Curriculum for Graduate Courses in Amplification

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Although acknowledgments generally come at the end of a manuscript seemingly representing afterthoughts, I am compelled to acknowledge a group of people prior to presenting this material. The material as presented would not exist without the combined efforts of these individuals and their influence on me as a teacher, clinician, and researcher.

Several individuals are directly responsible for individual segments of this curriculum or for the general thought process that constitutes this work. Mead Killion taught the advanced course in hearing aids at Northwestern University and although I could not imagine why I needed to understand the acoustics of moving systems at the time or why plotting a vent response should thrill me, it is now an integral part of my teaching. He also demonstrated, created, and made us make things work in order for us to take ownership of the material.

Although I never had the pleasure of attending classes conducted by David Hawkins, I did have the good fortune to have one of his students as a clinical supervisor, Kelly Macauley Frost. She shared her class outlines and knowledge with me and this is largely reflected in the diagnostic/measurement portion of the outline and the connection between original measurements and verification strategies.

Thanks to Laura Ann Wilber who taught us that any set of information can be organized into meaningful and integrated pieces if one only takes the time to find the logical structure. The course structure has evolved over the past 10 years from when I was a teaching assistant for Mead Killion to teaching the graduate level courses in amplification at the University of Pittsburgh. I would like to thank all of the students who motivated the de-

velopment of a way to think about hearing aid evaluation, selection, fitting, and advanced technology in graduate amplification courses. In addition, I would like to thank the professional audiology community in Pittsburgh who have been instrumental in providing feedback regarding their practices and our students' abilities to access the information they have to offer. Many thanks to professionals in Tennessee, Illinois, and Pennsylvania who have invited me to their state meetings and have provided feedback regarding the utility of this format for practicing audiologists.

Any level of organization and academic teaching will not succeed without an integrated academic/clinical training program. The lines between academics and clinic should be invisible to the students, faculty, and staff. In a research university this is only possible if the clinical coordinator is dedicated to this mission. The amplification courses in their present form would not be possible without our clinical coordinator's dedication to practicing what is taught and involving faculty in all clinical matters. Many thanks go to Elaine Mormer who in the final analysis is the one who makes all of this work. Finally, thanks to Dana Raubenstrauch Moses who put Appendix B on disk so we could get organized and to George Lindley who assisted in the editing process. In addition, four reviewers from *Trends in Amplification* including Michael Valente and Carol Sammeth provided helpful comments and insights regarding the content and presentation of this material.

INTRODUCTION

Most academic programs have acknowledged that at least two courses devoted to amplification as well as extensive clinical practice are necessary

for the adequate mastering of basic hearing aid evaluation, selection, fitting, verification, and validation. This, of course, would be in addition to courses in managing hearing loss (aural rehabilitation) in adults and children where assistive listening technology other than hearing aids also would be covered. A two-course sequence is often motivated by simply not having enough time to cover all of the material in one term. Therefore, it is tempting to try to find a logical breaking point and simply divide the material in two. It is the author's experience that this does not work when teaching and learning in the area of amplification. Students need a systematic course which presents the entire hearing aid fitting process and which flows without interruption. There is this need partially to create a logical presentation of the material and partially because of the demands of clinical practicum. The second course is then devoted to indepth examination of various areas covered in the preliminary course. The students leave the first course with a basic working knowledge of fitting hearing aids. They bring this knowledge to clinical practicum and to the second course and can then work with much more advanced material. When the course is simply split in two, the students do not come away with a complete picture and therefore are not able to apply the more indepth information.

This curriculum covers a two-course sequence, but the second course is really a more indepth examination taken from the same outline. Appendix A provides an example syllabus for the first course. Each class period is divided into lecture/discussion and lab. The intention is to provide both the theoretical basis for the topic and the clinical application in the same class period in order to encourage the students to think of the two as inseparable and often indistinguishable.

The second course is organized in a seminar format where each student is responsible for one course period (approximately 3 hours). The first few class periods are conducted by the instructor, clinical supervisors, and/or invited guest experts. This provides the students with several weeks in which to plan their sessions. Each student picks a topic related to amplification and must create a reading list, homework assignment, and activity for their class meeting. The student provides his/her classmates with all of the necessary materials and assignments two weeks prior to the class meeting. Although this allows a great deal of latitude in terms of topics, critical areas are chosen each semester. By the end of the first course, stu-

dents are well aware of the areas that they need more knowledge and experience in and these tend to include: compression and the interaction of variable time constants, adaptation to hearing aid use, tinnitus evaluation and remediation, implantable hearing aids, transposition hearing aids, empirical evidence related to multi-channel and multi-memory technology, advanced microphone technology, verification techniques, etc. As mentioned, the students provide a required reading list to their classmates and some sort of assignment. Assignments have included dividing the class in two and creating teams that debated the existence (based on empirical data) of auditory perceptual learning, role playing regarding hearing aid trouble shooting and repair, comparing various programmable hearing aids in terms of programmable parameters, etc. Students also may use sessions of the course (beyond the one that they are responsible for) to bring in guest speakers (e.g., hearing aid repair workshop, hearing aid representatives presenting specific information, individuals presenting fitting protocols, etc.).

The curriculum presented within these pages is meant to be a format within which to learn and think about amplification. In that sense, it is a living, changing document. This format has been developed over a period of a decade of fitting hearing aids and teaching about fitting hearing aids. Both activities have aided in the development of the structure of the curriculum. Students are able to manage the material and therefore expend their energy on the higher cognitive tasks of integrating and relating material from different courses and different components of the course when the material is presented in a logical structure related to fitting amplification. The format of the course has become so essential due to the content literally changing by the time a student graduates that students now are provided with the notebook dividers (Figure 1) that will organize the material and their thinking related to amplification.

The major headings: introduction to hearing aids, diagnosis, up-front considerations, ordering/selecting the hearing aids, fine-tuning/verification of selection, orientation/follow-up/benefit, and trouble shooting have never changed. These take the student logically from the beginning to the end (the word "end" is used loosely) of a hearing aid fitting. Audiologists will always need to measure something about the auditory system or decide to use average data, the hearing aids will have to be obtained and pre-set, some sort of ver-

Figure 1. Sections of the hearing aid notebook.

ification will always be necessary to insure that the audiologist has done what was planned, and an evaluation of some kind will be necessary to establish that the hearing aids have impacted the individual in some positive way. The subheadings have changed over the past decade, most notably under the up-front considerations (some headings have been deleted, some have been added) and under ordering/selecting the hearing aids. The subheadings are meant to change to reflect current practice and current empirical data. Most importantly, the readings under each subheading change constantly in order to reflect the most recent information on a given topic. This structure allows one to continue to integrate new information into the course and into clinical practice without having to start from scratch each time. As the students leave the program, the course outline provides them with a way to continue to learn about hearing aids as new information is reported. Furthermore, the format provides a method for evaluating new information and to see how it fits in with previous information and practice.

COURSE OBJECTIVES

The goal is to work through a comprehensive needs assessment, selection, fitting, and validation of personal amplification based on clinical experience and empirical data. Emphasis is placed on developing clinical scientists who apply theoretical foundations to data driven decisions in hearing aid fittings. Special attention is given to the topics of circuitry/hearing aid options, selection protocols, different fitting strategies for new and previous hearing aid users, appropriate validation techniques,

documenting treatment efficacy, and providing a systematic hearing aid orientation and trial period. This format should allow the student to explore hearing aid fitting across the age range (infant to geriatric).

Students should be able to do the following at various points during the course:

1. conduct a comprehensive, systematic communication needs assessment and abilities assessment that leads to specific hearing aid recommendations,
2. judge the value of a variety of common and new diagnostic procedures as they relate to obtaining information necessary in the selection, fitting, and validation of hearing aids,
3. discuss the myriad of up-front decisions that must be considered prior to selecting hearing aid circuitry, styles, etc. and base these decisions on individual patient and/or empirical data,
4. select specific hearing aid parameters using each of three published fitting protocols,
5. identify hearing aids that are suitable based on selection results,
6. identify circuitry options and counseling strategies that are appropriate for new and previous hearing aid users based on clinical cases and empirical data,
7. identify verification and evaluation procedures (including test box measures, patient perception, and real ear measures) based on the original amplification goal, the selection strategy, and the particular circuitry that has been chosen, and
8. describe the potential impact of acclimatization to amplified sound on selection, fitting, and validation.

Instructors in various settings may need to restructure the outline and/or activities in this curriculum to meet their particular needs, but the content that is described within this document should be addressed somewhere within the educational program. All of the activities described in the course outline (Appendix A) have worked well with classes consisting of up to eight students. Some of the activities may need to be modified for larger class sizes. The presentation of this material and the rate at which it is covered assumes that students have had auditory anatomy and physiology, hearing science, and a basic diagnostic audiology course. No special background in math or physics is required.

CLASS PATIENT AND HEARING AID FITTING PROTOCOL

Two activities are used to integrate all of the information presented in the course. The class patient and development of a hearing aid fitting protocol activities permeate the entire course and lend to the overall structure of the course so these activities will be described prior to discussing the individual components of the course outline.

Class Patient

The most important part of the course that has been added in recent years is the evaluation, selection, and fitting of hearing aids on a real patient who participates throughout the semester. As can be seen from the course syllabus in Appendix A, the patient visits the class seven times. Although it is unlikely that a clinician would see a patient this many times in a hearing aid fitting, the activities are divided to go along with the course format. For instance, initial evaluation is conducted over two sessions, earmold impressions have their own session, etc. In addition, the reader will notice that students collect loudness contour, real ear to coupler difference (RECD), and real ear unaided response (REUR) data on the patient. This provides practice with the various measures, but more importantly, supplies the students with all of the current fitting data that might be used in a hearing aid fitting. It is up to the student to decide which data will be used for the actual hearing aid fitting. Having the students put their course work into action and make real-world decisions based on patient desires, abilities, and needs solidifies their understanding of the process of evaluating, selecting, and fitting hearing aids to a degree that no report, exam, or laboratory activity can achieve. Although all graduate students have clinical placements where they will be gaining hearing aid experience, it is impossible to assure that they are participating in the entire process and are being given the opportunity to think through all of the choices in each step. Realistically, the clinic must enter the classroom in order to obtain the desired level of understanding. The end result is graduate students who can go to their clinical placements with much more confidence and the ability to learn at a higher level because of this initial experience.

So, how is an unsuspecting hearing aid candidate convinced to come to class seven times and be questioned and tested by a group of students?

We were very fortunate in enlisting the support of a hearing aid manufacturer (Danavox) and most importantly our excellent local representative (Jamie Katz) who were willing to donate binaural hearing aids to this cause. They agreed that the students could choose the most appropriate instruments from their entire line. Mr. Katz provided each student with his/her own spec book of products and the programmable fitting software. In addition, he provided two class sections on using NOAH and using the Danavox programming software.

Although it is important to have a variety of manufacturers' software and hearing aids available for teaching purposes, using a single manufacturer for this exercise works very well. It is important to choose a manufacturer who has a wide range of products so it is likely that something in the line will be appropriate for the patient. In addition, choose a programmable product that allows entry of any fitting strategy as opposed to dictating use of the manufacturer's proprietary fitting strategy. The exercise of by-passing the manufacturer's automatic fitting strategy also empowers the students in knowing that they can choose how to fit hearing aids. It also is instructional to compare one of the manufacturer-independent fitting protocols to what the manufacturer would have recommended. Focusing on one programmable software with the instructor's assistance also provides the students with an opportunity to develop a sense of what features they value in programmable software and hearing aids. Rather than restricting the students, providing an opportunity for intimate familiarity with one programmable product actually helps students branch out into a variety of programmable instruments through their clinic placements because they understand the basics of any programmable instrument (e.g., what are the manipulable parameters, how are the parameters manipulated, what type of verification data are provided).

A by-product of involving a patient in the course is that the instructor is forced to move along from one topic to another because the students have to be prepared to perform the evaluation, earmold impression, selection, etc. by a certain date. The reader will notice that many of the homework assignments listed on the syllabus are timed for the students to practice and think about activities that need to be completed (Appendix A). In addition, this activity supports the whole notion of the framework that is being presented in the course and the students can see how it is put in

action clinically. Each student goes through the entire decision making process and keeps a patient file. Admittedly there are parts of the file that would not appear in a standard clinical file, including the entire list of up-front considerations and how each decision was made. This is an academic experience that will become largely automatic for the clinician. It is not a bad idea, however, to update the automatic list of up-front considerations every now and then and to make sure that decisions are based on the most current information available.

One patient per class has worked well with classes of up to eight students. An instructor may want to consider more patients but should also consider the ability to obtain more free hearing aids, the class time for multiple assessments, and the instructors' time in terms of supervision and monitoring the hearing aid fitting process. These issues may make the inclusion of multiple patients within the course prohibitive.

Hearing Aid Fitting Protocol Assignment

As can be seen from the outline (Table 1), homework activities (Appendix A), and activities associated with the class patient (Appendix A), students are exposed to and perform a variety of measurements, hearing aid fitting procedures, and verification/validation techniques. In order to assist the students in evaluating all of the information and deciding what they feel can be supported by the literature and clinical practice, the students are required to construct their own hearing aid fitting protocol (one for children and one for adults, or combined with alterations for specific populations). Each step of the protocol must be supported by empirical evidence if possible. The protocol may take any form and students have generated computer programs, flow charts, note cards, etc. The students are encouraged to use a format that is conducive to change so the protocol can be updated as they practice and continue their education post graduate school. This activity is very helpful in their subsequent clinical placements and in studying for cumulative and/or national exams.

SPECIFIC NOTES REGARDING EACH SECTION OF THE OUTLINE

In this section, specific educational goals, teaching strategies, and activities will be described for each section of the course outline.

I. Introduction to Hearing Aids

- A. History
- B. Hearing through an impaired system
- C. Who is a candidate?
- D. The process of remediating hearing loss
- E. Infection control
- F. The manufacturers

The introduction section provides the students with the basics. Although there is enough new material to take up an entire semester, a basic history is essential for students to appreciate where the state-of-the-art currently resides. Introduction to the manufacturers is a starting point where the students learn that these will be a group of professionals on whom they will rely for a great deal of information.

The most emphasis is placed on "Hearing through an impaired system." The variety of up-front considerations (described later) are continually related back to this section in order to make the connection between applying various technology to what we know (or do not know) about the impaired system. This is stressed through the topic paper associated with the course (Appendix A). The students must pick a technology (signal processing scheme) and defend or criticize it through use of the literature that explores what we know about the functioning of the impaired system. For example, a student might select the Oticon DigiFocus technology and then would need to describe the processing in the low and high frequency bands (wide dynamic range compression and linear with adaptive gain, respectively). The student would have to incorporate a review of the existence and impact of upward spread of masking (in the low frequencies) and the possible negative impact of syllabic compression (in the high frequencies) in order to evaluate the use of this technology. Although this is a demanding assignment for the student new to amplification, it solidifies his/her confidence in evaluating technology and provides them with an approach to all new technology introduced to them by hearing aid manufacturer representatives, meetings, and printed material.

The audio demonstrations (Figure 2) for Perceptual Consequences of Cochlear Damage (Moore, 1995) are used to demonstrate hearing through an impaired system. The CD comes with the textbook or can be obtained separately from Brian Moore, 44-223-333564 FAX, email to bcjm@uk.ac.cam. phx. Specifically, Demonstration 1-6 (a total of 76 tracks) takes the listener through simulations of

Table 1. A framework in which to teach and think about hearing aid evaluation, selection, and fitting.

I. Introduction to Hearing Aids	III. Up-front Considerations (continued)
A. History	J. Compression options
B. Hearing through an impaired system	K. Noise reduction
C. Who is a candidate	L. Output limiting
D. The process of remediating hearing loss	M. Multi-channel
E. Infection control	N. Ability to fine-tune
F. The manufacturers	O. Multi-memory
II. Diagnosis/Measurement	P. Analog vs digital
A. Patient needs/potential benefit	Q. Previous experience
B. What we're trying to hear	R. Coupling to ALDs
C. Dynamic range	S. Frequency transposition
D. HL to SPL/Transducers	T. Batteries
E. Understanding speech	IV. Ordering/Selecting the Hearing Aids
F. Cerumen management	A. Two dimensional: Gain as a function of frequency response
G. Real ear measurement	B. Three dimensional: Gain as a function of frequency response and input level
H. Coupler measurement	V. Fine-tuning/Verification of the Selection
I. Real ear characteristics	A. Learning and adaptation
J. Real ear to coupler differences	B. Functional gain
III. Up-front Considerations	C. Insertion gain
A. Making our decisions	D. Auditory mapping/Real ear aided response
B. Style/type/spare	E. Loudness ratings
C. Monaural vs. binaural	F. Rating speech
D. Microphone type/location	G. Articulation index
E. Earmold material/type/color	VI. Orientation/Follow-up/Evaluation of Benefit
F. Earmold length/vent	VII. Trouble shooting
G. Sound channel (receiver to ear canal)	A. Trouble shooting/modifications
H. Bandwidth	B. Special solutions
I. Receiver type	

the effects of threshold elevation and loudness recruitment, reduced frequency selectivity, and reduced frequency selectivity combined with threshold elevation and loudness recruitment using both music and speech.

II. Diagnosis/Measurement

A. Patient needs/potential benefit

B. What we're trying to hear

C. Dynamic range

D. HL to SPL

E. Understanding speech

F. Cerumen management

G. Real ear measurement

H. Coupler measurement

I. Real ear characteristics

J. Real ear to coupler differences

Figure 2. CDs that demonstrate key points.

The main focus in this section is that compromises are made each time average data are used regarding a patient's responses or regarding individual ear characteristics. These compromises may be worth making for the sake of time management, but it is important for the students to understand that they are making a choice. Students perform threshold and frequency specific uncomfortable loudness level testing as well as obtaining individual loudness contours on each other and on the class patient. The reader can obtain instructions and a paper and pencil version of Robyn Cox's Loudness Contour Test by contacting her at the University of Memphis, 807 Jefferson Avenue, Memphis, TN 38105-5094, (901) 678-5831, FAX (901) 525-1282. The reader can access updated information regarding the Loudness Contour Test, VIOLA fitting software (discussed later), and the APHAB (discussed later) from Dr. Cox's laboratory through the internet at www.ausp.memphis.edu/harl. Measures in HL and SPL are performed and appropriate conversions are applied where necessary. Students are encouraged to formulate their own opinions about what compromises are reasonable as they put together their own hearing aid fitting protocols.

Real ear measures are introduced in this section because they can play a role in both diagnostic measures prior to ordering the hearing aids and in verification measures. An ongoing theme from diagnostics to verification is that the amplification goal must be established at the time of measurement in order to realistically expect success in the verification process. For example, if one intends to verify the fitting with insertion gain

measurements, one would want to measure the real ear unaided response and select a fitting protocol allowing for its incorporation. In addition, the fitting protocol should include insertion gain targets for use in verification. In this way, the students start to connect the pieces of the evaluation, selection, and fitting. The hearing aid fitting goal should be consistent across procedures and must be understood early on in order for the correct measurements, selection procedure, and validation measures to be used.

In addition, the individual's perceived needs and desired benefits are stressed in this section. Reliable, valid measures are explored for these purposes and include the Abbreviated Profile of Hearing Aid Benefit (Cox and Alexander, 1995), the Profile of Hearing Aid Benefit (Cox and Gilmore, 1990), the patient expectation worksheet (Palmer and Morner, 1996), and the Client Oriented Scale of Improvement (COSI), (Dillon et al, 1997). This provides the student with an excellent introduction to evaluating clinical tools for their usefulness as pre- and post-therapy measures. These subjective measures currently form the basis for any type of final outcome measure or examination of efficacy in the hearing aid fitting. We discuss hearing handicap inventories separately in the adult aural rehabilitation course.

In the "Understanding speech" section, students are encouraged to critically evaluate the role word recognition and speech understanding may play in the evaluation and selection of hearing aids. Tests including traditional word recognition (Thornton and Raffin, 1978), the Speech in Noise Test (Kalikow et al, 1977), the Hearing In Noise Test (Soli and Nilsson, 1994), and the nonsense syllable tests (Dubno and Dirks, 1982; Dubno et al, 1982) are reviewed. Students determine how these tests might be used to either determine hearing aid candidacy or to document hearing aid benefit based on the properties of each test.

Currently, cerumen management resides in the diagnostic section because the reason for managing cerumen is to insure that it does not interfere with measurements and/or hearing aid fitting. Adequate practical experience is not provided in class for students to be competent in removing cerumen. Students are encouraged to pursue workshops that lead to certification in this area if they are so inclined. Scope of practice is discussed in this topic area since cerumen removal by audiologists is not covered currently in the scope of practice in Pennsylvania.

III. Up-front Considerations

- A. Making our decisions
- B. Style/type/spare
- C. Monaural vs. binaural
- D. Microphone type/location
- E. Earmold material/type/color
- F. Earmold length/vent
- G. Sound channel (receiver to ear canal)
- H. Bandwidth
- I. Receiver type
- J. Compression options
- K. Noise reduction
- L. Output limiting
- M. Multi-channel
- N. Ability to fine tune
- O. Multi-memory
- P. Analog vs digital
- Q. Previous Experience
- R. Coupling to ALDs
- S. Frequency Transposition
- T. Batteries

There are 19 up-front decisions to make prior to ordering the hearing aids. The list is meant to include all of the features whether electronic or physical that will impact the final selection of particular hearing aids. Depending on the instructor's biases, some topics will be given more time than others. The readings under each topic provide data that can be applied to making the decisions. This framework helps the student understand the level of expertise that is required to fit appropriate hearing aids. Table 2 illustrates how this material is presented. Not only is each category discussed, but how the decision is made is the focus of the discussion. This often requires the student to revisit the measurement section to see if there are some data relating to the decision or if something else should have been measured in order to make these decisions. The class patient also is a critical part of tackling the up-front decisions. This allows the student to work with hearing data, needs data, and a patient who has opinions on some of these up-front considerations. The students are given Table 2 without the X's filled in so they can make these decisions on their own. In addition, the X's change each year as new empirical data are reported.

It is worthwhile as practicing clinicians to update and think about the up-front decisions every now and then. Many of these decisions are made automatically once a clinician has a great deal of experience, but revisiting them is always a good idea. The clinician can approach many continuing

education courses and materials by asking "Does this information add an up-front decision or in any way alter the decision I would make?"

The reader will notice that there is no up-front consideration labeled "programmable." Instead, the section labeled "ability to fine-tune" is meant to cover every type of programmability (computer, screw driver, etc.). It is stressed in this section that the patient is not usually the candidate for fine-tuning ability, but rather the audiologist is the candidate for the various levels of technology. In cases of fluctuating or progressive hearing loss, the patient may be the candidate for fine-tuning as opposed to the clinician. In addition, the decision of whether to have a great deal of fine-tuning ability or not will impact what initial measurements are necessary. In other words, the less flexibility, the more important to collect individual data that could potentially impact the final response of the hearing aids. One of the homework assignments (Appendix A) assists the students in evaluating programming and multi-memory features. Students create a comparison chart of at least three programmable instruments that allows the viewer to determine what parameters (e.g., compression ratio, release time, etc.) are programmable and in what memories (if they are multi-memory). This encourages discussion of how one determines how to manipulate a particular parameter and what patient and/or environmental characteristics might prompt one to want to change the parameters between memories.

As can be seen in Appendix B, several of the up-front consideration sub-headings contain fairly complete reference lists (monaural versus binaural, compression options, noise reduction, multi-channel, multi-memory, and previous experience). These are areas that will either aid in the students' research for their circuitry paper or topic areas that will be developed further in the second hearing aid course.

In several up-front considerations, auditory demonstrations are very useful to the student. The audio demonstrations (Figure 2) for "Hair Cells and Hearing Aids" (Berlin, 1995) demonstrate several of the up-front considerations. This CD arrives with the textbook or can be obtained separately from Etymotic Research. Table 3 provides the CD tracks that are used for the demonstration of various up-front considerations. In addition, Hawkins' tape recording of peak clipping and output compression limiting is an excellent demonstration for the Output Limiting section and Palmer's tape recording of Class A and Class

Table 2. Making up-front decisions in hearing aid selection.

Upfront Consideration	How do we make our decision?			
	Our Experience	Individual Preference	Empirical Data	Diagnostic Test/Demo
ITE vs BTE vs ITC vs CIC	X	X	X	
CROS, BICROS	X	X		
air vs bone conduction	X		X	
spare	X	X		
monaural vs binaural	X	X	X	X
microphone type/location	X		X	
earmold material/type/color	X	X	X	
earmold length/vent	X		X	
sound channel	X			
bandwidth	X		X	
receiver type	X		X	
compression options	X		X	
noise reduction	X	X	X	X
output limiting	X		X	
multi-channel	X		X	
ability to fine tune	X			
multi-memory	X	X	X	
analog vs digital	X	X		
previous experience	X	X		
coupling ALDs	X			X
frequency transposition	X	X		X
batteries	X			

D circuits as a function of input level work well in the Receiver section. Hawkins can be contacted at (904) 953-2000 and Palmer can be contacted at (412) 647-1361 or cvp@vms.cis.pitt.edu.

Activities Related to Up-front Considerations

Several activities are used in the up-front considerations and they are highlighted below.

Acoustics of a Moving System

Table 4 provides the information that the student requires to complete the demonstrations de-

Table 3. Compact disc demonstrations of up-front considerations ("*Hair Cells and Hearing Aids*," Berlin, 1995).

Up-front Consideration	Demonstration
compression	restoring normal loudness through compression (track 1)
bandwidth	effects of various bandwidths (tracks 6-17)
bandwidth and sound quality	narrow and wide hearing aid responses with distortion (tracks 18-19)
earmold length/vent	demonstration of occlusion effect (tracks 26-33)

scribed below. Rather than providing students with the completed table, the table is completed as a group activity going through each system (mechanics, acoustics, and electronics) for each category (push, motion, etc.). The mechanical system is familiar to most students and helps introduce the other two systems in a meaningful way. It is the acoustic information that is of interest when examining vents and sound channels and the electronics that is of interest when considering circuitry. The demonstrations are primarily focused on the acoustic system and will lead the student to predicting individual vent responses. The purpose of exposing students to these basic formulas is to empower them with the ability to quantify the impact of acoustic modifications that they can choose related to an individual hearing aid.

Figure 3 shows the simple, household tools including springs, bottle, tape measure, wrench, plastic syringe (the pharmacy carries these as medi-

Figure 3. Demonstrating the acoustics of moving systems.

against the wall so his/her hand does not move. Have another student with a second hand on his/her watch tell a third student when to pull down and release the spring. All members of the class can count the number of times the spring bounces back down. The time keeper should stop the counting after 30 seconds have passed. Simple division should allow the students to estimate the resonant frequency of the system. This demonstration can be repeated with the other spring in order to demonstrate that the resonant frequency will change when part of the system is changed. Now have the students use the formula for resonant frequency from the Acoustics of Moving Systems chart (Table 4) in order to calculate the resonant frequency for the large and small spring system. The "m" in the equation is mechanical mass (formula provided) and the "c" in the equation is mechanical compliance (students already determined this in Demonstration 1). Now compare the estimated resonant frequency with the calculated resonant frequency.

Demonstration 4 (Table 4). This demonstration and assignment leads to the spreadsheet calculations that the students will perform to obtain the performance of various earmold vents. Have a student partially fill the bottle with water. Have another student demonstrate how one can hear the resonant frequency of the resulting volume by blowing across the top of the bottle. Empty some of the water and blow across the top again in order to demonstrate the change and direction of change in resonant frequency due to the change in volume (with water emptied, the volume is bigger). Now empty the bottle. The bottle mimics a Helmholtz Resonator (Figure 4). The Helmholtz Resonator consists of a mass component (the tube of air) and a stiffness component (the volume of air in the larger cavity). Lay the bottle on its side and compare the tube and volume to the tube and volume that are created by the vent of an earmold and the remaining space in the ear canal (Figure 4). Just as the resonant frequency of the bottle changed as the amount of volume was changed, the resonant frequency of a vent changes if either the tube (vent) or volume (residual space in the ear canal) is changed. Have the students calculate the resonant frequency of the Helmholtz Resonator (bottle) using the formula from the Acoustics of Moving Systems chart (Table 4). In addition they will need the formula for volume (length $\times$ area) and for area (πr^2). Prior to the calculations, have the students try to match the pitch of the bottle (blowing across the top) with a frequency

from an audiometer. They can compare how well they matched the pitch to the calculated resonant frequency of the system.

Quantifying the Impact of Venting

Understanding of acoustic modifications and their impact on the signal received by the ear is essential in understanding hearing aid fitting. After completing the Acoustics of Moving Systems section, students are equipped with all of the formulae needed to assess the frequency and gain characteristics of a vent placed in an earmold or shell of an in-the-ear hearing aid. The spreadsheet presented in Table 5 provides the format in which the vent response can be calculated. The actual formulas used in the various boxes are provided at the bottom of the spreadsheet (interested readers can obtain a disk copy of this spreadsheet by mailing a disk to Catherine Palmer, 4033 Forbes Tower, University of Pittsburgh, Pittsburgh, PA 15260). If one of the goals of the lesson is to have students discover how to write these formulae, the instructor can delete them from the handout.

Figure 4. (a) A bottle creating a Helmholtz resonator and (b) the Helmholtz resonator created by the earmold inserted into the ear canal.

Table 5. Vent frequency response.

	A	B	C	D	E	F	G	H	I	J	K	L	M
3	USER ENTERS VALUES												
4	LENGTH OF VENT	1.25											
5	RADIUS OF VENT	0.1	Ma	0.063694268									
6	VOLUME IN CC	2.2	Ca	1.57143E-06									
7	RESISTANCE	100	fo	503.3184609									
8													
9	FREQUENCY	Xm	Xc	R	Z	FREQUENCY	Xm dB	Xc dB	R dB	Z dB	(ptotal/ztotal)	FREQUENCY	Pressure at Drum
10	100	40	1013.317892	100	978.4414747	100	32.04119983	60.11491422	40	59.81069707	14.18930293	100	74.30421715
11	125	50	810.6543138	100	767.1994429	125	33.97940009	58.17671396	40	57.69816558	16.30183442	125	74.47854839
12	160	64	633.3236827	100	578.0393202	160	36.12359948	56.03251457	40	55.23914763	18.76085237	160	74.79336694
13	200	80	506.6589461	100	438.2212413	200	38.06179974	54.09431431	40	52.83386849	21.16613151	200	75.26044582
14	250	100	405.3271569	100	321.2859673	250	40	52.15611405	40	50.13783515	23.86216485	250	76.0182789
15	316	126.4	320.6702191	100	218.496952	316	42.03494148	50.12117257	40	46.78890766	27.21109234	316	77.3326491
16	400	160	253.3294731	100	136.7859296	400	44.08239965	48.0737144	40	42.72082853	31.27917147	400	79.35288587
17	500	200	202.6635785	100	100.035467	500	46.02059991	46.13551414	40	40.00308007	33.99691993	500	80.13243406
18	630	252	160.8441099	100	135.3122179	630	48.02801082	44.12810323	40	42.62674025	31.37325975	630	75.50136298
19	800	320	126.6647365	100	217.6660839	800	50.10299957	42.05311448	40	46.75581528	27.24418472	800	69.2972992
20	1000	400	101.3317892	100	314.9646014	1000	52.04119983	40.11491422	40	49.96523493	24.03476507	1000	64.14967929
21	1250	500	81.06543138	100	430.7042753	1250	53.97940009	38.17671396	40	52.68358365	21.31641635	1250	59.49313031
22	1600	640	63.33236827	100	585.2739166	1600	56.12359948	36.03251457	40	55.34718339	18.65281661	1600	54.68533117
23	2000	800	50.66589461	100	755.9772493	2000	58.06179974	34.09431431	40	57.57017452	16.42982548	2000	50.52413979
24	2500	1000	40.53271569	100	964.6644337	2500	60	32.15611405	40	59.68752534	14.31247466	2500	46.46858871
25	3160	1264	32.06702191	100	1235.984977	3160	62.03494148	30.12117257	40	61.84026384	12.15973616	3160	42.28090873
26	4000	1600	25.33294731	100	1577.839132	4000	64.08239965	28.0737144	40	63.96125446	10.03874554	4000	38.11245994

(continued)

Table 5. (continued)

	A	B	C	D	E	F	G	H	I	J	K	L	M
27	5000	2000	20.26635785	100	1982.257626	5000	66.02059991	26.13551414	40	65.94320194	8.056798056	5000	34.19231219
28	6300	2520	16.08441099	100	2505.911666	6300	68.02801082	24.12810323	40	67.97931516	6.020684842	6300	30.14878808
29	8000	3200	12.66647365	100	3188.90185	8000	70.10299957	22.05311448	40	70.07282305	3.927176951	8000	25.98029143
30	10000	4000	10.13317892	100	3991.119799	10000	72.04119983	20.11491422	40	72.02189528	1.978104721	10000	22.09301894
31													
32	$M_a = \text{SUM}((B4)*(0.0016)/(3.14*(B5)^2))$				$C_a = \text{SUM}(B6)/(1.4*10^6)$				$f_o = \text{SUM}(1/((2*(3.14)))*\text{SQRT}(1/((D5)*(D6))))$				
33	$X_m = \text{SUM}(2*(3.14)*\$D\$5*(A11))$				$X_m \text{ dB} = \text{SUM}(20*\text{LOG}(B10))$				$Z \text{ dB} = \text{SUM}(20*\text{LOG}(E10))$				
34	$X_c = \text{SUM}(1/2*(3.14)*(A11)*(\$D\$6))$				$X_c \text{ dB} = \text{SUM}(20*\text{LOG}(C10))$				$(\text{ptotal}/\text{ztotal}) = \text{SUM}(74 - (J10))$				
35	$Z = \text{SUM}(\text{SQRT}((D10)^2 + ((B10) - (C10))^2))$				$R \text{ dB} = \text{SUM}(20*\text{LOG}(D10))$				Pressure at Drum = $\text{SUM}(K10 + H10)$				

It has been our experience that if too much energy is placed into simply figuring out how to create a spreadsheet, the understanding of changes in vent response is lost. The user enters the values for length of vent and radius of vent and these can be measured from an example earmold. The user enters the residual volume left in the ear canal (between the end of the earmold and the tympanic membrane). This would be difficult to measure, so this number can be estimated (the longer the earmold or younger the child the less volume). The number for resistance is arbitrary since resistance is independent of frequency. The f_o cell provides the resonant frequency of this particular vent/patient combination. The remainder of the spreadsheet allows the student to plot the entire response of the vent across frequency. All of the headings (X_m , X_c , etc.) were explained in the Acoustics of Moving Systems chart (Table 4). The quantities are converted to dB since audiologists are used to looking at frequency response as a function of dB. The resulting graph should display "Frequency" on the X axis and the "Pressure at the Drum in dB" on the Y axis. From looking at the "Pressure at the Drum" column in Table 5, it is evident that this vent/patient combination provides no attenuation of sound through 250 Hz with a slight boost in response from 316 to 630 Hz (around resonant frequency) and then the response falls off after 630 Hz (sound is no longer passed through the vent). It is important to understand that vents work in both directions and these data indicate what passes through the vent naturally as well as what sound building up in the ear canal (resulting from the individual's own voice) will pass back out through the vent.

Once the students have completed the spreadsheet, it is used to compare various vent modifications. Students are presented with a series of user complaints or problems and are asked to create solutions through modifying the vent. Examples of user complaints and problems include: my voice sounds awful (increase length if possible, increase vent radius if length increase is not possible), the earmold is uncomfortably long (decrease length), feedback (increase length and/or decrease vent size). The changes in the vent are entered into the length of vent, radius of vent, or volume in cc and new graphs are plotted. The students are asked to describe what change in frequency response resulted from the modification. In addition, they are asked to indicate what if any changes will now be necessary to the electronic processing of the hearing aid assuming that the original response was

Table 6. Input/output curves for various signal processing approaches.

Compression Options

Many practicing clinicians never drew an input/output curve during their training programs because when the majority of technology was linear, input/output curves were not that interesting. With the advent of compression technology incorporated in commercial hearing aids over the past 25 years, the appreciation and understanding of input/output curves cannot be overstated. Most manufacturers and the advanced fitting programs use this terminology to communicate what their products do as a function of input level. The assignment presented in Table 6 allows the student to plot a variety of common processing schemes. By plotting all of the schemes on one low and one high frequency graph, students start to appreciate the fundamental differences in the philosophies behind each fitting strategy. Students may want to copy the blank plots onto overheads and draw each assignment separately. Then the overheads can be overlaid in order to make comparisons. The plots are used as a springboard for all of the discussion around linear and compression technology and how one might go about making informed choices for a patient based on the literature and the patient data. Table 7 provides two

examples of completed input/output curves. This assignment ignores the dynamics of compression as dictated by time constants (i.e., attack and release times). This topic is covered through lecture in this course and through literature discussion in the second course.

IV. Ordering/Selecting the Hearing Aids

- A. Two dimensional: Gain as a function of frequency response
- B. Three dimensional: Gain as a function of frequency and input level

The ordering/selecting the hearing aids section of the outline has gone through the most iterations in the past few years. At this point, the section has been simplified to represent the two basic fitting philosophies that exist: a two dimensional or a three dimensional approach to signal processing. A quick acknowledgment is extended to Jerry Yanz of Micro-Tech for the particular terminology. The three dimensional section is further divided into sections related to using average data to estimate the dynamic range and using individual data to measure actual loudness growth. This

Table 7. Example circuit responses from assignment #1 and #4 from Table 6. Arrows represent the patient's dynamic range in the low and high frequencies.

illustrates the current research and clinical emphasis on determining if individual loudness perception data are needed in hearing aid fitting. One would expect this section to continue to change on a regular basis.

Concepts related to selecting the hearing aids currently are taught through the use of three fitting protocols (FIG6, Gittles and Niquette, 1995; Visual input/output locator algorithm (VIOLA) of the Independent Hearing Aid Fitting Forum (IHAF), Cox, 1995; Desired Sensation Level, DSL[i/o], Cornelisse, et al, 1994). Use of all three protocols with the class patient data serve as the

structure of this section of the course. This ties in what measurements would be needed in order to use each fitting technique, the differences in what each fitting technique recommends, how each fitting technique meets the requirements of our original goals for this patient, and what verification/validation techniques each fitting protocol demands in order to stay in-line with the goals of the fitting technique. Understanding the data that must be supplied for each fitting protocol and the verification techniques assists the students in identifying appropriate populations (children and adults) for the various protocols. The students are required

Table 8. Comparing the recommendations of DSL, FIG6, and IHAF for the class patient. Data for the right ear are presented (thresholds, CT = compression thresholds, CR = compression ratios, gain for various input levels).

Frequency (Hz)	250	500	1000	2000	3000	4000	6000
Thresholds (dB HL)	15	15	25	25	50	50	35

Frequency				
	Low	Mid	High	
CT	45	45	45	DSL
	40	—	40	FIG6
	45	—	45	IHAF
CR	1.2	1.3	1.8	DSL
	1.1	—	1.5	FIG6
	1.2	—	1.2	IHAF

Frequency				
	Low	Mid	High	
Soft	7	23	36	DSL
	0	6	28	FIG6
	0	—	28	IHAF
Average	5	20	29	DSL
	0	4	26	FIG6
	0	—	26	IHAF
Loud	3	16	22	DSL
	0	1	0	FIG6
	0	—	19	IHAF

Input Level

to provide a rationale for selecting one of the fitting protocols for the final selection of the hearing aid responses for the class patient. They also must select hearing aids that meet the requirements of the fitting technique and all of the up-front considerations made previously.

Students create a chart of the recommendations from each of the three fitting protocols. An example of a chart created for one of the class patients is provided in Table 8. This encourages discussion about what is different between the fitting protocols, whether we would expect these differences to be meaningful, and whether we would expect to be able to achieve these differences (e.g., small differences in compression ratio) given current technology. Ricketts (1997) has provided a nice comparison of the differences between these fitting protocols and this aids the students in making their final decision regarding which fitting protocol to use with a particular patient.

FIG6 and VIOLA can be obtained from contacting the sources supplied in Table 9. The DSL costs approximately \$70.00 but may be obtained without cost if it is used strictly for educational purposes. All three programs are worth obtaining (Figure 5). Our students usually receive their own copies of FIG6 and VIOLA in order to have the manuals and to be on the mailing lists for updates.

The National Acoustics Laboratory fitting protocol (NAL-R), (Byrne and Dillon, 1986) and prescription of gain and output (POGO, McCandless and Lyregaard, 1983) also are introduced in this portion of the course. The data obtained from one of these fitting protocols is compared with the data from the three on which we have concentrated. This assists the student in understanding the purpose of a two dimensional fitting protocol and the potential limitations in the data provided.

Figure 5. Fitting software.

It is a common misconception that all three fitting protocols are biased to fitting nonlinear technology. Actually, all three deal with using linear or nonlinear technology differently. In the DSL, one must choose to pursue linear or nonlinear amplification as an up-front decision. The fitting prescription is provided based on this original decision. If compression (nonlinear) has been chosen, DSL will provide a warning that linear may be a more appropriate choice if a compression ratio over 4:1 is recommended. FIG6 provides the needed compression ratios, coupler gain at three input levels, and real ear insertion gain at three input levels to achieve the target. Depending on the hearing loss, FIG6 could recommend a compression ratio of 1:1. In addition, FIG6 cautions users that a compression ratio greater than 3:1 may indicate the need for linear amplification with compression output limiting. Since the VIOLA provides the targets and meeting them is completely up to the user, linear processing can be chosen and the user can visually evaluate if this meets the targets adequately.

The class focuses on these fitting protocols because they are device independent. Many manufacturers are now providing their own fitting algorithms with their programmable hearing aids (e.g., Widex, Oticon, Danavox, Resound). It is very useful to explore a few of these programmable de-

Table 9. Contacts for computer (a) and paper and pencil (b) versions of fitting protocols.

Fitting Protocol	Contact
DSL[i/o]	Hearing Health Care Research Unit The University of Western Ontario, Elborn College London, Ontario N6G 1H1 CANADA 519-661-3901 FAX 519-661-3805
FIG6	1-888-FIG6-HLP
IHAFF	a. Dennis Van Vliet 17021 Yorba Linda Blvd. #130 Yorba Linda, CA 92686 or Robyn Cox FAX 901-525-1282
	b. Ruth Bentler University of Iowa Speech Pathology and Audiology Iowa City, IA 52242 319-335-8718 FAX 319-335-8851

vices and show the students how one can use the manufacturer's fitting algorithm or bypass it and enter the fitting prescribed from one of the independent fitting programs. Users should not feel controlled by fitting software associated with programmable hearing aids. In addition, students become aware that some hearing aid manufacturers incorporate the device-independent fitting software into their programmable hearing aids (e.g., Siemens) and this may make that device attractive if this is the fitting rationale that the student chooses to use.

To further de-mystify this process, students perform each fitting protocol by hand. Table 9 provides the contacts for obtaining the paper and pencil versions of the DSL, FIG6, and VIOLA. This activity would only be worth the energy once, but it is valuable for the students to see that the final frequency/gain response, compression threshold, compression ratio, gain at various input levels, and maximum output are arrived at through a logical series of manipulations based on the assumptions of the fitting protocol.

Students also use the measured RECD and REUR from the example patient to manipulate each of the prescriptive fitting formulas in order to insure that they understand how these data are applied and are not restricted to using these data only if a program has a convenient set of boxes for entering the data. On the other hand, this exercise makes students appreciate particular features of various programs.

For class purposes, the students then select "conventional" hearing aids (not programmable with a computer on site) and programmable hearing aids that would be suitable for the class patient from the manufacturer that we happen to be working with for the semester. Going directly to the programmable hearing aids is not useful in teaching the students how to use the hearing aid specifications from manufacturers in order to select hearing aids. Students are encouraged to contact technical support if they need more information in order to make their choice. The students must then make a final selection between the conventional and programmable hearing aids for the patient. It is probably not surprising that the programmable hearing aids are selected most of the time (Note: the patient is not paying for the hearing aids so this is an up-front consideration that we acknowledge but upon which we do not have to act.).

V. Fine-tuning/Verification of the Selection

A. Learning and adaptation

- B. Functional gain
- C. Insertion gain
- D. Auditory mapping/Real Ear Aided Response
- E. Loudness ratings
- F. Rating speech
- G. Articulation index

Each of the areas in fine-tuning/verification of the selection is examined in light of the class patient. Which procedures make sense based on our original goals, up-front considerations, and final choice of fitting procedure? For instance if one has chosen to fit linear technology then assessing loudness ratings across input levels in order to verify the fitting not only does not make sense, but it is unfair to the manufacturer from whom you ordered the hearing aids. On the other hand, if your original goal was to return normal loudness perception, then some sort of evaluation to see if this has been achieved would seem to be essential.

Using the data from the prescriptive fitting to pre-set a programmable instrument or verify the response of a conventional instrument prior to the patient's arrival is highlighted. This is performed prior to the class patient coming in for the fitting. Students manipulate the hearing aid settings and make test box measurements until they are satisfied that the instruments agree with the coupler verification data supplied by the fitting protocol. This includes measuring gain at several input levels, determining compression threshold and ratio (in all channels), and determining maximum output.

The students create a plan for what tests will be performed with the patient present with attention to avoiding collecting redundant data and attention to collecting data that directly relates to their original fitting goals. Once the sequence has been agreed upon by all students and the instructor, tasks are divided between the students. A great deal of time must be allotted for this exercise so adjustments and new measurements can be performed by the students during the evaluation. This past year's patient was an excellent example where the students chose to ignore RECD when obtaining the desired response of the hearing aids, pre-set the hearing aids accurately, and then fell short of the loudness ratings they expected. Upon re-examination of RECD, they realized that they were fitting an adult who had large negative RECDs. When these values were used to correct the original fitting, the loudness ratings fell right in line with what was expected. This is the type of learning experience that cannot be duplicated in a lecture or book.

At this point in the course, students already

have studied real ear measures in the diagnostic portion, have conducted a variety of real ear measurements on the class patient (REUR, RECD), and have experimented with the measurements through homework assignments. Therefore, during this phase of the course they can concentrate on which measures will give them needed information and how to interpret that information as opposed to focusing on the mechanics of the measurements. As students choose which real ear measures to obtain and identify what their target is (what will they be comparing their measurement to) they also get an appreciation for the features of real ear equipment (signal choices, level choices, built-in fitting protocols with targets displayed, ability to enter your own target, etc.).

It is stressed in this section that verification is different from evaluating the benefit of the hearing aids. Just because all of the targets are achieved does not necessarily result in a successful and/or satisfied patient. Evaluation is addressed in the next section.

VI. Orientation/Follow-up/Evaluation of Benefit

As can be seen in Appendix B, the orientation and follow-up program that has been published from our clinical program is used in this course. This is a systematic program that helps lead the students through all the necessary steps. Hopefully quite a few references can be added to this section in the near future, but currently there are few reliable, valid ways to determine benefit. Re-administration of the patient expectation worksheet and the Abbreviated Profile of Hearing Aid Benefit (APHAB) introduced in the diagnostic/measurement section constitute the measure of benefit. Most importantly, the need for a measure of benefit and therefore efficacy is stressed in this portion. This is important to the patient, the clinician's practice, and potential third party payers.

If the hearing aid fitting has progressed in a timely manner there should be time for the students to perform all of the follow-up and post-tests for the class patient. The class patient is transitioned to our clinical program in order to insure continuous follow-up care.

VII. Trouble Shooting

- A. Trouble shooting/modifications
- B. Special Solutions

Although the "Trouble-Shooting" section is situated at the end of the material, it permeates the

entire course. Trouble shooting is introduced in the second lecture by handing each student a "broken" hearing aid. Figure 6 illustrates the tools to which students have access during class trouble shooting (listening stethoscope or their own listening mold by mid-semester and a battery tester). Although it would require too much class time for students to use a test box in the middle of class, students are encouraged to write down the steps they would go through to trouble shoot and potentially fix the hearing aid and those steps may include other equipment. Most hearing aid companies have trouble-shooting guides that list common problems, causes, and solutions and will be happy to send complimentary copies to instructors and students.

Table 10 provides some examples of easy to create trouble-shooting situations for the class. Manufacturers are more than happy to send old functioning and broken hearing aids and earmolds to programs for teaching purposes. These hearing aids are used for the trouble-shooting exercises.

No matter what the complaint, each student (or pair of students) is provided with a hearing aid to

Figure 6. Trouble shooting hearing aids.

Table 10. Trouble-shooting activities.

Class 2 <i>Causes</i> cracked tubing cracked earmold cracked shell cerumen in ear canal select-a-vent insert has fallen out	"My hearing aid is squealing" <i>Provide Student With . . .</i> BTE with tubing (cracked) attached to earmold BTE attached to earmold (cracked) ITE or BTE with cracked shell functioning ITE or ITC binaural aids/earmolds and have one earmold with a select-a-vent inserted and one without, provide an audiogram that indicates that the loss is symmetrical
Class 4 <i>Causes</i> change in hearing, patient wearing VC at highest level, patient has grown peaky response, interaction with the telephone chewing	"My hearing aid is squealing" <i>Provide Student With . . .</i> functioning hearing aid (any type) functioning BTE with earmold (child size), audiogram with child's birth date a note indicating that the hearing aid squeals when the volume control is turned up, functioning hearing aid with peak in response a note indicating that the squealing is a problem when using the telephone, functioning hearing aid with telecoil (patient may need to be reinstructed regarding use of the telecoil with the telephone) functioning ITE, ITC, or CIC, include a note indicating that the hearing aid functions well except while eating and trying to have a conversation
Class 6 <i>Causes</i> dead battery dead battery reversed battery t-switch on clogged tubing wrong size battery	"My hearing aid is dead" <i>Provide Student With . . .</i> functioning hearing aid with dead battery nonfunctioning hearing aid with dead battery hearing aid with battery inserted backwards functioning hearing aid set to t-switch functioning BTE with clogged tubing functioning ITE with incorrect battery inserted
Class 8 <i>Causes</i> hearing aid off microphone plugged receiver plugged battery with tab on bent battery contacts dead hearing aid clogged earmold	"My hearing aid is dead" <i>Provide Student With . . .</i> functioning hearing aid set to off switch functioning hearing aid with some funtak in the microphone port functioning hearing aid with some funtak in the receiver port functioning hearing aid with battery inserted with tab still on functioning hearing aid with battery contacts that do not make contact nonfunctioning hearing aid because of internal damage functioning BTE with clogged earmold
Class 10 <i>Causes</i> dirty battery contacts volume control with dirt in it loose battery compartment	"My hearing aid comes on and off (intermittent)" <i>Provide Student With . . .</i> functioning hearing aid with dirty or corroded battery contacts functioning hearing aid with sticky, dirty VC functioning hearing aid with very loose battery compartment
Class 12 <i>Causes</i> change in hearing partially blocked microphone partially blocked receiver partially blocked earhook tone controls manipulated	"My hearing aid is weak, doesn't sound the same" <i>Provide Student With . . .</i> functioning hearing aid hearing aid with funtak partially blocking microphone hearing aid with funtak partially blocking receiver BTE hearing aid with funtak partially blocking earhook BTE with available tone controls to manipulate (may want to indicate that the patient happens to be an engineer)

examine. In each case they are told that Mr., Ms., or child Patient has dropped the aid off with the secretary and left the following message (whatever the complaint is). The student must systematically go through the steps of trouble shooting the hearing aid. Each student has the same complaint on a given day but a different cause. The students write down the steps they would take and anything that

they feel that they should do that is not available to them (use a test box, examine the patient's ear, etc.). After a few minutes, each student presents the process they went through and what they have determined to be the problem or at least a short list of possible problems. A number of the examples are designed so the student cannot pinpoint the problem without more advanced equipment.

These should lead to discussion regarding the steps of trouble shooting. In addition to introducing the students to the most common causes of hearing aid malfunction, these exercises guarantee that students are handling and manipulating a variety of hearing aids throughout the semester.

Examples are always kept of the various "special solutions" (super seals, huggies, etc., see Appendix B) that may be used with hearing aid wearers. Most of the class patients will need at least one of these solutions so the students will have some hands-on experience. Most importantly, students should have the attitude that if there is a problem experienced by the patient, most likely there is an existing solution or if not, they should create a solution.

MANUFACTURERS AS PARTNERS IN EDUCATION

The goal of a course in amplification should be to provide the students with a way of thinking about amplification and a way of integrating new information. In this sense, the material and education should not be product specific. On the other hand, the practicing clinician deals with specific products every day and must evaluate them in terms of use in a particular practice or with a particular patient. Manufacturers can be excellent partners in educating new students if their materials are used appropriately. Many manufacturers and distributors have been supportive of our educational program in terms of technology donations: Siemens, Instrumentation Associates, Qualitone, Starkey, Oticon, Danavox, Audio-D, Resound, Sonar, Micro-Tech, Argosy, Unitron and Etymotic Research. It is, of course, to the manufacturer's benefit to introduce students to their services and products.

Historically, manufacturers have provided extremely product specific materials, but more recently they have realized general education about processing schemes is needed in order to create informed consumers. Where the individual instructor does not necessarily have the time to create great interactive demonstrations of technology, many manufacturers do and are happy to provide you with these teaching tools at no charge. Figures 7 through 13 provide examples of manufacturer provided tools for education.

Figure 7 is a display board of hearing aid circuitry that is very convenient when discussing the various parts of the hearing aid (provided by Unitron). Figure 8 shows a few examples of computer

Figure 7. Hearing instruments pieces and parts.

CD's recently produced by manufacturers. "Hearing instrument distortion" by Micro-Tech and "The Dynamics of Compression" by Gennum are examples of tutorials that support specific products but that can be applied to any hearing aid. The Resound CD pictured in Figure 8 is an example of an educational tool related to a specific product. This can be used for the students to get familiar with various product choices as well as providing an avenue for students to critically evaluate what certain products have to offer. Figure 9 displays examples of videos distributed by manufacturers. Most of the videos are product specific and introduce students and clinicians to the claims and use of a particular product. These can provide excellent material for discussion whether they are viewed as part of class or as a homework assignment.

Figure 10 shows audio tapes that manufacturers distribute when attempting to provide auditory examples of some feature of their circuitry.

Figure 8. Free CDs from manufacturers.

In addition, watch for presentations by manufacturers or researchers who have taped examples of signal processing that would make good demonstrations. For instance, David Hawkins had a tape recording of the peak clipping and compression output limiting used in his study entitled “Comparison of sound quality with asymmetrical peak clipping and output limiting compression” at his poster session. There is no better way of explaining why peak clipping is not an appropriate up-front decision. Instructors often can obtain copies of these tapes from the authors.

Most manufacturers also are more than willing to send various representatives to University programs to introduce new products, new programmable software, provide signal processing lectures, etc. If anything, one must pick and choose who to invite because there is not enough time for all of the talks that are offered. Rather than include this type of presentation in a course, it is included in the one hour meetings that are held once a month (“Topics in Audiology”) during the semester. This

Figure 9. Free videos from manufacturers.

Figure 10. Free cassette tapes that demonstrate signal processing.

way all of the students and any interested local professionals can access this information.

Manufacturers also offer more formal workshops on specific topics at no charge to the program. One that we access repeatedly is Unitron's Light Repair workshop. This is a three hour workshop that provides each member with hearing aids and repair tools. Participants make the actual modifications and repairs while directed by the workshop leader. This is a great confidence builder for handling, modifying, and repairing hearing aids. By opening up face plates and poking around inside, students have an appreciation for the delicacy of the instrument but no longer view it as a mystery. Shell laboratories and earmold manufacturers are happy to send a “truck load” (Figure 11) of old hearing aids and earmolds so students can continue to practice modifications, grinding, buffing, etc.

Manufacturers are not limited to those who sell hearing aids. Equipment and software manufacturers can add a great deal to your educational program as well. The group from Hearing Health Care Research Unit at The University of Western Ontario who produce DSL and the group from Etymotic Research who produce FIG6 provide an excellent lecture and demonstration on how to use these fitting protocols. See Table 9 for contact information.

Frye Electronics, Inc. produced an entire workbook (Figure 12) that takes students through each step of ANSI measurements and general test box procedures. The students do not need to be working with Frye equipment in order to follow the workbook. This workbook has been part of the course for the past several years and it provides

Figure 11. A truckload of earmolds and shells for modifying.

the students with a systematic introduction to the actual measurements and use of the information obtained from these measurements. Frye Electronics provided permission to copy the workbook so each student has their own. These activities are done as homework assignments and the entire workbook is checked at the end of the semester.

Figure 12. ANSI S3.22 Workbook from Frye Electronics.

Instructors can request a comprehensive earmold package from Westone for teaching purposes (Figure 13). The box contains earmold impression material, ear lights, otoblocks, and syringes for each student. In addition reprints of useful articles and an excellent video of earmold impression taking procedures are included. This is used as an integral portion of the earmold class. Once students have practiced making earmolds, they make impressions for each other and send them in for listening molds. Westone provides all of these materials and the listening molds at no cost. Best of all, the listening molds arrive with a rating sheet that provides the impression taker with a critique of the earmold impression that was sent. The more one fits hearing aids and teaches amplification, the more appreciation one has for the earmold impression. One class session does not suffice for training students all of the techniques and problems involved with earmold impression taking. Extra sessions with our clinical supervisors and practicum experience for the students are essential to refine the student's earmold impression taking skills with children and adults. Students should leave class with the basic technique of making a deep earmold impression and the ability to critique an earmold impression.

In addition, both Westone ((800) 525-5071) and Microsonic ((800) 523-7672) provide excellent texts on earmold types and venting in the form of their catalogs. Copies are obtained at no charge for students each year. If our class patient is fit with behind-the-ear hearing aids, the students use these catalogs for ordering purposes.

Hearing Components (200 Crestview Drive, Maplewood, MN 55119, (800) 872-8986) provides an exceptional video entitled "Endoscopy of the

Figure 13. Making listening molds.

Living Ear.” The tape is provided without charge to educational programs. The video provides the student with a detailed analysis and demonstration of the ear canal as a dynamic system which is often asked to accommodate an inflexible earmold and/or hearing aid shell. If a video otoscope is available, it also is worthwhile to demonstrate the movement of the ear canal with the students from the class. Even with a video otoscope, the tape is worth getting for the detailed description and MRI analysis that it provides.

CONCLUSIONS

The preceding material is meant to present a framework in which students and practitioners can acquire new knowledge and integrate advances into the evaluation, selection, and fitting of hearing

aids. The focus throughout the course as presented to new students is the integration of material between sections. Appendix C provides example questions that may assist the student in bringing the material together in a meaningful way.

As can be seen in Appendix B, historical and current literature guide the course and function as the primary readings and teaching materials. Depending on journal articles (from trade journals and scientific journals) acknowledges that the knowledge base in hearing aid fitting is changing rapidly. As of yet, there is no single text book that covers all necessary aspects of amplification. There are a number of excellent texts dealing with various topics and a list of hearing aid texts is supplied in Appendix D. These are all made available to students. One text is chosen each year to accompany the course (Appendix A).

APPENDIX A

Example of a syllabus for a first semester hearing aid course
Hearing Aids CS&D
97-2

Instructor:	Catherine Palmer	Meetings:	1:00 - 3:45PM
Office Hours:	by appointment 647-1361		
Readings:	Textbook readings are assigned below: Valente, M. (1994). Strategies for Selecting and Verifying Hearing Aid Fittings. New York: Thieme Medical Publishers, Inc. Journal and misc. readings as indicated in the handout Microsonic Custom Earmold Manual Westone Custom Earmold Catalog Fonix ANSI S3.22 Workbook		
Homework:	Homework will be assigned each week		
Labs:	There will be inclass and supplemental labs throughout the semester		
Assessment:	Class participation in discussion and laboratory sections is required. Each student will write-up the results of laboratory sections held within class period and independent lab assignments. Together, this will be worth 10% of your grade. The midterm will be worth 25% of your grade and the final will count for 25% of the grade. Your topic paper will count for 20% and your hearing aid protocol will count for 20%.		
Philosophy:	Each class contains a theoretical basis for the clinical applications that are discussed. The classes build upon each other in order to take you through a data-driven hearing selection, evaluation, and validation process. As part of the course we will work with a patient in order to go through this entire process. The patient will come into class every other week. Because of the philosophy and structure of the course it is essential that you attend every session.		

NO LATE ASSIGNMENTS WILL BE ACCEPTED.

Topic Paper: Identify a type of circuitry or an electroacoustic parameter used in hearing aids (1984-1997). Describe in detail what it does to the signal. Search the literature and write a critical essay on whether the technique can be supported in the literature.

Hearing Aid Protocol: Each student will be responsible for turning in a complete hearing aid protocol for the evaluation, selection, and fitting of hearing aids on adults and children. You can use whatever format is conducive to thinking through the process. You must include every decision/step that you will go through and possible outcomes. Another individual should be able to pick this up and follow it in order to perform a complete hearing aid evaluation, selection, and fitting.

Class	Text	Topic	Lab	Homework #
1/9/97		Introduction History Hearing Through an Impaired System Selection, Evaluation, & Fitting as a process	Acoustics of Moving Systems	1,2
1/16/97	1,2,3	Diagnostic Info Required Needs Assessment Real Ear and Coupler Measurement	Real ear and coupler measurement	3,4
1/23/97	4	Diagnostic Info Cont.	Case History, audiometry, UCLs, APHAB, needs assessment (patient 2:30 - 4:00)	5,6,7
1/30/97	9	Upfront Considerations	Loudness Contour, RECD, REUR Expectations (patient 2:30 - 4:00)	8
2/6/97	10	Upfront Considerations (Continued) Understanding Acoustic Modifications	NOAH (presented by hearing aid rep)	9,10
2/13/97		Upfront Considerations (continued) Ordering/Selecting the Hearing Aid Input/ Output Curves for various technology	Ordering Hearing Aids for Our Patient (VIOLA, DSL, FIG6, NAL)	11,12
2/20/97		Earmolds	send earmold for listening mold, make earmold on class patient, hearing aid discussion with patient (3:00-4:00)	13
2/27/97		Continue working with fitting philosophies, programs. Working with hearing aid rep to order hearing aids	Programmable Hearing Aids (presented by hearing aid rep)	
3/6/97		SPRING BREAK		
3/13/97	5,6	Fine-tuning/Verification	use of coupler and probe microphone in verification	14

3/20/97	7	Validating and Evaluation	pre-set hearing aid plan next patient session	15
3/27/97	15	Orientation/Follow-Up	verify hearing aid fitting, modifications, orientation (patient 2:30 - 4:00)	16
4/3/97	8,11, 12	Trouble-Shooting Special Solutions	one week follow-up (patient 3:00-4:00)	
4/10/97	16	Tinnitus	two week follow-up APHAB and patient expectation (score) (patient 3:00-4:00)	17
4/17/97		AAA Convention NO CLASS		
4/24/97		10 minute topic paper presentations FINAL EXAM Due: topic paper, ANSI workbook, final patient report, protocol	final follow-up, recommendations for class patient (patient 3:00 - 4:00)	

Homework Assignments

1. Create a monaural or binaural hearing loss using a noise protector. Report your impressions.
2. Calculate the resonant frequency of a "Helmholtz Resonator." Use an audiometer to match the pitch of the resonator.
3. Calculate compliance and resonant frequency (from class) using a spreadsheet (homework problem #2 on spreadsheet).
4. Measure RECD of a classmate.
5. Write in a report how you would use the information from homework #4 and why it is potentially important.
6. Perform a loudness contour test on a classmate or patient (2 frequencies). Bring in the results.
7. Score the APHAB.
8. Write a diagnostic patient report with specific recommendations.
9. Plot the frequency response of an earmold vent on a spreadsheet.
10. Given clinical situations (from class), choose how to modify an earmold, make spreadsheets for comparison of response changes due to modifications.
11. Report the ANSI data for two hearing aids (start the ANSI workbook). Use the manual method to collect ANSI data for one of the hearing aids.
12. Using our class patient data, obtain NAL, DSL, FIG6, and VIOLA fitting recommendations by hand (see hand-outs).
13. Using our class patient data, enter values into the computer versions of NAL, DSL, FIG6, and VIOLA and bring the results to class.
14. Measure our patient's hearing aids on the test box and use the test box data to set the hearing aid according to DSL, FIG6, or VIOLA (student's choice).
15. With another student measure REUR, REAR, and the resulting REIR with a probe microphone. For REAR, use a laboratory hearing aid (record the exact volume control position). On a separate day, repeat this set of measures. Produce a report that describes and compares your results. Graph REAR 1 vs 2 and a difference plot. Graph REUR 1 vs 2 and a difference plot. Graph REIR 1 vs 2 and a difference plot. Try to offer an explanation for any changes in results.
16. Choose three programmable hearing aids for which we have software. Make a comparison chart that will reveal which parameters (e.g., compression ratio, cross over frequency, gain at low inputs, gain at high inputs, release time, etc.) are programmable for each instrument and in which memories (if multiple-memory).
17. Generate a final patient report.

APPENDIX B

Outline of the course with reading materials

I. Introduction to Hearing Aids

A. History

- Beck L. (1991). Issues in the assessment and use of hearing aid technology. *Ear Hear* 12(6 Suppl.):93S-99S.
- Harford E. (1990). Hearing aid dispensing. *Audiol Today* 2(6):22-24.

B. Hearing through an impaired system

1. Review/General:

- Humes L. (1991). Understanding the speech-understanding problems of the hearing impaired system. *J Amer Acad Audiol* 2:59-69.
- Kates J. (1991). Modeling normal and impaired hearing: Implications for hearing aid design. *Ear Hear* 12(Suppl. 6):162S-176S.
- Killion M. (1995). Talking hair cells: What they have to say about hearing aids. In Berlin C, (ed) *Hair Cells and Hearing Aids* San Diego: Singular Press, 125-172.
- Moore B. (1991). Characterization and simulation of impaired hearing: Implications for hearing aid design. *Ear Hear* 12(6 suppl):154-161.
- Moore B. (1996). Perceptual consequences of cochlear hearing loss and their implications for the design of hearing aids. *Ear Hear* 17:133-161.
- Moore B, Glasberg B. (1993). Simulation of the effects of loudness recruitment and threshold elevation in the intelligibility of speech in quiet and in a background of speech. *J Acoust Soc Amer* 94:2050-2062.

2. Specific psychoacoustic properties of the system:

- Baer T, Moore B. (1993). Effects of spectral smearing on the intelligibility of sentences in noise. *J Acoust Soc Amer* 94(3):1229-1241.
- Bonding P. (1979). Frequency selectivity and speech discrimination in sensorineural hearing loss. *Scan Audiol* 8(4):205-215.
- Delgutte B. (1990). Physiological mechanisms of psychophysical masking: Observations from auditory-nerve fibers. *J Acoust Soc Amer* 87(2):791-809.
- Dijkhuizen J, Anema P, Plomp R. (1989) The effect of varying the slope of the amplitude-frequency response on the masked speech-reception threshold of sentences for hearing-impaired listeners. *J Acoust Soc Amer* 86:621-628.
- Dreschler W, Leeuw A. (1990). The temporal resolution factor with and without background noise. *Audiol* 29:61-75.
- Dreschler W, Plomp R. (1985). Relations between psychophysical data and speech perception for hearing-impaired subjects. *J Acoust Soc Amer* 78:1261-1270.
- Drullman R. (1995). Temporal and fine structure cues for speech intelligibility. *J Acoust Soc Amer* 97:585-592.
- Dubno J, Dirks D. (1990). Associations among frequency and temporal resolution and consonant recognition for hearing-impaired listeners. *Acta Otolaryngol* (Suppl. 469):23-29.

- Dubno J, Schaefer A. (1991). Frequency selectivity for hearing-impaired and broadband-noise-masked normal listeners. *Quart J of Exp Psych. A, Human Exp Psych* 43(3):543-564.
- Festen J, Plomp R. (1983). Relations between auditory functions in impaired hearing. *J Acoust Soc Amer* 88:1725-1736.
- Florentine M, Buus S, Scharf B, Zwicker E. (1980). Frequency selectivity in normally-hearing and hearing-impaired observers. *J Speech Hear Res* 23(3):646-669.
- Freyman R, Nerbonne G. (1989). The importance of consonant-vowel intensity ratio in the intelligibility of voiceless consonants. *J Speech Hear Res* 32: 524-535.
- Gagne J. (1988). Excess masking among listeners with a sensorineural hearing loss. *J Acoust Soc Amer* 83(6): 2311-2321.
- Glasberg B, Moore B. (1989). Psychoacoustic abilities of subjects with unilateral and bilateral hearing impairments and their relationship to understanding speech. *Scan Audiol* (Suppl 32):1-25.
- Glasberg B, Moore, B (1986). Auditory filter shapes in subjects with unilateral and bilateral cochlear impairments. *J Acoust Soc Amer* 79:1020-1033.
- Hall J, Davis A, Haggard M, Pillsbury H. (1988). Spectro-temporal analysis in normal-hearing and cochlear-impaired listeners. *J Acoust Soc Amer* 84(4):1325-1331.
- Holube I, Kollmeier B. (1996). Speech intelligibility prediction in hearing-impaired listeners based on a psychoacoustically motivated perception. *J Acoust Soc Amer* 100(3):1703-1716.
- Irwin R, Hinchcliffe L, Kemp S. (1981). Temporal acuity in normal and hearing-impaired listeners. *Audiol* 20:234-243.
- Leek M, Summers V. (1996). Reduced frequency selectivity and the preservation of spectral contrast in noise. *J Acoust Soc Amer* 100(3):1796-1806.
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- Moore B, Glasberg B, Donaldson E, McPherson T, Plack C. (1989). Detection of temporal gaps in sinusoids by normally hearing and hearing-impaired subjects. *J Acoust Soc Amer* 85(3):1266-1275.
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- Moore B. (1985). Frequency selectivity and temporal resolution in normal and hearing-impaired listeners. *Bri J Audiol* 19(3):189-201.
- Nelson D, Freyman R. (1987). Temporal resolution in

- sensorineural hearing-impaired listeners. *J Acoust Soc Amer* 81:709-720.
- Nelson D. (1991). High-level psychophysical tuning curves: Forward masking in normal-hearing and hearing impaired listeners. *J Speech Hear Res* 34: 1233-1249.
- Picard M, Couture-Metz F. (1985). Upward spread of masking in normal and abnormal ears. *Audiol* 24(2): 81-91.
- Preminger J, Willey T. (1985). Frequency selectivity and consonant intelligibility in sensorineural hearing loss. *J Speech Hear Res* 28:197-206.
- Rosen S, Fourcin A. (1986). Frequency selectivity and the perception of speech. In Moore BCJ (ed). *Frequency Selectivity in Hearing*, London: Academic Press, 373-487.
- Rutten W. (1986). The influence of cochlear hearing loss and probe tone level on compound action potential tuning curves in humans. *Hear Res* 21(3):195-204.
- Schorn K, Zwicker E. (1990). Frequency selectivity and temporal resolution in patients with various inner ear disorders. *Audiol* 29(1):8-20.
- Simpson A, Moore B, Glasberg B. (1990). Spectral enhancement to improve the intelligibility of speech in noise for hearing-impaired listeners. *Acta Otolaryngol* (Suppl. 469):101-107.
- Stone M, Moore B. (1992). Spectral feature enhancement for people with sensorineural hearing impairment. Effects on speech intelligibility and quality. *J Rehab Res Dev* 29:39-56.
- Turner C, Holte L, Relkin E. (1987). Auditory filtering and the discrimination of spectral shapes by normal and hearing-impaired subjects. *Journal of Rehabilitation Research and Development* 24(4):229-238.
- Tyler R, Summerfield Q, Wood E, Fernandes M. (1982). Psychoacoustic and phonetic temporal processing in normal and hearing-impaired listeners. *J Acoust Soc Amer* 72:740-752.
- Villchur E. (1974). Simulation of the effect of recruitment on loudness relationships in speech. *J Acoust Soc Amer* 56:1601-1611.
- Zwicker E, Schorn K. (1978). Psychoacoustical tuning curves in audiology. *Audiol* 17(2):120-140.
- Zwicker E, Schorn K. (1982). Temporal resolution in hard-of-hearing patients. *Audiol* 21(6):474-492.
- 3. Additional psychoacoustic references:**
- Crandell C. (1991). Individual differences in speech recognition ability: Implications for hearing aid selection. *Ear Hear* 12(Suppl. 6):100S-108S.
- Dubno J, Schaefer A. (1992). Comparison of frequency selectivity and consonant recognition among hearing-impaired and masked normal-hearing listeners. *J Acoust Soc Amer* 91(4 pt 1):2110-2121.
- Gagne J, Erber N. (1987). Simulation of sensorineural hearing impairment. *Ear Hear* 8(4):232-243.
- Humes L. (1991). Understanding the speech-understanding problems of the hearing impaired. *J Amer Acad Audiol* 2(2):59-69.
- Needleman A, Crandell C. (1995). Speech recognition in noise by hearing-impaired and noise-masked normal-hearing listeners. *J Amer Acad Audiol* 6(6):414-424.
- Sommers M, Humes L. (1993). Auditory filter shapes in normal-hearing, noise-masked normal, and elderly listeners. *J Acoust Soc Amer* 93(5):2903-2914.
- Thibodeau L. (1991). Exploration of factors beyond audibility that may influence speech recognition. *Ear Hear* 12(Suppl. 6):109S-115S.
- van Rooij J, Plomp R. (1990). Auditive and cognitive factors in speech perception by elderly listeners. *Acta OtoLaryngol* (Suppl. 476):177-181.
- Van Tasell D. (1993). Hearing loss, speech, and hearing aids. *J Speech Hear Res* 36(2):228-244.
- C. Who is a candidate**
- Berger K. (1991). Some objective guidelines for determining hearing aid candidacy. *Hear J* 44(8):19-21.
- D. The process of remediating hearing loss**
- Hawkins D, Beck L, Bratt G, Fabry D, Mueller H, Stelmachowicz P. (1991). Vanderbilt VA. Hearing aid conference 1990 consensus statement. *Asha* 33(4): 37-38.
- Palmer C. (1995). Improvement of Hearing Function. In: Huntley R, Helfer K, (eds). *Communication Later in Life*, Boston: Butterworth-Heinemann, 181-224.
- E. Infection control**
- Klingler M, Liauba R. (1990). Infection control in the hearing instrument dispensary. *Hear Instrum* 41(12): 12-14.
- F. The manufacturers**
- Hearing Health Industry World Directory Issue (December issue each year). *Hear J*.
- II. Diagnostic/M Measurement**
- A. Patient Needs/Potential Benefit**
- Cox R, Gilmore C. (1990). Development of the profile of hearing aid performance (PHAP). *J Speech Hear Res* 33:343-357.
- Cox R, Alexander G. (1995). The abbreviated profile of hearing aid benefit. *Ear Hear* 16:176-183.
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- Palmer C, Mormer E. (1996). A systematic program for hearing aid orientation and adjustment. *Hear Rev* (Suppl. High Performance Hearing Solutions):45-52.
- B. What we're trying to hear**
- Corneliesse L, Gagne J, Seewald R. (1991). Ear level recordings of the long-term average spectrum of speech. *Ear Hear* 12(1):47-54.
- Stelmachowicz P, Kopun J, Mace A, Lewis D. (1996).

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- Stelmachowicz P, Mace A, Kopun J, Carney E. (1993). Long-term and short-term characteristics of speech: Implications for hearing aid selection for young children. *J Speech Hear Res* 36:609-620.

C. Dynamic Range

- Bentler R, Pavlovic C. (1989). Comparison of discomfort levels obtained with pure tones and multitone complexes. *J Acoust Soc Amer* 62:126-132.
- Cox, R. (1994). Memorandum: Administration of the Contour Test.
- Kamm C, Dirks D, Mickey M. (1977). Effect of sensorineural hearing loss on loudness discomfort level and most comfortable loudness judgments. *J Speech Hear Res* 21:668-681.
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- Northern J, Downs M. (1978). *Hearing in Children* Baltimore: Williams and Wilkins.
- Pascoe D. (1989). Clinical measurements of the auditory dynamic range and their relation to formulas for hearing aid gain. In Jensen JH (ed.) *Hearing Aid Fitting: Theoretical and Practical Views*, Proceedings of the 13th Danavox Symposium, Copenhagen, 129-152.
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- Valente M, Potts L, Valente M. (1997). Differences and intersubject variability of loudness discomfort levels measured in sound pressure level and hearing level for TDH-50P and ER-3A Earphones. *J Amer Acad Audiol* 8:59-67.

D. HL to SPL / Transducers

- Libby E. (1985). The LDL to SSPL 90 conversion dilemma. *Hear Instrum* 36(8) 15-16.
- Valente M, Potts L, Valente M. (1997). Differences and intersubject variability of loudness discomfort levels (LDL) measured in sound pressure level for the TDH-50P and ER-3A. *J Amer Acad Audiol* 8:59-67.
- Valente M, Potts L, Valente M, Vass W, Goebel J. (1994). Intersubject variability of the real ear sound pressure level: Conventional and insert earphones. *J Amer Acad Audiol* 5:390-398.

E. Understanding Speech

- Dubno J, Dirks D. (1982). Evaluation of hearing-impaired listeners using a nonsense-syllable test: I. Test Reliability. *J Speech Hear Res* 25:135-141.
- Dubno J, Dirks D, Langhofer L. (1982). Evaluation of hearing-impaired listeners using a nonsense-syllable test: II. Syllable recognition and consonant confusion patterns. *J Speech Hear Res* 25: 142-148.
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tence materials with controlled word predictability. *J Acoust Soc Amer* 61, 1337-1351.

- Soli S, Nilsson M. (1994). Assessment of communication handicap with the HINT. *Hear Instrum* 12(1): 15-16.
- Thornton A, Raffin M. (1978). Speech discrimination scores modeled as a binomial variable. *J Speech Hear Res* 21:507-518.

F. Cerumen Management

- American Speech-Language-Hearing Association (March 1992). External Auditory Canal Examination and Cerumen Management. *Asha* 34:(Suppl. 7), 22-24.
- Ballachanda B, Peers C. (1992). Cerumen management: Instruments and procedures. *Asha* 34(2):43-46.

G. Real ear measurement

- Dirks D, Ahlstrom J, Eisenberg L. (1996). Comparison of probe insertion methods on estimates of ear canal SPL. *J Amer Acad Audiol* 7:31-38.
- Feigin J, Kopun J, Stelmachowicz P, Gorga M. (1989). Probe-tube microphone measures of ear-canal sound pressure levels in infants and children. *Ear Hear* 10:254-258.
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- Preves D. (1987). Some issues in utilizing probe tube microphone systems. *Ear Hear* 8(suppl.):82-88.
- Valente M, Valente M, Goebel J. (1991) Reliability and intersubject variability of the real ear unaided response. *Ear Hear* 12(3):216-220.

H. Coupler measurement

- Agnew J. (1994). Measurement of distortion levels in hearing aids: It's not a simple matter. *Hear J* 47(5): 25-32.
- American National Standards Institute (1987). *Specification of Hearing Aid Characteristics*, ANSI S3.22 - 1987. New York: American Standards Institute, Inc.
- Revit L. (1991). New tests for signal-processing and multichannel hearing instruments. *Hear J* 44(5):20-23.

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- Erber N. (1973). Body-baffle effects and real-ear effects in the selection of hearing aids for deaf children. *J Speech Hear Dis* 38:224-231.

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J. Real ear to coupler difference

- Bentler R, Pavlovic C. (1989). Transfer functions and correction factors used in hearing aid evaluation and research. *Ear Hear* 10:58-63.
- Feigin J, Kopun J, Stelmachowicz P, Gorga M. (1989). Probe-tube microphone measures of ear-canal sound pressure levels in infants and children. *Ear Hear* 10(4):254-258.
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- Moodie K, Seewald R, Sinclair S. (1994). Procedure for predicting real-ear hearing aid performance in young children. *Amer J Audiol* 23-31.
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III. Up-front Considerations

A. Making our decisions

B. Style/type/spare

- Chartrand M. (1991). Transcranial or internal CROS fittings: Evaluation and validation protocol. *Hear J* 44(9):24-28.
- Consumer Reports. (November, 1992). How to buy a hearing aid. *Consumer Reports* 716-721.
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C. Monaural vs. Binaural

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- Chmiel R, Jerger J, Murphy E, Pirozzolo F, Tooley-Young C. (1997). Unsuccessful use of binaural amplification by an elderly person. *J Amer Acad Audiol* 8:1-10.
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- Valente M. (1982). Binaural amplification: Part 1. *Audiol: J for Continuing Education* 7(6).
- Valente M. (1982). Binaural amplification: Part 2. *Audiol: J for Continuing Education* 7(6).

2. Auditory Deprivation/Nonuse

- Batkin S, Ansberry M. (1964). Effects of auditory deprivation. *J Acoust Soc Amer* 36:598.
- Boothroyd A. (1993). Recovery of Speech Perception Performance after prolonged auditory deprivation: Case Study. *J Amer Acad Audiol* 4:331-337.
- Burkey J, Arkis P. (1993). Word recognition changes after monaural, binaural amplification. *Hear Instrum* 44:8-9.
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- Dieroff H. (1993). Late-onset auditory inactivity (deprivation) in persons with bilateral essentially symmetric and conductive hearing impairment. *J Amer Acad Audiol* 4:347-350.
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Agnew J. (1993). Determining the battery life of your customers' hearing aids. *Hear Instrum* 44(8):26-28.

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IV. Ordering /Selecting the Hearing Aids

deJonge, R. (1996). Microcomputer applications for hearing aid selection and fitting. *Trends in Amplification*. 1(3):86-114.

A. Two dimensional: Gain as a function of frequency response

Berger K. (1991). Introduction to three current hearing aid fitting methods. *Amer J Otol* 12(1):40-45.

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- V. Fine-tuning/Verification of the Selection**
- A. Learning and Adaptation**
- Arkis P, Burkey J. (1994). What WRS's say about client performance, adjustment to hearing aids. Word recognition scores: Do they support adaptation? *Hear Instrum* 45(1):24-25.
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learning in hearing-impaired subjects. *Ear Hear* 16: 417-427.

B. Functional Gain

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Humes L, Houghton R. (1992). Beyond insertion gain. *Hear Instrum* 43(3):32-35.

D. Auditory Mapping/Real Ear Aided Response

Humes L, Pavlovic C, Bray V, Barr, M. (1996). Real-ear measurement of hearing threshold and loudness. *Trends Amp* 1:121-135.

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McDaniel D, Cox R. (1992). Evaluation of the speech intelligibility rating (SIR) test for hearing aid comparisons. *J Speech Hear Res* 35:686-693.

G. Articulation Index

Mueller H, Killion M. (1990). An easy method for calculating the articulation index. *Hear J* 43(9):14-17.

VI. Orientation/Follow-up/Evaluation of Benefit

Cox R, Rivera I. (1992). Predictability and reliability of hearing aid benefit measured using the PHAB. *J Amer Acad Audiol* 3:242-254.

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VII. Trouble Shooting

A. Trouble Shooting/Modifications

Agnew J. (1996). Acoustic feedback and other audible artifacts in hearing aids. *Trends Amp* 1:45-82.

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Joson H, Asano F, Suzuki Y, Sone T. (1993). Adaptive feedback cancellation with frequency compression for hearing aids. *J Acoust Soc Amer* 94(6):3254-3258.

Oliveira R, Rose D. (March, 1994). Keep your wax guard up. *Amer J Audiol* 3(1):7-10.

B. Special Solutions

Super Seals, Just Bekuz Product, CO 303-688-5133 (note: these are sold through several earmold and hearing aid supply companies)

Dri-Aid Kits, Hal-Hen Company, Inc.

35-53 24th Street

Long Island City, NY 11106-4416

800-242-5436

(note: sold through many hearing aid suppliers)

Build-Up Materials (to build-up earmolds and/or shells)

Hal-Hen Company, Inc.

35-53 24th Street

Long Island City, NY 11106-4416

800-242-5436

(note: sold through many hearing aid suppliers)

Huggie Aids Ltd. Catalogue. Hearing Device Retainer Company.

837 N.W. 10 Street

Oklahoma City, OK 73106

405-232-7848

Wax Guards

Ad-Hear

200 Crestview Drive

Maplewood, MN 55119

800-872-8986

ER-13 Foam Rings for testing/reducing feedback

Etymotic Research

61 Martin Lane

Elk Grove Village, IL 60007

Telephone Comfort-Ear-Pads and Feedback Eliminators

Hal-Hen Company, Inc.

35-53 24th Street

Long Island City, NY 11106-4416

800-242-5436

(note: sold through many hearing aid suppliers)

APPENDIX C

Questions that bring the material together and/or address specific course objectives

Define real ear to coupler difference (RECD). Explain how RECD can be measured using standard clinical equipment. If one measures RECD, when and how are these data applied in the hearing aid selection, fitting, and validation process? If one does not apply the RECD, describe one possible result at the time of hearing aid verification/validation that could be explained by ignoring the RECD.

Discuss (in detail) the impact of an individual's ear canal, eardrum, middle ear, and cochlea in selecting a hearing aid response. At each level, describe the influence of the structure on the actual response of the hearing aid and indicate how we can measure this impact. Also describe what if anything should be done to control the structure's influence on the final response of the hearing aid.

As you know, the concept of adult auditory perceptual learning is a controversial one. For the purpose of discussion, let's assume adult auditory perceptual learning occurs (at least in some well-defined population). Please indicate how this information would impact each element of your hearing aid evaluation, selection, fitting (including test procedures and measurements), and orientation/trial period.

With the level of technology available for hearing aid design, the question no longer is what can a hearing aid do, but what should a hearing aid be designed to do. Much of this technology is chosen for a patient as part of your "up-front" decisions in fitting. Please describe all of the features (both physical and circuitry-related) that you would select for any adult hearing aid user. Support each of the features with an appropriate rationale.

You have measured your patient's thresholds and UCLs using TDH-50 earphones. These are the data that you enter into a prescriptive formula (doesn't matter which one) in order to select a hearing aid response that is appropriate for coupler measurements and predicted insertion gain measurements that you would expect if you fit the chosen hearing aid onto this patient. You order the hearing aid based on the desired coupler measurements and call the patient in to the clinic when the hearing aid arrives. When you do real-ear insertion gain measurements you do not get the predicted response produced by the prescriptive formula program. Provide any reasons (patient characteristics and/or equipment characteristics) that could explain why you

didn't measure what you predicted once the hearing aid was placed on the individual.

APPENDIX D

List of Hearing Aid Text Books for your Library

- Berlin C. (1995). *Hair Cells and Hearing Aids*. San Diego: Singular Press, Inc. Loavenbruck A, Madell J. (1981). *Hearing Aid Dispensing for Audiologists*. New York: Grune & Stratton, Inc.
- Mueller H, Hawkins D, Northern J. (1992). *Probe Microphone Measurements: Hearing Aid Selection and Assessment*. San Diego: Singular Publishing Group, Inc.
- Pollack, M.C. (Ed.). (1975). *Amplification for the Hearing-Impaired*. New York: Grune & Stratton.
- Rubin, M. (Ed.). (1976). *Hearing Aids: Current Developments and Concepts*. Baltimore: University Park Press.
- Sandlin, R.E. (Ed.). (1994). *Understanding Digitally Programmable Hearing Aids*. Boston: Allyn and Bacon.
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- Sandlin, R.E. (Ed.). (1990). *Handbook of Hearing Aid Amplification, Volume II: Clinical Considerations and Fitting Practices*. Boston: College Hill Press.
- Skinner M. (1988). *Hearing Aid Evaluation*. Englewood Cliffs, NJ: Prentice Hall.
- Studebaker G, Bess F, Beck L. (eds.). (1991). *The Vanderbilt Hearing Aid Report II*. Parkton, MD: York Press.
- Studebaker G, Hochberg I. (Eds.). (1993). *Acoustical Factors Affecting Hearing Aid Performance*. (2nd ed.). Boston: Allyn and Bacon.
- Valente M. (1996). *Hearing aids: Standards, Options, and Limitations*. New York: Thieme Medical Publishers, Inc.
- Valente M. (1994). *Strategies for Selecting and Verifying Hearing Aid Fittings*. New York: Thieme Medical Publishers, Inc.