SCREENING FOR NOISE-RELATED HEARING LOSS

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1. INTRODUCTION

Screening audiometry is a term applied to audiometric procedures used for the general population, and for workers in industry. The basic idea of screening audiometry is very simple: to select a subset for further testing.

All forms of screening audiometry have certain common features:

1: low probability of a 'hit', an abnormal result;

2: procedures must be simple and quick;

3: procedures must only require simple equipment;

4: tests may be performed by persons with minimal training;

5: tests often performed 'on site', using portable equipment and without benefit of audiological booths or other noise exclusion.

However industrial audiometry differs in several ways from the standard form of general population screening:

1: testing of adults rather than children;

2: periodic testing, rather than a once-only check;

3: industrial screening procedures and their results have legal implications, such as use in compensation claims;

4: there are also special management implications, to avoid further hearing loss once an early loss has been detected;

5: there is a need to make procedures as efficient as possible, for minimum disruption at the workplace, without sacrificing accuracy and reliability of results;

6: finally, the optimum equipment is very different for the two types of 'screening'.

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This paper reviews the particular legal, management, and ergonomic aspects of industrial screening for noise-related hearing loss. The requirements for an optimum 'industrial screener' are specified. Finally, we review research and development at Alfred Peters Ltd to provide equipment to fulfill the special requirements of industry.

2. SCREENING AUDIOMETERY

2.1 Terminology of Hearing Testing

There are many ways to test hearing, but all have two aspects: i) equipment and ii) procedures. The equipment can range from the very simple (a ticking watch; a tuning fork; a handclap) to the very complex, as in a signal averaging computer for measuring electrical signals in the auditory cortex. In every case, however, the equipment is only part of a hearing test. The test procedure is equally important, as the equipment can often be used in various ways, and for various purposes.

Because hearing varies with frequency, an essential aspect of most hearing tests are test signals with a known, and controlled, frequency spectrum. The standard approach, at least with persons over the age of approximately three years, is pure tone audiometry: testing of response to pure tones at various frequencies. The device which produces these sounds, with known levels calibrated with reference to normal hearing, is the pure tone audiometer.

However, an audiometer is the piece of equipment, and does not in itself define a hearing test, because it does not define the purpose or the procedures. Generally speaking there are two main reasons for testing hearing: to find out if there is a problem, and to find out what the problem is. These two aspects are often called screening and diagnosis. The point is that a pure tone audiometer can be used either for screening tests or diagnostic procedures, using the same equipment but using very different procedures for very different purposes.

2.2 General Characteristics of Screening Procedures

Screening audiometry is required whenever there is a rather large group of persons, and some small number of those persons can be expected to have a hearing problem requiring further attention. The purpose of screening audiometery is NOT to produce audiometric data on individual persons. It is to select a subset from a general population. The best screening procedure is that which selects the greatest number of those persons actually requiring further testing (the greatest number of hits), while simultaneously minimising further tests on

persons who do not need such tests (false alarms), and also minimising the rejection of persons who should be selected but are not (misses or false rejects).

If numbers (costs) can be put on hits, false alarms, and misses, and if costs (or at least relative costs) can also be assigned to the screening tests and to the further, more extensive tests, the whole question can be reduced to mathematics and an optimum strategy devised. Typically false alarms are encouraged, in order to minimise the false rejects.

The requirement for efficient screening tests is to do the least possible testing which still provides a good separation of the desired subset from the general population. It may well be possible to find all the 'at risk' subset by running a lengthy test on the whole population, but that approach to testing amounts to abandoning a screening test, and simply giving everyone the comprehensive tests. Therefore true screening tests are always minimal: the least possible testing which selects the subset.

The result of a screening test is defined in terms of the statistics on the population, in terms of separation of two groups. It is not a test on the individual, and really produces no reliable audiometric data on the individual. Thus it is a mistake to talk about someone who has 'passed' a screening test. The screening test is, by definition, a minimal effort approach, and so its results are always to be considered dubious for any individual.

Screening tests for hearing are applied in the UK to the general population of children, typically by health visitors during the first two years, and again during the early school years.

These are the only generally applied screening tests for hearing. There are three other main routes to hearing tests:

1: self diagnosis: persons who complain of a possible hearing problem to their own GP;

2: preventive care: persons who have a hearing test as part of a general medical check-up;

3: 'industrial screening': persons who have their hearing tested as a requirement of their employment.

The general technical, legal, managerial and ergonomic requirments of hearing testing relating to employment are presented in the next section.

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3. INDUSTRIAL AUDIOMETRY

3.1 Purpose of Industrial Hearing Tests

Industrial hearing testing is often referred to as 'industrial screening', and there is one sense in which the term screening is accurate: there is an element of selection in industrial procedures, to find out who in the general workforce has a hearing problem. However, this is only one requirement of hearing tests in industry. The full range of reasons for industrial audiological procedures includes:

1: to provide baseline hearing data on all employees;

2: to detect relatively small changes in hearing ability;

3: to provide legally acceptable evidence concerning a persons hearing throughout the course of that persons working life;

The above list could be extended, but it is already sufficient to show that industrial testing goes well beyond the ordinary definition of screening. Individual results are required, and required with an accuracy which, in the end, would stand up in court.

A further difference from screening is the accurate detection of small departures from normal hearing. Screening of children in the general population has as its main goal the detection of serious hearing impairment at the earliest possible age. Substantial departures from the norm are being sought, but amongst a population which may be difficult to test. In industry, cooperative adults are being tested, but it is important to detect any decrement in hearing. Early detection of small changes is vital in an industrial context: if the loss is related to industrial exposure, measures can be taken to prevent further deterioration

3.2 Results of Industrial Hearing Tests

The result of a screening test is essentially pass/fail, and neither outcome (especially the 'fail' outcome) has high statistical validity for an individual. Screening tests are tests of an entire population.

Industrial testing is thus never just screening. Obviously there is an element of selecting individuals with marked problems for further testing, but each individual test must be valid as an accurate representation of that persons hearing. The required test accuracy has two components:

i) precision: sufficient to detect small changes;
ii) reliability: acceptable in a medico-legal context.

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3.3 Equipment and Procedures for Industrial Audiometry
The screening of children in the general population does not require the same precision and reliability as for industrial audiometry. The selection of young children with a possible hearing problem can be based on using a simple test to check whether or not there is response to sound. Often the only written record of the test is a note made by the person conducting the test. An audiogram in NOT produced, only a pass fail indication. The target subset of the general population of children are, in particular, those with a sufficient hearing loss to require early remediation (such as provision of hearing aids).

For detection of noise-related hearing loss in industry, the target subset are person with a small hearing loss. There should always be a written record of the test. For full documentation of an employee's hearing, the test result should be an audiogram, covering the range from 250 Hz to 8000 Hz in steps of no more than an octave. The precision of the test should be valid to within 5 dB, and test-retest reliability should be at within 10 dB. The legal requirements may vary in detail across Europe, according to national and occupational legislation. Nevertheless there is a general, professional standard for pure tone audiograms which leads to the above mentioned figures of 5 dB precision and 10 dB reliability.

A 'screening' audiometer of the type used on children is often entirely inadequate for industrial purposes, as it may only test three frequencies, with only 20 dB precision (and possible even lower reliability).

Basic audiometry in industry requires a quiet test room. Screening of children for normal hearing vs serious impairment can use an ordinary room, often the child's home. There is no attempt to test at very low sound levels. Industrial testing is concerned primarily with early indications of loss. 'Early indications' means 'slight indications', and so testing for 0 dB vs 20 dB HL hearing thresholds is very relevant, and impossible in most ordinary rooms. Use of a specially treated room or booth is necessary to fulfill the basic purpose of industrial audiometry: accurate early detection of a problem.

Finally, screening of children's hearing usually only occurs from one to three times in a childs life, because it is concerned primarily with determining whether or not a child already has a substantial problem. Industrial testing must be at regular intervals, throughout the period of any employment with a risk of noise exposure, because it is concerned with determining whether a problem is beginning to develop.

3.4 Requirements for Basic Industrial Audiometry
Although it is common practice to refer to 'industrial screening' when discussing audiometric practices concerned with early detection of noise-related hearing loss, the above discussion has highlighted the many differences between industrial procedures and the usual type of screening test, as applied to children in the general population.

The general requirements for basic industrial testing can be summarised as follows:

1: the measurement of pure tone hearing thresholds for each ear

2: to a precision of 5 dB

3: with an accuracy of 10 dB (minimum)

4: across the frequency range from 250 Hz to 8000 Hz, at no more than one octave intervals

5: using an audiometer which meets the air conduction testing requirements of a Type 3 audiometer, according to IEC 645 Part 1

6: using an adequate test room or booth, according to ISO 8253 Part 1

7: with a written record of the test (an audiogram)

8: meeting all relevant standards, including IEC standards on equipment, ISO standards on procedures, the requirements of the International Organisation of Legal Metrology (OIML), an any additional national and industrial requirements

9: while still taking the minimum time per test

10: and making maximum use of the time of the person administering the test.

As an example of "additional national requirements", in the UK the Health and Safety Executive has a system for placing employees in categories according to the liklihood of hearing loss or risk of hearing loss, based not just on the audiogram but also on previous audiograms. It is an obvious advantage if the audiogram is produced in a form which readily allows such further calculations, and which readily allows comparison with previous results.

4. AN INDUSTRIAL SCREENING AUDIOMETER

The point of this paper is that it is not in any way sufficient to use a 'screening audiometer', of the type used for screening tests on the general population of children, for the purposes of general testing of adults. There is one similarity: in both child screening and in noise-induced hearing loss screening the object is separation of a subset from the general population. In every other aspect the two kinds of 'screening' differ.

In particular, there is a major difference in the equipment required for industrial hearing tests. The general performance characteristics were listed in the previous section. This paper concludes with a description of an audiometer designed specifically for the requirements of preliminary testing for noise-related hearing loss.

4.1 Principal features

The key design goals of the Alfred Peters AP250 Computerised Industrial Audiometer were as follows:

1: meeting all national and international standards and other requirements, in the UK and across Europe;

2: full, written records of all tests;

3: maximum efficiency.

4.2 Meeting Standards and Other Requirements

To meet all performance standards, the basic electronics used exceed the air conduction output requirements of a Type 2 audiometer, as per IEC 645 Part 1.

"Other requirements" pose a problem, as they vary according to the country and even the industry. Our solution was to incorporate within the audiometer sufficient potential to meet any requirement. This was accomplished by making a personal computer an integral part of the audiometer.

4.3 Record Keeping

There is only one way to provide a printed audiogram without compromising on test efficiency: by having the audiometer produce the audiogram automatically. This aspect is one of the clearest distinctions between screening tests for children, and so-called screening in an industrial context.

Therefore our industrial audiometer had to be a 'self-recording' audiometer. This requirement was easily met, as we had already decided upon having a personal computer as part of the system.

The computer could take care of any and all computations as discussed in the previous section, and it could also easily handle the printed output.

Further, use of a computer to produce the audiogram meant that the audiometric data were automatically in 'machine readable' format, as the results were inside the computer by the time they were printed. Thus data could be incorporated with other computer-based medical data, or placed in a data base. Indeed, we have made a database part of the standard package.

The database approace to audiometric records allows previous tests to be called up on a computer screen, and compared with the current test, and allows the computer to work out the Health and Safety Executive categorisation of the test results.

4.4 Efficiency
There are three aspects to the Peters Industrial Audiometer which improve testing efficiency:

1: automated testing - the subject controls the test using Bekesy-style pushbutton control. Because a computer is operating the audiometer circuits, any other type of automated testing is also possible, as is reversion to manual control. This type of testing has a precision of 1 dB. The accuracy varies according to subject, but can be as good as 3 dB.

2: automated record keeping - all data goes straight into the computer. The audiogram is printed by a conventional printer, and the numbers are saved in a database. There is no burden on the operator to provide these functions.

3: multi-station operation - for large-scale testing, multiple 'stations' can be controlled by one operator (and one computer), for simultaneous testing of groups of employees, and maximum system throughput.

5. CONCLUSIONS

Basic hearing tests in industry cannot use a simple screening audiometer as used for tests on children. The audiometer and the procedures must meet a range of standards, be of sufficient quality to provide accurate detection of small losses and small changes, and provide written records which are acceptable to hospitals and to courts.

The use of a computer-based, subject-operated, self-recording audiometer provides all the required capabilities, and does so in a way which is very efficient in terms of the time-per-test for each subject, and in terms of the time-per-subject for the person controlling the tests.