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Training in binaural hearing: towards its therapeutic use in clinical practice

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Abstract

Background: Interaural level differences (ILD) and interaural time differences (ITD) are binaural cues used in sound localisation and in detection of signals in noisy backgrounds. People with asymmetric hearing loss have poor binaural processing skills. Discrimination performance in ILD and ITD tasks substantially improves with training. Training in binaural hearing may be of clinical benefit to certain populations. *Objectives*: (1) What is the role of perceptual learning in auditory training? (2) Which regime trains binaural cue discrimination most effectively? *Methods*: (1) Subjects were trained on an identical, adaptive ILD-discrimination task presented within different procedures in each of four groups, then tested on all procedures post-training. (2) Subjects underwent either blocked or distributed training in ILD or ITD discrimination and were tested at intervals post-training. *Results*: (1) There was no significant difference in task performance post-training between the groups. (2) ILD and ITD discrimination performance was not significantly different in the blocked and distributed training groups. *Conclusions*: Perceptual learning occurred rapidly in auditory training. Significant, lasting training effects were found for both ILD and ITD tasks, and both blocked and distributed regimes were equally effective. These findings will guide further work on the potential therapeutic use of auditory training.

Keywords: Perceptual; Learning; ITD; ILD; Binaural

1. Introduction

Interaural level differences (ILD) and interaural time differences (ITD) are binaural cues used in sound localisation. They improve the ability to detect and analyse target

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sounds in noisy backgrounds, a skill that those with hearing loss find difficult. People with asymmetric hearing loss, such as children with a history of recurrent otitis media with effusion, have poor binaural processing skills [1].

Training substantially improves discrimination performance in ILD and ITD tasks [2]. Training in temporal, in contrast to spatial, tasks has led to improved language skills in children with language-learning impairment [3]. We hypothesize that training in ILD and ITD discrimination tasks may similarly produce an enhanced ability in a more complex task detection of sound sources in noisy backgrounds.

Both perceptual learning and procedural learning may contribute to any training effects we see. Perceptual learning is the effect of past experience on sensory perception. Procedural learning occurs by strengthening habits. Teasing apart the relative contributions of perceptual and procedural learning allows a better understanding of the mechanism of learning in binaural cue discrimination.

We addressed two specific questions in separate experiments, the first concerned with the mechanism and the second concerned with the characteristics of training in binaural hearing.

2. Experiment 1

2.1. What is the role of perceptual learning in auditory training?

2.1.1. Method 1

Four groups of audiometrically normal adults ($n = 32$) were trained in a 1-h block session on an ILD discrimination task using 4 kHz pure tones in a two-alternative forced choice task. After the first run, the starting ILD was adjusted to 2 dB above threshold for each individual. An adaptive staircase was employed for threshold estimation. The task was presented within a different procedure for each group. The alternatives were a two-interval task (A) or a three-interval task in which different intervals were fixed (B, C and D). Subjects were tested on all procedures post-training.

2.1.2. Result 1

See Fig. 1.

There was no significant difference between the thresholds in the four procedures tested within each group post-training.

2.1.3. Method 2

A further group of adults ($n = 8$) was trained at a fixed, supra-threshold level (S, signal ILD 15 dB) in the same task in two-interval format (as in A). During post-training testing, the adaptive staircase was introduced, allowing estimation of their discrimination threshold.

2.1.4. Result 2

See Fig. 2.

The supra-threshold group performed significantly worse than the equivalent trained group.

3. Experiment 2

3.1. Which regime trains binaural cue discrimination most effectively?

3.1.1. Method

Audiometrically normal adult listeners ($n = 23$) underwent training in ITD or ILD discrimination with tones of 500 Hz and 4 kHz, respectively. A two-alternative forced choice task was used, and an adaptive staircase was employed for threshold estimation. They were allocated to blocked (a single 2-h session) or distributed (4-h sessions) training regimes. Subjects were tested again 1 month post-training.

3.1.2. Results

See Fig. 3.

Significant learning occurred in all but the ILD-distributed training group. The mean improvement in discrimination performance across all groups was 38%. There was no significant difference between the immediate post-training performance levels in the blocked and distributed groups for each cue (ITD $p = 0.17$, ILD $p = 0.28$). At 1 month post-training, with no further exposure to the task, performance levels were near or better than the immediate post-training level for each group.

3.1.3. Discussion

Perceptual learning occurred rapidly in adaptive auditory training. The improvement in performance resulting from training is not solely due to procedural, or habit, learning. Significant, lasting training effects were found for both ILD and ITD tasks, and both blocked and distributed training regimes were equally effective. This work adds to our

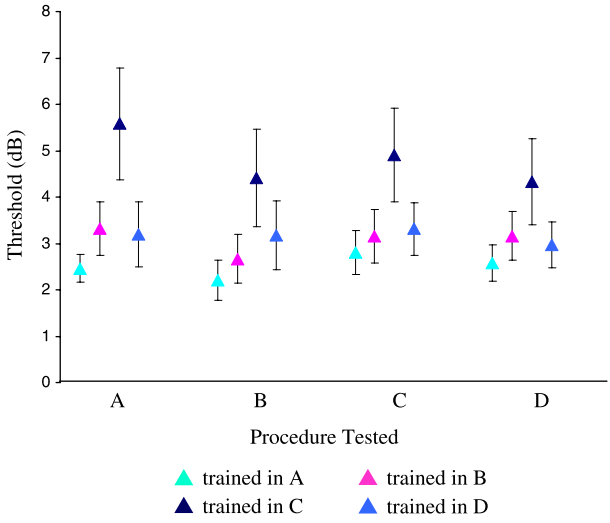

Fig. 1. Graph showing the mean post-training discrimination thresholds in each trained (in procedure A, B, C or D) group ± 1 S.E.M.

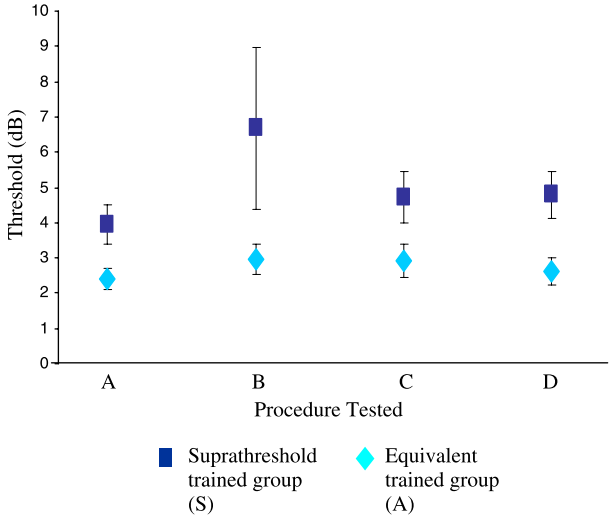

Fig. 2. Comparison of mean thresholds post-training in supra-threshold group (S) and equivalent group trained around threshold (A) ± 1 S.E.M.

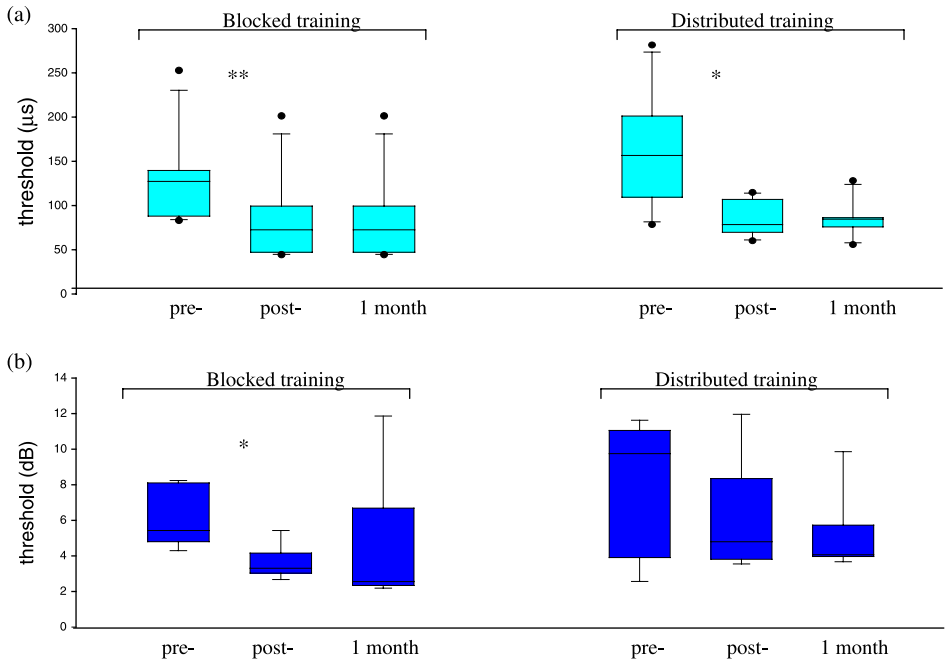

Fig. 3. Graphs showing effect of blocked and distributed training on (a) ILD and (b) ITD discrimination performance, immediately and 1 month post-training (*$p < 0.05$, **$p < 0.01$).

understanding of the mechanism and properties of training in binaural hearing, and takes us a step closer to determining its clinically useful potential. Further work is currently underway looking at the effect of ILD and ITD training on performance in more complex tasks, including discrimination of speech in background noise.

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