Trends in Amplification
Volume 12 Number 2
June 2008 113-120

10.1177/1084713808316172
http://tia.sagepub.com
hosted at
http://online.sagepub.com

Auditory Reality and Self-Assessment of Hearing

William Noble, PhD

Analyses are made of three problem areas in the realm of hearing disorder and its management, all of which are cogently informed by self-assessment: (a) prosthetic technology and the auditory ecology, (b) dimensions of benefit from amplification, and (c) dimensions of disability. Technology and ecology addresses the matter of "fitness for purpose" of different prosthetic schemes, moderated by people's hearing and listening environments (ecologies) and by what they bring to the task of hearing and listening. Dimensions of benefit covers what is achievable with prevailing technology, and also what people are aware of and identify as their needs. Dimensions of disability examines what has been recently learned about the range of hearing functions that need attending to in management of impaired hearing. A closing section provides a portrait of "auditory reality," whose characteristics may be better appreciated when analyzed in contrast to and comparison with "visual reality."

Keywords: rehabilitation; hearing aids; self-assessment

This article addresses the contributions of Stuart Gatehouse to three arenas of auditory rehabilitation: (a) different hearing aid configurations and resulting performance as a function of varying everyday listening demands, (b) hearing aid benefit, having regard to requirements of and constraints on individual listeners, (c) the range of hearing and related functions called into play so as to engage effectively with the everyday world. These arenas are not independent; furthermore, the approach to them can be seen to connect in two ways: (a) The approach looks to the world of the client/user, and (b) it relies on clients/users' awareness of their experience of that world and their judgment about their abilities in relation to that world—hence the title of this article. The notion of auditory reality, or the client's auditory world, will be discussed briefly in the next section and more extensively at the article's close.

Prosthetic Technology and the Auditory Ecology

An ecology can be understood as the niches occupied and generated by an organism. It is inseparable from the repertoire of activity in which an organism engages. An *auditory ecology* is definable as the sum of what an animal's behavior and conduct leads it to experience. Later, this concept will be compared with a somewhat different notion: namely, auditory reality. This refers to the sum of what an organism is exposed to as varyingly filtered by its changing capacities in its lifetime. Whereas an *ecology* is the product of the conduct of an animal, a *reality* includes that *plus* whatever else impinges on that animal.

Mild-to-moderate conductive hearing disorder reduces audibility without necessarily introducing other alterations in the character (fidelity) of the input signal transmitted to the central auditory nervous system. Such a form of hearing disorder is much less common than the sort that is caused by injury at the cochlear receptor level or beyond. That more common form of disorder has the consequence of reducing the capacity of the system to respond with precision, especially under adverse listening conditions; furthermore, there is reduction in the acoustic range between least audible and uncomfortably audible signal levels (Plomp, 1978, 1994). The result is that signals are not only reduced in audibility, but also they are relatively harder to hear under noisy listening conditions because of distortion in spectral and temporal resolving capacity and distorted loudness growth (Moore, 1996, 1998). By contrast, and by analogy, the equivalent of mild-to-moderate

From the University of New England, Australia.

Address correspondence to: William Noble, University of New England, Armidale 2351, Australia; e-mail: wnoble@une.edu.au.

conductive hearing loss characterizes most disorders of vision, meaning that optical correction alone overcomes the problem; the visual receptor surface is typically intact (Noble, 2006).

The difference between most of the hearing versus vision disorders, from a scientific point of view, is interesting but unremarkable. From the point of view of client management, the difference is immense. For the great majority of people who need to address impairments because of visual disorder, the technology that enables correction (optical prescription, minor surgery at the level of the cornea/lens) is relatively straightforward to conceptualize and to provide, is usually quite effective, consumes no power in its operation, and is comfortable to live with.

The same is not the case for auditory prosthesis. Hearing prosthesis design faces several difficult problems, not the least of which is creating something that will enhance the audibility of signals that a listener needs or wants to hear and minimize competition from other sounds, a feature that does not really arise in the visual world (a comparison of these worlds is offered in the final section of this article).

No single amplification strategy to try to overcome the above problems enjoys universal support (Dillon, 2001). The matter is made more complex by the fact that a strategy that promises to work in one set of listening conditions might not keep that promise in other ones (Gatehouse, Naylor, & Elberling, 2003). Because of this state of affairs, much research attention is needed, not only on the question of what is going to work technically but also what is going to work in different circumstances.

Fitting Profiles and Outcomes

The research led by Gatehouse and colleagues (Gatehouse, Naylor, & Elberling, 2006a, 2006b) penetrates this complex interaction between technology and ecology, employing a mixture of investigative techniques—a speech test involving listening conditions, in which different amplification strategies may be expected to yield different outcomes, and a range of self-assessment measures of benefit, expressed as three broad factors: listening comfort, satisfaction, and reported (speech) intelligibility. In addition, monitoring (dosimetry) of and self-reporting about acoustical environments was used to observe the interaction of fitting strategy and listeners' auditory ecologies (Gatehouse et al., 2003). There were also tests of psycho-acoustic function and of cognitive function.

To realize the above project, linear and nonlinear amplification strategies were constructed (five in all) in a close approximation to a double-blind, randomized controlled design: One linear strategy included a manual volume control and was always undergone first, and all other conditions were able to be completely masked as to their characteristics. There were 50 clinic clients involved in this experiment, and listening under each strategy was extensive (10 weeks), allowing for acclimatization effects. The two linear strategies differed from each other in that one, based on the NAL-RP formula (Byrne & Dillon, 1986), used a single-channel approach with output limiting and listener-controlled volume, whereas the other used two channels with output limiting and no volume control.

The three nonlinear fittings featured two-channel compression and varied from each other in terms of release times, being either fast (40 ms) or slow (640 ms) in both channels or fast in the low-frequency (< 1500 Hz) channel and slow in the high-frequency one. Attack times were uniformly 10 ms. These compression profiles correspond to different broader rationales about enhancing segmental audibility within a speech burst (fast release, referred to as "wide dynamic range compression") versus more across-segment changes in audibility (slow release, referred to as "automatic volume control") versus a combination that may capture beneficial elements of both.

At a group level, no differences were observable between the two linear fittings on listening comfort, satisfaction, and measured and self-assessed speech intelligibility. On listening comfort, the three nonlinear fittings were significantly better than the linear ones, especially the slow-release (both channels) profile. Satisfaction was significantly higher for the nonlinear compared with linear fittings. On both rated and tested speech intelligibility, the nonlinear fittings were significantly more beneficial, especially the ones featuring fast release times.

In an analysis within listeners, comparing their ratings or performance across the five fitting profiles, the frequency of each profile coming in first (winning), second, third, fourth, or fifth (losing) position was tallied on each of the above outcome measures, and the average score on each measure associated with each position was also computed. This allowed inspection of the distribution of relative benefit of fittings across listeners and of the magnitude of the benefit score accompanying any position. Such an analysis demonstrates the point that a given fitting may occupy the winning position more often than another one on a given outcome measure, but also the benefit score may nonetheless be stronger for the lesser number of listeners whose performance or ratings put a different fitting strategy in the number-one spot on that same outcome measure. When this analysis was re-run to take account of the magnitude of the average score difference from the winning spot to the next spot, it became more evident that no single fitting strategy could be generally identified as the "leader" across the outcome domains in question.

A really challenging aspect of this result is that the "domains in question" would by no means be argued as exhausting the suite of auditory functions called into service in the course of the average listener's day—a point that gains more prominence when analysis turns to the third topic of this article (dimensions of disability). We are not witnessing a situation in which fitting profile A comes out a winner in domain of hearing I, whereas profile B wins in domain II, and so forth. Rather, some listeners receive benefit from profile A in domain I, and others benefit from profile B in that same domain. With expansion in understanding of the range of domains constituting auditory reality—which goes beyond the realm of speech hearing in quiet or noise—the prospects of identifying an amplification strategy that is going to be optimal for a given listener may not be strong. Nonetheless, the research being analyzed here helps substantially in identifying what is entailed in approaching that goal.

Fitting Profiles and Auditory Ecology

Thus, the next aspect of the experiment by Gatehouse and colleagues (2006b) elucidates the foregoing outcome. Both of the linear hearing aid fittings turned out to show substantial negative correlations between the three self-rated benefit measures (listening comfort, satisfaction, and speech intelligibility) and self-ratings of the variability and level of demand in the listener's auditory ecology. Listeners exposed to less varying acoustic environments provided higher ratings on the three benefit measures when using linear profiles. These findings were largely paralleled by the measured variability, using noise dosimeter sampling, of the acoustic environments in which the listeners immersed themselves. By contrast, there were consistently positive correlations between rated benefit and rated (greater) variability or demand under the three nonlinear strategies.

A telling subcontrast is that the two profiles incorporating fast release times showed links between rated benefit and brief time-frame variability in the measured acoustic sample, whereas the profile using slow release times showed links between benefit measures and longer time-frame acoustic variability. This finding indicates that listeners are sensitive to the operation of fast-acting systems in more rapidly changing acoustic conditions and are also sensitive to the operation of slow-acting systems in less rapidly changing conditions.

The measure of cognitive function used in this experiment involved serial presentation of single digits between 1 and 8; the task was to respond when a sequence exhibited the property of being odd–even–odd (e.g., 3–6–7) and serial presentation of individual alphabetic letters, the task being to respond when three successive letters formed a real word (e.g., C–A–T). Both aspects of this task represent a test of the phonological component of working memory (Baddeley, 1986), because even though the material is presented visually, response to and rehearsal of it calls on subvocal encoding. Under conditions of listening with the two linear fittings, variations in performance on this task were found to be unrelated to any of the benefit measures. By contrast, better performance on this task was positively correlated with rated and measured speech intelligibility for the fitting using fast-acting release times in both channels; furthermore, there were signs of negative correlation on those same measures for the slow-acting profile.

In a further analysis, relations were examined between the predictor variables and differences in the benefit measures as between one fitting strategy and another. As could be expected from the opposing directions of correlation just noted, the factor of cognitive function becomes prominent in predicting the extent of differential benefit between fast versus slow-acting compression, a finding confirmed by Lunner and Sundewall-Thorén (2007). There were also opposing directions of correlation between variability or demand level of the auditory environment and benefit measures under linear versus nonlinear fittings. Thus, the factor of auditory ecology is strongly predictive of the differential benefit observed between nonlinear versus linear fittings.

The foregoing account does not cover the whole of the investigative canvas represented by the studies described. Also, as the authors themselves say, although the relationships observed are statistically significant, there remains "substantial residual unexplained variance," meaning that much of what is going on here cannot be determined from the factors that formed the experimental design. The design itself undoubtedly influenced the pattern of outcome. For example, chronological age was not related to any of the benefit measures or other assessed factors. The age range of the sample was 54 to 82, and it would be expected in a typical clinic or population sample that auditory threshold and cognitive function would decline with increasing age (Lindenberger & Baltes, 1994). The extent of the experiment, in terms of the commitment required, would undoubtedly influence the decision to participate, a point that the authors recognize. People whose overall mental and physical health is more robust would likely have formed the sample.

The key point is that factors like cognitive function and auditory ecology—factors that are independent of the usual set of measures considered in clinical decision making—are shown to play significant parts in moderating the benefit offered by different prosthetic approaches. In the management of disabilities caused by hearing impairment, it will not be sufficient to confine attention to purely audiometric characteristics of the client. What the person brings to the table and what order of life the person leads are shown by this sort of investigation to bear substantially on what they can handle and what they will need.

The outcomes from this work demonstrate a complex interplay among auditory, cognitive, and lifestyle variables. A question arises about causal links among these (and other potential) factors. As an example, declining hearing is associated with social withdrawal, and this in turn will affect the variability or demand level of one's auditory environment. Such a form of linkage can probably account for the finding (Gatehouse, 1991, 1994) that increasing age, both in a general population sample and a sample of first-time clients of a hearing clinic, is associated with decrease in self-rated hearing disability, even while associated with increase in measured impairment. As social horizons diminish because of increasing hearing impairment, the range of contexts that call for adequate unaided hearing ability also diminish. The result is that experienced disability reduces as challenges to the system recede. Of course, what is observed in the population generally may not fully translate to the clinic. Those people who turn up seeking help in a clinical setting are engaged in a journey that sets them apart from others in their age cohort; a matter that bears on the next topic of this article.

Benefit Dimensions (and Awareness)

For various reasons, and in different economic forms of health provision, a significant question to seek an answer to is the extent of benefit afforded by whatever is available to those seeking service. Whether funded privately or from public resource, the value of what is on offer calls for assessment. There has been an accumulation of market-oriented data (Kochkin, 1993, 2001, 2002) in the United States in the hope that improved hearing aid technology would see rising sales of available products. In a publicly funded system, such as the United Kingdom or Sweden, the pressure to assess benefit is also economic, with managers of financial systems concerned to demonstrate value for money that is being drawn from the public purse. Thus, for example, a recent review of benefit gained from fitting hearing aids to both ears (Arlinger et al., 2003) was undertaken to examine the worth of continued support for such provision in the face of economic pressure for public funding to cover only an initial (single) hearing aid.

How is benefit to be assessed? A number of formal self-rating measures exist in the clinical literature, and their properties have been subject to review (Noble, 1998, 2004). A feature common to most such scales is that the listening contexts described by individual items are taken to be uniformly experienced and uniformly significant for any respondent. But given the variability of auditory ecology across listeners, as characterized by the outcomes described in the previous section, a scale that takes this into account may give a more accurate picture of pre-intervention conditions and post-intervention outcomes. Certainly, that is the rationale offered in support of the design and structure of the Glasgow Hearing Aid Benefit Profile (Gatehouse, 1999), a protocol that takes clients through a series of staged inquiries about occurrence of a given listening situation, pre-aided disability and handicap in that situation, hearing aid use and benefit in that situation, residual (post-aided) disability, and satisfaction with the hearing aid in that situation.

It is emphasized that the terms *disability* and *handicap* used here are as defined by the World Health Organization (WHO, 1980), in which *disability* refers to limiting consequences of any physical disorder for the conduct of everyday (in this case, auditory) tasks and *handicap* refers to everyday (nonauditory) consequences of those disabilities. The more recent WHO categories (2001) of *activity limitation* and *participation restriction* do not neatly serve the case of impaired hearing. The clarity of the contrast in WHO (1980) is not so evident in the more recent concepts because the emotional distress that is so central to the *handicap* experience because of hearing impairment is less readily reflected in the concept of *participation restriction,* the focus of which is more on occupational, recreational, and/or social limitation as a potentially handicapping consequence of any disabling disorder. Those consequences are also, of course, part of the handicapping experience resulting from impaired hearing. These points are discussed in Noble, Tyler, Dunn, and Bhullar (2008).

The focus of the Glasgow Profile is on speech hearing in contexts having different degrees of listening difficulty (one-on-one, in a group, TV at a level suiting others, talking in a noisy background). Respondents are also invited to nominate up to four listening situations specific to their individual circumstances. Of the 24 topics listed as nominated in response to this invitation, the overwhelming majority also cover speech hearing in conditions of varying difficulty, with hearing domestic signals (doorbell, telephone) nominated by a small percentage, and telling the direction of sounds nominated by a further smaller percentage.

The Glasgow Profile was derived from a larger range (14) of listening contexts, all but one being on the topic of hearing speech. The research to develop the profile involved probe-tube measurement of the aided auditory spectrum and calculation of the improvement in audibility of speech when aided. It was demonstrable that variations in self-rated use, benefit, and satisfaction could be systematically related to the amount of improvement in speech audibility; this supports the clinical validity of the profile as a direct measure of benefit from amplification.

Although it is entirely defensible to give prominence to speech hearing as a powerful function in the everyday lives of almost everyone, the structure of inquiry leading to the development of the Glasgow Profile would very likely itself serve to focus respondents' attention almost exclusively on that function when invited to consider situations specific to their lives. Seen in the broader context of attendance at a hearing clinic, it is relevant to note that taking the step to seek such service is strongly influenced by family pressure (O'Mahoney, Stephens, & Cadge, 1996; van den Brink, Wit, Kempen, & van Heuvelen, 1996). That pressure derives from the handicaps experienced by others in the family in the face of hearing impairment exhibited by a family member (Hétu, Lalonde, & Getty, 1987). Chief among those handicaps for others in the family is disruption of communication, making problems in speech hearing the dominant note in family complaint.

Thus, what people are highly conscious of, in taking the step to seek help for hearing problems, is communicative function and what it means in terms of family relations. There can be no doubt that communication in the family is a substantial component of most people's everyday lives. It turns out, though, that a broader spectrum of hearing function drives the experience of handicap *for the individual*. It remains unknown whether individuals are conscious of the handicapping consequences of disturbances to non-speech hearing auditory functions in the way that they are made to be, in a sense, by the responses of others to disrupted communication. In the next section is an examination of those other functions and their bearing on handicap as personally experienced.

Dimensions of Disability

From different backgrounds in clinical and theoretical work, it has become increasingly evident that a focus on segmental speech intelligibility, in framing an understanding of the consequences of hearing impairment, is too narrow. The importance of sound localization has been argued for in connection with rehabilitative management (Byrne & Noble, 1998). Broader than that concept is one articulating the task of hearing as "auditory scene analysis" (Bregman, 1990), an approach whose grounding can, in part, be witnessed in the pioneering work of perception theorist James Gibson (1966). In these conceptualizations, the listener's task is to detect, externalize, locate, identify, and segregate components of a rich and dynamic input signal. In the domain of speech hearing, besides segmental intelligibility in supportive as well as challenging backgrounds, at times a listener has to suppress interfering speech, to monitor simultaneous speech streams, and to follow rapidly switching speech sources in group engagement.

It is clear that a new approach to clinical appraisal of hearing abilities is called for in light of an enlarged understanding of what hearing in the everyday world really encompasses. Drawing on these and related empirical and theoretical backgrounds has led to the development of the Speech, Spatial and Qualities of Hearing Scale (SSQ; Gatehouse & Noble, 2004). This scale is designed to cover all the aspects of speech hearing sketched above; spatial hearing, including movement, distance and directional judgments; sound segregation, clarity, and naturalness of everyday sounds, including music; identifiability of sounds; and listening effort. Questions are framed as scenarios designed to put a respondent in quite specific contexts and invite their rating on a scale from 0 (*unable*) to 10 (*highly able*).

An investigation of the properties of the new measure, in a group of new hearing clinic clients prior to any management decisions, demonstrated that outcomes were intelligible and interpretable, indicating that the scale had considerable meaning for respondents. An independently completed inventory of items on emotional distress and social restriction because of hearing impairment enabled the relationship to be scrutinized between disabilities, as expressed via the SSQ, and handicaps, as assessed by the distress and restriction items. In the speech–hearing domain, it emerged that the dominant influence on experienced handicap is represented by the items that tap into tasks that require selective and rapidly switching attention; that in the spatial domain, it is again the dynamic component (especially movement discrimination) that drives the experience of handicap. Furthermore, the links between dynamic spatial hearing disturbance and handicap are as strong, if not stronger, than with the speech items. Segregation and naturalness are components of the other qualities domains that are identifiable in connection with handicap experience.

The SSQ has thrown new and bright light on the matter of how to appreciate the consequences of impaired hearing. Observing the significance of dynamic components of the auditory ecosystem has already influenced the design of performance measures that will more aptly capture a listener's task in the real world (Gatehouse & Akeroyd, 2006). The scale has also allowed the real benefits of bilateral hearing aid fitting to be appreciated (Noble & Gatehouse, 2006). These benefits also lie particularly in the dynamic speech and spatial arenas.

The foregoing results underscore the point made in the previous section about what determines handicap as personally experienced, versus what drives handicap as a "socially distributed" phenomenon. It would repay further research attention to see whether respondents can identify for themselves whether the factors emerging from this recent body of self-assessment-based research also lie behind their own feelings of distress and restriction. It is quite possible that no one has an articulated sense of the links that are indicated between dynamic aspects of everyday hearing function and distressing and limiting consequences for life more generally. But even if not articulated, the connections make sense when it is realized that reduced capacity in the hustle and bustle of everyday, sometimes competitive, conversational engagement and a reduced sense of sure connectedness in the sometimes busy physical world, will have distressing emotional and social consequences for the person.

Self-assessment is a powerful research and clinical tool if devised and used appropriately in different contexts of appraisal. The three arenas analyzed in this article show the cogency that the methodology can bring to the task of answering significant clinical and research questions surrounding the management of hearing disability and rehabilitation.

Auditory Reality

Hearing disability cannot be fully understood without an appreciation of the way that auditory function is yoked to the audible world. The liaison between function and world can be portrayed by the concept of auditory reality. What is auditory reality? This rather fanciful term refers to the fabric of the audible world as encountered by anyone in the course of life. Auditory reality is not fixed in place, awaiting the introduction of the person, as though joining an audience at a theater performance: It is a product of the person's engagement with the world plus what the world provides. People do not determine the sounds that are caused by other agents—planes flying overhead, birds calling—but they nonetheless contribute to the whole corpus of their auditory reality in how they live, what they do; and, of course, people determine their own inputs to the total auditory reality picture.

Auditory reality, then, is a bit different from auditory ecology. The latter is more determined by the practices of the individual. Auditory reality is just whatever occurs in the life of any person, and it is definable as the set of inputs to which anyone is subject progressively. It is, thus, filtered by the capacity of the system with which the person operates, a point returned to presently.

The fabric of auditory reality is distinct from, though often entwined with, the fabric of visual reality. Confining analysis to the typical human case, visual reality at first seems cleaner than auditory reality: Visual reality is profoundly governed by the cycle of day and night. Auditory reality is strongly affected by that cycle (activities change between day and nighttime, so the fabric of the audible world changes); visual reality is profoundly dependent on the characteristic alterations in visible light values as between sunlight and night light.

The components of auditory reality often overlap in time and spectral-prosodic content: The components of visual reality are not mixed in this way. Visual layouts sometimes offer mixtures, as when reflections off a transparent surface are witnessed as in the same spatial sector as surfaces that lie behind the reflecting surface. Auditory reality is necessarily marked by such spatio-temporal overlaps, whereas visual reality is mostly marked by contiguity of layout. Contiguity is a feature of the visible world because light is propagated in straight lines, and absorption/reflection of light is abrupt at the edges of surfaces interposed between a *viewpoint* and more distant surfaces. Acoustic energy is diffuse and overlapping because boundaries of interposing objects do not offer abrupt discontinuities in the energy propagated from a more distant source relative to a "hearpoint." The way that light is propagated, therefore, means that the visible environment offers occlusion properties (Gibson, 1979), whereby surfaces mask elements of other surfaces, providing a rich pattern and flow of information about spatial relations among surfaces. There is no equivalent patterning in the audible world. The coherence of the audible world relies heavily on the integrity of the receptor surfaces exposed to auditory input signals.

Visual reality can be "noisy," as when a scene is to be witnessed in crowded conditions or navigation occurs in a busy and fast-changing environment—driving through an unfamiliar city in a foreign land. Atmospheric conditions (dust, fog) can obscure surfaces and their relations, just as acoustic conditions (wind, reverberation) can obscure auditory signals. Hence, there are analogues between the two realities. But to return this component of the present article to the introductory remarks, auditory reality, for its accurate detection and discrimination, is vitally dependent on the fidelity of receptor systems attuned to it. The same holds for visual reality; but critical loss of visual fidelity occurs at the extreme of the spectrum of visual disorder (go to www.brainconnection.com/topics/?main=anat/vision-path), whereas loss of auditory fidelity arises readily from common and moderate injury to the receptor surface just because of the way auditory reality is typically structured.

Stuart Gatehouse was interested in the realities confronting people with impaired hearing in the two senses of that statement: He was interested in, and devoted much thought and analysis to, the auditory worlds in which people with impaired hearing function; and he was both interested in and concerned about the problems they contend with when engaging with those worlds.

References

Arlinger, S., Brorsson, B., Lagerbring, C., Leijon, A., Rosenhall, U., & Schersten, T. (2003). *Hearing aids for adults—benefits and costs*. Stockholm: Swedish Council on Technology Assessment in Health Care.

Baddeley, A. D. (1986). *Working memory*. Oxford, UK: Oxford University Press.

Bregman, A. S. (1990). *Auditory scene analysis: The perceptual organization of sound*. Cambridge, MA: MIT Press.

Byrne, D., & Dillon, H. (1986). The National Acoustic Laboratories' new procedure for selecting the gain and frequency response of a hearing aid. *Ear & Hearing*, 7, 257-265.

Byrne, D., & Noble, W. (1998). Optimizing sound localization with hearing aids. *Trends in Amplification*, 3, 51-73.

Dillon, H. (2001). *Hearing aids*. Sydney, Australia: Boomerang Press.

Gatehouse, S. (1991). The role of non-auditory factors in measured and self-reported disability. *Acta Oto-laryngologica*, Suppl. 476, 249-256.

Gatehouse, S. (1994). Components and determinants of hearing aid benefit. *Ear & Hearing*, *15*(1), 30-49.

Gatehouse, S. (1999). Glasgow Hearing Aid Benefit Profile: Derivation and validation of a client-centred outcome measure for hearing aid services. *Journal of the American Academy of Audiology*, *10*, 80-103.

Gatehouse, S., & Akeroyd, M. (2006). Two-eared listening in dynamic situations. *International Journal of Audiology*, *45*(Suppl. 1), S120-S124.

Gatehouse, S., Naylor, G., & Elberling, C. (2003). Benefits from hearing aids in relation to the interaction between the user and the environment. *International Journal of Audiology*, *42*(Suppl. 1), S77-S85.

Gatehouse, S., Naylor, G., & Elberling, C. (2006a). Linear and nonlinear hearing aid fittings—1. Patterns of benefit. *International Journal of Audiology*, 45, 130-152.

Gatehouse, S., Naylor, G., & Elberling, C. (2006b). Linear and nonlinear hearing aid fittings—1. Patterns of candidature. *International Journal of Audiology*, 45, 153-171.

Gatehouse, S., & Noble, W. (2004). The Speech, Spatial and Qualities of Hearing Scale (SSQ). *International Journal of Audiology*, *43*(1), 85-99.

Gibson, J. J. (1966). *The senses considered as perceptual systems*. Boston: Houghton-Mifflin.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston: Houghton-Mifflin.

Hétu, R., Lalonde, M., & Getty, L. (1987). Psychosocial disadvantages associated with occupational hearing loss as experienced in the family. *Audiology*, *26*, 141-152.

Kochkin, S. (1993). MarkeTrak III: Why 20 million in U.S. don't use hearing aids for their hearing loss. *The Hearing Journal*, *46*(1), 20-27.

Kochkin, S. (2001). MarkeTrak VI: The VA and direct mail sales spark growth in hearing aid market. *The Hearing Review*, 8(12), 16-24, 63-65.

Kochkin, S. (2002). MarkeTrak VI: 10-year customer satisfaction trends in the U.S. hearing instrument market. *The Hearing Review*, *9*(10), 14-46.

Lindenberger, U., & Baltes, P. B. (1994). Sensory functioning and intelligence in old age: A strong connection. *Psychology and Aging*, *9*(3), 339-355.

Lunner, T., & Sundewall-Thorén, E. (2007). Interactions between cognition, compression, and listening conditions: Effects on speech-in-noise performance in a two-channel hearing aid. *Journal of the American Academy of Audiology*, *18*, 604-617.

Moore, B. C. J. (1996). Perceptual consequences of cochlear hearing loss and their implications for the design of hearing aids. *Ear & Hearing*, *17*, 133-160.

Moore, B. C. J. (1998). *Cochlear hearing loss*. London: Whurr.

Noble, W. (1998). *Self-assessment of hearing and related functions*. London: Whurr.

Noble, W. (2004). Hearing aid outcome measurement: Design issues and options in the self-assessment domain. *Zeitschrift für Audiologie*, *43*(1), 22-28.

Noble, W. (2006). Bilateral hearing aids: A review of self-reports of benefit in comparison with unilateral fitting. *International Journal of Audiology*, *45*(Suppl. 1).

Noble, W., & Gatehouse, S. (2006). Effects of bilateral versus unilateral hearing aid fitting on abilities measured by the speech, spatial, and qualities of hearing scale (SSQ). *International Journal of Audiology*, *45*(3), 172-181.

Noble, W., Tyler, R. S., Dunn, C., & Bhullar, N. (2008). Hearing handicap ratings among different profiles of adult cochlear implant users. *Ear & Hearing*, *29*(1), 112-120.

O'Mahoney, C. F., Stephens, S. D. G., & Cadge, B. A. (1996). Who prompts patients to consult about hearing loss? *British Journal of Audiology*, *30*, 153-158.

Plomp, R. (1978). Auditory handicap of hearing impairment and the limited benefit of hearing aids. *Journal of the Acoustical Society of America*, *63*, 533-549.

Plomp, R. (1994). Noise, amplification, and compression: Considerations of three main issues in hearing aid design. *Ear & Hearing*, *15*, 2-12.

van den Brink, R. H. S., Wit, H. P., Kempen, G. I. J. M., & van Heuvelen, M. J. G. (1996). Attitude and help-seeking for hearing impairment. *British Journal of Audiology*, *30*, 313-324.

World Health Organization (WHO). (1980). *International classification of impairments, disabilities, and handicaps*. Geneva, Switzerland: Author.

WHO. (2001). *International classification of functioning, disability and health*. Geneva, Switzerland: Author.