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Rapid Formation of Robust Auditory Memories: Insights from Noise

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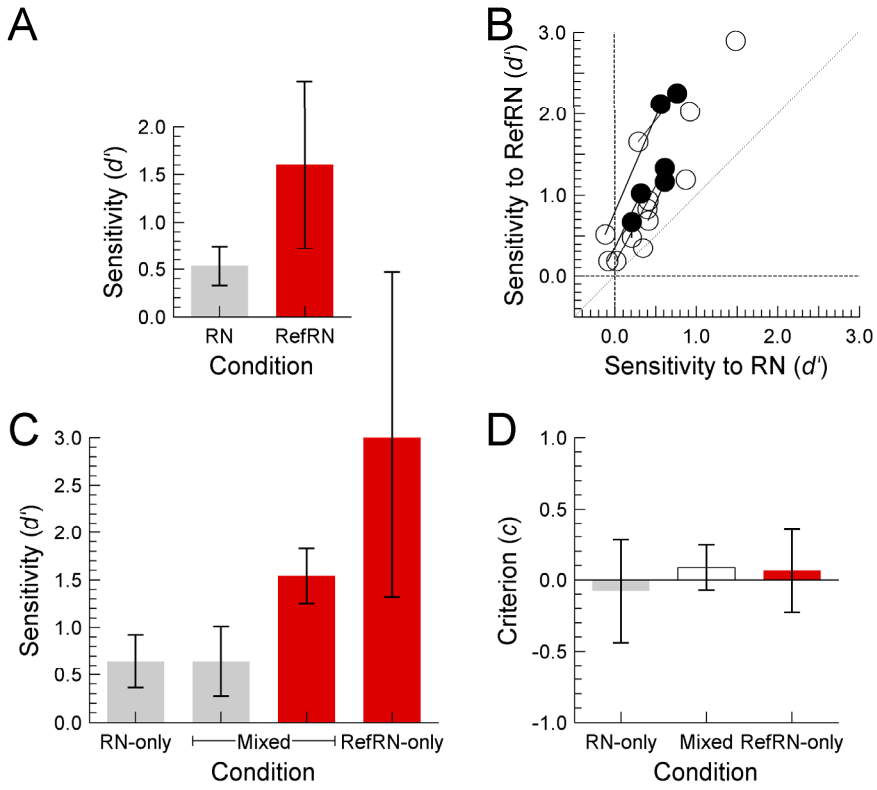

Figure S1. Effect of training and Supplemental Experiment S1

(A) Six listeners repeated Experiment 1 as "trained" listeners. Format as in Fig. 1A. The trained listeners improved in their ability to detect the RN (mean $d' = 0.5$ versus 0.1 for the same listeners in the first part of the experiment) [$t_5 = 3.82$, $p = 0.01$], but the improvement was even greater for the RefRN (mean $d' = 1.4$ versus 0.6) [$t_5 = 3.9$, $p = 0.01$].

(B) Individual data for Experiment 1. The RefRN sensitivity is plotted against RN sensitivity for naïve listeners (open circles) and trained listeners (filled circles) with the lines linking the results of the same listeners. All listeners that repeated the

experiment improved at detecting both the RN and the new RefRN, but particularly for the RefRN, so the effect of learning is enhanced for the trained listeners. Across both sets of results, the measures of sensitivity to RefRN and RN were positively correlated, [$r_{16} = 0.85$, $p < 0.001$].

(C) In Supplemental Experiment S1 (see Supplemental Experimental Procedures), RN and RefRN performance were measured in separate blocks ("RN-only" and "RefRN-only", respectively) as well as combined in the same block ("Mixed", duplicating the condition from Experiment 1). Results are displayed here. In the Mixed condition, a benefit for RefRN was observed over RN, replicating the result from Experiment 1 [$t_5 = 7.94$, $p = 0.001$]. Importantly, sensitivity to RN was the same in both the Mixed and RN-only conditions [$t_5 = 0.18$, $p = 0.99$]. This shows that the inclusion of RefRN trials does not impair sensitivity for RN trials. We also observed a trend for a better sensitivity for RefRN in the RefRN-only condition compared to the Mixed condition [$t_5 = 2.24$, $p = 0.08$]. It may have been easier to learn the RefRN trials in the present experiment as they occurred at a greater rate, and sometimes on subsequent trials. Error bars are 95% confidence intervals.

(D) The criterion for all conditions of Supplemental Experiment S1. A single criterion was computed for the Mixed condition, as subjects are thought to be unable to maintain separate criteria when performing interleaved detection tasks (Gorea & Sagi, 2000). There was no effect on criterion across conditions [$F_{2,10} = 1.06$, $p = 0.39$]. Error bars are 95% confidence intervals.

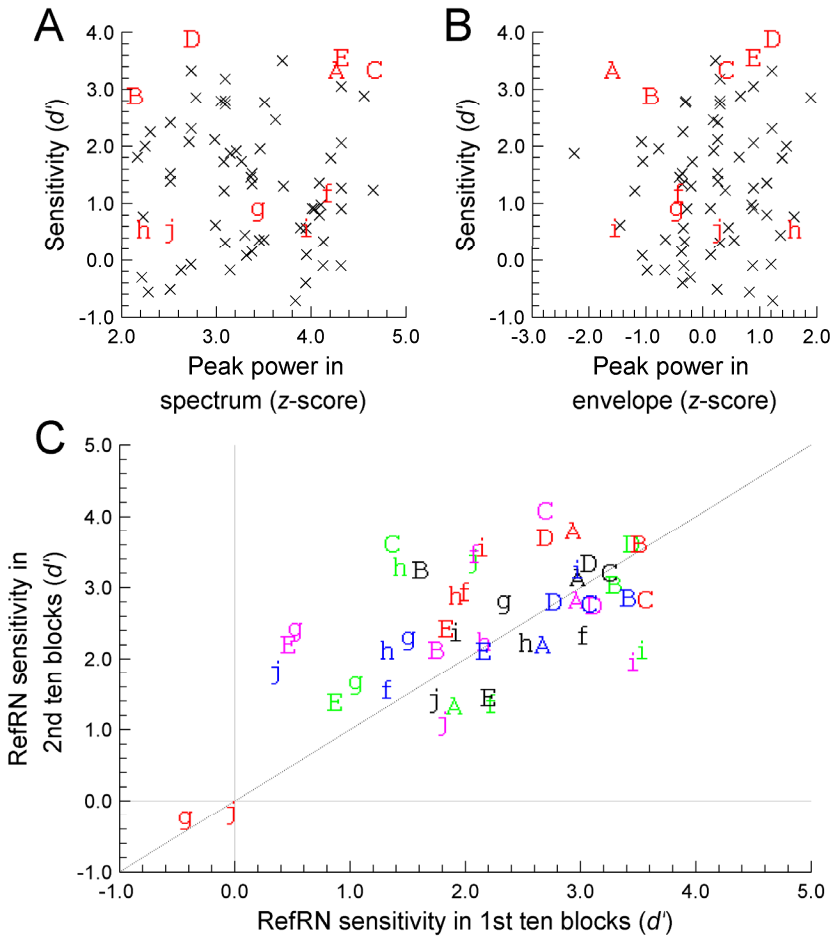

Figure S2. Good and bad noises

(A) Outstanding acoustical features were estimated for noise samples used in Experiment 1 and compared to behavioral performance. The RefRNs used in Experiment 1 were filtered by a 256-channel auditory filterbank, half-wave rectified, and smoothed with a time-constant of 8 ms to form a short-term excitation pattern (STEP; Moore, 1993). This provides the spectro-temporal envelope of the sound after taking into account auditory peripheral processing. The highest peaks in each frequency channel were measured and expressed as *z*-scores, relative to a distribution of peaks observed for 1000 random noises in the same frequency channel. The figure here shows the maximum *z*-score, representing the most unusually large peak

compared to the average noise STEP, plotted against behavioral performance (d'). The two measures are uncorrelated [$r_{70} = 0.02$, $p = 0.88$]. Good and bad noises subsequently selected for Experiment 2 are identified by red letters (upper case for good noises and lower case for bad noises). They are clearly clustered in terms of performance, but are each spread the entire range of acoustical measures.

(B) An equivalent analysis but based on the greatest peak in envelope, calculated as a peak in average power over all frequency channels of the STEP. The extent of the peak is also represented as a z-score, normalized by the equivalent peaks in 1000 random noises. Here again no correlation was found with behavioral sensitivity [$r_{70} = 0.08$, $p = 0.48$].

(C) Individual data for Experiment 2, with the d' of the second block for a given noise plotted against that of the first block. The different good and bad noises are identified by letters (same as panel A). Colors indicate listeners. The sensitivity observed in the first block was correlated to that observed in the second block [$r_{48} = 0.50$, $p < 0.001$]. This correlation was not driven by differences in the abilities of the listeners: a mixed listener-by-repetition ANOVA for the d's observed in each block showed no effect of listener [$F_{4,45} = 0.13$, $p = 0.97$], but a small improvement on average from the first ten blocks to the second ten blocks (mean $d' = 2.04$ versus 2.49) [$F_{1,45} = 6.56$, $p = 0.01$]. Apart from this test-retest correlation, there was no pattern across listeners for invariably high or invariably low performance with “good” and “bad” noises.

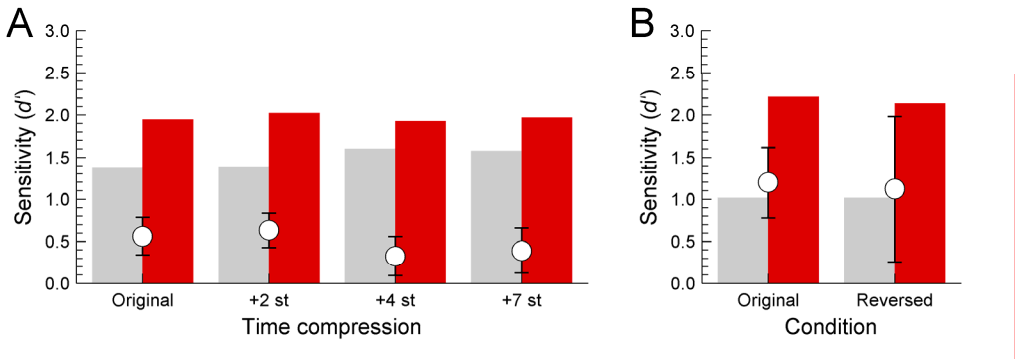

Figure S3. Re-learning after acoustic distortion

(A) Results of Experiment 5, same format as Fig. 4B. Here the last 10 blocks after time compression were analyzed. The RefRN advantage is now the same for all amounts of compression, which suggests that listeners re-learnt all of the transformed versions of the RefRN.

(B) Results of Experiment 6, same format as Fig. 4C, for the last 10 trials after time reversal.

Supplemental Experiment S1

Participants

There were 6 listeners, aged 21 to 30, five of whom had previously taken part in Experiment 1 and the sixth was the first author.

Stimuli

N, RN, and RefRN stimuli were generated as in Experiment 1.

Procedure

There were three conditions: Mixed, RN-only, and RefRN-only. The blocks of the Mixed condition were identical to those of Experiment 1 (100 N, 50 RN and 50 RefRN trials). In the RN-only condition, the RefRN trials were replaced by RN trials (100 N and 100 RN); conversely, in the RefRN-only condition, the RN trials were replaced by RefRN trials (100 N and 100 RefRN). Each listener completed four Mixed blocks, two RN-only blocks, and two RefRN-only blocks. Thus there were 200 RN trials in total for each of the RN-only and Mixed conditions, and the same number of RefRN trials in each of the RefRN-only and Mixed conditions. The blocks were grouped by condition, and the ordering of the three conditions formed a Latin square over all the listeners. Listeners were not told of the differences between the conditions.

Analysis

The d'_{RN}, d'_{RefRN} and c were calculated as in Experiment 1. In each of the RN-only and RefRN-only conditions, the criterion, c, was based on the RN or RefRN hit-rates alone.

SUPPLEMENTAL REFERENCES

Gorea, A., & Sagi, D. (2000). Failure to handle more than one internal representation in visual detection tasks. *Proc Natl Acad Sci USA, 97*(22), 12380-12384.

Moore, B. C. (1993). Temporal integration and context effects in hearing. *Journal of Phonetics, 31*, 563-574.