202
TOTAL		15,418	8,544	5,542	3,503	2,727	1,142	36,876

(a) All persons under 21 years of age included in this category irrespective of referral.
(b) Pensioners and their dependents are defined in the National Health Act.
(c) Persons referred by Department of Veteran's Affairs.

Abbreviations

NSW = New South Wales
ACT = Australian Capital Territory (Canberra)
VIC = Victoria
QLD = Queensland
S.A. = South Australia
N.T. = Northern Territory
W.A. = Western Australia
TAS = Tasmania
AUST = Australia

FIGURE 2—Children fitted with hearing aids in the State of Queensland; details of deaf children known as at 3/31/81

Year of Birth	No. of Live Births	Age at Fitting in Months									Total Fitted	Rate per 1000	Rubella	3 Freq. Avg. H/L			Number fitted in last 12 months
		0-2 / 12	3-5 / 12	6-8 / 12	9-11 / 12	12-14 / 12	15-17 / 12	18-23 / 12	24+ / 12	Unknown				≤60	dB 61-90	91+	
1963	35,934			1	1	2	2	3	99		108	3.01	8	73	19	16	2
1964	34,972		1	5	4	12	10	21	195		248	7.09	128	115	66	67	4
1965	33,551				2	2	4	6	146		160	4.77	22	107	33	20	9
1966	32,843			3	5	3	3	5	92		111	3.38	34	62	26	23	8
1967	34,692				7	4	8	3	120		142	4.09	36	75	35	32	9
1968	35,190			2	3	2	1	1	109		117	3.32	11	83	15	19	6
1969	36,576			4	5	9	6	11	112		147	4.02	43	74	30	43	10
1970	37,530		3	10	6	5	4	17	107		152	4.05	45	75	41	36	5
1971	39,971	1	5	3	3	3	6	4	107		132	3.30	28	73	38	21	11
1972	39,251	1	3	2	1	1	3	5	78		94	2.39	4	62	22	10	5
1973	38,067			5	2	2	3	9	46		67	1.76	17	28	18	21	8
1974	37,904		2	3	1	5	5	8	44		68	1.79	8	29	19	20	12
1975	36,402	1	1	1	4	5	8	7	30		57	1.57	19	16	18	23	10
1976	35,246			2	4	3	6	10	26		51	1.45	15	10	16	25	12
1977	34,963			2	2	3	4	4	9		24	0.69	5	7	4	13	12
1978	34,620			1	3		2				6	0.17	0	1	2	3	3
1979	27,162 To Sept.		3	2	1						6	0.17	0	1	4	4	6
1980																	
TOTAL	613,927	3	18	46	53	61	75	114	1320		1690	2.75	423	891	403	396	133

fail screening tests are typically referred by their family doctor to ENT specialists or hospital-based specialists. In regional hospitals with audiologists on staff, children assessed with a social handicap loss may be referred to the hospital ENT specialist before referral to NAL for prospective hearing-aid fitting. There are, in addition, many children who are referred directly to NAL hearing centers. These referrals may come from medical sources (most frequently pediatricians) as well as other sources, including self-referrals.

Infants who fail the Infant Welfare tests, carried out by Nursing Sisters, are referred increasingly to Victorian Health Commission Audiologists for secondary assessments. If a child is found to have a potential hearing-aid loss he is then referred directly and quickly to a NAL Hearing Centre. The family doctor is still the anchor in the overall continuous Hearing Health Care and is kept fully advised.

Initial counseling is provided to the parents and an ascertainment committee is notified. The main metropolitan ascertainment committee consists of an educational psychologist, an ENT specialist and a speech pathologist. The committee has the power to co-opt other examining professionals who may be of help in the ascertainment process. Regional ascertainment committees are of similar structure and in recent years greater use has been made of speech pathologists and audiologists, when appropriate.

The role of the ascertainment committee is to review the child's situation and recommend placement, e.g., at a special school or nursery. Reports and opinions are obtained from all relevant examining and other sources prior to a decision being made. The ascertainment committee works closely with the parents on post aid-fitting care, and provides long-term guidance and help in placing the child in an appropriate school. This system of providing the family with individualized long-term advice and guidance is modelled on the Manchester or Ewing-type approach.

The schools for the deaf and special units in regular schools are well staffed and well equipped. Auditory training is supported by the Department of Social Security whereas the hearing aids and technical services are provided by the National Acoustic Laboratories. There is a close liasion between the NAL hearing centers and the schools for the deaf.

In Queensland, the identification of hearing impairment in young children is left primarily to otologists and audiologists based on referrals from pediatricians, family members, and others in direct contact with the child. Once a hearing impairment has been identified, the child is sent to a pre-school for the hearing impaired. The pre-school will accept hearing-impaired children of any age. Once the child has been accepted, a decision is made as to the extent that the pre-school can be helpful and how often the child should be seen. The parents are also advised regarding the child's subsequent schooling. The pre-school is usually staffed by teachers, speech therapists, and physiotherapists. In at least one case (the main pre-school in Brisbane) staffing includes occupational therapists as well. There is a pre-school in each major town. There are two such units in Brisbane, plus an additional parochial unit which follows the cued speech philosophy.

The decision as to where to place a school-age child is

made by the parents on the advice of a guidance officer from the Special Education Branch of the State Education Department. The recommendations are reviewed regularly and are based on assessments from teachers and others on the child's intelligence and rate of progress in the child's current setting. A hearing-level criterion is not used.

The choice in placement is typically between a school for the deaf, a regular school with a special unit for the hearing impaired, or integration into classes of normal-hearing children in regular schools which do not have a special unit. Those who are attending regular schools include a signficant number of severely deaf children as well as many with lesser degrees of impairment.

Hearing-impaired children who attend regular schools receive support from the State Education Department Advisory Visiting Teachers for the Hearing Impaired. The visiting teachers are based all over the state, with more of them concentrated in areas of greater population.

The state-supported schools for the deaf follow the Total Communication philosophy of education. The special units at regular schools typically follow the Oral philosophy. The Cued-Speech approach has been adopted in at least one parochial unit.

Queensland thus provides fewer state-supported services than Victoria, although the basic services are provided. Perhaps the most important difference is the network of screening services available in Victoria for the early detection of hearing impairment. It is probably because of this difference that there is much greater use of the NAL hearing centers for the detection of hearing impairments in Queensland. As shown in Table 1, the ratio of number of new cases examined to number of hearing aids fitted is considerably higher in Queensland (for persons under 21 years of age) than for any other state.

The services offered by the states and by NAL complement each other rather well, although there are more support services offered in some states than in others. A potential problem is that if resources become more restricted, any reduction of services offered by NAL will be felt especially keenly in those states with a less well-developed network of state-supported services.

Preparation of Professional Personnel

The major training program for audiologists in Australia is run by the Department of Otolaryngology at the University of Melbourne. Audiology is taught as an area of specialization at the postgraduate level. A bachelor's degree in a related scientific area (e.g., psychology, physics) is a pre-requisite. The 1-year, full-time training program leads to the Diploma in Audiology, but the student can continue for a Master of Science in Audiology.

The course covers six subjects: audiology, acoustics, anatomy and physiology, biophysics, otolaryngology, and psychology. Audiology, being the largest component of the training program, is subdivided into seven units: general audiology, geriatric audiology, educational audiology, hearing aids, industrial audiology, pediatric audiology, and speech and language. The topics covered by these units are as follows:

General Audiology: Pure tone audiometry, masking, speech audiometry, differential diagnosis of deafness, impedance audiometry, non-organic hearing loss, evoked response audiometry, brain-stem audiometry, central auditory problems, history taking and clinical examination, interpretation of results, ethics, psycho-acoustics, and instrumentation and calibration.

Geriatric Audiology: The aging process, hearing aids for the elderly, aural rehabilitation, speech reading, clinical assessment of the elderly and presbycusis.

Educational Audiology: Psychology of deafness, role of the family, the deaf child at home and at school, parent guidance, auditory training, educational guidance and school placement, vocational guidance for the deaf, hearing aids for home and school, language assessment in the classroom, educational management of the hearing-impaired child, the multiple-handicapped deaf child and sensory approaches to speech and language development.

Hearing Aids: The design and operation of hearing aids, hearing-aid characteristics, selection and evaluation of hearing aids, binaural listening, hearing aids for home and school, counseling and aural rehabilitation, and the rationale for hearing-aid fitting.

Industrial Audiology: Instrumentation, noise abatement, hearing conservation programs, acoustic trauma, hearing handicap, noise and communication, and medico-legal aspects.

Pediatric Audiology: Development of the infant and young child, emotional and social development of children with impaired hearing, causes of deafness, hearing assessment in infants and children, registers of those at risk, genetics, communication disorders and auditory information processing, mental retardation, cerebral palsy, autism and psychoses, central language disorders, psychogenic deafness, deprivation, and the multiple-handicapped deaf child.

Speech and Language: Anatomy, physiology, pathology of the vocal tract, acoustic phonetics, linguistics, psycholinguistics, normal speech and language development, language of the deaf child, speech pathology, and rehabilitation.

Each of the above units involves between 20 and 30 hours of lectures, demonstrations, and clinical work. Each student is required to attend roughly four ½-day clinical sessions per week. Clinical experience is provided at several locations, including the Royal Victorian Eye and Ear Hospital, the Royal Children's Hospital, the State Health Department, and the National Acoustic Laboratories. Each student's clinical work is assessed during training and by clinical examinations in general audiology and pediatric audiology; the latter also involves assessment in aural rehabilitation.

The seven units in audiology comprise about 60 percent of the curriculum. The remaining five subjects deal with the scientific and medical underpinnings of audiology and are made up of 1 unit each. Each unit involves between 20 and 30 hours of lectures plus additional demonstrations and practical work. The topics covered by these supporting units are as follows:

Acoustics: Wave motion and vibrations in gases, liquids and solids, sound absorption and reflection, acoustical impedance, room acoustics, sound fields and noise, the measurement of sound, and psychoacoustics.

Anatomy and Physiology: Anatomy of the ear, the

histology and ultrastructure of the inner ear, middle ear function, cochlear physiology, psychoacoustics, vestibular neuroanatomy, auditory and vestibular neuro-physiology.

Biophysics: Instrumentation, electroacoustical transducers, basic electronics, electrical safety, data acquisition and processing in biology.

Otolaryngology: Pathology of the ear, methods of clinical examination, diseases of the external ear, diseases of the middle ear, diseases of the inner ear, congenital deafness, otosclerosis, presbycusis, acoustic neuroma, Meniere's disease, vestibular disorders, otoneurology.

Psychology: Cognitive development, personality, neuropsychology, psychophysics and the rehabilitative counselling of the sensorily deprived.

In addition, a course in basic statistics is required for those candidates without training in statistics. Students who meet this requirement take an advanced unit in communication disorders.

TABLE 3.
The Bachelor of Speech Therapy Course; subject codes and credit point values of courses

Year 1

SUBJECTS	C.P.V.	Semester
Anatomy	20	Y[a]
Linguistics IA	10	1
Linguistics IB	10	2
Psychology IA	10	2
Psychology IB	10	1
Psychology IC	5	2
Speech Pathology & Therapeutics (1)	15	1
Speech Pathology & Therapeutics (2)	13	2
Total Credit Points	93	

Year II

SUBJECTS	C.P.V.	Semester
Mammalian Physiology I	10	1
Mammalian Physiology II	10	2
Advanced Neurophysiology	3	2
Applied Psycholinguistics	10	1
Experimental Design and Anaylsis	10	2
Acoustic and Practical Phonetics	10	1
Speech Pathology & Therapeutics (3)	10	1
Speech Pathology & Therapeutics (4)	10	2
Clinical Practice[a]	18	Y[a]
Total Credit Points	91	

Year III

SUBJECTS	C.P.V.	Semester
Medical Specialties (STIII) 1	10	1
Medical Specialties (STIII) 2	10	2
Psychology electives[b]	15	1;2
Audiology (1)	12	1
Audiology (2)	12	2
Language Learning Disorders (1)	12	1
Language Learning Disorders (2)	12	2
Speech Pathology & Therapeutics (5)	10	1
Speech Pathology & Therapeutics (6)	10	2
Clinical Practice[a]	23	Y[a]
Total Credit Points	126	

[a]Extends into vacation period.
[b]A candidate must obtain credit for 15 credit points of advanced Psychology subjects, approved by the Head of the Department of Speech and Hearing. All students must have a minimum of 60 credit points taken in the Department of Psychology over the three years of the Speech Therapy Course.

Training in speech and language pathology (still referred to as speech therapy in Australia) is, for the most part, provided by colleges of advanced education. Queensland is the only state that provides university-level training in speech therapy. The Department of Speech and Hearing at the University of Queensland offers an undergraduate program leading to the Bachelor of Speech Therapy Degree. The department also offers a postgraduate course in speech therapy and audiology leading to the postgraduate Honours degree. Students can also continue for Master's and Doctoral level degrees.

The course work in speech and hearing at the University of Queensland covers relevant areas in several disciplines including psychology, physiology, and linguistics. A summary of the courses for the Bachelor of Speech Therapy degree is given in Table 3. Two-thirds of the courses shown (plus clinical practice) are in the area of speech and hearing. The remaining courses are equally divided between linguistics, physiology and medically-oriented courses (1 in anatomy, and 2 interdisciplinary medical courses).

Clinical experience is obtained by placement in clinics under the supervision of senior clinicians. The level of clinical training is systematically increased over the period of study. The amount of clinical training varies between the programs. At the University of Queensland, for example, the course in clinical practice is taken for four consecutive semesters, including portions of the intervening vacation periods. On completion of the training program the new graduate is expected to obtain additional full-time clinical experience before being considered a fully trained professional.

Training programs typically work in cooperation with several different clinics in order to provide their students with a broad range of clinical experiences. These include hospital clinics, child welfare centers, and both state and federal health centers.

The National Acoustic Laboratories (NAL), because of its large network of hearing centers, plays a major role in providing clinical training facilities. The cooperation between NAL and clinical training programs is mutually beneficial. NAL assists in providing clinical experiences to students in training and is the major employer of the graduates of these programs. The programs, in turn, are cognizant of the needs of the National Acoustic Laboratories and have geared relevant portions of the curriculum towards those needs.

In summary, the training of professional personnel in audiology and speech pathology is strongly interdisciplinary with a distinct emphasis on psychology. This approach is not very different from that at several leading speech and hearing programs in the United States where students in speech and hearing take a minor in either psychology or linguistics. In contrast to the American model, there is a marked disparity between the academic status of audiology and that of speech pathology. Audiology is accorded university status and is taught at the postgraduate level. In contrast, training in speech therapy (as it is called) is typically provided at colleges of advanced education. The gap between the two fields is gradually being narrowed and in one state (Queensland), it is now possible to study speech therapy at the university level. The program at the University of Queensland, which is the first of its type, has many similarities with the American model.

Research on Acoustic Amplification, Audiological Techniques, and Innovative Prosthetic Aids.

Two major research efforts on prosthetic aids for the hearing impaired are currently in progress in Australia. The National Acoustic Laboratories is concerned with research and development on conventional hearing aids, and the University of Melbourne has a major ongoing project on the development and evaluation of a cochlear implant prosthesis.

The research effort at the National Acoustic Laboratories covers three broad areas: hearing, acoustic amplification for the hearing impaired, and the effects of noise on man. The second of these three areas was of primary interest in the study visit. The NAL group most directly concerned with research on acoustic amplification for the hearing impaired and on associated audiological procedures is the Audiology Development Section under the direction of Mr. Denis Byrne. This group is currently working on hearing-aid selection procedures, the validation of these procedures, binaural hearing aids, group amplification systems, and a programmable multi-channel hearing aid.

The work on hearing-aid selection procedures includes the development and refinement of the Byrne and Tonisson (1976) procedure for selecting the frequency-gain characteristic of a hearing aid. The technique requires the measurement of hearing threshold levels from which is estimated the frequency-gain characteristic that will place the speech signal at close to the most comfortable level across the frequency range. The procedure has been extended to the case for severely hearing-impaired children (Byrne, 1978). Refinements and more detailed validation of these procedures are currently in progress. These include an analysis of preferred listening levels for different frequency bands of speech (Christen and Byrne, 1980 a) and the problem of test-retest variability in measuring most comfortable level directly (Christen and Byrne, 1980 b).

A major concern of the National Acoustic Laboratories is whether or not to prescribe binaural hearing aids. Consequently, the Audiology Development Section has engaged in what is probably the largest study yet on the relative advantages of binaural hearing aids (Byrne, 1980). During a trial period of 28 months, approximately 2,500 children were fitted with binaural hearing aids. The children were seen routinely at one month and 6 month intervals after fitting. The information obtained on each child included: a case history (e.g., onset and cause of deafness, stability of hearing levels, other handicaps); aided thresholds (left, right, binaural); history of hearing-aid experience; details of current hearing-aid use (e.g., settings normally used, and measured gain at these settings for selected frequencies); and questionnaire information from the parents on the child's acceptance of the hearing aids and the degree of benefit observed. In addition to the field trials with children, just over 100 hearing-impaired adults participated in several experiments designed to measure a binaural summation, auditory localization, and speech discrimination with binaural hearing aids.

The results of these studies showed a consistent pattern of improvement for the binaural over the monaural hearing aid. Binaural summation on the order of 3 to 5 dB was obtained at sensation levels of 10 to 40 dB (Dermody and Byrne, 1975a). A loudness-balance technique with narrow

bands of noise was used. Auditory localization was also found to be superior for binaural as opposed to monaural hearing aids. (Dermody and Byrne, 1975 b). The advantage in auditory localization was found to be greatest at low sensation levels. At higher sensation levels auditory localization with the monaural hearing aid is improved significantly because of the contribution of the unaided ear at these high levels. The studies also showed that the binaural advantage can be obtained with body-worn hearing aids as well as with earlevel aids, provided the microphones are spaced 7 to 10 inches apart.

The study on speech discrimination showed advantages for the binaurally aided case for most subjects. Test-retest variability on speech discrimination tests is relatively high, however, and the binaural advantage is not as easily measured as in the other experiments. A number of incidental advantages of binaural hearing aids were also observed in these experiments. These include the reduction of head shadow and body baffle effects, and the "cross-over" effect. The latter effect applies to the case where one ear is better than the other for certain frequencies only; a properly prescribed binaural hearing aid makes most effective use of the available hearing at all frequencies, thereby allowing the better ear at each frequency to carry the bulk of the auditory input.

The body of data that provided the strongest support for the binaural hearing aid came from the questionnaire studies. These studies show a preference by the majority of users for the binaural hearing aid except under conditions of speech in noise. Similar results were obtained in questionnaire studies involving parents and teachers of deaf children.

An important practical advance (in the Field Service Section) has been the development of a new earmold-impression technique that reduces acoustic feedback significantly (Fifield, Earnshaw and Smither, 1980). An important feature of the technique is that the impression is built up in stages. A primary impression is made using a heavy bodied silicone rubber material. A thin coating of a medium-bodied silicone is then applied to the surface of the primary impression. The impression is re-seated in the ear. The silicone coating, while soft, flows into those regions not forming a good seal between the impression and the canal wall. The material is allowed to set and the seal is tested by increasing the air pressure in the ear canal using the air pump on an impedance meter. A good seal is expected to maintain a maximum pressure of 200 mm water for 5 seconds without any discernible loss in pressure. A third layer is then added, this time using a thin-bodied silicone material. In this way the fine detail of the ear's structure is recorded on the impression.

The work on group-amplification systems has been geared to the refinement and more efficient utilization of radio transmission systems (e.g., in a classroom or lecture hall). A set of practical guidelines has been developed (Christen and Plant, 1976) which provides for immediate improvements in the utilization of existing systems. Techniques for more efficient use and allocation of available transmission channels have also been developed (Burgess, Christen, Donald and Lowe, 1979). The new infra-red transmission systems (Leshowitz, 1979) have recently been introduced to Australia.

Work on a programmable, multi-channel, amplitude-compression hearing aid is currently in progress (Byrne and Walker, 1979). The main thrust of the project is to develop a digitally programmable system in which gain, amplitude compression, and limiting can be controlled independently for each channel and matched to the individual requirements of each user. The system offers advantages not available in conventional hearing aids. It should be particularly useful for sensorineural impairments in which the ear's dynamic range is severely limited by recruitment.

Other ongoing research includes mathematical modelling of the sound transmission characteristics between hearing-aid receiver and eardrum, and the development of a wide-band hearing aid. A conventional hearing-aid receiver is coupled to a miniature acoustic horn designed to extend the high-frequency of the hearing-aid receiver. Bandwidth up to 18,000 Hz can be obtained (Macrae, 1980). Methods of improving sound localization by placing the hearing-aid microphone in the ear, at the entrance to the ear canal, are also being investigated.

Cochlear Implant Study—One of the most exciting ongoing research projects is the cochlear implant study currently in progress in the Department of Otolarnygology at the University of Melbourne. The project, under the direction of Dr. Graeme Clark, has developed a multiple-channel electrode array for insertion in the cochlea (Clark and Hallworth, 1976). Two subjects have been implanted thus far, with good results. Test scores, before and after implantation, show improved speech communication skills with the potential for even greater improvements.

A major strength of the project is the use of 10 independent channels to deliver the coded speech signal. A crucial limitation of previous attempts at developing an effective cochlear prothesis is that, until very recently, only one channel has been used. A single-channel cochlear implant is highly unlikely to produce intelligible speech, since it is well known that the specch signal contains important information in many different frequency bands (Levitt, Pickett, and Houde, 1980). The important question is not whether a single-channel cochlear implant will be effective, but rather how many channels are necessary for an effective implant. The choice of 10 channels by Clark and his research team appears adequate, since intelligible speech can be obtained from a well designed 10-channel Vocoder.

The present electrode array consists of 20 platinum bands around the outside of a silicone rubber tube. Each band is welded to a Teflon-coated platinum wire which passes down the center of the tube. The spacing between electrodes in the array has been designed to produce independent stimulation of adjacent groups of nerve fibers in the cochlea (Clark, et al., 1978).

The array is inserted surgically through the round window (Clark, Pyman, and Bailey, 1979). The unit is stabilized by seating it in a Silastic mold. A receiver coil is placed in a bed created in the mastoid part of the temporal bone. The transmitter coil is placed externally just behind the pinna.

The 10-channel electrode array is stimulated by a coded speech signal. The fundamental frequency of the voice is extracted from the acoustic signal as well as the frequency and energy of the dominant spectral peak in the mid-

frequency range; the latter serves as an estimate of the second formant. The electrodes are stimulated by bipolar pulses. Fundamental frequency is coded as the rate of stimulation. The frequency of the estimated second formant determines which electrode is stimulated (according to the tonotopic organization of the cochlea); the intensity of the spectral peak determines the current level.

The assessment of the cochlear implant includes clinical evaluation of the ear and balance mechanism, radiological evaluation to check for anatomical variations or pathologies prior to and after surgery, a detailed audiological and psychoacoustic evaluation (pre- and post-surgery), and a basic psychological evaluation (Clark et al, 1977, Tong, et al., 1979). The medical, radiological and psychological evaluations showed no adverse effects resulting from the surgery. The audiological and psychoacoustic evaluations showed significantly improved pure-tone thresholds, and an ability to perceive pitch and loudness changes. Subjects were also able to identify differences in vowel spectra, the electrodes being stimulated according to the tonotopic organization of the cochlea.

Results on a word identification task showed significantly improved scores between multiple-channel and single-channel stimulation (48.5 percent vs 15.2 percent), the latter score being typical of that obtained without the implant. After some training, additional improvements were obtained—from a discrimination score of 48.5 percent to 52 percent, averaged over two tests (Clark, Tong, and Martin, 1980). More detailed testing on a variety of speech and psychoacoustic tests is currently in progress.

In summary, the multiple channel cochlear implant developed at the University of Melbourne appears particularly promising. All major aspects of the problem have been taken into account, including the technological problems of creating a suitable flexible array, the signal processing necessary to encode the speech signal in an intelligent way, the physiological problem of stimulating independently separate groups of nerve fibers, the medical, audiological and psychological factors involved in assessing the effect of the implant and, of course, the surgical procedures to implant the device safely.

Great strides are being made in Australia in the development of more effective prosthetic aids for the hearing-impaired. The approaches used and the methods of practical implementation, including the delivery of services, should serve as models for comparable programs in the United States and elsewhere.

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