

Assistive Technology for the Hearing-impaired, Deaf and Deafblind

Springer

London

Berlin

Heidelberg

New York

Hong Kong

Milan

Paris

Tokyo

Marion A. Hersh, Michael A. Johnson (Eds.)

with Conny Andersson, Douglas Campbell, Alistair Farquharson, Stephen Furner, John Gill, Alan Jackson, Jay Lucker, Keith Nolde, Erhard Werner and Mike Whybray

Assistive Technology for the Hearing-impaired, Deaf and Deafblind



Springer

Marion A. Hersh, MSc, PhD

Department of Electronic and Electrical Engineering, University of Glasgow,
Glasgow, G12 8LT, UK

Michael A. Johnson, MSc, PhD

Department of Electronic and Electrical Engineering, University of Strathclyde,
Glasgow, G1 1QE, UK

British Library Cataloguing in Publication Data

Assistive technology for the hearing-impaired, deaf and
deafblind

1. Self-help devices for people with disabilities 2. Hearing
impaired 3. Hearing aids – Design and
construction

I. Hersh, Marion A. II. Johnson, Michael A. (Michael Arthur),

1948-

617.8'9

ISBN 1852333820

Library of Congress Cataloging-in-Publication Data

Assistive technology for the hearing-impaired, deaf and deafblind / Marion A. Hersh,
Michael A. Johnson (eds), with Conny Andersson ... [et al.].

p. cm.

Includes bibliographical references and index.

ISBN 1-85233-382-0 (alk. paper)

1. Deaf--Means of communication. 2. Communication devices for people with
disabilities. 3. Deaf--Means of communication--Technological innovations. 4.

Communication devices for people with disabilities--Technological innovations. I. Hersh,
Marion A., 1956- II. Johnson, Michael A., 1948-

HV2502.A875 2003

362.4'283--dc21

2002044538

Apart from any fair dealing for the purposes of research or private study, or criticism or review, as permitted under the Copyright, Designs and Patents Act 1988, this publication may only be reproduced, stored or transmitted, in any form or by any means, with the prior permission in writing of the publishers, or in the case of reprographic reproduction in accordance with the terms of licences issued by the Copyright Licensing Agency. Enquiries concerning reproduction outside those terms should be sent to the publishers.

ISBN 1-85233-382-0 Springer-Verlag London Berlin Heidelberg
a member of BertelsmannSpringer Science+Business Media GmbH

© Springer-Verlag London Limited 2003

The use of registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant laws and regulations and therefore free for general use.

Product liability: The publisher can give no guarantee for information about drug dosage and application thereof contained in this book. In every individual case the respective user must check its accuracy by consulting other pharmaceutical literature.

Typeset by Ian Kingston Editorial Services, Nottingham, UK
Printed and bound in the United States of America
28/3830-543210 Printed on acid-free paper SPIN 10781975

For my mother and father
Marion A. Hersh

That this book might inspire my two young friends, Holly and Joe
Michael A. Johnson

Preface

Affirmative legislative action in many countries now requires public spaces to be accessible and service providers to change or introduce practices, policies, or procedures that allow equal accessibility by disabled people. Although this is often interpreted as access for wheelchair users, such legislation also covers people with vision or hearing impairments. In these cases it is often the provision of advanced technological devices that enable people with sensory impairments to enjoy the theatre, cinema, a political meeting or a religious meeting to the full. Hearing-impaired and deaf people have been especial beneficiaries of this slow, but growing, technological provision, and this book is about this particular branch of assistive technology.

The field of assistive technology has steadily grown, driven by the desire to provide disabled people with equal access to the facilities and products of society and to provide an enhanced quality of life for this community group. Many different engineering ideas and disciplines have been used to produce the technological solutions required. However, there have been few, if any, systematic attempts to draw together the themes of assistive technology and create a coherent technological and engineering discipline. It is true that organisations like the Rehabilitation Engineering Society of North America (RESNA) and the Association for the Advancement of Assistive Technology in Europe (AAATE) try to present a cohesive programme for assistive technology, but our experience has been that, although many engineers are active in these organisations, assistive technology has not yet become part of mainstream engineering.

Part of the problem is simply the lack of a coherent educational framework for involving *engineers* in the assistive technology field. This is not to say that engineers do not wish to study the subject, since our experience is that young undergraduate and postgraduate engineers relish the idea of trying to solve problems in assistive engineering. Indeed, there are some really challenging technical problems still to be tackled. What is missing are books that demonstrate that it is possible to bring together the themes of human physiology, fundamental engineering principles, design principles, engineering technology, and human end-user issues (such as ethics) to make a coherent course that can contribute to the higher education of electrical and mechanical engineers. This particular collaborative book is an attempt to demonstrate just how this might be accomplished for the assistive technology needed by the hearing impaired and deaf community. The book is envisaged as the first of a series of three texts dealing, in turn, with assistive technologies and devices for people with hearing, vision and mobility impairments.

In parallel with developing this textbook, we have been pioneering the introduction of a course module on Assistive Technology in the Electronic and Electrical Engineering degrees at our respective universities. The experience gained in developing the educational framework has also been fed into the book as it progressed. The consequence has been a strong editorial steer on the various chapters to give the type of information required in degree courses and the strong engineering approach in the book. This particular book is about the application of electrical technology to all aspects of communication and daily living for those people with hearing impairments. The first chapter, on physiological aspects of hearing, sets the background for the various technological areas, namely hearing-aid development, induction and infrared communications for public spaces, and accessibility. The book then continues with facilitating technologies and devices for telephony and daily living. The penultimate chapter takes a look at assistive technology for deafblind people, a really challenging area with a number of unsolved research questions. The final chapter of the book presents a basic introduction to human end-user issues and ethics, as well as the distribution of devices to end users. This is not a long chapter, but it deals with topics that are often omitted from existing engineering courses.

We believe we set ourselves ambitious objectives in writing this book, which could not have been accomplished without the cooperation and enthusiasm of our collaborating authors. We would like to thank them all for their help and patience in seeing the project come to fruition. We have been lucky to meet many of our collaborators at the Conference and Workshop on Assistive Technologies for Vision and Hearing Impairment, which we organise with invaluable European Union support (from the High Level Scientific Conference Programme), and this has given us the opportunity to discuss and debate together many of the engineering ideas and techniques reported in the book. Needless to say, we have made many new friends in the process and gained many useful insights into assistive technology for people with hearing and vision impairments. We hope this book will inspire many new projects, new courses and new ways to assist people with sensory impairments.

*Marion Hersh and Michael Johnson
Glasgow, Scotland, UK*

Who Should Read This Book

This book is designed to inform a wide range of current and future professionals about basic engineering principles and the way these principles are turned into assistive technology devices, the possible future technology developments, and the human end-user aspects in assistive technology for hearing-impaired and deaf people. As far as we have been able to ascertain, there are no other textbooks for electrical engineering, mechanical engineering and scientific professionals on this technological area at this depth or with this higher educational approach. This is expected to change as legislative pressures drive the need for more engineering and social professionals to become aware of

these technologies. Similarly, we have not been able to find any undergraduate course texts of adequate detail and depth for the discipline of assistive technology. Thus, we hope this book will be well placed to meet this need, as it has been designed to be read by electrical engineering undergraduates as a course book or to supplement existing courses. The authors have been encouraged to see many engineering undergraduates enjoy this type of material, and it is hoped that this enjoyment will fire the ingenuity of engineering students to find new and innovative ways to develop technology to support hearing-impaired and deaf people.

An Overview of the Book

This book provides detailed coverage of the full range of assistive technologies used to support deaf and hearing-impaired people, including state-of-the-art techniques. Division into chapters is based on either the type of technology or the field of application. The following applications are discussed: audiology and assessment of hearing loss, hearing aids, telecommunications, devices for daily living and devices for deafblind people. Systems and devices based on the induction-loop technology and infrared technology are presented. To provide a background to the technologies, particularly the hearing assessment and hearing-aid technologies, the first chapter discusses the physiology of the ear and causes of deafness.

The book is designed so that each chapter is self-contained and can be read on its own, though familiarity with the material in Chapter 1 will be assumed in some of the other chapters. Each chapter is motivated by specific learning objectives and contains an introduction to the subject, such as the basic principles of the underlying technology or the application area. This is usually followed by a full discussion of the applications of the technology to support the hearing impaired. The chapters close with suggestions for projects and reference to further reading sources, books, journal and conference papers and Web sites. There may be many professionals for whom this is a new area and who may not be familiar with the underpinning pedagogical engineering topics covered in the various chapters, so Table 1 is given to provide an outline plan of the book and the disciplines involved.

Editorial Responsibilities

The concept of this book originated with Marion Hersh and Michael Johnson, who were also responsible for the overall task of collating and integrating the various contributions. The book is more a close collaboration between editors and chapter contributors than the usual book of edited chapters and papers. This was necessary to try and obtain the style of a textbook on assistive technology for hearing-impaired and deaf people.

Table 1 An outline plan of book and pedagogical fundamentals.

Chapter	Key fundamentals in the chapter
1 Anatomy and Physiology of Hearing, Hearing Impairment and Treatment	Human physiology (of the ear) Acoustics, speech and sound Hearing-loss categories
2 Audiology: The Measurement of Hearing	Measurement principles Frequency response and decibels Instrumentation – medical Calibration and standards
3 Hearing-aid Principles and Technology	Signal-processing principles Human body as an engineering environment Electronics – analogue and digital
4 Induction-loop Systems	Electromagnetic principles Electrical circuit equivalents Calibration and standards
5 Infrared Communication Systems	Electromagnetic spectrum Basic communication system principles Diodes – LEDs and IREds System design, construction and standards
6 Telephone Technology	Basic telephony principles Electromagnetic induction Textphone principles Videophone principles Ergonomics
7 Alarm and Alerting Systems for Hearing-impaired and Deaf People	Unifying generic system structures Sensors, transmission modules and actuators Amplifier types and principles Interface design and ergonomics
8 Dual Sensory Impairment: Devices for Deafblind People	Sensory impairment demography and classes Braille principles Sensors and actuators Difficult interface design and ergonomics Information technology
9 The Final Product: Issues in the Design and Distribution of Assistive Technology Devices	Human issues Working with end users Social research methods Ethics for engineers and other professionals

Chapter Contributions

Chapter 1 on, Anatomy and Physiology of Hearing, Hearing Impairment and Treatment, was the work of Jay Lucker with input from Marion Hersh. Marion Hersh and Michael Johnson contributed Chapter 2, on Audiology: The Measurement of Hearing, in which an engineering perspective to the measurement aspect of audiology is taken. Douglas Campbell, who was a Leverhulme Fellow in Hearing Aid Technology, contributed Chapter 3, Hearing-aid Principles and Technology. Bo-Edin is a Swedish company specialising in induction-loop technology, and Conny Andersson drew on his wide applications experience to write Chapter 4 on Induction-loop Systems. Similarly, Erhard Werner used his deep technical expertise garnered from a long career with the Sennheiser

Company to write Chapter 5 on Infrared Communications Systems. British Telecommunications research laboratories, located within BTextact at Adastral Park in Suffolk, have a world renowned reputation in assistive technology for telecommunications. Stephen Furner and his colleagues from BT at Adastral Park wrote Chapter 6 on Telephone Technology for hearing-impaired people. Chapter 7, on Alarm and Alerting Systems for Hearing-impaired and Deaf People, was written by Marion Hersh with input from Jay Lucker. The presentation of a common and generic engineering framework in which to discuss the various devices was an important component of this chapter. John Gill used his long association with the RNIB to write Chapter 8, Dual Sensory Impairment: Devices for Deafblind People; this material was augmented by contributions from Marion Hersh. Finally, Chapter 9, The Final Product: Issues in the Design and Distribution of Assistive Technology Devices, was contributed by Marion Hersh.

The Contributors and Their Affiliations

Marion Hersh, Department of Electronics and Electrical Engineering, University of Glasgow, Glasgow G12 8LT, Scotland, UK.

Michael A. Johnson, Department of Electronic and Electrical Engineering, University of Strathclyde, Glasgow G1 1QE, Scotland, UK.

Jay R. Lucker, formerly with Department of Audiology & Speech-Language Pathology, Gallaudet University, Washington, DC 20002-3695, USA. Now in private practice: PO Box 4177, Silver Spring, MD 20914-4177, USA.

Douglas R. Campbell, School of Information and Communication Technologies, University of Paisley, High Street, Paisley, PA1 2BE, Scotland, UK.

Conny Andersson, Bo-Edin, S-18175 Lidingo, Sweden.

Erhard Werner, formerly with Sennheiser, Germany.

Stephen Furner, Alan Jackson, Keith Nolde, Mike Whybray and Alistair Farquharson, British Telecommunications, Adastral Park, Martlesham Heath, Suffolk IP5 3RE, UK.

John Gill, Royal National Institute for the Blind, Falcon Park, Neasden Lane, London NW10 1RN, England, UK.

More detailed biographical sketches of the individual contributors can be found at the end of the book.

Contents

1 Anatomy and Physiology of Hearing, Hearing Impairment and Treatment	1
1.1 Introduction	1
1.1.1 Learning Objectives	1
1.1.2 Overview of Hearing	2
1.1.3 The Auditory System in Engineering Terms	3
1.2 Acoustics of Hearing	4
1.2.1 Amplitude	6
1.2.2 Phase	7
1.2.3 Frequency and Period	8
1.2.4 Sound Intensity and the Decibel Scale	8
1.2.5 Simple and Complex Sounds	9
1.2.6 Spectral Analysis of Complex Sounds	10
1.2.7 Filtering Sound	10
1.3 Anatomy and Physiology of the Auditory System	14
1.3.1 Some Terminology Used in Describing Anatomical Structures	14
1.4 The Anatomy and Functions of the Outer-ear Structures	15
1.4.1 The Pinna	16
1.4.2 External Auditory Meatus	16
1.4.3 Functions of the Outer-ear Structures	17
1.5 The Anatomy and Functions of the Middle-ear Structures	18
1.5.1 The Tympanic Membrane	18
1.5.2 Middle-ear Ossicles	19
1.5.3 The Middle-ear Cavity	20
1.5.4 The Functions of the Middle-ear Structures	22
1.6 The Anatomy and Functions of the Inner-ear Structures	23
1.6.1 Vestibule	24
1.6.2 The Cochlea	24
1.6.3 Sound Processing in the Cochlea	27
1.7 The Central Auditory Nervous System	27
1.8 Classification of Hearing Loss	29
1.8.1 Degrees of Hearing Loss	31
1.8.2 Hearing Loss Due to Problems in the Outer Ear	31
1.8.3 Hearing Loss Due to Problems in Middle Ear	32
1.8.4 Hearing Loss Due to Problems in the Cochlea	32

1.8.5	Problems in the Auditory (Eighth) Nerve and Central Auditory Pathways	33
1.9	Medical and Non-medical Treatments	36
1.9.1	Medical and Surgical Treatment of Problems in the Auditory System	36
1.9.2	Non-medical or Non-surgical Interventions	36
1.10	Learning Highlights of the Chapter	37
	Projects and Investigations	38
	References and Further Reading	39
2	Audiology: The Measurement of Hearing	41
2.1	Introduction: The Measurement of Hearing	41
2.1.1	Learning Objectives	41
2.2	Measurement Systems	42
2.2.1	Definitions	42
2.2.2	Frequency-response Curves	43
2.2.3	Gain in Decibels	43
2.2.4	Amplifiers	44
2.3	Measurement of Biological Variables and Sources of Error	44
2.3.1	Types of Error	44
2.3.2	Physiological and Environmental Sources of Error	45
2.4	The Test Decision Process	46
2.5	Pure-tone Audiometry	47
2.5.1	Audiograms	47
2.5.2	Noise	48
2.5.3	The Test	48
2.5.4	Masking	51
2.5.5	Instrumentation	52
2.5.6	Technical Description of an Audiometer	53
2.5.7	Technical Specifications	55
2.6	Immittance Audiometry	56
2.6.1	Definitions	56
2.6.2	Measurement	57
2.6.3	Static Acoustic Immittance	58
2.6.4	Tympanometry	58
2.6.5	Acoustic Reflex Threshold	59
2.7	Electric Response Audiometry (ERA)	59
2.7.1	Electrocochleography	60
2.7.2	Brain-stem Response Audiometry	61
2.8	Standards	61
2.9	Audiometric Equipment Design and Calibration	62
2.9.1	Earphone Calibration	63
2.9.2	Calibration of Pure-tone Audiometers	64
2.9.3	Calibration of Couplers and Sound-level Meters	64
2.9.4	Calibration of Bone Vibrators	65
2.9.5	Calibration of Acoustic Immittance Devices	65
2.10	Artificial Ears	65
2.10.1	The 2cc Coupler	66
2.10.2	Zwislocki Coupler	67
2.10.3	KEMAR	67

2.11	Learning Highlights of the Chapter	68
	Acknowledgements	68
	Projects and Investigations	68
	References and Further Reading	69
3	Hearing-aid Principles and Technology	71
3.1	Learning Objectives	71
3.2	Introduction	71
3.2.1	Review of Technical Terms	73
3.2.2	Human Hearing Viewed from an Engineering Perspective	73
3.2.3	Hearing-aid Prescription (in Brief)	77
3.3	Categories of Electronic Aids	80
3.3.1	Body-worn Aid	81
3.3.2	Behind-the-ear Aid	81
3.3.3	Spectacles Aid	83
3.3.4	In-the-ear Aid	83
3.3.5	Bone-conduction Aid	84
3.3.6	Middle-ear Implant Aid	85
3.3.7	Cochlear Implant Aid	85
3.3.8	Auditory Brain-stem Implant Aid	86
3.4	Historical Background	87
3.5	The Ear as an Environment	88
3.5.1	Aid-on-body Considerations	88
3.5.2	Body-on-aid Considerations	90
3.6	Processing Strategies	91
3.6.1	Single-channel Processing Schemes	91
3.6.2	Multiple-channel Processing Schemes	103
3.7	Modern Hearing-aid Technology	106
3.7.1	Analogue Hearing Aids	106
3.7.2	Digital Hearing Aids	106
3.7.3	Portable Speech Processors	108
3.8	Conclusion and Learning Highlights of the Chapter	109
3.8.1	Current Research	110
3.8.2	A Future Possibility?	110
3.8.3	Learning Highlights of the Chapter	110
	Acknowledgements	111
	Projects and Investigations	111
	References and Further Reading	113
4	Induction-loop Systems	117
4.1	Learning Objectives	117
4.2	Audio-frequency Induction-loop Systems	117
4.3	The Electromagnetic Principles of a Loop System	118
4.4	Induction-loop Systems	121
4.4.1	Hearing-aid Receiver or Telecoil	121
4.4.2	The Effect of Different Materials and Loop Shapes	122
4.4.3	Magnetic Field Strength	123
4.4.4	Magnetic Field Direction	124
4.4.5	Magnetic Field Distribution	124

4.4.6	Overspill	128
4.5	Loop Installation	132
4.5.1	Multi-combination Loop System	136
4.6	The Electrical Equivalent of a Loop System	136
4.6.1	Loop Inductance	137
4.6.2	Loop Resistance	137
4.6.3	Loop Impedance	137
4.6.4	Two-turn Loop	141
4.7	Automatic Gain Control	143
4.8	Loop System Measurements	146
4.8.1	The Dynamic Range of a Loop System	146
4.8.2	Magnetic Field Strength as a Function of Level and Frequency	147
4.8.3	Measurement of the Loop Amplifier	147
4.8.4	Field-strength Meters	148
4.9	Standards for Loop Systems	149
4.10	Learning Highlights for the Chapter	150
	Projects and Investigations	151
	References and Further Reading	152
5	Infrared Communication Systems	153
5.1	Learning Objectives and Introduction	153
5.1.1	Learning Objectives	153
5.2	Basic Principles	153
5.2.1	General Technical Requirements for Audio Applications	154
5.2.2	Applications	155
5.2.3	Technical Features and Application Requirements	157
5.3	System Components	158
5.3.1	Audio Sources and Signal Processing in the Transmitter	159
5.3.2	Radiators	160
5.3.3	Receivers	164
5.4	Compatibility and Use with Hearing Aids	169
5.5	Design Issues	169
5.5.1	System Placement	170
5.5.2	Interference Issues	170
5.5.3	Ergonomic and Operational Issues	170
5.6	Technical Standards and Regulations	172
5.7	Advantages and Disadvantages of Infrared Systems	172
5.8	Conclusions and Learning Highlights	173
5.8.1	Learning Highlights of the Chapter	173
	Acknowledgements	173
	Projects and Investigations	174
	References and Further Reading	175
6	Telephone Technology	177
6.1	Introducing Telephony and Learning Objectives	177
6.2	User-centred Telephone Design	178
6.2.1	Designing for Hearing Impairment	178

6.2.2	Putting It All Together	180
6.3	Design of an Electronic Telephone	180
6.3.1	Introducing the Modern Telephone	182
6.3.2	Indication of the Start of the Call	184
6.3.3	Transmission of Signalling Information	184
6.3.4	Design of the Transmission Circuit	187
6.3.5	Call Arrival Indication (Ringing)	190
6.3.6	Telephone Design Enhancements to Provide Additional Accessibility Features	192
6.4	The Text Telephone	195
6.4.1	Introduction	195
6.4.2	Basic Principles	196
6.5	The Videophone	203
6.5.1	Basic Principles	203
6.5.2	Application Aspects	206
6.5.3	Systems and Standards	208
6.5.4	Future Systems	210
6.6	Conclusions and Learning Highlights	210
6.6.1	Learning Highlights of the Chapter	210
	Projects and Investigations	211
	References and Further Reading	212
7	Alarm and Alerting Systems for Hearing-impaired and Deaf People	215
7.1	Learning Objectives	215
7.2	The Engineering Principles of Alarm and Alerting Devices	215
7.2.1	Design Issues	216
7.2.2	Categorisation of Alarm and Alerting Systems	218
7.3	Sensors, Transducers and Actuators	220
7.3.1	The Sensors in Fire Alarms	221
7.3.2	Carbon Monoxide Sensors	223
7.3.3	Intruder Detectors	225
7.3.4	Piezoelectric Sensors: Sound and Pressure	226
7.3.5	Microphones: Sound Sensors	228
7.4	Signal Conditioning	229
7.4.1	Voltage and Power Amplifiers	230
7.4.2	Transistor	231
7.4.3	Voltage Amplifiers	233
7.4.4	Small-signal Tuned Amplifiers	234
7.4.5	Class C Power Amplifiers	235
7.4.6	Class AB Power Amplifiers	237
7.5	Radio Frequency Transmission	237
7.5.1	Transmitter	238
7.5.2	Superheterodyne Receiver	239
7.5.3	Modulation	241
7.5.4	Modulator	242
7.5.5	Demodulator	244
7.6	Actuators	246
7.6.1	Auditory Signals: Loud Bells and Buzzers	246
7.6.2	Lights	247

7.6.3	Light-emitting Diodes	248
7.6.4	Television	248
7.6.5	Vibro-tactile Devices	249
7.6.6	Electro-tactile Devices	250
7.6.7	Paging Systems	250
7.7	Learning Highlights of the Chapter	253
	Projects and Investigations	253
	References and Further Reading	254
8	Dual Sensory Impairment: Devices for Deafblind People	257
8.1	Learning Objectives	257
8.2	Definitions and Demographics of Deafblindness	257
8.3	Communication for Deafblind People	258
8.3.1	Assistive Technology for Deafblind Communication	261
8.4	Braille Devices	262
8.4.1	Braille Displays	262
8.4.2	Multifunction Braille Notetakers	263
8.4.3	Text-Braille Conversion and Braille Embossers	264
8.5	Automating Fingerspelling for Deafblind Communication	266
8.5.1	Developing Mechanical Fingerspelling Hands for Deafblind People	266
8.5.2	Dexter I	267
8.5.3	Dexter II and III	268
8.5.4	Fingerspelling Hand for Gallaudet	268
8.5.5	Ralph	270
8.5.6	The Handtapper – a UK Development	271
8.5.7	Speaking Hands and Talking Gloves	272
8.5.8	Comparison and Availability	273
8.6	Other Communication Aids	274
8.6.1	The Optacon and Optical Character Recognition (OCR)	274
8.6.2	Tactile Sound-recognition Devices	275
8.7	Low-technology Devices and Domestic Appliances	276
8.8	Bluetooth	278
8.9	Alerting Devices for Deafblind People	279
8.9.1	Vibrating Alarm Clocks	280
8.9.2	A Multifunction Domestic Alert System	282
8.9.3	Tactiwatch	284
8.9.4	Tam	284
8.10	Access to Information Technology	284
8.10.1	The Universal Communications Text Browser (Ucon)	286
8.11	Provision of Telecommunications Equipment and Services	286
8.11.1	Hardware	287
8.11.2	Software and Access to Telecommunications	289
8.12	Future Research Directions	290
	Projects and Investigations	292
	References and Further Reading	293

- 9 The Final Product: Issues in the Design and Distribution of Assistive Technology Devices 297**
- 9.1 Development and Distribution of Devices 297
- 9.2 Working with End Users 299
 - 9.2.1 Methods for Involving End Users 300
 - 9.2.2 FORTUNE Concept of User Participation in Projects . . 300
- 9.3 Communication Issues 301
- 9.4 Other Important Issues 302
 - 9.4.1 Deaf Culture and Deaf Awareness 302
 - 9.4.2 Ethical Issues 303
 - 9.4.3 Data Protection Legislation 304
- Acknowledgements 304
- References and Further Reading 305

- Biographies of the Contributors (in Alphabetical Order of Family Name) 307**

- Index 313**