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Comodulation detection differences for fixed-frequency and roved-frequency maskers

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Abstract

This study investigated comodulation detection differences (CDD) for fixed- and roved-frequency maskers. The objective was to determine whether CDD could be accounted for better in terms of energetic masking or in terms of perceptual fusion/segregation related to comodulation. Roved-frequency maskers were used in order to minimize the role of energetic masking, allowing possible effects related to perceptual fusion/segregation to be revealed. The signals and maskers were composed of 30-Hz-wide noise bands. The signal was either comodulated with the masker (A/A condition) or had a temporal envelope that was independent (A/B condition). The masker was either gated synchronously with the signal or had a leading temporal fringe of 200 ms. In the fixed-frequency masker conditions, listeners with low A/A thresholds showed little masking release due to masker temporal fringe and had CDDs that could be accounted for by energetic masking. Listeners with higher A/A thresholds in the fixed-frequency masker conditions showed relatively large CDDs and large masking release due to a masker temporal fringe. The CDDs of these listeners may have arisen, at least in part, from processes related to perceptual segregation. Some listeners in the roved masker conditions also had large CDDs that appeared to be related to perceptual segregation.

INTRODUCTION

There has long been interest in the possible role of comodulation among frequency-distributed spectral components in auditory perceptual organization (e.g., Broadbent and Ladefoged, 1957; Darwin, 1981; Bregman et al., 1985). Such a role has been suggested for both comodulation masking release (CMR) (e.g., Hall et al., 1984) and for comodulation detection differences (CDD) (Cohen and Schubert, 1987; McFadden, 1987; Wright, 1990). In the CDD paradigm, the detectability of a narrow band of noise depends upon the relation between its modulation pattern and the pattern(s) of modulation carried by spectrally distributed masking bands. When the signal and masking bands are comodulated (referred to here as the A/A condition), detection is relatively poor, but when the signal has a temporal envelope that is independent from the masker (referred to here as the A/B condition), detection improves. McFadden (1987) and Cohen and Schubert (1987) suggested that the good performance in the A/B condition arises because the across-frequency difference in modulation pattern allows the signal band to be segregated perceptually from the masker. By this interpretation, at least part of the masking in the A/A condition is due to a perceptual organization effect where detection is hampered by a difficulty in perceptually segregating comodulated noise stimuli. Recently, however, it has been suggested that CDD can be accounted for by peripheral auditory processes (Borrill and Moore, 2002; Moore and Borrill, 2002). Moore and Borrill (2002) pointed out that in the A/A condition, energetic masking is very efficient because the energy peaks of the masker coincide with the energy peaks of the signal; in the A/B condition, the energy peaks of the

signal will sometimes coincide with the energy dips of the masker, making the masking less efficient. Moore and Borrill (2002) further pointed out that a contribution to masking based upon basilar membrane suppression would have a similar effect; that is, in the A/A condition, the peaks of the masker would provide efficient suppression of the peaks of the signal, but in the A/B condition, some of the peaks of the signal would not coincide with masker peaks, and, thus, would not be suppressed as effectively. This argument assumes that the effects of suppression are virtually instantaneous (Arthur et al., 1971).

Although the within-channel account of CDD given above is parsimonious and sound, it does not necessarily rule out the possibility that central processes related to perceptual fusion/segregation can contribute to CDD. The purpose of the present study was to explore this issue. The core of the approach was the use of informational masking involving masker frequency uncertainty (e.g., Neff and Callaghan, 1987; Neff and Green, 1987; e.g., Neff and Callaghan, 1988; Lutfi, 1990; Leek et al., 1991; Kidd et al., 1994; Kidd et al., 2002; Richards et al., 2002; Kidd et al., 2003) within the CDD paradigm. A major benefit of this approach is that it limits the contribution of peripheral factors related to energetic masking/suppression, increasing the power to measure possible central contributions to observed differences between A/A and A/B masking conditions. In this approach, we varied the masker spectral composition on an interval-by-interval basis. In many listeners, this results in relatively high (poor) signal thresholds that are determined primarily by central factors (e.g., Neff and Callaghan, 1987; Kidd et al., 1994). Kidd et al. (1994) showed that listeners can gain release from informational masking if cues are available that enable the signal to be segregated perceptually from the masker. Of particular interest here was whether across-frequency differences in temporal envelope would be associated with a release from informational masking.

One of the most important findings of Moore and Borrill (2002) pertained to conditions where the masker had a leading temporal fringe. They found that such a fringe had no effect on masked thresholds. This is highly significant from the standpoint of evaluating the hypothesis that one factor limiting the detection of the signal in the A/A condition is a difficulty in perceptually segregating the signal from its comodulated flanking bands. If such a perceptual segregation difficulty had been a material factor, then the segregation cue provided by a masker temporal fringe should have been associated with an improvement in the A/A threshold. The lack of such an effect was strong support for the hypothesis that CDD effects are driven by peripheral factors as opposed to factors associated with perceptual segregation. The current investigation employed a masker temporal fringe in some conditions in order to gain further insight into the possible role of cues related to perceptual segregation.

A general expectation in the present study was that individual differences might be prominent. McFadden and Wright (1990) found that individual differences were common in the CDD paradigm, with some listeners showing very low masked thresholds, and others showing considerably higher thresholds. Individual differences were also expected from the standpoint of informational masking, as it is often the case that some listeners show very little informational masking while others show informational masking effects of 40 dB or more (e.g., Kidd et al., 1994; Neff and Dethlefs, 1995).

I. METHODS

A. Listeners

The listeners were two males and six females, ranging in age from 23 to 50 years. All listeners had previously participated in psychoacoustical tasks. Listeners had thresholds of 20 dB HL (ANSI, 2004) or better between octave frequencies of 0.25 and 8.0 kHz.

B. Stimuli

The masker/signal combinations were composed of sets of 30-Hz wide bands of noise. The signal band was always centered on 2 kHz. The stimuli were played out of one channel of a real time processor (RP2, TDT) at a rate of 24.4 kHz, routed to a headphone buffer (HB7, TDT) and presented over the left earphone of a pair of Sennheiser headphones (HD 265). There were two paradigms, one with fixed masker frequencies and the other in which the masker frequencies were roved. For each, the masker was composed of six noise bands. In the Fixed-Masker conditions, the center frequencies of the masking bands were 0.870 kHz, 1.169 kHz, 1.540 kHz, 2.570 kHz, 3.280 kHz, and 4.160 kHz. These frequencies were selected to leave approximately two non-overlapping equivalent rectangular bandwidths for normal hearing ears (ERB_N) between the edge frequencies of neighboring bands (Moore and Glasberg, 1983). In the Roved-Masker conditions, the masker frequencies on a given trial were chosen at random from a uniform distribution of log frequency, with the following restrictions: 1) the lower frequency limit was 0.25 kHz and the upper frequency limit was 8 kHz; 2) the edges of neighboring bands (including the signal band) were separated by at least two non-overlapping ERB_N s. This criterion insured that the bands were no more closely spaced in the Roved-Masker conditions than in the Fixed-Masker conditions. In each paradigm, thresholds were obtained for both A/A (masking and signal bands all comodulated) and A/B (masking bands comodulated but the signal band random) stimuli. Each masker band was presented at a level of 48 dB SPL (a pressure spectrum level of approximately 33 dB/Hz).

In all conditions, stimuli were generated digitally based on arrays that were comprised of 2^{15} points, resulting in a total stimulus duration of 1.3 seconds prior to gating. Both the signal and masking bands were generated in the frequency domain based on Gaussian-distributed real and imaginary components. The same amplitude and phase draws were used to generate all bands in the A/A conditions. In the A/B conditions, the same draws were used to generate all masker bands, and independent draws were used to generate the signal band. The signal and the masker arrays were converted to the time domain via an inverse FFT.

The effect of signal/masker synchrony was investigated in both the Fixed-Masker and Roved-Masker conditions. The signal and masking bands were either gated synchronously, or in such a way that the masker bands had a 200-ms leading temporal fringe with respect to the signal band (all bands were coterminous). All gating was shaped via multiplication with a 50-ms, raised cosine, and durations were defined with reference to the 50% rise points. In the temporal fringe conditions, both the signal and masking bands were gated on synchronously and had a total duration of 500 ms. In the asynchronous gating conditions, the maskers were gated on, the signal was gated on 200-ms later, and both were gated off 500-ms later, resulting in a total duration of 700 ms. The inter-stimulus interval was always 400 ms.

The use of the leading temporal fringe introduces an issue with respect to informational masking in the Roved-Masker condition. We have previously found order effects related to a masker temporal fringe in conditions involving masker frequency uncertainty (Hall et al., 2005). Not only does such a fringe usually result in a large release from informational masking, but it can sometimes also be associated with a reduction in informational masking in a subsequent condition where the fringe is absent. Because this creates a potentially important order effect, the presentation order in the Roved-Masker conditions is a relevant consideration. The Roved-Masker conditions were therefore performed twice. For the first round, threshold estimates for a Fringe-Absent condition were run and then threshold estimates were obtained for the same condition but with the fringe present. This is referred to as the Fringe-Absent/Fringe-Present presentation order. After all Roved-Masker conditions were completed in this order, a second set of conditions was completed where threshold estimates for a Fringe-Present condition were run and then threshold estimates were obtained for the same condition but with the fringe absent. This is referred to as the Fringe-Present/Fringe-Absent order. One listener

(L5) completed only the Fringe-Absent/Fringe-Present order. Extensive practice was provided to all listeners. The practice included completion of all of the conditions of the experiment and comprised approximately 50 threshold runs.

C. Procedure

Stimuli were presented in blocks of three-alternative, forced-choice trials, using a 2-down 1-up adaptive tracking procedure estimating the 70.7% correct point on the psychometric function (Levitt, 1971). The starting signal level was chosen such that the signal was clearly detectable. An initial step-size of 4 dB was reduced to 2 dB after the second reversal. The run included eight reversals, with the signal threshold estimated as the average signal level at the final six reversals. A run typically consisted of 25–30 trials. Three to five such threshold estimates were obtained for each condition, with the final threshold taken as the mean of the estimates obtained.

II. RESULTS AND DISCUSSION

The average masked thresholds of the individual listeners are summarized in Table I and Fig. 1 (Fixed-Masker conditions), and in Tables II and III, and Fig. 2 (Roved-Masker conditions). Listeners are ordered (L1–L8) in terms of masked thresholds in the Fixed-Masker, Fringe-Absent, A/A condition (which ranged from 17.4–48.2 dB SPL). Before examining CDD effects in detail, it should be noted that there were large individual differences in the masked threshold data in terms of both the amount of masking in the Fixed-Masker conditions and the amount of informational masking in the Roved-Masker conditions. This is consistent with previous reports of substantial individual differences in susceptibility to masking in the CDD paradigm (e.g., McFadden and Wright, 1990) and in informational masking paradigms (e.g., Kidd et al., 1994; Neff and Dethlefs, 1995). Although Fig. 2 shows that most listeners had high A/A thresholds in the Roved-Masker, Fringe-Absent conditions (indicating substantial informational masking), for two listeners (L2 and L4), thresholds in the Roved-Masker conditions were relatively low, indicating little informational masking. Listener L2 had demonstrated substantially higher Roved-Masker thresholds in the initial practice runs, but had apparently learned a strategy to overcome such masking by the time the final data were taken. Over all listeners, the A/A thresholds in the Roved-Masker conditions (temporal fringe absent) ranged from 18.8 to 74.3 dB SPL. The substantial variation in performance across listeners makes statistics based upon mean comparisons relatively uninformative. The analyses of data below therefore involve correlation and the examination of individual differences.

A. Fixed-Masker conditions

Table 1 shows Fixed-Masker thresholds along with two kinds of derived measures, CDD and masking release resulting from temporal fringe. For Fringe-Absent conditions, CDD varied widely among listeners, ranging from 0.3 dB (L1) to 19.2 dB (L6). The average CDD across all listeners was 8.5 dB. Generally, the listeners with the higher A/A masked thresholds had larger CDDs ($r=0.79$; $p=.02$). It was also the case that listeners with the higher A/A thresholds obtained relatively great masking release when a temporal fringe was available in this condition ($r=0.90$; $p=0.002$). This masking release due to temporal fringe ranged from –1.1 dB (L1) to 12.3 dB (L8) and averaged 4.4 dB. Some listeners also showed a masking release in the A/B condition when a temporal fringe was available. However, this masking release was small (1.6 dB on average). A CDD can also be calculated for the Fringe-Present A/A and A/B conditions. This CDD ranged from 4.1 dB (L1) to 9.3 dB (L6) and averaged 5.7 dB.

B. Roved-Masker conditions

We will first consider conditions where the order of presentation was Fringe-Absent/Fringe-Present. Table II shows Roved-Masker thresholds along with the CDD and the temporal-fringe

derived measures. As with the Fixed-Masker conditions, CDDs in the Roved-Masker condition with the temporal fringe absent varied widely across listeners, ranging from -5.4 dB (L3) to 26.1 dB (L6). The average CDD across all listeners was 10.0 dB. The masking release due to temporal fringe in the A/A condition ranged from -0.8 dB (L4) to 55.4 dB (L3) and averaged 30.7 dB. The correlation between the A/A masked threshold and CDD was not significant ($r=-0.12$; $p=.98$), but the correlation between the A/A threshold and the masking release obtained when a temporal fringe was present was significant ($r=0.87$; $p=0.005$). The masking release due to temporal fringe in the A/B condition ranged from 1.7 dB (L4) to 64.6 dB (L3) and averaged 25.8 dB. Note that whereas the effect of temporal fringe in the A/B condition was relatively large, it was minimal in the previously described Fixed-Masker conditions. One reason why the A/B temporal fringe effect was relatively large in the Roved-Masker conditions is that, for some listeners, the across-frequency envelope cue available in the synchronous A/B condition was not potent in achieving release from informational masking. This left a large potential range for masking release to occur when the temporal fringe cue was available. In line with this interpretation, the masking release obtained with temporal fringe in the A/B condition was highly correlated with the A/B masked threshold with fringe absent ($r=0.92$; $p=0.001$).

Table III shows Roved-Masker thresholds and derived measures for the Fringe-Present/Fringe-Absent presentation order. Again, CDD with the masker fringe absent varied widely across listeners, ranging from 0.3 dB (L1) to 48.9 dB (L3). The average CDD across all listeners was 20.2 dB. The masking release due to temporal fringe in the A/A condition ranged from -0.6 dB (L4) to 54.2 dB (L3) with an average masking release of 27.6 dB. The masking release due to temporal fringe in the A/B condition ranged from -1.0 dB (L6) to 47.0 dB (L1) and averaged 11.2 dB. The correlation between the A/A masked threshold and CDD was not significant ($r=0.51$; $p=.25$). However, the correlation between the A/A threshold and the masking release obtained when a temporal fringe was present was significant ($r=0.82$; $p=0.02$).

Although there were similarities in the data patterns between the two orders of presentation (particularly for the Fringe-Present conditions), a comparison between Tables II and III reveals that there were individual cases where the A/B thresholds differed substantially between the two orders of presentation. Individual differences in the Roved-Masker conditions will now be examined in some detail.

C. Individual differences in Roved-Masker conditions

Two examples of individual variability within the Roved-Masker data set should be highlighted. The first involves Listeners L3 and L8. Both of these listeners showed very large CDDs in the Fringe-Absent case, but only in the Fringe-Present/Fringe-Absent presentation order (cf. Tables II and III). For these listeners, the A/A thresholds with fringe absent were quite high for both orders of presentation (near 68 dB SPL for L3 and 63 – 74 dB SPL for L8), but the A/B threshold was much lower for the Fringe-Present/Fringe-Absent order (19.1 dB SPL for L3 and 28.7 dB SPL for L8) than for the Fringe-Absent/Fringe-Present order (over 70 dB SPL for both of these listeners). Because this effect of presentation order was remarkable, listener L8 was asked to repeat some of the Roved-Masker conditions approximately one month after completing the experiment. The listener first completed three A/B conditions in the order: Fringe-Absent, Fringe-Present, Fringe-Absent. This resulted in thresholds of 62.0 , 28.4 , and 31.6 dB SPL for these three conditions, respectively. This confirmed the previous finding that the listener performs poorly on the A/B Fringe-Absent condition, but improves on this condition immediately after listening to the A/B Fringe-Present condition. The A/A condition was then completed in the same order (Fringe-Absent, Fringe-Present, Fringe-Absent), and thresholds of 67.0 , 34.3 , and 68.6 dB SPL were obtained. This confirmed the previous finding that the listener performs poorly on the A/A Fringe-Absent condition, and does not improve

on this condition after listening to the A/A Fringe-Present condition. The finding that a large CDD occurred for two listeners only when the A/B Fringe-Absent condition was preceded by the Fringe-Present condition is consistent with an interpretation that the across-frequency temporal envelope cue is useful to these listeners only after the Fringe-Present condition has primed the listeners to “hear out” the signal. For these listeners, the across-frequency envelope cue in the Roved-Masker condition is not particularly robust in isolation.

The other individual difference of note pertains to the Roved-Masker, Fringe-Absent data of listener L1. This listener showed a CDD of 17.5 dB in the Fringe-Absent/Fringe-Present order, but showed essentially no CDD in the Fringe-Present/Fringe-Absent order. As with L3 and L8, this effect was driven primarily by variability in the A/B threshold. Inspection of L1’s practice data revealed that whereas the A/A threshold was consistently high when fringe was absent (ranging from 60 to 73 dB SPL), the A/B threshold with fringe absent was highly inconsistent both within and between testing days (ranging from 17 dB SPL to 68 dB SPL). This suggests that the across-frequency envelope cue was not sufficiently strong to make it reliably useful for this listener. Thus, the results from L1 are also consistent with an interpretation that the across-frequency envelope cue in the Roved-Masker condition is not particularly robust. This interpretation is considered more generally in the following section.

D. Relative effectiveness of across-frequency envelope cues for release from informational masking

Several studies have shown that informational masking for roved-frequency maskers can be reduced substantially if cues are present that help the auditory system segregate the signal from the masker. For example, informational masking can be reduced by presenting the signal to one ear and the masker diotically (Kidd et al., 1994). Here, informational masking is reduced by providing a spatial-hearing segregation cue. Informational masking can also be reduced by giving the masker a temporal fringe or a temporal pattern that is different from that of the signal (present study; Kidd et al., 1994). Durlach et al. (2003) suggested that informational masking can be reduced by providing cues that make the signal sound different from the masker. The present A/B Roved-Masker condition can be considered a test of whether informational masking with roved-frequency maskers can be reduced by providing across-frequency differences in temporal envelope. The results suggest that this type of cue can provide release from informational masking. However, the cue does not appear to be as robust as the cue of temporal fringe. This question can be examined by considering the listeners who clearly showed informational masking in the Roved Masker conditions (L1, L3, L5, L6, L7, and L8) and contrasting the informational masking release due to temporal envelope cues (the CDD for Fringe-Absent) and the masking release due to temporal fringe for the A/A stimulus. For the Fringe-Absent/Fringe-Present order, this contrast reveals that all six of the listeners with informational masking showed a masking release of more than 15 dB for the temporal fringe cue, but only three of six (L1, L5, and L6) showed masking release of more than 15 dB for the temporal envelope cue. For the Fringe-Present/Fringe-Absent order, this contrast reveals that all five of the listeners with high informational masking (L5 did not participate) showed a masking release of more than 15 dB for the temporal fringe cue, but only three of five (L3, L6, and L8) showed masking release of more than 15 dB for the temporal envelope cue. Thus, for the present listeners, across-frequency differences in temporal envelope were less reliable than temporal fringe in yielding substantial release (more than 15 dB) from informational masking.

III. GENERAL DISCUSSION

A. Fixed-Masker conditions

Borrill and Moore (2002) and Moore and Borrill (2002) suggested that CDD could be accounted for by peripheral factors (masking/suppression). The results from our listeners

having the lowest masked thresholds are in good agreement with this idea. For example, whereas the five listeners having the lowest A/A thresholds (L1–L5) had an average CDD of approximately 5 dB, their average masking release due to temporal fringe in the A/A condition was only 0.2 dB. If their CDDs had been associated with a central mechanism related to perceptual segregation, a masking release due to temporal fringe would have been expected. The Fixed-Masker CDDs of these listeners are therefore consistent with a peripheral masking/suppression account.

It is likely that more central factors contributed to the CDDs of the present listeners who had higher masked thresholds in the Fixed-Masker A/A condition. The three listeners with the highest A/A thresholds (L6, L7, and L8) had CDDs of over 10 dB and masking release due to temporal fringe of over 10 dB. The observation that these listeners obtained a masking release with a temporal fringe is consistent with an interpretation that their A/A thresholds may not have been limited solely by peripheral factors. One possible interpretation is that the A/A thresholds of these listeners were limited by a failure to segregate the comodulated signal and masking bands (McFadden, 1987). By such a perceptual segregation account, the masking release associated with a temporal fringe should be greater for the A/A condition than for the A/B condition. The masking release for temporal fringe in the A/B condition would be smaller because the across-frequency temporal envelope cue would have already contributed to the perceptual segregation of the signal from the masker. For the three listeners with the highest A/A thresholds, the average masking release resulting from a temporal fringe was 11.5 dB for the A/A condition but only 2.0 dB for the A/B condition. This pattern of results is consistent with expectation based upon perceptual segregation.

Whereas three of our eight listeners showed a substantial masking release due to temporal fringe in the Fixed-Masker, A/A condition, none of the three listeners tested in Moore and Borrill's (2002) conditions investigating temporal fringe showed such a masking release. Given the marked individual differences observed here and in previous data sets, it is possible that this discrepancy may be due entirely to subject sampling. Another possibility is that the difference in the pattern of results between the two studies is related to listener training. Although all of the listeners of the present study completed approximately 50 practice threshold runs on the conditions of this experiment before final data were collected, the listeners of Moore and Borrill (2002) may have been more highly practiced on CDD conditions. Moore and Borrill reported that their listeners had completed several previous CDD experiments in addition to receiving practice on the particular temporal fringe conditions completed. It is possible that perceptual fusion effects related to comodulation (as indicated by relatively poor A/A thresholds) can be reduced with extensive training.

B. Roved-Masker conditions

The Roved-Masker paradigm was employed to increase the opportunity of observing central contributions to CDD. Some listeners showed very high thresholds in the A/A Fringe-Absent condition, presumably due to informational rather than energetic masking. In some of the listeners, the A/A threshold for the signal band was higher in level than the levels of the individual masker bands (48 dB SPL). This was true for L1, L3, L6, L7, and L8 in the Fringe-Absent/Fringe-Present order and for L1, L3, L7, and L8 in the Fringe-Present/Fringe-Absent order. The CDDs of these listeners ranged from –5.4 to 51.5 dB, averaging 9.6 dB in the Fringe-Absent/Fringe-Present order and 32.3 dB in the Fringe-Present/Fringe-Absent order. It is very likely that the A/A thresholds of these listeners were determined primarily by central rather than peripheral factors. For example, because the signal band was well above the level of the masking bands at masked threshold, it is very unlikely that the flanking bands suppressed the signal band. In general, the Roved-Masker results are consistent with the idea that sensitivity

to across-frequency differences in temporal envelope can result in masking release (CDD), although less robustly than for the segregation cue of masker temporal fringe.

As noted above, there were many individual differences in the Roved-Masker paradigm, including differences in susceptibility to informational masking, and in the ability to benefit from cues associated with across-frequency differences in temporal envelope. One possible source of variation in informational masking studies such as this may be an individual's ability to monitor a variety of detection cues throughout the course of an adaptive threshold run. For example, whereas all listeners may be able to use an overall energy cue to detect a signal in a roved masker when the signal to noise ratio is high, listeners may vary in their ability to switch to a different cue (e.g., across-frequency difference in temporal envelope) as the signal-to-noise ratio decreases. It is possible that the ability to switch among cues as the signal-to-noise ratio changes contributes to the individual differences found in complex listening tasks.

IV. CONCLUSIONS

1. In Fixed-Masker conditions, the CDDs of some listeners are compatible with an interpretation based upon peripheral masking/suppression. These listeners had relatively low masked thresholds in the A/A condition, and had little or no masking release related to a masker temporal fringe.
2. Other listeners had relatively high A/A thresholds in the Fixed-Masker conditions and had relatively larger CDDs in the Fringe-Absent conditions. These listeners showed substantial masking release related to a temporal fringe in the A/A condition, but considerably less for the A/B condition. These results are consistent with an interpretation that at least part of the CDD in these listeners arises from across-frequency envelope cues that help the listener segregate the signal from the masker.
3. In the Roved-Masker conditions, the results of several listeners were again compatible with an interpretation that CDD can result from across-frequency temporal envelope cues that help the listener segregate the signal from the masker. Here, substantial CDDs sometimes occurred in cases where peripheral masking and suppression were very unlikely to have contributed significantly to the A/A thresholds.
4. Several aspects of the results indicate that release from informational masking related to across-frequency differences in temporal envelope is not as robust as informational masking release related to temporal onset asynchrony.

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Fig. 1. A/A (circles) and A/B (squares) thresholds for individual listeners in the Fixed-Masker conditions.

Fig. 2.

A/A (circles) and A/B (squares) thresholds for individual listeners in the Roved-Masker conditions. The open symbols show data for the Fringe-Absent/Fringe-Present order of presentation and the gray symbols show data for the Fringe-Present/Fringe-Absent order of presentation.

Table 1
A/A and A/B thresholds (dB SPL) and derived measures of CDD and masking release (dB) due to masker fringe. Data are for the Fixed-Masker conditions. Standard deviations for the mean data are shown in parentheses.

	Fringe Absent		Fringe Present		Masking release due to fringe	
	A/A	A/B	CDD	A/A	A/B	A/B
L1	17.4	17.1	0.3	18.6	14.5	4.1
L2	20.8	16.3	4.5	21.8	15.2	6.6
L3	21.0	17.1	3.9	19.6	15.3	4.3
L4	27.2	22.4	4.8	27.0	21.1	5.9
L5	31.0	22.2	8.8	29.3	22.1	7.2
L6	34.9	15.7	19.2	23.4	14.1	9.3
L7	46.3	36.0	10.3	35.7	31.8	3.9
L8	48.2	31.6	16.6	35.9	31.3	4.6
Mean	30.8 (11.6)	22.3 (7.6)	8.5 (6.6)	26.4 (6.8)	20.7 (7.4)	5.7 (1.9)
						4.4 (5.9)
						1.6 (1.3)

Table II

A/A and A/B thresholds (dB SPL) and derived measures of CDD and masking release (dB) due to masker fringe. Data are for the Roved-Masker conditions for the presentation order Fringe-Absent/Fringe-Present. Standard deviations for the mean data are shown in parentheses.

	Fringe Absent		Fringe Present		Masking release due to fringe		
	A/A	A/B	CDD	A/A	A/B	A/A	A/B
L1	60.2	42.7	17.5	10.6	7.6	49.6	35.1
L2	22.9	15.5	7.4	13.6	9.7	9.3	5.8
L3	67.5	72.9	-5.4	12.1	8.3	55.4	64.6
L4	18.8	14.9	3.9	19.7	13.2	-0.8	1.7
L5	39.1	18.1	21.0	19.9	14.8	19.2	3.3
L6	65.2	39.1	26.1	14.9	12.2	50.3	26.9
L7	63.2	56.8	6.4	38.8	33.3	24.4	23.5
L8	74.3	71.0	3.3	35.8	25.8	38.5	45.2
Mean	51.4 (21.4)	41.4 (24.0)	10.0 (10.5)	20.7 (10.8)	15.6 (9.2)	30.7 (20.8)	25.8 (22.3)

A/A and A/B thresholds (dB SPL) and derived measures of CDD and masking release (dB) due to masker fringe. Data are for the Roved-Masker conditions for the presentation order Fringe-Present/Fringe-Absent. Standard deviations for the mean data are shown in parentheses.

Table III

	Fringe Absent		Fringe Present		Masking release due to fringe		
	A/A	A/B	CDD	A/A	A/B	A/A	A/B
L1	56.0	55.7	0.3	9.2	8.7	46.8	47.0
L2	28.2	8.5	19.7	11.4	6.7	16.8	1.8
L3	68.0	19.1	48.9	13.8	9.1	54.2	10.0
L4	20.2	19.3	0.9	20.8	15.7	-0.6	5.1
L6	45.5	16.7	28.8	20.2	17.7	25.3	-1.0
L7	59.6	51.5	8.1	37.9	37.7	21.7	13.8
L8	63.1	28.7	34.4	33.8	25.6	29.3	3.1
Mean	48.6 (18.2)	28.5 (18.2)	20.2 (18.3)	21.0 (11.0)	17.3 (11.1)	27.6 (18.4)	11.2 (16.6)