A TRIAL PROGNOSTIC EVALUATION
OF OCCUPATIONAL HEARING LOSS
BY HOMOGENEOUS ABSORBING
MARKOV CHAINS

It is indicated that occupational hearing loss is
progressive, and analysis of the progression is thought to be of fundamental importance. In the
present study we intended to evaluate the progression of occupational hearing loss quantitatively by
means of a mathematical analysis of two successive
cross-sectional audiometric data.

Materials and methods

We analyzed audiograms of workers in a metal
industry, where those with more than 20dB hearing
loss at 4kHz were reexamined in detail. From 1978 to 1979, 97 workers received repeated audiometric
examinations with an interval of approximately 12 months. All of the workers were male and aged 24 to 59 years. The average sound level of their work place was 86 (82-90) dB(A) during
6 hours in a day.

A mathematical model of homogeneous absorbing
Markov chain was used to predict progression of
hearing loss. In homogeneous Markov chains the probability \( P \) does not depend on the number of
step order \( n \), so it is easily seen that

\[
A^{(1)} = A^{(0)} \times P,
A^{(2)} = A^{(1)} \times P = A^{(0)} \times P^2,
\]

and

\[
A^{(n)} = A^{(n-1)} \times P = \ldots = A^{(0)} \times P^n,
\]

(1)

where \( A^{(0)} \) is the initial pattern. Supposing all the
workers are in the State I

\[
A^{(0)} = (1, 0, 0, 0, 0).
\]

A micro-computer Canon \( \text{BX-1} \) was used for
calculation and graphic demonstration.

Results

Before processing data, each worker’s bilateral
hearing losses at 4kHz were averaged and classified
into the following state categories.

Table 1. Transition of ninety-seven noise exposed

<table>
<thead>
<tr>
<th>State in 1979</th>
<th>Total</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>21</td>
<td>0.29</td>
<td>0.71</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>II</td>
<td>35</td>
<td>0.14</td>
<td>0.66</td>
<td>0.17</td>
<td>0.03</td>
<td>0</td>
</tr>
<tr>
<td>III</td>
<td>19</td>
<td>0.05</td>
<td>0.11</td>
<td>0.58</td>
<td>0.26</td>
<td>0</td>
</tr>
<tr>
<td>IV</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>0.21</td>
<td>0.58</td>
<td>0.21</td>
</tr>
<tr>
<td>V</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Each element \( p_{ij} \) was estimated by

\[
p_{ij} = \frac{(\text{Number of workers in State } S_j \text{ at 1979's audiogram})}{\Sigma (\text{Number of workers in State } S_i \text{ at 1978's audiogram})}.
\]

State I less than 30dB
State II 30dB to 39dB
State III 40dB to 49dB
State IV 50dB to 59dB
State V 60dB and more

Table 1 indicates the state transition during the
period of 1978 to 1979, where each element \( p_{ij} \) was estimated by

\[
p_{ij} = \frac{(\text{Number of workers in State } S_j \text{ at 1979's audiogram})}{\Sigma (\text{Number of workers in State } S_i \text{ at 1978's audiogram})}.
\]

This set of fractions can be regarded as a transition probability matrix \( P = \{ p_{ij} \} \).

Using the Eq. (1) we obtained the transition of

Fig. 1. Time course of the worker number ratios in
each state of hearing loss supposing all the workers
are in State I at the initial step.
the worker number ratios in each state as shown in Fig. 1.

The average individual worker's hearing loss progression can be calculated by

\[ T = \{ S_1, S_2, S_3, S_4, S_5 \} = \{ 25, 35, 45, 55, 65 \} \]

where each number indicates the unilateral hearing level in dB. The results are shown in Fig. 2.

**Discussion and conclusion**

Schneider *et al.*\(^1\) indicated that as a general course occupational hearing loss progressed rapidly until the level reached 30 to 40dB in 4kHz frequency area, and then progressed slowly. Our result shown in Fig. 2, though lacking of data of 20dB or less hearing loss, fits well with this principle. If data of 20dB or less hearing are added, the course of hearing loss would progress more steeply in the early steps. Thus, using homogeneous Markov chain, we would be able to predict future hearing levels of noise-exposed workers without following up for a long time.

Characteristic values of Markov chains will give further informations including absorbing time and simulation errors. The values will be given in our following paper with further justification of this model application.

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**References**


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