The terminology used in studies documenting changes in auditory performance following fitting of hearing aids has been diverse. Definitions for the auditory deprivation effect and auditory acclimatization are offered as a first step in rationalization. Two statements summarize current knowledge concerning auditory deprivation effects and auditory acclimatization, as well as considering the potential implications for research, field trial and clinical practice applications. Potential areas for future research are identified.

**INTRODUCTION**

The seven substantive articles in this volume provide an analysis of the available literature, evidence concerning auditory deprivation effects and acclimatization, and the authors' synthesis of their findings and implications, both in relation to hearing aid research and practice. In addition, links are drawn to other areas of auditory performance and basic neuroscience. This eighth contribution to the volume aims to condense that synthesis into a series of statements reflecting the considered views and experience of the Workshop participants.

**DEFINITIONS**

In any area of research endeavor where novel results and concepts are proffered, the opportunity arises for confusion and conflict in the terminology used to describe the phenomena. One objective of the Workshop was to produce an agreed set of definitions. Although the focus of the Workshop concentrated on issues related to changes in hearing aid benefit across time, the coverage has included the deficits that can occur following provision of a single hearing aid, often referred to in the literature as late-onset auditory deprivation. As a general definition, the Workshop offered the following:

**Auditory deprivation effect:** The auditory deprivation effect is a systematic decrease over time in auditory performance associated with the reduced availability of acoustic information.

This is a general definition equally applicable across the range of severity of hearing impairments and across the range of ages of hearing-impaired listeners, and it is independent of the symmetry or otherwise of the acoustic information available to the listener. It does not make any assumptions concerning the aspect of auditory performance that may decrease, although results published so far have been focused on speech recognition. Neither does the definition make any assumptions about the cause of reduction of acoustic cues. It was not deemed appropriate to provide specific definitions applicable to auditory deprivation effects that may be observed to occur in adults with bilateral sensorineural hearing loss who are long-term users of a single hearing aid, but rather to ensure that investigations or statements regarding particular subsets of hearing-impaired listeners were available to the reader.

In contrast to the literature on auditory deprivation, the published work concerning if and how listeners' performance with hearing aids may change across time has been associated with a variety of terminological labels, including maturaion of hearing aid benefit, learning effects, training, adaptation, habituation, and acclimatization. The Workshop declined to provide separate and individual definitions for each of these terms, but rather proceeded to produce a definition of the terminology it deemed most appropriate. Given its relative lack of prior association with other concepts and the majority (though not total) adoption of use in this field, the Workshop converged on "acclimatization" as an appropriate term to encompass the concept.

**Auditory acclimatization:** Auditory acclimatization is a systematic change in auditory performance with time, linked to a change in the acoustic information available to the listener. It involves an improvement in performance that cannot be attributed purely to task, procedural or training effects.

It should be noted that the definition aims to be both general and generally applicable, and makes no assumptions concerning the aspects of auditory performance that may change across time (in, for example, aspects of speech identification ability or psychoacoustical abilities, including binaural or localization abilities), nor does it make any assump-
tion concerning the mechanism by which auditory information available to the listener is changed (for example, because of the provision of a hearing aid or aids, a significant change in amplification, or the alteration of auditory function following otological surgery). Although the definition does not assume or preclude a decrease in auditory performance in some conditions, it does require that the response of the auditory system to particular stimuli, by some mechanism or mechanisms, exhibits an improvement in performance following the change in information available. Such changes should not be able to be accounted for merely by procedural aspects of the experiment unrelated to the changes in auditory information.

The participants of the Workshop argue that careful attention to the definitions in describing results or considering the implications of the body of published literature will reduce the opportunity for misinterpretation.

**WORKSHOP FORMAT**

The participants at the three-day Eriksholm Workshop included a group of individuals who had actively contributed to the published evidence on auditory deprivation effects and auditory acclimatization. Some data had shown statistically significant results, and other sets had not (refer to the articles in this volume by Turner et al. concerning acclimatization and by Neuman concerning deprivation for details). In producing the statements on the final day of the Workshop, the participants consisted of two groups: 1) those who had actively contributed evidence to the available literature (Bentler, Cox, Gatehouse, Humes, Robinson, Silman, and Turner); and 2) those who have not actively contributed evidence to the available literature and who were, to some extent, independent of the current debate concerning interpretation (Arlinger, Byrne, Dirks, Neuman, Ponton, Summerfield, Tyler, and Willott). This latter group, under the chairmanship of Stig Arlinger, constituted the “panel” (or “jury”) soliciting evidence from the “witness” group as information from which they would build their statements. The statements that follow represent the considered evaluation of this latter subset of the Workshop participants during the third and final day of the Workshop.

The draft statements from the “panel” were available for comment by the “witness” group and underwent further subsequent amendment by the “panel.” As such, the draft statements are primarily the product of the independent “panel,” although with input available from the experience and interpretation of the individuals who had active research contributions to the areas.

**CONSENSUS STATEMENTS**

**Auditory Deprivation Effects in Adult Users of Single Hearing Aids**

S. Arlinger, D. Byrne, D. D. Dirks, A. Neuman, C. Ponton, A. Q. Summerfield, R. S. Tyler, and J. F. Willott

Current evidence indicates that an auditory deprivation effect occurs. It is manifested as a statistically significant reduction in speech recognition performance. The effect appears to occur only in a subset of those who experience monaural auditory deprivation. It is not known how large this subset is. However, a substantial number of subjects who possess at least a moderate degree of bilateral hearing loss, but receive unilateral hearing aid fittings, display the effect when tested in the unaided ear. Currently, there is no way of predicting who will show the effect. It is not known whether the effect also occurs in cases of bilateral deprivation (i.e., with a bilateral hearing loss and no hearing aid on either ear). Because most of the evidence of the auditory deprivation effect has been obtained from retrospective studies, the time course of the effect is not known in detail, nor is the magnitude of the effect or how subject-related variables determine the way in which the effect is manifested. Current data indicate that the effect is typically not measurable until two to three years of deprivation has occurred, although it may also occur after less than one year. In some cases, but not all, recovery has been demonstrated by converting a monaural hearing aid fitting to a binaural fitting. Present knowledge does not allow the prediction of who will and who will not recover. The exact audiometric profile of those who may exhibit the auditory deprivation effect is not known, but those with a moderate or greater hearing loss appear to be at risk. Further research is necessary to determine if those with mild hearing loss may also be at risk. The auditory deprivation effect may be assessed by speech audiometry using recorded stimuli, with scoring based on at least 50, preferably 100, test items, along with an assessment of the statistical reliability of scores in relation to binomial properties. There is a clear need for prospective studies in order to establish better knowledge about the incidence, magnitude, and time course of the auditory deprivation effect. The implications for clinical practice are that a binaural hearing aid fitting is indicated in cases of moderate to severe binaural hearing loss. The audiologist should document the recommendation for a bilateral fitting. In subjects who prefer a unilateral fitting,
Auditory Acclimatization

The available evidence indicates that auditory acclimatization does occur, and that it is a phenomenon with importance for research, and with potential implications for field trials of hearing aids and clinical practice. We are unable to conclude under what conditions it does and does not occur, how prevalent it is, exactly the size of the effect, or its full time course. However, the results presented so far indicate that the effect is not always observed for current linear hearing aids when the dependent variable is a measure of speech identification ability. The mean reported improvement in benefit over time is in the range of 0 to 10% across a wide range of speech materials and presentation conditions. The time course of acclimatization does not appear to be completed until after at least a number of months. We recommend that studies be designed to resolve these questions. The practical importance of acclimatization will only be clear once the results of these studies are known. It will be important for future studies of acclimatization following the fitting of hearing aids to ensure (i) that the aid makes useful new information available to the listener, (ii) that outcome measures should be sensitive to the effects of that new information, and (iii) that outcome measures should be sufficiently reliable to show an effect of the expected size, including being free from floor and ceiling effects. We recommend that all studies should report both the absolute levels of outcome and the difference in outcome between aided and unaided conditions.

Although it is possible and appropriate to make relatively detailed statements concerning auditory deprivation effects following hearing aid fittings in adults, the situation of auditory acclimatization is less clear. This uncertainty arises from the apparent divergences in the literature, which themselves have origins both in the underlying differences between subjects and also in the variability inherent in procedures used to assess speech identification abilities, which often form the outcome measure of interest. The cautious tone of this consensus statement reflects the fact that the area does have substantial uncertainties, and arises from a balanced and responsible approach rather than reflecting extreme positions from groups or individuals with particular viewpoints. The statement aims to discourage extreme and unwarranted views, which might unduly influence the conduct of research, clinical trials, or clinical practice.

Potential Avenues for Future Research Effort

Contained in the consensus statements above and running through the Workshop itself and the seven articles in this volume are areas that have been identified where current knowledge is deficient and where future research might be appropriate. At the final session of the Workshop, participants identified potential research areas that, although not necessarily universally regarded with high priority, were recognized as avenues for future effort and study. The objective in collecting these is to make available to the reader the areas where current understanding needs to be improved. It is intended that such a list be informative rather than prescriptive or restrictive, serving as a general overview of the ways in which further knowledge might be improved.

In organizing this list, the subject areas have been allocated no particular order or priority, but some attention has been paid to the elimination of overlap between categories. Thus, a list of potential areas for future endeavor includes:

- To document the existence, magnitude, prevalence, and generality of acclimatization.
- To investigate whether the conclusions about the relative effectiveness of different amplification systems alter if evaluations are performed after a period of acclimatization, rather than immediately after fitting.
- To conduct research to determine the full time course of acclimatization.
- To investigate whether acclimatization effects for a given individual are the same for different amplification processing strategies.
- To investigate the effects of age, as well as degree and pattern of hearing loss, on acclimatization and deprivation.
- To conduct research on the reversibility of acclimatization and deprivation.
- To investigate the effects of binaural and monaural aiding on acclimatization.
- To investigate the effects of symmetry of aided hearing on acclimatization and deprivation.
- To conduct research on aspects of binaural function and auditory localization following acclimatization and deprivation.
To conduct research bearing results indicating at what time periods the effects of auditory deprivation can first be observed.

To investigate the relationship between changes in psychoacoustical abilities (such as loudness mapping and intensity discrimination) and acclimatization to the understanding of everyday speech.

To conduct psychoacoustic studies to determine the underlying mechanism of acclimatization.

To investigate possible mechanisms by which acclimatization effects might be amplified and accelerated.

To investigate the extent to which outcomes from cochlear implantation also predict outcomes from management with hearing aids.

To conduct research on the relationships between psychophysical and electrophysiological/imaging techniques in acclimatization and deprivation to understand the anatomical and physiological changes underlying changes in performance.

To formulate an animal model for acclimatization.

**SUMMARY**

The proffered definitions for auditory deprivation effects and auditory acclimatization provide a terminological framework so that a common understanding can be achieved when considering and discussing how auditory performance may change following the fitting of a hearing aid or hearing aids. In particular, they lay down the circumstances in which such changes might be considered to be a consequence of auditory deprivation or acclimatization rather than surrogates of other factors in the experimental design. As such, they identify aspects which require control or deliberate experimental design in future experimental situations.

The statements concerning our current understanding of acclimatization and auditory deprivation effects represent a balanced view of what is believed to be known and, perhaps more importantly, identify areas where our knowledge and understanding is inadequate. As such, they aim to encourage and, to some extent, to guide further research into deprivation and acclimatization by identifying what we know and don't know about these subjects. The cautious tone of the statements may disappoint some readers but reflects the fact that these topics do contain uncertainties—the very rationale for the Workshop concept.

As a consequence, the identification of areas for potential research is extensive, even though relatively general groupings of concepts are achieved rather than the description of particular experi-

**REFERENCES**


Byrne, D., Noble, W., & Glauerdt, B. (in press). Effects of ear mould type on ability to locate sounds when wearing hearing aids. *Ear and Hearing*.


**References**


