AD-A218 416

DTIC FILE COPY

UNCLASSIFIED 2 FEB 1990

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE 5 Feb 90

3. REPORT TYPE AND DATES COVERED FINAL - 1 Nov 88 to 31 Oct 89

4. TITLE AND SUBTITLE

Auditory spectro-temporal pattern analysis

5. FUNDING NUMBERS

G-AFOSR-87-0083
PE - 61102F
PR - 2313
TA - A6

6. AUTHOR(S)

Dr Joseph W Hall

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

The University of North Carolina at Chapel Hill
School of Medicine, Dept of Surgery
CB# 7070, Burnett-Womack Clinical Bldg
Chapel Hill, NC 27599-7070

8. PERFORMING ORGANIZATION REPORT NUMBER

AFOSR-TR- 90-0267

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

AFOSR/NL
Program Manager JOHN F TANGNEY
Bldg 410
Bolling AFB, DC 200332-6448

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The project period spanned November 1, 1986 through October 31, 1989. The Major aims of the project were to establish what aspect of the across-frequency modulation pattern is utilized to obtain release from masking in modulated noise; to determine whether CMR occurs for multi-component signals (as contrasted with pure-tone signals used for previous investigations); to determine whether CMR may apply to comodulation signals (in contrast with comodulated maskers used in previous investigations); to examine the possible relation between CMR and the MLD; and to examine possible relations between CMR and temporal resolution.

14. SUBJECT TERMS

15. NUMBER OF PAGES 7

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
U	U	U	

NSN 7540-01-280-5500 UNCLASSIFIED Standard Form 298 (Rev. 2-89) Prescribed by ANSI Std. Z39-18

FINAL PROGRESS REPORT : "Auditory spectro-temporal pattern analysis," (AFOSR 87-003)

Personnel

Joseph W. Hall, Ph.D., Associate Professor	Nov., 1986 to present
John Grose, Ph.D., Assistant Research Professor	Jan., 1987 to present
Carmen White, M.A., Research Assistant	Feb., 1987 to Jul., 1988
Adam Wilson, B.S., Graduate Student	Aug. 1988 to present
Deborah Hatch, M.A., Research Assistant	Sep, 1988 to present

The project period spanned November 1, 1986 through October 31, 1989. The major aims of this project were to establish what aspect of the across-frequency modulation pattern is utilized to obtain release from masking in modulated noise; to determine whether CMR occurs for multi-component signals (as contrasted with the pure-tone signals used in previous investigations); to determine whether CMR may apply to comodulated signals (in contrast with the comodulated maskers used in previous investigations); to examine the possible relation between CMR and the MLD; and to the examine possible relations between CMR and temporal resolution. Our progress in these areas is summarized below.

A. **"Comodulation masking release for multi-component signals" : Hall, J.W., Grose, J.H. and Haggard, M.P. (1988).** We investigated the detection of one, two, or three-component signals in comodulated and noncomodulated noise backgrounds. The noise was composed of from one to three 30-Hz-wide noise bands. We found that substantial CMRs (approximately 8 dB) occurred for multi-component signals, but that CMR was largest for a single pure tone signal presented in a three-component comodulated noise background. We tested the ability of three different models to account for the data: one based upon envelope correlation differences between bands; a second based upon subtraction of the envelope at the signal frequency from the envelope at flanking bands; and a third based upon detection of energy in masker dips. The model that proved to be most consistent with the data was the envelope subtraction model, a model conceptually similar to the equalization/cancellation MLD model of Durlach.

B. **"Combined monaural and binaural masking release": Hall, J.W., Cokely, J. and Grose, J.H. (1988).** We examined CMR for conditions in which both MLD and CMR cues were present. Of interest was whether CMR resulted in further masking release, given a baseline where a masking release due to MLD was already present. An So or $S\pi$ 500-Hz pure tone signal was presented either in a single narrowband noise centered on 500 Hz, or with a second comodulated band also present at 400 Hz. The results indicated that most subjects were able to achieve larger masking release for combined CMR and MLD cues, over and above the masking release due to MLD alone. Of particular interest was that a CMR occurred at all in the $NoS\pi$ case, given that the $NoS\pi$ threshold without the 400-Hz flanking band present was at a signal-to-noise ratio much lower than that for the CMR. For example, the $NoS\pi$ threshold without the 400-Hz flanking band was about 15 dB lower than the NoSo threshold with the flanking band present. This raised the question of how the CMR cue could have contributed significantly to $S\pi$ detection. One possibility discussed was that an across-frequency comparison (CMR) process might occur on the output of the MLD equalization-cancellation mechanism (after the binaural analysis stage). Another possibility noted was that the 400-Hz flanking band might suppress the 500-Hz masker, thus effectively reducing the level of the on-signal masker prior to binaural analysis. A post-hoc test showing that a flanking band was as effective below the signal frequency as above it did not support the suppression hypothesis.

C. **"Comodulation masking release: Evidence for multiple cues" : Hall, J.W. and Grose, J.H. (1988).** We examined signal detection in conditions where the masker was a 10-Hz-wide noise band centered on the signal, and in conditions where either a comodulated or noncomodulated noise band (centered at 0.8 times the signal frequency) was also present. Signal frequencies of 500 or 2000 Hz were investigated. In one condition, the signal was exactly the same 10-Hz-wide noise band as the masker, added to the masker in phase. This condition limited the availability of cues based upon dip-listening, suppression, beating, or across-frequency differences in noise envelope correlation, but afforded a cue based upon across-frequency envelope amplitude difference. This result suggested that one important cue for CMR is an across-frequency difference in envelope amplitude. Stimulus conditions in a second experiment were intended to disrupt cues of across-frequency envelope amplitude difference, but to afford cues based upon across-frequency differences in noise envelope correlation. In this experiment cues based upon envelope amplitude were reduced by randomly varying the level of the flanking band from interval to interval, and by adjusting the level in the on-signal band to be the same in the non-signal intervals as the level of noise + signal in the signal interval. Substantial CMRs again occurred, suggesting that another cue for CMR may be envelope pattern or correlation. The results of these experiments indicated that CMR is probably based upon more than one stimulus variable.

D. **"Across-frequency processing in temporal gap detection" : Grose, J.H. and Hall, Joseph W. (1988).** We examined the ability of the auditory system to combine information about temporal envelope across frequency in order to aid gap detection. The results indicated that when narrow bands of noise were comodulated across frequency, gap detection was not appreciably better than for one noise component alone. However, when the narrow bands of noise were not comodulated, gap detection improved as a function of the number of noise bands present. The results indicated that the auditory system is able to combine independent temporal envelope information across critical bands in order to improve temporal resolution. Our interpretation of this result was that the cue accounting for the better performance with multiple noncomodulated noise bands was an across-frequency correlation of temporal envelope which occurred during the gap interval. However, Hafter (published comment accompanying paper) noted that the results might also be accounted for by assuming that the auditory system makes an independent decision about the occurrence of a gap in each band, and improves detection by integrating information across bands. Further research is required to test between these hypotheses.

E. **"Comodulation Masking Release using SAM tonal complex maskers: effects of modulation depth and signal position" : Grose, J.H. and Hall, J.W. (1989).** We examined whether CMR effects could be observed for non-noise maskers

The purpose of this investigation was to examine two stimulus parameters which were reasoned to be of importance to CMR: modulation depth, and placement of signal in peak vs. dip position. The results showed that when the on-frequency component had a modulation depth of 100%, the threshold for a pure tone signal improved monotonically as the modulation depths of the flanking components increased from 0 to 100%. When the on-frequency component had a modulation depth of 63%, some listeners performed optimally when the flanking components also exhibited a modulation depth of 63%, whereas others performed best when the flankers had modulation depths of 100%. Dip placement of the signal resulted in substantially better signal detection than did peak placement. The results were considered in terms of proposed mechanisms underlying CMR and it was concluded that the evidence did not clearly support a single CMR mechanism.

F. **"Gap detection in narrow bands of noise as a function of the number and proximity of the bands" : Grose, J.H. and Hall, J.W. (1989).** CMR suggests that the auditory system is sensitive to across-frequency differences in modulation pattern. This raises the question of whether it is as sensitive to modulation differences due to the absence of activity (a silent interval) as it is to the presence of additional of activity (a signal). If so, gap detection in a narrow-band noise would be expected to be better in the presence of a comodulated flanking band than in the presence of a noncomodulated flanking band. In contrast, auditory grouping theory would predict that the presence of a comodulated flanking band would result in a fused auditory image of the two bands, rendering a momentary silent interval in one of the bands less noticeable. The present study was designed to test between these divergent hypotheses. Gap detection was measured in a 25-Hz-wide narrow-band noise centered at either 0.5, 1.0 or 1.5 kHz. A second 25-Hz band of noise, centered between 0.5 and 1.5 kHz, was then added which was either comodulated or noncomodulated with the target band. The most striking result was that gap detection deteriorated markedly with the addition of a second noise band, irrespective of its modulation pattern. Further testing suggested that this deterioration was due to a process of modulation masking. The variable data prevented a firm conclusion being drawn regarding the relative effect of a comodulated versus a noncomodulated flanking band. A manuscript on this project is in preparation.

G. **"The effect of signal-frequency uncertainty on comodulation masking release" : Grose, J.H. and Hall, J.W. (1990).** Several models have been suggested to account for CMR, and a recurrent theme is that an across-frequency difference occurs upon the presentation of the signal; it is the detection of this dissimilarity which is supposed to cue the presence of the signal. In its simplest form, such a cuing mechanism could operate quite independently of any *a priori* information of which channel contained the signal. In other words, the cue should function independently of signal channel. However, it is evident from the data of several studies that CMR may be asymmetric; that is, the amount of CMR depends on whether the flanking band is placed above or below the on-frequency band (McFadden, 1986; Cohen and Schubert, 1987a; Schooneveldt and Moore, 1987; Hall et al.,1988a). Such data argue that CMR does depend to some extent on the placement of the signal in the array of comodulating channels. The present investigation was designed to pursue this question further by exploring the dependency of CMR on signal channel using the paradigm of signal-frequency uncertainty. If the mechanism underlying CMR is insensitive to signal channel, then the effect of signal-frequency uncertainty would be expected to be reduced in a comodulated masker relative to a noncomodulated masker. The investigation used maskers consisting of harmonically-spaced amplitude-modulated tones as well as maskers consisting of logarithmically-spaced narrow bands of noise. In both cases, a significant effect of signal-frequency uncertainty was observed, but the trend was for the effect to be somewhat reduced in a comodulated masker.

H. **"CMR for comodulated signals" : Hall and Grose (1990).** This experiment examined whether there are monaural masking release effects for comodulated signals. The signals were either comodulated narrow bands of noise (NBNs), or NBNs having no envelope correlation. The masker is a broadband unmodulated noise. The baseline conditions for this experiment are detection for a single 50-Hz-wide NBN centered at 1000 Hz. In the experimental conditions, either two, three, five or 10 50-Hz-wide NBNs comprise the signals. The bands are spaced 100 or 200 Hz apart. Detection in the comodulated conditions is being contrasted with detection in conditions in which the signals are noncomodulated, to assess comodulation effect. Masking release effects for comodulated signals appear to be absent or small.

I. **"Effects of flanking band proximity, number, and modulation pattern on comodulation masking release": Hall, J.W. Grose, J.H. and Haggard, M.P. (1990).** In this experiment, we measured CMR for a 700-Hz pure-tone signal masked by a 20-Hz-wide noise centered on 700 Hz, as a function of the number and spectral positions of 20-Hz-wide comodulated flanking bands. The number of bands is extended either symmetrically around the signal frequency, below the signal frequency, or above the signal frequency. The number of flanking bands is varied from one to eight. The results indicated 1) an effect of proximity, where bands closer to the signal result in larger masking release, and 2) an effect of number-of-bands, where more bands give rise to larger CMR (but with diminishing returns after at least two flanking bands were present). The benefit of adding comodulated bands is greater than expected from statistical summation (i.e., $> \sqrt{N}$) for increases in band numbers from one to four. The effect of removing two of eight flanking bands was also examined, with regard to the spectral positions of the removed bands. This manipulation appears to have very little effect, regardless of the spectral positions of the removed bands. This is the only condition examined where a proximity effect does not occur. Data were also collected in a paradigm where the baseline condition calls for detection of a 700-Hz pure tone presented in a 20-Hz-wide noise band centered on 700 Hz. In one experimental condition, nine 20-Hz-wide comodulated noise bands were presented, centered at 100-Hz intervals from 300 to 1100 Hz (including the band centered on the signal frequency, 700 Hz). This resulted in a CMR of about 16 dB (using signal threshold with a single masker band centered on 700 Hz as the baseline). Experimental conditions were also run where pairs of bands are replaced with bands that are not comodulated with respect to the signal band or the other six comodulated flanking bands. These divided into conditions where the two "replacement" bands are comodulated with respect to each other (codeviant bands), but have a modulation pattern different from the other bands, and conditions where each of the two replacement bands has a unique randomly derived modulation pattern (bideviant bands). When all eight flanking bands were comodulated with the signal band, an envelope comparison between the signal band and any flanking band is potentially informative about the presence of a signal. However, if some of the flanking bands are not comodulated with the band centered on the signal, comparisons involving these bands would not be beneficial. The presence of such bands could even be detrimental if their envelopes were included in the across-frequency comparison process, as they would indicate an across-frequency difference in modulation even when the signal was not present. In general, adding pairs of bands that are not comodulated with respect to the remaining comodulated bands reduces CMR. This reduction is greatest for the noncomodulated pairs closest to the signal frequency. However, there is still reduction in CMR for the most distal placement (300 and 1100 Hz) of the deviant pair. The bideviant pairs generally result in thresholds 1-2 dB worse than for codeviant bands. The results indicate that the more complex the background fluctuation pattern, the smaller are the effects of CMR.

J. **"Comodulation Masking Release as a function of bandwidth and test frequency" : Haggard, M.P., Hall, J.W. and Grose, J.H. (1990).** CMR was investigated as a function of the signal frequency (500 to 4000 Hz) and the total bandwidth f the masking noise. Taking non-comodulated noise of the same reference condition, CMR for modulated noise increased with increasing bandwidth of the masking noise outside the critical band centered on the signal. However, this growth asymptoted for broad overall bandwidths. These bandwidth effects were expressed by scaling the width of the flanking bands beyond the critical band centered on the signal frequency, approximately according to a critical bandwidth scale. After the scaling, signal frequency had negligible effect on CMR magnitude.

Publications resulting from "Auditory spectro-temporal pattern analysis," (AFOSR 87-003)

Haggard, M.P., Hall, J.W. and Grose, J.H. (**1990**). "Comodulation Masking Release as a function of bandwidth and test frequency," Journal of the Acoustical Society of America, in press.

Grose, J.H. and Hall, J.W. (**1990**). "The effect of signal-frequency uncertainty on comodulation masking release," Journal of the Acoustical Society of America, in press.

Hall, J.W. Grose, J.H. and Haggard, M.P. (**1990**). "Effects of flanking band proximity, number, and modulation pattern on comodulation masking release, " Journal of the Acoustical Society of America, 87, 269-283.

Grose, J.H. and Hall, J.W. (1989). "Gap detection in narrow bands of noise as a function of the number and proximity of the bands," Journal of the Acoustical Society of America Suppl. 1 **86**, S122.

Grose, J.H. and Hall, J.W. (**1989**). "Comodulation Masking Release using SAM tonal complex maskers: effects of modulation depth and signal position," Journal of the Acoustical Society of America **85**, 1276-1284.

Hall, J.W. and Grose, J.H. (**1988**). "Comodulation masking release: Evidence for multiple cues," Journal of the Acoustical Society of America 84, 1669-1675.

Hall, J.W., Grose, J.H. and Haggard, M.P. (**1988**). "Comodulation masking release for multi-component signals," Journal of the Acoustical Society of America **83**, 677-686.

Grose, J.H. and Hall, Joseph W. (**1988**). "Across-frequency processing in temporal gap detection," in Basic Issues in Hearing: Proceedings of the 8th International Symposium on Hearing, eds., H. Duifhaus, H.P. Wit, and J.P. Horst .

Hall, J.W., Cokely, J. and Grose, J.H. (**1988**). "Combined monaural and binaural masking release," Journal of the Acoustical Society of America **83**, 1839-1845.

Hall, J.W. (**1987**). "Experiments on Comodulation Masking Release," in Auditory Processing of Complex Sounds, edited by W. Yost and C. Watson, Lawrence Erlbaum (New Jersey).