Book Reviews / Évaluation des ressources écrits

Auditory Sound Transmission (2002)

Jozef J. Zwislocki

Publisher:

Lawrence Erlbaum Associates

Available from:

www.erlbaum.com or www.amazon.ca

Cost:

$74.00

Reviewer:

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In the preface of the book Zwislocki writes: "The book is intended as the culmination of my life's research on sound transmission in the human ear... Advanced science cannot exist without mathematics... the universal language of quantitative science [which] serves as a universal glue for binding pieces of experimental evidence together. This is how I have used it in this book." As a consequence, reading and studying this book requires a level of technical understanding comparable to at least first-year undergraduate physics or engineering.

Jozef Zwislocki divided his scientific attention between theoretical and mechanical models of the outer-, middle-, and inner-ear, and explaining psychoacoustical findings on the basis of the properties of the auditory periphery. His heart is in the mechanics of the ear, and his engineering approach is obvious from the detailed quantitative measurements and descriptions of models of the outer ear and, specifically, middle ear. This approach led to the design of the famous Acoustic Ear Simulator used for calibration of headphones, and the not less famous Acoustic Impedance Bridge used for tympanometry.

Sound transmission in the ear. Before I discuss the individual chapters, I will present some background to the topic of the book. The book deals with part of the peripheral auditory system that consists of the external ear, the middle ear, the inner ear or cochlea, and the auditory nerve. The external ear canal has some weak resonating properties; it acts as an open organ pipe that is not well terminated (in the acoustical impedance sense) at the end. Most of the energy transmitted into the ear canal is reflected back by the eardrum and this may lead to standing waves in the ear canal for certain frequencies. In adult humans this resonant mode is found in a broad region around 2.7 kHz. In infants, who have shorter ear canals, consequently the resonant frequency is higher. When testing participants with inserts or circumaural earphones these standing wave properties are different, and measurements of the sound pressure at or near the eardrum are therefore necessary for accuracy and calibration.

The middle ear, comprised of the eardrum and a set of three articulating ossicles, is primarily an impedance transformer, matching as well as possible the low acoustic impedance of air to the high acoustic impedance of the inner ear fluid. Because the specific acoustic impedance is given by ρc, where ρ is the density of the medium (20°C; air: 1.2 kg/m3, water: 998 kg/m3) and c the velocity of sound (20°C; air: 343 m/s, perilymph: 1481 m/s), the ratio of the acoustic impedances of water and air is about a factor 3560 (35.5 dB). This means that passing sound from air into the cochlea would be very inefficient without the action of the middle ear. The way the impedance transformation is accomplished is usually explained according to hydraulic principles; the ear drum area is about a factor 100 larger than the area of the stapes foot plate. The latter acts as a piston on the cochlear fluid. The result of this area ratio is, assuming that no energy is lost in friction, an approximate 100 times (20 dB) amplification of the pressure (force/area). Differences in effective length of the ossicles relative to the articulation point produce a lever action of about a factor 1.3 (about 4 dB) so that the total compensation of the 36 dB difference in acoustic impedances is about 24 dB. Because this is still far from perfect a relatively large amount of the incident acoustic energy is reflected back from the eardrum. The above explanation assumes that the diameter of the stapes is of the same order of magnitude as the wavelength of the sound. This is not true, at 10 kHz the wavelength of sound in air is about 3.4 cm and thus far larger than the stapes. Therefore, the impedance of the middle ear is not purely resistive and impedance matching of the middle ear will be frequency dependent. The small size of the stapes foot plate compared to the wavelength of sound necessitates the use of the radiation impedance of the cochlea which can be approximated by (Kinsler & Frey, 1962):

$$Z_R = (2\pi\rho/c)f^2 + j(16\rho/3\pi a)f$$

where Z_R is the acoustic radiation impedance, ρ is the density of air, c the velocity of sound in air, a is the equivalent radius of the stapes, and f is the frequency. Thus, the output impedance of the cochlea is complex and consists of a resistive part (the first term) and an imaginary part (the second term). Substitution of the appropriate constants into equation results in:

$$Z_R \bullet 2.10^{-7}.f^2 + j.2.10^{-2}.f$$

For frequencies in the audio range the first term can be neglected relative to the second one which is a mass-controlled term.

Matching the acoustic input impedance of the cochlea (Z_C; i.e., the output impedance of the middle ear) to the radiation (output) impedance (Z_R) of the cochlea requires a pressure transformation $N = (Z_C/Z_R)^{0.5}$. Substitution of Zwislocki's suggestion (p. 128 of the book) for Z_C, which is purely resistive, suggests that for perfect impedance matching one requires a pressure ratio of:

$$P_{stapes}/P_{eardrum} \bullet 3.10^3 / f^{0.5}$$

Thus, the required pressure transformation needed at the cochlea decreases with 10 dB/octave. This corresponds to a desired 50 dB pressure gain for a frequency of 100 Hz and to a 30 dB pressure gain at 10 kHz.

Note that on basis of area ratios of eardrum and stapes and lever functions for the ossicles one predicts a frequency independent gain provided by the middle ear of at most 30 dB. Thus the middle ear would fall short by about 20 dB at the low frequency end. The external ear is, however, able to provide some additional gain. Notably at the external ear resonance frequency (f = 2.7 kHz) the extra gain is about 15 dB. Thus, the external ear resonance frequency combined with the action of the external ear and middle ear provides a reasonable impedance match in the speech frequency region.

The inner ear effectively transduces mechanical energy, introduced by the relative movement of stapes and cochlear fluid, into electrical signals and ultimately into electrical activity in the approximately 40,000 auditory nerve fibres. Inner ears, frequency-tuned systems, have evolved to carry out this transduction with a high suppression of noise. Each part of the basilar membrane is tuned to a limited range of frequencies. The basilar membrane movement is, in the long-wave approximation, determined by the following differential equation (de Boer & Nuttall, 1999):

$$\frac{d^2}{dx^2} p(x,\omega) = \frac{-i\omega\rho}{h_{eff}} v_{BM}(x,\omega)$$

where, p is the pressure, v_{BM} is the basilar membrane velocity, x is the longitudinal length of the basilar membrane, $\omega = 2\pi f$ is the angular frequency, ρ is the density of the cochlear fluid, and h_{eff} is the effective height of the cochlea. This equation states that, e.g., sinusoidal pressure in the perilymph, which is incompressible, necessitates that the basilar membrane also moves sinusoidally. The relationship between the pressure difference across the basilar membrane and velocity is given by the basilar membrane impedance, $Z_{BM} = 2p/v$, which is stiffness controlled and changes exponentially with x, as follows:

$$Z_{BM}(x,\omega) = \frac{C_0}{i\omega} \exp(-\alpha x)$$

with C_0 the stiffness of the basilar membrane at the stapes (x = 0). These two equations, for the long-wave approximation, describe the basilar membrane movement in a dead cochlea.

In a live cochlea an extra active term is added to the impedance which determines the relationship between the excitation signal of the outer hair cells and the basilar membrane velocity. The excitation signal produces an additive component to the pressure that acts locally on the basilar membrane (de Boer & Nuttal, 2002). This increases the basilar membrane velocity on the basal side of the place of the response peak in the dead cochlea and results in the sharp frequency-tuning and high sensitivity seen in live cochleae.

Each inner hair cell with its free-standing stereocilia acts as a tiny hydrophone and is therefore only activated by a very limited range of frequencies in the acoustic spectrum. The outer hair cells are powerful electromechanical motors that enhance the movement of the basilar membrane by about 40 dB (a factor 10,000) and so produce larger electric signals in the inner hair cells.

The book. If you have found this summary of the mechanics of the auditory periphery of interest, you will likely enjoy Zwislocki's book. The book is, save for a short closing chapter on pitch and loudness, exclusively concerned with structural and mechanical issues of the external, middle, and inner ear. Zwislocki was the first to write an acceptable theoretical foundation for the mechanical frequency tuning in human cadaver ear discovered by von Békésy. He seems to have been very influenced by von Békésy's (1960) style of writing and even adopted his detailed description of how new instruments were developed and used to further his research. Zwislocki is much more theoretically inclined than von Békésy ever was, however during the course of his career he adopted part of von Békésy's experimental style as well.

The preface of the book chronicles Zwislocki's formative years and also contains some amusing typos. For instance, von Békésy is described as "a small man in a grey lab coat, rather *bold*, with a large nose separated from a small mouth by a small, graying moustache." All chapters contain autobiographical observations about how ideas were promoted and changed and how individual researchers clashed in the process. Chapter 1 describes the anatomy of the peripheral auditory system. Chapter 2 describes in great detail the acoustical properties of the external ear and models it as an electrical transmission line. From this analogy, a tube analogue of the external ear was built as an "acoustic ear simulator" and promoted for use in earphone calibration. Chapter 3 describes studies of middle ear function made possible by Zwislocki's design of the acoustic-impedance bridge that was subsequently manufactured by Grason-Staedler for clinical use. Electric analogue models for normal and pathological middle ear function are described, specifically for missing or ruptured tympanic membrane, missing incus, and otosclerotic ears. Middle ear transfer functions appear to differ little in dead compared to live cochleae. It is obvious from a comparison of middle ear transfer functions and thresholds of hearing that the external and middle ear determine how well we hear, provided that the cochlear hair cells are working properly. The chapter ends with "...it is somewhat unfortunate that currently used clinical methods for measurement of the acoustic impedance and related variables at the tympanic membrane, although rapid and convenient, do not provide accurate information about absolute values of these variables."

Chapter 4 deals with the mechanics of the dead cochlea at length. This is in effect Zwislocki's Ph.D. dissertation which provided the first plausible theoretical description of cochlear mechanics. It was published in *Acta Oto-Laryngologica* as Supplement 72 (1948). This work is replicated and updated here; basilar membrane displacement patterns, travel time, and wave velocities are calculated on basis of detailed measurements of the passive properties of the cochlea. An interesting aspect of the original work, now fully confirmed and known to be due to boundary-layer absorption (de Boer & Nuttall, 1999), was the conclusion that the tuning of the basilar membrane in the dead cochlea was not due to resonance as previously assumed. Historically, the dead cochlea was an important starting point, and it also was Zwislocki's entry to the world of auditory research. This may be enough justification for including this analysis which furthermore is still useful in understanding mechanical processing in cochleae largely devoid of outer hair cells.

Chapter 5 is equally lengthy and gives abundant detail about properties of the live cochlea in comparison to the dead cochlea. Measurements of tectorial membrane properties such as stiffness and mass in gerbils are added, and important aspects of recent measurements of in vivo basilar membrane movement by others are reviewed. Measurements of cochlear microphonics (CM) recorded from inside Hensen's cells by Zwislocki's research group are then used to infer response patterns of the basilar membrane on the basis of direct proportionality of CM amplitude and basilar membrane displacement. Inferences from the gerbil cochlear mechanics towards the human one are made.

Chapter 6 describes a mechanical model of the mass loading of the organ of Corti and outer hair cell stereo cilia by the tectorial membrane. One of the properties of this model, backed up by measurements in the gerbil, is the presumed high flexibility of the tectorial membrane combined with a substantial mass. Because of the shearing motion between the reticular lamina and the tectorial membrane, the motion of the basilar and tectorial membrane is out of phase. As a result, enhancement and reductions in the movement of the basilar membrane occur in a frequency dependent manner. An in depth analysis of an electrical network analogue of this model is presented to describe the passive properties of the live cochlea, as well as a mechanism for active feedback via the outer hair cells. The proposed model is different from most current basilar membrane models as it includes the tectorial membrane movement. To the dismay of the author this tectorial membrane contribution is largely neglected by the "...surprisingly conservative nature of the scientific establishment in auditory physiology and biophysics." But then, of course, science is always conservative and will use existing successful models (e.g., cochlear mechanics) until they can no longer explain the data; only then are new elements added or models discarded.

The final chapter aims to relate pitch and loudness entirely to the excitation patterns on the basilar membrane, as purportedly reflected in the CM of Hensen's cells. Pitch needs to be related to the apical cut-off of the excitation profile on the basilar membrane since this is the only part of the profile that is intensity independent. Loudness, and also loudness recruitment, appear to be completely determined by the cochlear excitation profiles. The obvious transformations in the auditory pathway do not seem to be necessary. If all of perception was at the cochlear level, and more over if all would be contained in the mechanics, the presence of an elaborate and plastic central nervous system (at least as clever as Zwislocki's) seems all that is needed to extract the right correlates. Yet, current emphasis on reorganization of tonotopic maps in cortex and potentially subcortical structures also suggests profound effects of these changes in the number of neurons activated by a specific frequency in the perception of loudness and specifically recruitment. These changes are not explained by activation patterns in the cochlea.

This book describes the many glories and some frustrations in the scientific life of Jozef Zwislocki. So who should read this book? Everyone concerned with middle ear research should. For good measure, students of cochlear mechanics may find a fine introduction into the basics and some ideas for further consideration. For most audiology students, most chapters in the book will be far too mathematical in scope. Consequently, I do not recommend it as a textbook for them. However, students in biomedical engineering concerned with acoustics and auditory sound transmission would benefit from this detailed and rich account of 60 years of research in hearing.

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Counseling Persons with Communication Disorders and Their Families (2002)

David M. Luterman

Publisher:

Pro-Ed, Austin, TX

Available from:

www.proedinc.com

Cost:

$52.95

Reviewer:

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This book was written for the audiologist and speech-language pathologist with the expressed purpose "to demystify the counseling experience for the professional working within the field of communication disorders" (p. xxv). Dr. Luterman's basic premise is that the simple desire to 'help' is not going to be good enough. The clinician needs to have a fundamental understanding of how a communication disorder influences the person and his/her family and how to guide them through the therapeutic process to achieve a successful outcome.

The book is divided into nine chapters, each of which builds on previous information. The first three chapters discuss the current status of counseling in audiology and speech-language pathology, current theories of counseling and the Erikson Life Style and Relationships and how it relates to the therapeutic process. According to Dr. Luterman, many clinicians counsel by 'informing' (i.e., explaining the diagnosis) and 'persuading' (i.e., determining what would be best for the child/client). The difficulty with this approach is that it removes all power from the client and it emotionally detaches the clinician. The author is a proponent of 'counseling by listening and valuing.' In this approach the client is perceived as being able to make good decisions with the clinician's role being to provide the specialized knowledge to help 'illuminate' the possibilities for them. "Counseling by Speech-Language Pathologists and Audiologists should be problem centred for individuals who are emotionally upset by the issue at hand" (p. 5).

Chapters 4 through 6 discuss the emotional impact of communication disorders and specific counseling methods for the diagnostic and therapeutic process. In Chapter 4 Dr. Luterman outlines the emotions connected with communication disorders (grief, anger, guilt, vulnerability, and confusion) and the coping cycle (denial, resistance, affirmation and integration). What is particularly interesting about this discussion is that Dr. Luterman relates these to specific behaviors on the part of the family and/or client. For example, during the resistance phase clients are unwilling to allow other agencies to help, as they want to conquer the disorder on their own. This can result in a rejection of a professional's intervention.

In discussing counseling methods (Chapters 5 and 6), the author repeats the theme that diagnosis and therapy can only be as good as the counseling that accompanies them. As well, he makes the point that one cannot push clients and their families faster then they are willing to go. This may require delaying treatment until the family is ready. Specific techniques in counseling are explained in detail with examples provided.

Chapters 7 and 8 discuss the professional's role with group counseling and working with families (spouses, siblings, grandparents, and parents). As with individual counseling, the primary error made by clinicians is keeping support groups information-based and under the control of the clinician. Dr. Luterman advocates giving control of the group to its members. He discusses the developmental process of group formation as well as many of the pitfalls that can derail a group. Chapter 8 offers an excellent discussion on all aspects of family dynamics and their impact on therapeutic outcomes. According to Dr. Luterman, any approach that focuses on the client alone is likely to fail as "the family is a system in which all of the components are interdependent" (p. 139).

Chapter 9 discusses educating audiologists and speech-language pathologists on counseling, whether they are student clinicians or have been practising for a number of years. Dr. Luterman contends that training programs are lagging behind the fields' needs in counseling and he relates this lack of training as a contributing factor in professional burnout. The last section of this chapter discusses the limits of counseling for speech-language pathologists and audiologists. Not all client needs can be met by the clinician and, at that point, the client and family may need to be referred to a mental health professional.

This book is well written with the author weaving together published research, professional experiences and personal story in a manner that is informative and interesting. The chapters are thought provoking and memorable. Dr. Luterman clearly states opinions that are his own and justifies them using a variety of personal philosophy, current research results his own experiences. He readily shares his clinical triumphs and failures. The largest drawback to this book is that Dr. Luterman focuses primarily on the field of audiology and frequently makes the assumption that it is the same for speech-language pathologists. Through the course of the book Dr. Luterman discusses the need for the clinician to be aware of his or her own emotions and life philosophy. He firmly believes that in order to help our clients 'grow' we need to grow as well, both personally and professionally. This book would be a valuable resource for students of communication disorders and for clinicians who have been working for many years.

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Resource Reviews / Évaluation des ressources

Building Language: Word Meanings (1996)

Robyn Dower and Jan Mackey

Publisher:

Helios Art and Book Co.
Adelaide, South Australia

Available from:

www.patsy.ac.uk/worksorder.html

Cost:

$74.00

Reviewer:

Kathy Mullin, MSc
Private Practice
Quispamsis, New Brunswick

Building Language: Word Meanings was created as a manual of language exercises for adults and adolescents and was intended for use in the treatment of adults with dysphasia, adolescents with language/learning disorders, and students of English as a second language (ESL).

This manual provides worksheets for pursuing the following four treatment goals:

- Picture Meanings: the learner must choose the one picture that does not belong in the group.
- Spoken Word - Picture Links: the learner must point to a picture named by the helper.
- Written Word - Picture Links: the learner must match a printed word with a picture.
- Words in Groups: the learner must identify or name words which belong in a specific group or category.

Some worksheets provide only picture cues or only written cues while others combine picture and print. The activities are systematically graded for difficulty level in terms of vocabulary items (e.g., everyday vs. specialized words, high- vs. low-image ability), semantic relatedness, number of choices and task complexity. The clinician is permitted to photocopy the worksheets as needed for therapy use and written instructions for the client's "helper" accompany each section. The authors intended for all of these features of the manual to provide the busy clinician with an efficient, graded tool for treatment.

The line drawings in this manual are well done and clearly identifiable. The grading of tasks is explained at the beginning of the book and each worksheet is coded at the bottom so clinicians can easily locate the most appropriate levels of complexity for their clients. The authors have incorporated principles of learning to create a very useful clinical tool which carefully reflects the gradual progression of treatment goals from the concrete to the more abstract, from limited choices to more options, from distinctly unrelated vocabulary to more subtle differences in meaning.

In my opinion, Dower and Mackey have succeeded in providing us with a carefully crafted treatment tool that would be of particular benefit to clinicians specializing in dysphasia. This manual may also be a helpful resource for clinicians looking for prepared activities for vocabulary enrichment for older students or ESL learners. This is a versatile material with photocopying fully permitted containing multiple language exercises. Because of this, Building Language: Word Meanings would be a useful addition to many clinics.

Building Language: Word Sounds (1998)

Robyn Dower and Jan Mackey

Publisher:

Words Work.
Victoria, Australia

Available from:

www.patsy.ac.uk/worksorder.html

Cost:

$74.00

Reviewer:

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Building Language: Word Sounds is "a manual of language exercises designed to enhance, and as the title suggests-build, recognition and production of speech sounds and letters within words." This manual is a companion to Building Language: Word Meanings and again targets several populations: adults with dysphasia, students with language/ literacy deficits and students learning English as a second language (ESL).

The book is divided into four sections:

- Hear the Difference: requires the learner to discriminate minimal pairs (initial and final consonants, voiced vs. voiceless consonants, initial consonant blends).
- The Shape of Words: the learner must choose the printed word which matches the picture.
- Sounds and Letters: using printed minimal pair stimuli; the learner must choose the correct word to complete a phrase or sentence.
- Spell the Rhyme: the learner must find or name rhyming words which may follow regular or irregular spelling patterns.

These activities are designed to provide students with practice in speech sound discrimination and to teach connections between written and spoken words, or sounds and letters. As in its companion volume, the authors have systematically varied the complexity of the activities by controlling auditory contrast (how many distinctive features differ in the minimal pairs?), visual contrast (e.g., can the sound be lip read?), phoneme position within the word, and frequency of vocabulary. The word shape (visual pattern) of minimal pairs stimuli was also controlled, as was the predictability of the spelling/phonics rules involved. For example, a student may begin the section entitled "Hear the Difference" with the minimal pair "pan/fan" which are phonologically and visually distinct and complete the discrimination section with the minimal pair "lock/clock" which is both phonologically and visually similar.

Once again, the line drawings are excellent and the clinician is permitted to photocopy worksheets and "instructions to helpers" for treatment use. The activities progress in their complexity just as they would in a treatment plan, allowing clinicians easy access to clear, graded material for training essential speech and reading skills. This manual would be particularly useful to supportive personnel, to the teacher's assistants, or to parents who wish to augment treatment practice, under the advice of a clinician.

In summary, Building Language: Word Sounds hits the mark as a beneficial tool for a variety of populations, from clients with dysphasia through those students who demonstrate and present with language, literacy, and learning difficulties. The material is applicable to a range of ages and provides a graded group of worksheets for auditory processing, spelling and reading goals.

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