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MASKING OVERSHOOT: EFFECTS OF IPSILATERAL, BILATERAL AND CONTRALATERAL PRIMING

by

MAUREEN CONNINGTON

A dissertation submitted to the Graduate Faculty in Speech and Hearing Sciences in partial fulfillment of the requirements for the degree of Doctor Of Philosophy, The City University of New York

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ABSTRACT

MASKING OVERSHOOT: EFFECTS OF IPSILATERAL, BILATERAL AND CONTRALATERAL PRIMING

by

Maureen Connington

Advisor: Professor Arthur Boothroyd

This study was concerned with masking overshoot, the elevation of the threshold of a brief signal when it is presented at the onset of a masking noise rather than at its temporal center. More specifically, it was concerned with the release from overshoot (i.e., threshold improvement) produced by priming stimuli, presented ipsilaterally, bilaterally and contralaterally at primer-masker gaps of 20, 40 and 80 msec. The more general purpose of the study was to assess the contributions of peripheral and central factors to the overshoot and overshoot-release phenomena.

The primers and masking stimuli consisted of white noise bursts of 200 and 400 msec duration, respectively. The probe signal was a 20 msec 4kHz tone. The tone and masker were always presented in one ear. There were, however, 3 modes of primer presentation: ipsilateral, bilateral (identical waveforms to both ears) and contralateral. Three primer-masker gaps of 20, 40 and 80

msec were used. Five normally hearing adults were tested at primer and masker levels of 80 dB HL.

Four of the five subjects exhibited significant masking overshoot, when tested without priming. Ipsilateral priming with 20 and 40 msec gaps produced significant masking release from overshoot. Threshold became poorer, however with increasing gap duration and with increasing distance of the perceived primer from the test ear (i.e. ipsilateral priming produced better thresholds than did bilateral priming and bilateral priming produced better thresholds than contralateral priming). There was significant masking enhancement (i.e. threshold was significantly poorer than in the unprimed probe at onset condition) with the contralateral 80 msec primer. The fact that ipsilateral and bilateral primers performed differently does not support the theory that masking overshoot and its release are solely the results of peripheral adaptation. In fact, the group results support the conclusion that masking overshoot is influenced by central factors. However, there were marked inter-subject differences. It seems possible that masking overshoot and its release are influenced by both peripheral adaptation effects and central processes and that the balance between the two is subject-dependent.

This dissertation is lovingly dedicated to the memory of
my father, John Connington
and my brother, Robert Connington

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CHAPTER 1
INTRODUCTION AND PURPOSE

Overshoot refers to the phenomenon whereby a short duration stimulus is more easily masked when placed at the temporal onset versus the temporal center of a longer duration masker.

Zwicker identified the overshoot phenomenon in 1965. Recently, there has been renewed interest in this phenomenon, from both a behavioral and a physiological perspective. Masking overshoot is affected by a number of factors. Overshoot is more pronounced at higher probe frequencies and shorter probe durations. It increases with increasing masker bandwidth and increasing masker intensity. More recent studies have examined conditions under which overshoot is reduced or eliminated in an effort to understand the underlying cochlear physiology. Such conditions include temporary threshold shift, aspirin ingestion, and prior stimulation by ipsilateral and contralateral noise bursts.

While most theories of overshoot claim that peripheral neural adaptation is responsible for the effect, peripheral adaptation does not appear to account for the entire phenomenon. A recent study found that overshoot declines (threshold at onset improves) when prior stimulation in the form of a noise burst is presented to the contralateral ear (Turner and Doherty,

1995). While a decline in overshoot with prior stimulation presented ipsilaterally can be accounted for by peripheral adaptation of primary auditory nerve fibers, this cannot be the case with prior stimulation presented contralaterally.

An alternative explanation, however, is that masking overshoot is caused by centrally mediated processes. These centrally-mediated processes may fall into three categories: 1) The efferent system may have some effect on the response of auditory nerve fibers, perhaps by interfering with the active process of the cochlea. 2) Neurons at the level of the auditory cortex may have an effect (either inhibitive or enhancing) on processes at the level of the cochlea or 3) Cognitive processes in the cortex involved in decision-making operations may have an effect on overshoot and/or overshoot release.

Understanding the underlying physiology with respect to the overshoot phenomenon can provide information about areas of the auditory system responsible for release from masking. Ultimately, this understanding may provide us with useful information on speech perception in noise.

This dissertation was designed to examine the effects of prior noise stimulation (located at various time intervals before onset of a probe in a broadband

noise stimulus) on the masking overshoot effect. The general purpose was to learn about the role of central and peripheral factors responsible for the overshoot effect. The specific purpose was to examine the influences, on overshoot of the timing of prior stimulation (in relation to masker onset) presented ipsilaterally, contralaterally and bilaterally on the overshoot effect.

CHAPTER 2
BACKGROUND AND REVIEW OF THE LITERATURE

Effects of bandwidth, intensity, frequency, and duration

Zwicker (1965) investigated the overshoot phenomenon as a function of bandwidth, center frequency of the masker and temporal locations and duration of the probe. Specifically, he examined the effects of a white noise and pure tone masker on the threshold of a white noise, pure tone or narrowband signal. For the white noise signal, there was variability in masking effect across different temporal locations, with earlier temporal locations producing more masking effects than later ones. This effect was more pronounced with increasing probe frequency. In his examination of the effect of bandwidth, threshold for a 2 msec duration white noise probe with a temporal location (in the masker) of 2 msecs, was poorer than with a pure tone masker, indicating that frequency components outside of the critical bandwidth are contributing to the masking of the probe. There was an improvement in threshold with increasing probe duration for probes at the 2 and 200 msecs temporal locations. When a pure tone rather than white noise was used as the probe stimulus there was not a significant difference in thresholds between the two locations. When pure tone pulses were used as the probe stimulus, significant

overshoot was found. The overshoot effect was also more pronounced for the 5KHz than for the 1KHz probe tone signal. With masker intensity, Zwicker (1965) found that the amount of overshoot was fairly constant as long as the masker intensity was 20dB above threshold for a 5KHz probe tone. At higher intensities, overshoot was independent of masker level. With respect to masker duration, threshold became poorer as masker duration increased from 5 to 20 msecs for both a white noise and a pure tone signal. Thereafter, there was a slight improvement in threshold up to masker durations of 500 msecs. As was previously noted, more masking effect was noted with white noise vs. pure tone maskers.

Fastl (1976a, 1976b, 1979) examined the effect of numerous parameters of the masker and signal on the overshoot effect. Among the parameters were center frequency, bandwidth, intensity, duration, rise-fall time, and temporal location. For long duration probe tones (500 msecs) he found equal masking effect across frequencies of 0.2 to 12kHz, while at short durations (10 msecs), there was greater masking effect on high frequencies above 2KHz. There was greater masking effect for temporal location of 1 vs. 150 msecs with no further improvement in threshold for locations 150 to 400 msecs.

There was improvement in threshold with increasing probe tone duration up to 50 msecs, after which there was a plateau. Increased masking effect was found with masker levels up to 50dB at which point there was a plateau in the masking function. For the narrowband masker, Fastl (1976b) found similar results. There was greater narrowband masking effect at earlier temporal locations and improvement in threshold with increasing probe duration. As a function of frequency, greater masking effect was noted for higher frequencies than for lower frequencies. There was greater masking effect with increasing masker intensity up to levels of 80dB, however the function was non-linear. These findings are contrary to those of later studies which found that overshoot declined when maskers were less than two critical bandwidths. For the pure tone masker, Fastl (1979) again found similar patterns. There was greater masking effect at earlier vs. later temporal locations and greater masking for shorter vs. longer duration probe tones. There was also greater masking effect for high vs. low frequencies and increased non-linear masking effects as a function of masker intensity.

Bacon and Viemeister (1985) examined the overshoot phenomenon in tone-on-tone masking for a 1kHz, 20 msec

signal with maskers below, at and above the probe frequency at temporal locations from 0 to 200 msec for a 200 msec duration masker, and from 0 to 800 for an 800 msec duration masker. The masker intensity was either 60 or 80dB. Masker duration had no effect on threshold when the probe was at masker onset and probe and masker frequency were the same. When the masker frequency was above the probe (1250 Hz), the effect of probe location was an improved threshold at 400 msec delay re: onset and an elevation in threshold thereafter through 800 msec. This held true for both the 60dB and 80dB SPL intensity maskers. For the masker frequency below the probe (800 Hz), similar results were found. There were, however considerable differences among the three subjects tested. For the masker frequency equal to the probe frequency, similar results were noted, but the overshoot was much smaller (3 to 5 dB vs. 5 to 15 dB for the 800 and 1250 Hz maskers respectively).

Bacon and Moore (1986) studied the effects of signal frequency, masker frequency, and masker duration and level. Both signals and maskers were pure tones. Signal frequencies were 0.5, 1, 2, 4 and 8kHz. The masker frequency was 1.2 times the signal frequency. Duration of the masker was 20, 50, 100, 200, 400 or 800 msec and the

intensity was either 60dB or 80dB SPL. The signal was temporally centered in the masker. The higher intensity masker produced more masking effect, but the effect of masker duration was similar for both masker levels. For low frequency signals the greater amount of masking occurred for the short duration maskers. As masker duration increased, signal threshold improved. Masking increased as signal frequency increased for a constant masker duration, but the effect of different masker durations was independent of the signal frequency. Threshold decreased as signal onset was delayed, but increased slightly as signal approached masker offset. The slope of the masking function was steeper for a signal at the beginning of the masker vs. center or offset locations. This is contrary to Fastl's findings which indicated that the slope of the masking function was independent of temporal location.

Bacon and Moore (1986b) obtained temporal psychophysical tuning curves with a 400 msec, 1KHz probe tone temporally located at the beginning, center and end of a masker. Thresholds were best for the probe situated at temporal center, poorer for probes situated at onset and poorest for probes situated at offset. The psychophysical tuning curves were broadest for a signal

at the beginning of the masker and sharpest at temporal center with greater individual differences at the high frequency side of the psychophysical tuning curve.

Bacon (1990) examined the effect of masker level on overshoot using a 400 msec broadband masker and a 10 msec, 4KHz pure tone signal. He used temporal locations of 1 or 195 msec and masker spectrum levels of 10 to 50dB SPL. In a second experiment, masker duration was reduced to 100 msec with a 1 or 70 msec temporal location and masker intensities of 10, 30 or 50dB SPL. At levels up to 10dB, overshoot was negligible, increased to about 10dB at levels of 20 to 30 dB and declined to 0 at levels of 50dB. Bacon attributes these differences in overshoot to the differences in two populations of auditory fibers: 1) the high spontaneous (low threshold) rate fibers which exhibit sharp perstimulus time histograms and 2) the low spontaneous (high threshold) rate fibers which exhibit flat perstimulus time histograms. If the response to the higher masker levels is dominated by the low spontaneous rate, high threshold fibers, one might not expect overshoot at high masker levels at the high frequency side of the psychophysical tuning curve.

In summary, the overshoot effect increases with signal frequency and increased masker bandwidth.

Threshold improves with increasing signal duration up to 50 msec and with temporal locations up to about 150 to 400 msec. It should be noted that great individual differences exist within and across overshoot studies with overshoot as small as 2dB and as great as 20dB.

Effects of hearing impairment, simulated hearing loss, noise exposure, and aspirin use

Kimberley, Nelson and Bacon, (1989) examined the overshoot phenomenon in normal and hearing-impaired individuals. Two normally hearing and two hearing impaired listeners with moderate to moderately-severe impairment served as subjects. Both the masker and probes were pure tones. The masker was 400 msec in duration, while the probe was 20 msec long. In the normal listeners, the signal was easier to mask in the onset vs. temporal center of the masker. The differences became greater with increasing frequency. Kimberley et al. posit two components to the overshoot phenomenon; one is independent of masker/signal frequency ratio (this particular component is about 7dB) and the second is restricted to the high frequency side of the psychophysical tuning curve. The psychophysical tuning curves for the hearing-impaired individuals were relatively flat compared to the normal hearers. Though overshoot was evident, it was not frequency dependent.

The authors speculate that the frequency-dependent component to overshoot is associated with active non-linear tuning mechanisms that lead to sharp tuning in normal ccchleas.

Bacon and Takahashi (1992) also examined overshoot in normal hearing and hearing-impaired subjects. They examined overshoot over a range of masker levels at two signal frequencies; 1Khz, where the hearing impaired had normal sensitivity and 4khz, where pure tone threshold was elevated. The masker spectrum levels were 20, 30 or 40dB SPL. The onset of the signal was at the temporal onset (1 msec) or temporal center (195 msec) of the masker. For the 1kHz signal, masked thresholds for the normal and impaired ears overlapped. However, there were more normal than impaired ears that yielded overshoot values of > 5dB. For the 4kHz signal, there was a tendency for masked threshold in the impaired ears to be better than those in the normal ears. In the normal ears the magnitude of the overshoot decreased with increasing masker level, but was usually always > 5dB. For the impaired ears, overshoot was never > 5dB. For the normal ears, however, overshoot was extremely variable across subjects with values ranging from 7-26dB. This variability is almost exclusively due to the variability

in thresholds at the 1 msec temporal location. Bacon and Takahashi suggest that a finding of reduced overshoot in the context of normal peripheral adaptation lends support to the suggestion that overshoot cannot be accounted for entirely by adaptation of auditory nerve fibers tuned to the signal frequency. Other processing which incorporates frequency regions remote from the signal frequency must be considered. It may be this additional off-frequency component that is susceptible to cochlear damage.

Carlyon and Sloan (1987) also examined overshoot in impaired ears. They examined subjects with unilateral or asymmetrical hearing loss so that their normal or better ear could serve as a control. Overshoot of about 5dB was found, which did not vary with ear tested (normal or impaired) or with masker level. As thresholds in impaired ears are elevated for longer duration signals, the authors conclude that masked thresholds vary less with signal duration in impaired than in normal ears. Carlyon's and Sloan's findings are contrary to previous studies (Kimberley et al. 1989, Bacon and Takahashi, 1992) that found reduced overshoot effects in sensorineural impaired subjects.

Champlin and McFadden, (1989) looked at the effects of intense sound exposure on the overshoot phenomenon.

They were specifically interested in determining whether the short-term peripheral adaptation presumed to underlie overshoot was affected when long-term adaptation (presumed to underlie temporary threshold shift) was induced. Pre- and post-exposure measurements were obtained in two psychophysical tasks; detection in quiet (absolute threshold) and overshoot (masked threshold at onset and later temporal locations). The noise exposure stimulus (2.5kHz tone) and level were chosen so that they would produce a 12-15dB temporary threshold shift at 3.55 KHz. Both 2.5 and 3.5KHz signals were tested under absolute threshold and overshoot conditions. Prior to exposure, masked thresholds in the longer-delay condition were 10-13dB better than in the short-delay condition. However, after exposure (which produced 10-17dB of temporary threshold shift in the frequency region of 3.55KHz), overshoot declined at 3.55khz. Masked thresholds for the short-delay condition improved over pre-exposure values. Over the recovery period, masked thresholds for the short-delay condition worsened to their pre-exposure values.

McFadden and Champlin (1990) reported reductions in overshoot during aspirin use. The threshold for a 6 msecs 3550 Hz signal located at 2 and 190 msec in a 200 msec

wideband masker was measured for five subjects before and after ingestion of three, 325 mg. doses of aspirin four times per day for 4 days. Thresholds for 200 msec tones at 2500, 3550 and 5000 Hz in quiet were also measured for comparison. All subjects showed significant overshoot (5-11dB) prior to aspirin ingestion. In the quiet condition, ingestion of aspirin produced a loss of sensitivity across the three test frequencies measured (range 5-16dB). For four of the five subjects, overshoot was abolished after ingestion of aspirin. While the long-delay threshold (190 msecs) remained the same, the short-delay threshold (6 msecs) improved. This effect was reversed 26 hours after cessation of aspirin use. Audibility thresholds in quiet also returned to their pre-drug values at this point. These results were quite similar to those of Champlin and McFadden (1989a) who found reduced overshoot following noise exposure. The primary difference was that the noise exposure produced greater reduction in overshoot than did aspirin. Also, while 10dB of temporary threshold shift was enough to produce an improvement in threshold in the short-delay condition (Champlin and McFadden, 1989a), only 5dB of aspirin-induced threshold shift in quiet was sufficient to produce improvement in the short-delay condition.

In a second experiment within the same study, McFadden and Champlin (1989a) examined whether the introduction of a second masker would improve the short-delay threshold in the same way as noise exposure and aspirin did. Using a narrowband masker at three spectrum levels and a wideband masker at two spectrum levels, the experiment was conducted in the same fashion as for the aspirin condition. Results indicated that when the masker produced threshold shifts of 20dB or more, thresholds for the short- and long-delay conditions remained the same as in the "overshoot with no background noise" condition. However, when the threshold shifts exceeded 20dB, overshoot declined. The magnitude of the effect was much smaller than that found with temporary threshold shift or aspirin. McFadden and Champlin conclude that the results of this study along with the previous results of the Champlin and McFadden (1989a) study suggest an interruption in the normal balance between the high- and low-saturation response of auditory nerve fibers. The noise exposure and aspirin would have a greater effect on the high-spontaneous high-sensitivity rate fibers which would lead to greater reliance on the low-spontaneous rate low-sensitivity rate fibers. Therefore, temporary hearing loss in the form of a masker does not produce the

same effect as a true temporary threshold shift brought about by intense noise exposure or aspirin use.

The effects of prior stimulation on the masking overshoot effect

Studies which examine the effects of prior stimulation or different contributions of the frequency elements of a broadband noise may be helpful in discovering the underlying mechanisms responsible for the overshoot effect. Studies which assess the effect of prior stimulation on masking overshoot refer to gap insertion in a masker, precursors, priming noise or masker fringes placed before a masker containing a probe. All of the studies are assessing the same phenomenon, which is the effect of a noise placed previous to the masker on the overshoot effect.

McFadden (1988) explored the effect of inserting a gap into a noise 4 msec prior to signal onset. He was specifically interested in discovering those specific spectral regions which, when gapped resulted in greater overshoot. The signal was a 6 msec, 2500 Hz tone. Three noises were used; a narrowband noise centered at 2500 Hz, a high-pass band which passed all components above the high frequency edge of the narrowband noise and a low-pass band, which passed all components below the low

frequency edge of the narrowband noise. The narrowband noise was either 750, 1700 or 3000 Hz wide. The narrowband noise was presented alone or with the flanking high- and low-pass bands. The gaps (ranging from 10 to 300 msec in duration) were placed between the flanking and narrowband noises or within the narrowband noise.

Overshoot of about 9 to 10dB was demonstrated in the ungapped broadband condition. For the ungapped narrowband condition, overshoot was still evident, but dropped to 3 to 8dB. When all three bands were gapped, there was a gradual decrease in sensitivity (enhancement of overshoot) as the duration of the temporal gap was extended from 10 to 300 msec. When only the 750 Hz wide center band was gapped, but the flanking bands were not, there was no decrease in sensitivity even when the gap was 300 msec long. However, when the center band was 3000 Hz wide, there was enhancement of overshoot. Therefore, the frequency components within the 750 Hz wide band responsible for masking the 2500 Hz tone are not the frequencies responsible for the enhancement of overshoot (reduction in hearing sensitivity). The frequency components in the 3000 Hz wide band, however are responsible for the enhancement of overshoot. When only the flanking bands were gapped, but the 750 Hz center

band was not, there was enhancement of overshoot, while the reverse was true for the 3000 Hz wide center band condition. Finally when only the center band was gapped and no flanking bands were present, there was enhancement of overshoot, but at a smaller rate than in the other conditions. It appears that the frequency components responsible for the enhancement of overshoot lie outside the region of the critical band. It would seem therefore, that the neural firing rates of fibers at the signal frequency are affected by the drop in neural firing rate of adjacent (both higher and lower frequency) fibers, which in some way cause masking of the signal or an increase in the magnitude of the overshoot phenomenon.

Carlyon and White (1991) examined the effects of signal frequency, masker level and masker bandwidth on the overshoot effect. In addition, they duplicated McFadden's earlier study of inserting gaps between narrowband and flanking bands of noise. Using signal frequencies of 2.5 and 6.5kHz with both narrowband and broadband maskers, the threshold of a signal located at either 4 or 300 msec in a 350 msec duration masker was measured. Masker levels of 35, 55 or 75dB SPL were used. There was significant overshoot in the 55dB SPL narrowband condition with the 6500 Hz signal. In the 55dB

SPL wideband condition, although overshoot was still evident, it was smaller and more variable across subjects. While increasing bandwidth did not have an effect on overshoot at 55dB SPL, it did at 35 and 75dB SPL. However, variability across subjects was noted. For the 2500 Hz signal frequency, overshoot of about 5dB was present with a wideband masker, but disappeared with a narrowband masker. This was true at all three masker levels. Overall, higher overshoot values were found at 6.5 than at 2.5kHz.

In a second experiment Carlyon and White (1991) introduced a 300 msec gap in a continuous wideband masker 4 msec before the onset of the signal. Two additional noises consisting of a continuous narrowband noise with flanking bands that were turned off for 300 msecs prior to the observation interval (middle band continuous condition) and continuous flanking bands with a narrowband noise that was turned off for 300 msec prior to the observation interval (flanking band continuous condition) were used. In both cases the signal was presented 4 msec after the noise was turned back on. When the flanking bands were continuous, thresholds were better than in the continuous wideband condition for both the 2.5 and 6.6kHz signal indicating that off-frequency

components are responsible for overshoot. When the middle band was continuous, little reduction over the continuous wideband condition was noted for the 2.5kHz signal. For the 6.5kHz signal at 55dB SPL, threshold reduction over the wideband condition was evident. This last finding indicates that on-frequency components are responsible for overshoot. As both on-frequency and off-frequency components appear to be responsible for the overshoot effect, a theory based solely on peripheral adaptation cannot account for the entire phenomenon. Clearly, mechanisms above the level of the auditory nerve must be considered when examining physiological hypotheses.

Carlyon (1989) examined the effect of prior stimulation on the masked threshold of brief tones using notched noise as the masker. The effect was examined as a function of the width of the spectral notch of the masker and primer and as a function of the interval between primer and masker. The notch widths of the primer and masking noises were 0, 0.1, 0.2, 0.3, 0.4 and 0.5khz with the notch centered at 1kHz. The presence of the primer had no effect on thresholds for the zero-notch condition, but lowered thresholds for all other notch widths, with the greatest masking reduction at notch widths of 0.2 and

0.3kHz. It should be noted that there was great variability between subjects.

Carlyon (1989) also examined the effect of the spectrum level of the primer on masked thresholds. If the masking release was due to peripheral adaptation of auditory nerve fibers, raising the level of the primer should result in greater reduction in masked thresholds. Using a notch width of 0.2kHz (chosen because this resulted in the greatest reduction in masking in the first experiment), thresholds for a tone in notched noise were measured for primer spectrum levels of 0 to 30dB re masker level. In addition, they compared the masking effects of the upper vs. lower band of the notched-noise primer. In all, there were four noises used in the experiment: a notched noise with a 0.2kHz wide notch, the lower band of the same notched noise, the upper band of the same notched noise and a narrowband noise 0.4kHz wide centered on 1kHz (the signal frequency). Thresholds did not vary significantly across primer levels for all of the noise conditions. The notched primer produced the lowest thresholds, followed by the lower band of the noise, the upper band of the noise and the narrowband noise, which produced a significant increase in threshold over the unprimed condition. This result appears to be in

agreement with other studies that showed that frequencies above the probe frequency produced more masking effect than did frequencies below the probe frequency.

In the last part of his study, Carlyon (1989) examined the effects of altering the temporal parameters of the primer, masker and probe. He measured thresholds for tones in notched noise as a function of masker and signal duration in the presence and absence of a 200 msec primer. The durations were 5, 10, 20, 40, 80 and 160 msecs, while the primer was 10 msec in all conditions. In addition he examined the effect of altering the length of the primer-masker gap. The gap lengths were 5, 10, 20, 40, 80, 160 and 320 msec. For two of the three subjects tested, the differences between primed and unprimed conditions disappeared when the masker and signal duration increased to 40 to 80 msec. However, for a third subject, the difference between primed and unprimed thresholds was almost independent of masker duration up to 80 msecs. It should be noted however, that there was a great deal of inter-subject variability for this task. The notched noise primer was much more effective in producing masking release than the narrowband primer. However, differences between the two primers was evident even after a gap as long as 320 msecs.

As masking release occurred independent of masker level, Carlyon argues against an explanation in terms of peripheral adaptation. Since cochlear processing is level-dependent and since the primer appears to have been processed independent of its level, he believes that this processing takes place above the periphery.

Carlyon (1989) puts forth a "grouping hypothesis," in which the amplitude envelopes of the masker and signal are highly correlated. Because the amplitude envelopes of the two stimuli are grouped together, the listener cannot detect the signal by attending to the output of only one filter. However, if the notched noise primer causes a decorrelation of the two filters, it would allow the listener to selectively attend to the auditory filter containing the signal. Carlyon posits further evidence for his "grouping hypothesis" by citing the finding of decreased masking release as masker and signal duration are increased. As the duration of the masker and signal are increased the correlation between their envelopes decreases, leading to less grouping of the masker and signal. The primer, therefore would have a lesser effect on decorrelating their envelope.

Hicks and Bacon (1991) studied the effects of a pure tone forward masker on the overshoot effect. The

experimental conditions were as follows: 1) Forward masking of a 4kHz signal by a 3.6, 4.0 or 4.2kHz pure tone forward masker presented 10, 20, 40 or 80 msec prior to signal onset, 2) Simultaneous masking of a 4KHz signal presented at either 1 or 195 msec after the onset of a broadband masker (overshoot condition) and 3) A combined forward masking/simultaneous masking condition in which the broadband masker followed the offset of the pure tone and the onset of the signal occurred 1 msec after masker onset. This final condition essentially examined the effects of priming on the overshoot effect. Pure tone forward masking resulted in a 10 to 20dB shift in the threshold of the 4KHz signal. Overshoot values for three subjects ranged from 9 to 14dB. With the introduction of the pure tone forward masker, threshold values for the 1 msec delay condition were within 3 to 4 dB of those obtained in the absence of a forward masker.

In a series of experiments, Bacon and Smith (1991) examined the effect of varying the frequency, intensity and temporal parameters of a primer on the overshoot effect. Prior to examining the effects of the primer, Bacon and Smith (1991) examined the effect of masker bandwidth to determine if frequency elements near or remote from the signal were responsible for overshoot.

The result would serve to determine the parameters of the masker for the other experiments. Overshoot was measured using masker bandwidths of 0.4, 0.8, 1.6, 3.2, 4.8, 6.4 and 8khz. The masker was 400 msec in duration and the probe was a 10 msec, 4khz tone. Overshoot was not present for the 0.4 and 0.8 bandwidths, but overshoot of about 5 to 15dB was observed with bandwidths of 1.6 to 8khz respectively. In the following experiments, Bacon and Smith (1991) examined the effects of bandwidth, notch-width, and intensity of a primer on the overshoot effect in addition to the recovery and growth of the masking release. Using bandwidths of 0.4, 0.8, 1.6 or 4.8kHz for the primer, overshoot for a 10 msec, 4kHz signal presented in a 400 msec, 8kHz bandwidth noise was measured. The primer reduced the threshold of the probe at onset by about 3dB for the 0.4 bandwidth noise with further reductions in threshold with increasing bandwidth. Overshoot was completely diminished by the 4.8kHz bandwidth. In the next experiment, the primer was the same as the masker except that a notch centered at the signal frequency was inserted into the primer. The notch widths were 0.4, 0.8, 1.6, 3.2 or 4.8khz. Only the threshold at the onset of the masker was measured. Threshold increased as notch-width increased indicating

that frequency elements both near and remote from the signal frequency are responsible for the overshoot effect. In the next experiment, Bacon and Smith (1991) examined the effect of varying the intensity of the primer. Using either a 1.2 bandwidth primer centered at 4kHz or a broadband notched primer with a relative notch width of 0.2 centered at 4kHz, threshold for the 10 msec 4kHz signal at onset of a 400 msec broadband masker was measured as a function of intensity of the primer which varied from -40 to 10dB relative to the masker. For the bandpass primer, threshold remained unchanged for primer intensities of -40 to -30dB, decreased for primer intensities of -20 to -10dB and increased for primer intensities above -10dB. For the notched noise primer, similar results were found. Threshold remained unchanged at low primer intensities, declined as primer intensity increased and reached steady state levels at 0 to 10dB. The bandpass noise was about 5dB more effective than the notched noise in producing masking effect. This last finding provides further evidence that frequency elements both near and remote from the signal frequency are important in the overshoot effect.

In the preceding experiments, the primer was continuous with the masker (i.e. there was no gap between

the primer and the masker). In their final two experiments, Bacon and Smith (1991) attempted to determine if the recovery and growth of the masking release followed the pattern of recovery and growth of peripheral auditory nerve fiber adaptation or if suppression might be responsible for the effect. To examine the recovery function, the threshold for a signal at the onset of a 400 msec masker was measured in the presence of a 400 msec primer with a relative notchwidth of 0.2 centered at 4kHz at primer-masker gaps of 1, 25, 50, 100 or 200 msec. Threshold for the 1 msec primer-masker gap was similar to that observed at the 195 msec signal location in the absence of a primer, suggesting that suppression did not influence thresholds in the presence of an additional noise. Threshold increased as primer-masker gap increased. In the last experiment, the duration of the primer was varied from 1 to 200 msec. The notchwidth and center frequency were the same as in the previous experiment. The rise/fall time was also varied from 1 to 25 msec for durations of 3, 6, 12 and 25 msec or 5 msec for durations of 25, 50 100 and 200 msec. The primer-masker gap was 1 msec. Thresholds decreased as noise duration was increased from 3 to about 50 to 100 msecs.

Kidd and Wright (1994) examined the detectability of a brief tone using forward and backward masker fringes with a notched noise. They measured the threshold of a 4 msec, 1kHz tone in a 22 msec broadband notched noise (1400 hz wide, centered at 1Khz). To this was added either a 150 msec forward or backward fringe (for a total noise duration of 172 msecs), presented either ipsilaterally, bilaterally or contralaterally. For the ipsilateral condition, the forward fringe threshold was significantly better (by 15dB) than the noise burst threshold, but there was great variability across subjects. The backward fringe also improved thresholds (by about 9dB) with less variability among subjects. For the contralateral condition, thresholds for the forward fringe were not significantly different from those obtained under the noise burst condition. Backward fringe thresholds were about 5dB poorer than for the noise burst condition. There was more variability across subjects for the forward fringe condition, while the backward fringe condition was more stable. For the bilateral condition, the forward fringe was not significantly different than the ipsilateral condition, but thresholds were significantly different than the noise burst condition. Backward fringe thresholds were poorer than those

obtained with the ipsilateral condition, but not significantly so, nor were they significantly different from the noise burst condition. When the level of the fringe in the contralateral ear was varied from 3 to 43 dB, performance declined and when the contralateral component of the bilateral backward fringe was delayed from the onset of the ipsilateral component, thresholds declined. Because there was no difference between the ipsilateral and bilateral forward fringe thresholds, a monaural phenomenon seems likely, and therefore not under the influence of higher level auditory processes. Because, however there was no difference between the noise burst condition and the contralateral backward fringe condition, the authors conclude that central processes are responsible for this phenomenon. They point out that input to the contralateral ear reduced the effect relative to the forward fringe condition. It should be noted that overshoot is greatest at frequencies above 1kHz. As the probe signal in this experiment was 1kHz, it is possible that results may have been different had higher signal frequencies been used.

Overson et al. (1995) examined the effect of level and relative frequency region on release from overshoot. Because prior studies have showed discrepancies in the

time course of release from overshoot, varying from as short as 100 to 200 msec (Zwicker, 1965a and Elliott, 1969) to more than 300 msec, (McFadden, 1969), Overson et al. examined whether these differences were due to differences in stimulus levels or to individual subject differences. Previous studies (Bacon and Smith, 1989 and McFadden, 1989) have shown that recovery from overshoot is faster at lower intensities than at higher ones. It has also been shown that frequency regions remote from the signal frequency (particularly higher frequencies) were important in controlling the recovery from overshoot (McFadden, 1989). The masker was a 400 msec broadband noise and the probe stimulus was a 10 msec, 4kHz sinusoid. It was placed at either the temporal onset or temporal center of the masker. Overshoot increased with increasing masker level up to a level of about 30dB SPL and then decreased with masker levels above 30dB SPL. Overson et al (1995) also examined the effects of a 400 msec primer at primer-masker gaps of 1, 25, 50, 100, 200 or 400 msec. The two masker levels chosen were selected from the first experiment; a high and low intensity masker that yielded equal amounts of overshoot for each subject. Thresholds increased as the primer-masker gap increased from 1 to 100 msecs with very little change in

threshold thereafter. There was no difference in the recovery function for the two masker levels. In a final portion of their experiment, Overson et al. (1995) examined which frequency region relative to the signal frequency is more important for release from overshoot. The experiment was the same as in the previous experiment, except that the primer was low-passed or high-passed filtered at 4kHz and the primer-masker gaps were 1, 50, 100 and 200 msec. Overall, the high-pass and low-pass condition yielded similar results, but on average there was a 2-3dB greater recovery in the high-pass condition.

Turner and Doherty (1995) performed a study in which they examined the effect of contralateral priming on overshoot. They performed two experiments; one in which they presented a 4kHz tone burst in a broadband masker at temporal locations of either 1 or 195 msec and one in which they presented the same stimuli but preceded by a 200 msec broadband (priming) noise presented to the contralateral ear 10 msec prior to the stimulus to the ipsilateral ear. Both normal listeners and hearing impaired individuals served as subjects. For the normal subjects, overshoot was as much as 8dB, but there was a great deal of variability among subjects, with two

subjects showing no overshoot at all. A contralateral primer reduced the overshoot by about 5dB (with ranges of 1 to 10dB). The sensorineural group showed no overshoot. While the thresholds at the 195 msec temporal location were the same as for the normals, the threshold at onset was lower than the normal group. With contralateral stimulation, no change in threshold for the 1 or 195 msec temporal locations was noted. Turner and Doherty suggest that the better-than-normal masked thresholds for the hearing impaired listeners in the 1 msec temporal location is due to a weakened or absent active process in these listeners relative to the strong active process present in normal listeners prior to efferent activation. Physiological studies have shown that contralateral stimulation provides an increment in efferent activity which may effect cochlear mechanics.

McFadden (1988) examined the overshoot effect in a dichotic masking condition in an attempt to determine the underlying physiological mechanism for the overshoot effect. Although his study does not deal with the effect of priming on overshoot, his results have implications for determining the underlying mechanism for overshoot. McFadden (1988) argued that detectability in a diotic condition is attributed to neural firing rates, while in

a dichotic condition it is attributed to interaural time differences. Therefore, examining the overshoot effect in a masking level difference paradigm may help provide additional evidence as to the underlying physiological mechanism responsible for the overshoot effect. Using a 350 msec broadband masker and a 14 msec, 750 Hz probe stimulus, McFadden obtained thresholds with signal and masker in phase and signal and masker 180 degrees out of phase. When masker and signal were in phase, overshoot (on the order of about 6dB) was obtained. In contrast, when the signal and masker were 180 degrees out of phase no overshoot was evident. McFadden asserts that the presence of overshoot in the non-masking level difference(NoSo, both noise and signal are in phase) condition confirms a peripheral neural adaptation theory of overshoot, while the absence of overshoot in the masking level difference condition confirms the importance of interaural time/intensity cues in dichotic listening conditions.

A Physiological Perspective

Many of the previously cited studies of overshoot have attempted to examine the underlying physiological mechanism responsible for overshoot. While short-term peripheral adaptation of primary neural fibers is the

most frequently cited theory of overshoot, it does not appear to account for the entire phenomenon. The common theories of overshoot are as follows:

1. Short-term adaptation of primary neural fibers.

Since overshoot declines with intense noise exposure (temporary threshold shift), it is thought that the improvement in threshold at onset is due to the reduction of the onset responses of primary auditory fibers.

2. Greater contribution of high spontaneous rate, low response threshold neural fibers.

The majority of primary fibers exhibit high spontaneous rates of firing and low response thresholds, while 10% have low spontaneous rates and high thresholds. The brief masked thresholds may be mediated primarily by the high spontaneous rate cells and overshoot is seen because of the onset response of these units. However, with noise exposure, the normal balance between low and high spontaneous rate cells is disrupted because the high spontaneous rate cells are more affected than the low spontaneous rate cells and the contribution of the overall level of activity of the high spontaneous rate cells is reduced compared to that of the low spontaneous rate cells.

3. Splatter or spread of masking energy resulting from gating or the sudden onset of a stimulus which would therefore increase threshold at onset.

4. Contribution of the efferent system.

The efferent system may play a role in overshoot by increasing the detectability of signals in noise. Since this active process may be impaired in ears with outer hair cell damage, this may account for reduced or absent overshoot in individuals with sensorineural hearing loss and masking release in individuals with normal hearing.

Summary of the literature

Overshoot is more pronounced at higher probe frequencies, increases with increasing bandwidth (indicating frequency elements outside the critical band contributing to the effect) and is more pronounced with shorter probe durations. However, there are great individual differences observed in overshoot experiments with overshoot ranging from as small as 2dB to as great as 20dB.

Both on-frequency and off-frequency elements seem to be responsible for overshoot and overshoot release, so a theory based solely on peripheral adaptation is not likely to be adequate.

Hearing loss, noise exposure and aspirin ingestion appear to reduce the overshoot effect by improving threshold at onset, lending support to a peripheral adaptation mechanism for overshoot.

Masking overshoot release (examined via the introduction of a priming noise into the masking paradigm) is faster at lower intensities than at higher intensities. Frequency regions remote from the signal frequency (particularly higher frequencies) are important in controlling overshoot. There is greater recovery from overshoot with high-pass vs low-pass primers.

Purpose of the study

The general purpose of the present study was to determine if masking overshoot and masking overshoot release is a peripheral phenomenon (i.e. mediated at the level of the cochlea or primary nerve fibers) or whether it is due to processes higher in the auditory system. These higher processes can be divided into several groups: 1) Efferent processes at the level of the superior olivary complex, specifically the medial superior olivary complex, which are thought to have an effect on the active processes of the cochlea. This effect may be facilitatory or inhibitory. 2) Processes in the auditory cortex thought to be responsible for

interpretation of complex stimuli, or 3) Processes in the cortex thought to be related to cognitive (decision-making) factors.

The specific purpose of this study was to examine the effects of the ipsilateral, contralateral and bilateral primers (located at primer-masker gaps of 20, 40 and 80 msecs) on the masking overshoot effect. Examining the differences in overshoot as a function of ipsilateral, contralateral and bilateral priming may assist in determining whether the underlying mechanism is peripheral, central or both.

It was hypothesized that if the phenomenon was a purely peripheral one, there would be no significant difference between ipsilateral and bilateral priming conditions. As the superior olivary complex is the first level at which binaural stimuli are processed, a significant difference between bilateral and ipsilateral primers would not support a peripheral basis for masking overshoot and its release. If bilateral and ipsilateral primers produced the same result, the phenomenon would appear to be a monaural one, in which auditory pathways above the cochlea would exert little or no effect. Additionally, if the phenomenon was purely peripheral, the contralateral primer threshold would not be

significantly different from the unprimed probe-at-onset threshold.

Any other combination of results would not support a primarily peripheral mechanism for masking overshoot and masking overshoot release.

CHAPTER 3
METHOD

This experiment examined the different effects of ipsilateral, bilateral and contralateral priming on masking overshoot, to determine whether masking overshoot and overshoot release is a solely peripheral phenomenon or whether processes above the cochlea may contribute to the effect.

Subjects

Five normally hearing individuals served as subjects. Subjects ranged in age from 34 to 45 years of age with a mean age of 39. All subjects were female. Each subject had pure tone thresholds within 20dB HL from 0.25 to 8kHz. All subjects were experienced with psychoacoustic experiments.

Stimuli for the overshoot experiment

The masker was a 400 msec white noise with 10 msec raised cosine ramps (rise/fall time). The signal was a 20 msec, 4kHz tone with 10 msec raised cosine ramps (rise/fall time). The probe was placed either at temporal onset or temporal center of the masker. For the overshoot conditions (measurement of signal threshold at onset and center of the white noise), twenty different stimulus files corresponding to a different signal-to-noise ratio were generated. The intensity of the noise was held

constant, while the intensity of the probe tone declined by 2dB from one stimulus file to the next lower one. Five different random noises were generated to avoid "frozen noise" effect, which may provide other cues to stimulus identification. Thresholds were calculated in dB signal-to-noise ratio.

Stimuli for the priming experiment

The masker was a 400 msec white noise with 10 msec raised cosine ramps (rise/fall times). The primer was a 200 msec white noise with 10 msec raised cosine ramps. The signal was a 20 msec, 4KHz tone with 10 msec raised cosine ramps. Worksheet calculations for the ipsilateral and contralateral primers are presented in Appendix A.1. The stimuli were generated off-line using signal processing software from DaDisp. Dadisp Worksheet calculations for the bilateral primer are presented in Appendix A.2. As with the overshoot stimuli, five different maskers and primers were generated to reduce the possibility of "frozen noise" effects. The bilateral primers were synchronous (employed identical waveforms) so that the perceived locus of the primer was at midline.

Procedure

Stimuli were played through a digital-to-analog converter and then passed through a Grason Stadler model

10 audiometer and delivered to the subjects' ear(s) through insert earphones (ER-20B). Initial internal levels were set through the computer's soundblaster board. The masker level was set at 85dB HL via the audiometer attenuator.

This study consisted of two separate conditions:

1) Unprimed or overshoot condition: In this condition, subjects were required to track their threshold for a probe in white noise. The probe was located at either masker onset or masker center. Stimuli were presented to all subjects' right ears. The difference between the probe-at-onset and probe-at-center thresholds provided a measure of overshoot magnitude.

2) Primed condition: In this condition, subjects were required to track their threshold for a probe situated at the onset of a 400 msec white noise. The white noise was preceded by a 200 msec white noise primer presented ipsilaterally, bilaterally or contralaterally at primer-masker gaps of 20, 40 or 80 msec.

Subjects were tested in a double-walled sound suite. Instructions were provided both verbally and in written form. Subjects were also given an informed consent to sign which included a description and purpose of the experiment. One trial provided one threshold measurement.

Subjects typically did not participate in more than 4 to 6 trials in succession without a 5 to 10 minute rest period.

I. Overshoot (or unprimed) condition

All subjects participated in the unprimed or overshoot experiment first, tracking thresholds for the probe-at-center and then probe-at-onset location. One trial provided one threshold measurement. A trial consisted of the subject tracking her threshold via a two-alternative forced-choice procedure. Three correct responses were required before a decrease in the stimulus level, while 1 incorrect response was required before an increase in stimulus level (3 down-1 up decision rules). This decision rule estimated the 79.4% point on the psychometric function. Thresholds were obtained via a computerized program called "Pyscho" created by Boothroyd (1996). Eight trials were obtained in the probe-at-center location and then probe-at-onset location and these conditions were repeated for a total of 16 trials each for the center and onset locations.

II. Priming condition

Three primer masker-gaps were used. These intervals were 20, 40 and 80 msecs. In the priming conditions, signal threshold was measured only at masker onset,

because this is the threshold shown to improve in previous studies. Priming conditions were randomly ordered across subjects. All subjects were required to execute 8 trials for each priming condition (ipsilateral, contralateral and bilateral) at each primer-masker gap (20, 40 and 80 msec). As in the overshoot experiment, these conditions were repeated for a total of 16 trials for each primer at each primer-masker gap. A schematic representation of the two unprimed and three primed conditions is illustrated in Figure 3.1.

III. Repeat of Unprimed Condition

After each subject was tested under the entire set of priming conditions, she was required to track her threshold again for the unprimed conditions. These thresholds were obtained in the same way as before- 8 trials with the probe at center, 8 trials with the probe at onset and then a repetition of the conditions for a total of 16 trials each for the probe at onset and probe at center conditions. A summary of the experimental conditions is presented in Table 3.1.

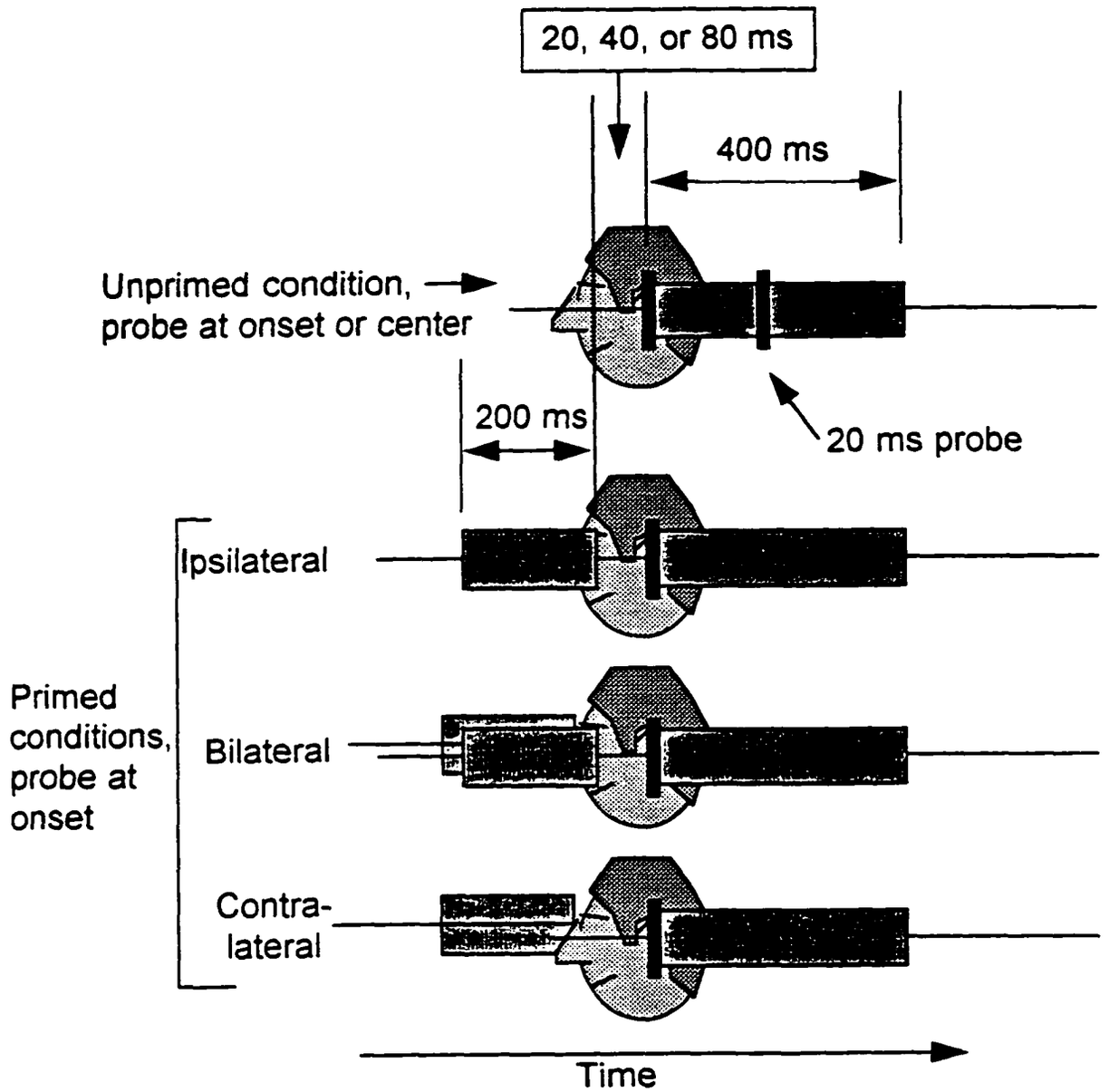


Figure 3.1. Schematic illustration of 5 test conditions. The subject's task was to identify the presence of the probe in a 2-interval forced-choice task.

Table 3.1 Summary of experimental conditions with respect to presentation order and number of trials. The unprimed probe-at-center and probe-at-onset thresholds were obtained first and last. The primed thresholds were obtained in between the initial and final unprimed conditions.

Presentation order	Condition	Minimum # of trials
1	Unprimed probe at center	8
2	Unprimed probe at onset	8
3	Unprimed probe at center	8
4	Unprimed probe at onset	8
Varied across subjects	Ipsilateral primer, 20 msec	8
" " "	Ipsilateral primer, 40 msec	8
" " "	Ipsilateral primer, 80 msec	8
" " "	Bilateral primer, 20 msec	8
" " "	Bilateral primer, 40 msec	8
" " "	Bilateral primer, 80 msec	8
" " "	Contralateral primer, 20 msec	8
" " "	Contralateral primer, 40 msec	8
" " "	Contralateral primer, 80 msec	8
" " "	Ipsilateral primer, 20 msec	8
" " "	Ipsilateral primer, 40 msec	8
" " "	Ipsilateral primer, 80 msec	8
" " "	Bilateral primer, 20 msec	8
" " "	Bilateral primer, 40 msec	8
" " "	Bilateral primer, 80 msec	8
" " "	Contralateral primer, 20 msec	8
" " "	Contralateral primer, 40 msec	8
" " "	Contralateral primer, 80 msec	8
23	Unprimed probe at center	8
24	Unprimed probe at onset	8
25	Unprimed probe at center	8
26	Unprimed probe at onset	8

CHAPTER 4
RESULTS

THRESHOLD DATA

The last 10 threshold estimates under each of 11 conditions for each subject were used for the data analysis. Two of the conditions were without priming (probe at temporal center and onset of a masker). Nine were with priming (3 primer modes by 3 primer-masker gaps). The probe was at masker onset for all primed conditions. Individual threshold values, with means and standard deviations for the 11 conditions will be found in Appendices B through E. Table 4.1 shows the 11 average threshold values for each subject, together with overshoot values, group means, standard deviations and standard errors. The data were analyzed first as a group design and then for individual subjects.

GROUP ANALYSIS

For the group design, the mean thresholds for each subject for each condition (as presented in Table 4.1) were subjected to a one-way repeated-measures analysis of variance with condition (at 11 levels) as the single effect. This analysis of variance is presented in Table 4.2. Clearly, there were highly significant differences in mean threshold among the 11 conditions.

The least significant difference post-hoc analyses for the group allowed for interpretation of overshoot amplitude, extent of masking release and/or masking enhancement and differences among primer types and primer locations. (See Table 4.3).

TABLE 4.1 Group and individual probe thresholds in dB S/N ratio obtained under 11 conditions (two unprimed-probe at temporal onset and center of the masker and 9 primed conditions; 3 primers (ipsilateral, bilateral and contralateral) and 3 primer-masker gaps (20, 40 and, 80 msec). Also included are the mean, standard deviation and standard error and the amount of overshoot (unprimed condition) and masking release.

			SUBJECTS								
PRIMER TYPE	GAP LENGTH	PROBE LOCUS IN MASKER	S #1	S #2	S #3	S #4	S #5	MEAN	MASKING RELEASE (IN dB)	SD	SE
none	---	CENTER	-7.9	-7.2	-1.5	-2.8	-6.3	-4.9	---	2.77	1.24
none	---	ONSET	-6.3	-3.1	2.4	2.9	1.3	-0.6	4.3	3.99	1.79
ipsi	20	ONSET	-10.0	-6.3	-1.0	3.6	-3.2	-3.4	2.8	5.23	2.34
	40	ONSET	-9.2	-5.3	-2.4	2.6	-5.4	-3.9	3.3	4.37	1.96
	80	ONSET	-6.7	-2.6	-0.1	5.2	-3.9	-1.6	1.0	4.49	2.01
bilat	20	ONSET	-6.9	-3.4	0.5	3.4	-0.8	-1.4	0.8	3.89	1.74
	40	ONSET	-8.2	-1.6	1.6	2.4	1.5	-0.9	0.3	4.40	1.97
	80	ONSET	-6.3	-2.9	1.8	5.3	-1.3	-0.7	0.1	4.43	1.98
contra	20	ONSET	-7.3	-0.5	2.6	7.0	-3.5	-0.3	-0.3	5.48	2.44
	40	ONSET	-6.1	-0.1	2.6	6.6	1.3	0.9	-1.5	4.59	2.05
	80	ONSET	-2.2	0.3	2.5	8.6	1.2	2.1	-2.7	4.01	1.79

TABLE 4.2 One-way repeated measures analysis of variance for the group with condition as the sole variable at 11 levels.

Effect	df effect	MS effect	df error	MS error	F	p-level
Condition	10	21.25	40	2.22	9.58	<0.0005

TABLE 4.3. Least Significant Difference Post-hoc analysis for the group with condition as the sole variable at 11 levels. Numbers in bold italics indicate significant effects at the 5% level of confidence.

COND.	CENTER	ONSET	I 20	I 40	I 80	B 20	B 40	B 80	C 20	C 40	C 80
CENTER		***0.00004***	0.10235	0.30445	***0.00115***	***0.00640***	***0.00011***	***0.00005***	***0.00002***	***0.00001***	***0.00001***
ONSET	***0.00004***		***0.00528***	***0.00091***	0.26943	0.36400	0074780	0.92856	0.79208	0.14230	***0.00758***
I 20	0.10235	***0.00527***		0.53123	0.07453	***0.04874***	***0.01214***	***0.00669***	***0.00257***	***0.00007***	***0.00001***
1 40	0.30445	***0.00091***	0.53123		***0.01819***	***0.01106***	***0.00228***	***0.00118***	***0.00042***	***0.00001***	***0.00001***
1 80	***0.00115***	0.26943	0.07453	***0.01819***		0.84118	0.43064	0.30934	0.17364	***0.01247***	***0.00033***
B 20	***0.00064***	0.36400	***0.04874***	***0.01106***	0.84118		0.55555	0.41258	0.24355	***0.02040***	***0.00060***
B 40	***0.00011***	0.74780	***0.01214***	***0.00229***	0.43264	0.55555		0.81654	0.55907	0.07617	***0.00325***
B 80	***0.00005***	0.92855	***0.00669***	***0.00118***	0.30934	0.41258	0.81654		0.72400	0.12039	***0.00607***
C 20	***0.00002***	0.79208	***0.00257***	***0.00042***	0.17364	0.24355	0.55907	0.72400		0.22537	***0.01499***
C 40	***0.00001***	0.14230	***0.00007***	***0.00001***	***0.01247***	***0.02040***	0.07617	0.12039	0.22537		0.19734
C 80	***0.00001***	***0.00768***	***0.00001***	***0.00001***	***0.00033***	***0.00060***	***0.00325***	***0.00607***	***0.01499***	0.19734	

I 20=Ipsilateral 20 msec B 20=Bilateral 20 msec C 20=Contralateral 20 msec

I 40-Ipsilateral 40 msec B 40=Bilateral 40 msec C 40=Contralateral 40 msec

I 80=Ipsilateral 80 msec B 80=Bilateral 80 msec C 80=Contralateral 80 msec

OVERSHOOT FINDINGS

As this study was concerned with release from masking overshoot, it is appropriate to ask first, whether these subjects exhibited masking overshoot and if so, how much?

For each subject, the unprimed threshold at the temporal center was subtracted from the unprimed threshold at the onset of the masker to give a value of masking overshoot. The results are illustrated in Figure 4.1. Subjects are placed in descending order of overshoot magnitude. Group mean thresholds in the two unprimed conditions were -4.9dB (temporal center) and -0.6dB (temporal onset). The difference of 4.3dB is the average unprimed overshoot. The 95% confidence limits for the group mean overshoot can be computed from the following equation:

se=the square root of (e x 2/N),

where se=the standard error of the difference between two means

n=the number of data points contributing to a single mean

e=the estimated mean square error (from the ANOVA table 4.2)

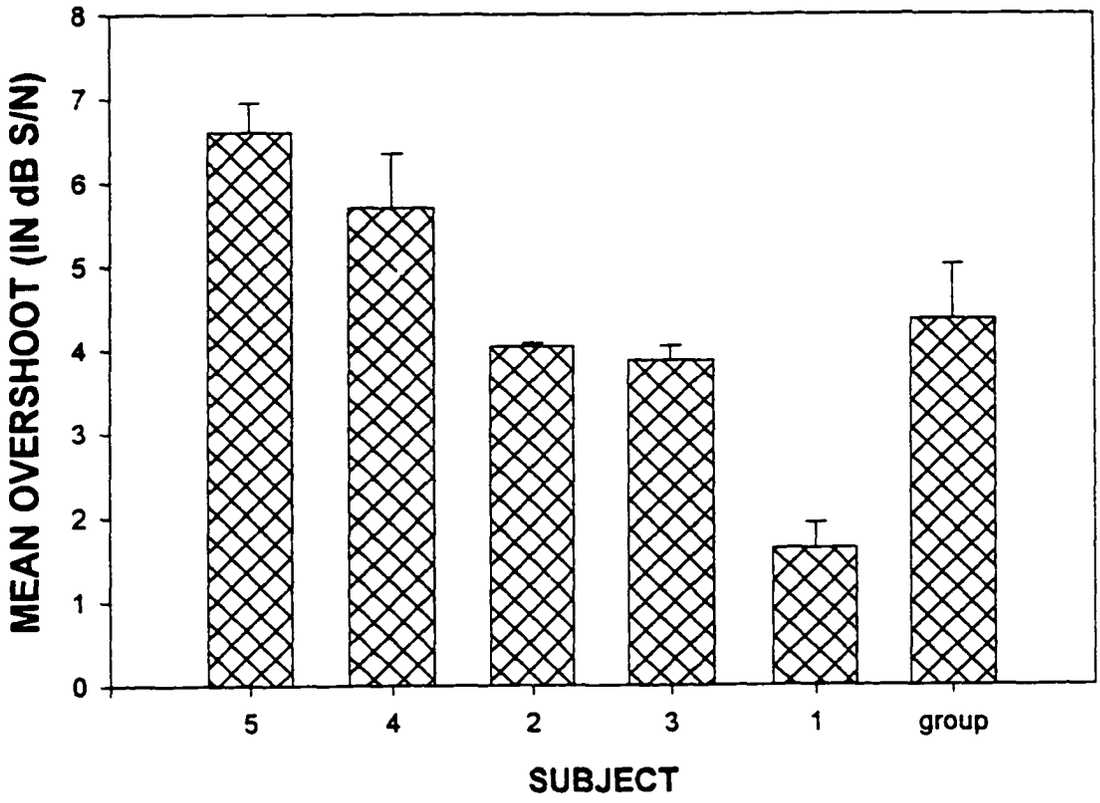


Figure 4.1 Mean overshoot for each subject and for the group. Means for subjects are rank-ordered from greatest to least amount of overshoot. Error bars are the difference between the standard errors for the unprimed probe-at-onset and the unprimed probe-at-center mean thresholds.

In the present case, e=2.21 dB and n=40. The resulting standard error is therefore, se=0.94 dB. Multiplying this standard error by the value of t for 40 degrees of freedom (2.02) gives 95% confidence limits for the mean overshoot of +/- 1.9 dB. It may be concluded, therefore, that for the population represented by these subjects, the mean magnitude of overshoot, under the conditions of this experiment, most probably lies between 2.45 and 6.25 dB.

EFFECT OF PRIMING

We now turn to the effects of the primers. Figure 4.2 shows group mean threshold for each primer as a function of primer-masker gap. The dark horizontal lines at top and bottom of the figure represent the unprimed threshold at onset and unprimed threshold at center, respectively. The shaded areas indicate the 95% confidence limits for the unprimed threshold at onset and unprimed threshold at center. Any primed threshold falling below the 95% confidence limits for threshold at onset indicates significant masking release. If the threshold is so far below as to fall within the 95% confidence limits for masking at center, then the release may be assumed to be complete. If the primed threshold

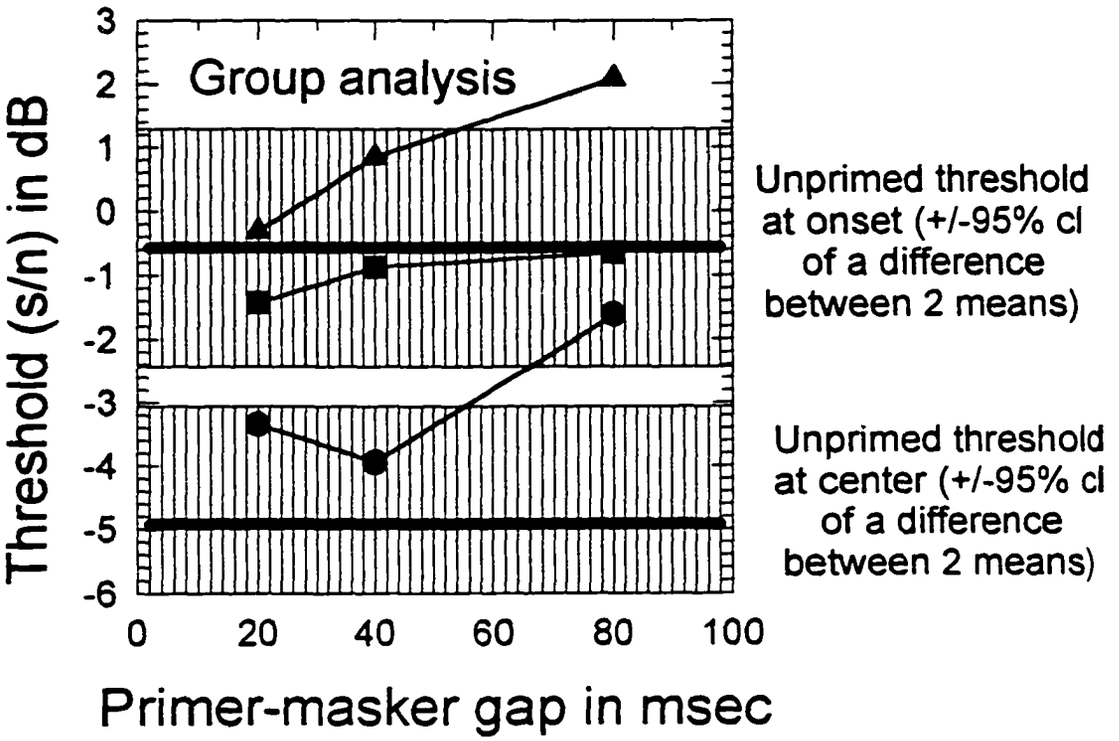


Figure 4.2 Data points show mean primed thresholds for 5 subjects, as function of primer and primer-masker gap. The dark horizontal lines show the unprimed thresholds at the onset and temporal center of the masker. The confidence limits were derived from an estimate of between-subject variance and therefore, apply to the means of the population represented by this sample.

falls above the 95% confidence limits for threshold at onset, this may be taken as showing masking enhancement.

From the post-hoc analysis (Table 4.3) using the least significant difference test, it can be shown that the ipsilateral 20 and 40 msec and the contralateral 80 msec primer-masker gap thresholds were significantly different from the unprimed probe at onset condition. There is significant masking release with the ipsilateral 20 and 40 msec primer-masker gaps and significant masking enhancement with the contralateral 80 msec primer-masker gap. The extent of masking release is given by the difference between the unprimed probe at center and the primed threshold. Any primed threshold that is not significantly different from the unprimed probe at onset threshold indicates complete masking release. Post-hoc analysis revealed complete release for the ipsilateral 20 and 40 msec primer-masker gaps.

There was not a significant difference between the unprimed probe at onset and the ipsilateral 80, contralateral 20 and 40 and the bilateral 20, 40 and 80 msec primer-masker gaps indicating no significant masking release or masking enhancement. There may be release but, if so, its magnitude is too small to be detected in this study.

Two other questions of interest are whether there are significant differences between the different primers and among the different primer-masker gaps. The post-hoc analysis revealed no significant difference between the bilateral and contralateral primers across all primer-masker gaps. The ipsilateral and bilateral primers were significantly different from one another at the 20 and 40 msec primer-masker gaps, but not at the 80 msec primer-masker gap. With respect to differences across the primer-masker gaps, post-hoc analysis revealed a significant difference between the 20 and 80 msec primer-masker gaps for the ipsilateral and contralateral primers, while the bilateral 20, 40 and 80 msec primer-masker gaps were not significantly different from one another.

To determine if there was a significant interaction between primer type and primer location, a two-way analysis of variance was performed with primer type (3 levels) and primer location (3 levels) as the two variables. This two-way analysis of variance is presented in Table 4.4. While there were significant main effects of primer type and primer-masker gap, there was not a significant interaction between these two variables. Therefore, while threshold varies as a function of primer

type, the differences are similar across primer-masker gaps. Conversely, while threshold varies as a function of primer-masker gap, the differences are similar across primer types.

TABLE 4.4 Two-way analysis of variance in the primed data for Table 4.1 with primer and gap length as the two variables at 3 levels. There were significant main effects of primer and gap length, but not a significant interaction between the two variables.

Effect	df effect	MS effect	df error	MS error	F	p-level
primer	2	55.27	8	2.24	24.66	<0.0005
gap length	2	10.98	8	1.78	6.19	0.0237
primer X gap length	4	2.13	16	1.38	1.55	0.2354

In summary, for the means of the population represented by this sample and under the conditions of this experiment, there is significant overshoot and significant main effects of primer type and primer-masker gap, but not a significant interaction between these last two variables. Significant masking release (possibly complete) was noted for the ipsilateral 20 and 40 msec primer-masker gaps and significant masking enhancement for the contralateral 80 msec primer-masker gap. The 20 and 40 msec primer-masker gaps were not significantly different from one another.

INDIVIDUAL SUBJECT ANALYSES

For the individual subjects, one-way analyses of variance were performed with condition as the single

variable at 11 levels (2 unprimed and 9 primed conditions). Each subject's thresholds for 10 trials across 11 conditions were analyzed. Within subject trial-to-trial differences provided the error variance. The analyses of variance for the five subjects are presented in Table 4.5.

Mean threshold for each primer type as a function of primer-masker gap for all subjects is presented in Figure 4.3. The shaded areas indicate the 95% confidence intervals of a difference between two means. Any primed threshold falling below the 95% confidence limits for threshold at onset indicates significant masking release. If the threshold is so far below as to fall within the 95% confidence limits for the unprimed probe at onset threshold, then the release can be assumed to be complete. If the threshold falls below the 95% confidence limits for the unprimed probe at center, such that threshold in the primed condition is better than in the unprimed probe-at-center condition, then undershoot has occurred. If the primed threshold falls above the 95% confidence limits for threshold at onset, then there is masking enhancement. Each subject's analysis will be presented separately.

TABLE 4.5 One-way analysis of variance for each subject with condition as the sole variable at 11 levels. Each subject showed a significant main effect of condition.

S#	Effect	df effect	Ms effect	df error	Ms error	F	p-level
1	Condition	10	42.22	90	4.92	8.59	<0.0005
2	Condition	10	61.87	90	2.73	22.64	<0.0005
3	Condition	10	32.70	90	1.42	23.06	<0.0005
4	Condition	10	91.43	90	3.97	23.06	<0.0005
5	Condition	10	73.03	90	2.84	15.09	<0.0005

Subject 1

The analysis of variance for subject 1 revealed a significant main effect of condition. Post-hoc analysis revealed no significant overshoot for this subject. She is the only subject who did not demonstrate significant overshoot in the one-way analysis of variance. Nevertheless, masking release was noted for the ipsilateral 20 and 40 msec and the bilateral 40 msec conditions, with complete release occurring only at the ipsilateral 40 msec condition. Subject 1 demonstrated masking enhancement at the contralateral 80 msec condition. Subject 1 is the only individual showing undershoot. That is, a threshold in the primed condition (ipsilateral 20 msec) that is even better than that for the unprimed probe at onset threshold.

Post-hoc results, presented in Table 4.6, revealed significant differences across primers, particularly between the ipsilateral and contralateral primers across all primer-masker gaps. This subject exhibited no

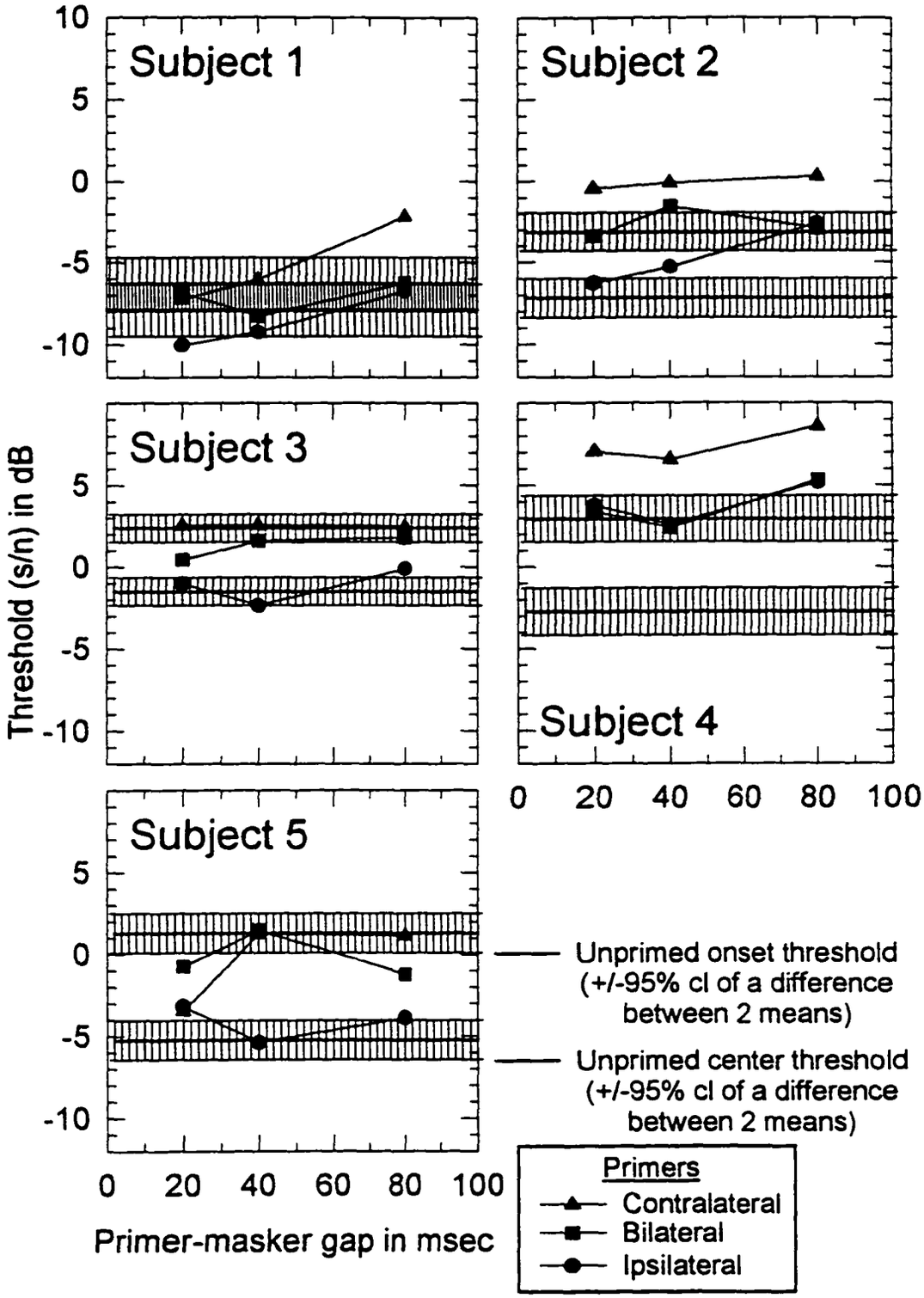


Figure 4.3 Data points show mean primed thresholds across 10 replications for each subject as a function of primer-masker gap. The dark horizontal lines show the unprimed thresholds at the onset and temporal center of the masker. The confidence limits were derived from an estimate of between-replication variance.

TABLE 4.6. Least Significant Difference Post-hoc analysis for subject 1 with condition as the sole variable at 11 levels. Numbers in bold italics indicate significant effects at the 5% level of confidence.

COND.	CENTER	ONSET	I 20	I 40	I 80	B 20	B 40	B 80	C 20	C 40	C 80
CENTER		0.10480	***0.03698***	0.19325	0.22945	0.28128	0.72498	0.09469	0.49786	0.06189	***0.00001***
ONSET	0.10479		***0.00031***	***0.00406***	0.66928	0.58055	***0.04946***	0.95990	0.34067	0.80155	***0.00007***
I 20	***0.03698***	***0.00031***		0.42198	***0.00127***	***0.00189***	0.08103	***0.00026***	***0.00629***	***0.00013***	***0.00001***
I 40	0.19325	***0.00406***	0.42198		***0.01347***	***0.01870***	0.34067	***0.00349***	***0.04946***	***0.00189***	***0.00001***
I 80	0.22945	0.66928	***0.00127***	***0.01347***		0.90000	0.12158	0.63313	0.59785	0.49786	***0.00001***
B 20	0.28128	0.58055	***0.00189***	***0.01870***	0.89998		0.15422	0.54670	0.68766	0.42198	***0.00001***
B 40	0.72498	***0.04946***	0.08103	0.34067	0.12158	0.15422		***0.04409***	0.30412	***0.02732***	***0.00001***
B 80	0.09469	0.95990	***0.00026***	***0.00349***	0.63313	0.54670	***0.04409***		0.31600	0.84063	***0.00008***
C 20	0.49786	0.34067	***0.00629***	***0.04946***	0.59785	0.68766	0.30412	0.31600		0.22945	***0.00001***
C 40	0.06189	0.80155	***0.00013***	***0.00189***	0.49786	0.42198	***0.02732***	0.84063	0.22945		***0.00017***
C 80	***0.00001***	***0.00007***	***0.00001***	***0.00001***	***0.00001***	***0.00001***	***0.00001***	***0.00008***	***0.00001***	***0.00017***	

I 20=Ipsilateral 20 msec B 20=Bilateral 20 msec C 20=Contralateral 20 msec

I 40-Ipsilateral 40 msec B 40=Bilateral 40 msec C 40=Contralateral 40 msec

I 80=Ipsilateral 80 msec B 80=Bilateral 80 msec C 80=Contralateral 80 msec

difference between ipsilateral and bilateral priming at the 40 and 80 msec primer-masker gaps and no significant difference between the bilateral and contralateral primers at the 20 and 40 msec primer-masker gaps.

The 20 and 40 msec primer-masker gaps were not significantly different from one another across all priming conditions.

A two-way analysis of variance with primer (at 3 levels) and primer-masker gap (at 3 levels) revealed significant main effects of primer type and primer-masker gaps and a significant interaction between these two variables. This analysis of variance is presented in Table 4.7.

TABLE 4.7 Two-way analysis of variance for subject #1 with primer and gap length as the two variables at 3 levels. There were significant main effects of primer and gap length and a significant primer x gap length interaction.

Effect	df effect	MS effect	df error	MS error	F	p-level
Primer	2	92.80	18	7.44	12.47	<0.0005
Gap length	2	84.62	18	5.63	15.02	<0.0005
Primer x Gap length	4	13.47	36	4.80	2.81	0.0397

Subject 2

The analysis of variance for subject 2 revealed a significant main effect of condition. Post-hoc analysis, presented in Table 4.8, revealed significant overshoot. There was significant masking release with the ipsilateral 20 and 40 msec primer-masker gaps with

TABLE 4.8. Least Significant Difference Post-hoc analysis for Subject 2 with condition as the sole variable at 11 levels. Numbers in bold italics indicate significant effects at the 5% level of confidence.

COND.	CENTER	ONSET	I 20	I 40	I 80	B 20	B 40	B 80	C 20	C 40	C 80
CENTER		***0.00001***	0.22664	***0.01293***	***0.00001***	***0.00001***	***0.00001***	***0.00001***	***0.00001***	***0.00001***	***0.00001***
ONSET	***0.00001***		***0.00005***	***0.00415***	0.45884	0.71078	***0.03586***	0.73603	***0.00049***	***0.00009***	***0.00001***
I 20	0.22664	***0.00005***		0.19057	***0.00001***	***0.00019***	***0.00001***	***0.00001***	***0.00001***	***0.00001***	***0.00001***
1 40	***0.01293***	***0.00415***	0.19057		***0.00039***	***0.01181***	***0.00001***	***0.00148***	***0.00001***	***0.00001***	***0.00001***
1 80	***0.00001***	0.45884	***0.00001***	***0.00039***		0.26742	0.16903	0.68585	***0.00505***	***0.00119***	***0.00017***
B 20	***0.00001***	0.71078	***0.00019***	***0.01181***	0.26742		***0.01414***	0.47945	***0.00013***	***0.00002***	***0.00001***
B 40	***0.00001***	***0.03586***	***0.00001***	***0.00001***	0.16903	***0.01414***		0.07645	0.14027	0.05928	***0.01293***
B 80	***0.00001***	0.73603	***0.00001***	***0.00148***	0.68585	0.47945	0.07645		***0.00148***	***0.00031***	***0.00004***
C 20	***0.00001***	***0.00049***	***0.00001***	***0.00001***	***0.00505***	***0.00013***	0.14027	***0.00148***		0.06371	0.29730
C 40	***0.00001***	***0.00009***	***0.00001***	***0.00001***	***0.00119***	***0.00002***	0.05293	***0.00031***	0.63705		0.56681
C 80	***0.00001***	***0.00001***	***0.00001***	***0.00001***	***0.00017***	***0.00001***	***0.01293***	***0.00004***	0.29730	0.56681	

I 20=Ipsilateral 20 msec B 20=Bilateral 20 msec C 20=Contralateral 20 msec

I 40-Ipsilateral 40 msec B 40=Bilateral 40 msec C 40=Contralateral 40 msec

I 80=Ipsilateral 80 msec B 80=Bilateral 80 msec C 80=Contralateral 80 msec

complete release at the ipsilateral 20 msec condition. Significant masking enhancement was noted with the bilateral 40 msec and contralateral 20, 40 and 80 msec primer-masker gaps. These effects are illustrated in Figure 4.3.

Examination of differences across primer-masker gaps for each primer revealed significant differences between the 20 and 80 msec and between the 40 and 80 msec primer-masker gaps for ipsilateral priming. For bilateral priming, there was a significant difference only between the 20 and 40 msec primer-masker gaps. There were no significant differences across gap lengths for the contralateral primer. For this particular subject, gap length has no effect on thresholds for contralateral priming.

Post-hoc testing revealed significant differences across all primers. In particular, the ipsilateral and contralateral primers were significantly different from one another across all primer-masker gaps. The ipsilateral and bilateral primers were not significantly different from one another at the 80 msec primer-masker gap, while the contralateral and bilateral primers were not significantly different from one another at the 40 msec primer-masker gap.

A two-way analysis of variance with primer (at 3 levels) and primer-masker gap (at 3 levels) revealed significant main effects of primer type and primer-masker gap and a significant interaction between these two variables. This two-way analysis of variance is shown in Table 4.9.

TABLE 4.9 Two-way analysis of variance for subject #2 with primer and gap length as the two variables at 3 levels. There were significant main effects of primer and gap length and a significant primer x gap length interaction.

Effect	df effect	MS effect	df error	MS error	F	p-level
Primer	2	162.04	18	2.31	70.23	<0.0005
Gap length	2	21.34	18	3.82	5.59	<0.0005
Primer x Gap length	4	13.02	36	3.11	4.18	<0.0005

Subject 3

Subject 3 exhibited significant overshoot and significant masking release for the ipsilateral 20, 40 and 80 and bilateral 20 msec primer-masker gaps. Masking release was complete at the ipsilateral 20 and 40 msec gaps. Subject 3 exhibited no masking enhancement for any primer condition. Threshold for each primer as a function of primer-masker gap is presented in Figure 4.3.

Post-hoc results, presented in Table 4.10, revealed significant differences across primers, most particularly between the ipsilateral and contralateral primers and between the ipsilateral and bilateral primers. The bilateral and contralateral primers were not

TABLE 4.10. Least Significant Difference Post-hoc analysis for Subject 3 with condition as the sole variable at 11 levels. Numbers in bold italics indicate significant effects at the 5% level of confidence.

COND.	CENTER	ONSET	I 20	I 40	I 80	B 20	B 40	B 80	C 20	C 40	C 80
CENTER		***0.00001***	0.37477	0.11394	***0.01007***	***0.00042***	***0.00001***	***0.00001***	***0.00001***	***0.00001***	***0.00001***
ONSET	***0.00001***		***0.00001***	***0.00001***	***0.00001***	***0.00050***	0.14904	0.28312	0.74319	0.70811	0.81494
I 20	0.37477	***0.00001***		***0.01468***	0.08580	***0.00681***	***0.00001***	***0.00001***	***0.00001***	***0.00001***	***0.00001***
1 40	0.11294	***0.00001***	***0.01468***		***0.00006***	***0.00001***	***0.00001***	***0.00001***	***0.00001***	***0.00001***	***0.00001***
1 80	***0.01007***	***0.00001***	0.08580	***0.00006***		0.30444	***0.00194***	***0.00058***	***0.00001***	***0.00001***	***0.00001***
B 20	***0.00042***	***0.00050***	***0.00681***	***0.00001***	0.30444		***0.03346***	***0.01297***	***0.00016***	***0.00013***	***0.00022***
B 40	***0.00001***	0.14904	***0.00001***	***0.00001***	***0.00194***	***0.03346***		0.70811	0.07779	0.07041	0.09447
B 80	***0.00001***	0.28312	***0.00001***	***0.00001***	***0.00058***	***0.01297***	0.07081		0.16245	0.14904	0.19200
C 20	***0.00001***	0.74319	***0.00001***	***0.00001***	***0.00001***	***0.00016***	0.07779	0.16245		0.96266	0.92540
C 40	***0.00001***	0.70811	***0.00001***	***0.00001***	***0.00001***	***0.00013***	0.07041	0.14904	0.96266		0.88831
C 80	***0.00001***	0.81494	***0.00001***	***0.00001***	***0.00001***	***0.00022***	0.09447	0.19200	0.92540	0.88831	

I 20=Ipsilateral 20 msec B 20=Bilateral 20 msec C 20=Contralateral 20 msec

I 40-Ipsilateral 40 msec B 40=Bilateral 40 msec C 40=Contralateral 40 msec

I 80=Ipsilateral 80 msec B 80=Bilateral 80 msec C 80=Contralateral 80 msec

significantly different from one another at the 40 and 80 msec primer-masker gaps.

With respect to differences across the primer-masker gaps, 20 and 40 msec were significantly different from one another and 40 and 80 msec were significantly different from one another ipsilaterally. For the bilateral primer, the 20 and 40 msec gaps were significantly different from one another as were the 20 and 80 msec gaps. Primer-masker gaps did not significantly differ from one another for the contralateral primer.

A two-way analysis of variance with primer (at 3 levels) and primer-masker gap (at 3 levels) revealed significant main effects of primer type and primer-masker gap and a significant interaction between these two variables. This analysis of variance is shown in Table 4.11.

TABLE 4.11 Two-way analysis of variance for subject #3 with primer and gap length as the two variables at 3 levels. There were significant main effects of primer and gap length and a significant primer x gap interaction.

Effect	df effect	MS effect	df error	MS error	F	p-level
Primer	2	106.18	18	2.39	44.44	<0.0005
Gap length	2	5.90	18	1.04	5.65	<0.0005
Primer x Gap length	4	6.11	36	1.26	4.84	<0.0005

Subject 4

Subject 4 demonstrated significant overshoot, but was the only subject who had no masking release under any priming condition. She demonstrated significant masking enhancement at the ipsilateral 80, bilateral 80 and contralateral 20, 40 and 80 msec locations. She is the only subject to exhibit masking enhancement with an ipsilateral primer. Threshold for each primer as a function of primer-masker gap is presented in Figure 4.3.

Post-hoc results, presented in Table 4.12, revealed significant differences between the ipsilateral and contralateral primers and significant differences between the bilateral and contralateral primers at all primer-masker gaps. Ipsilateral and bilateral primers were not significantly different from one another across all gap locations.

With respect to differences across primer-masker gaps, post-hoc results revealed a significant difference between the 40 and 80 msec gaps for the ipsilateral and contralateral primers. For the bilateral primers, there was a significant difference between the 20 and 80 msec gaps and between the 40 and 80 msec gaps.

A two-way analysis of variance with primer (at 3 levels) and primer-masker gap (at 3 levels), revealed

TABLE 4.12. Least Significant Difference Post-hoc analysis for Subject 4 with condition as the sole variable at 11 levels. Numbers in bold italics indicate significant effects at the 5% level of confidence.

COND.	CENTER	ONSET	I 20	I 40	I 80	B 20	B 40	B 80	C 20	C 40	C 80
CENTER		***0.00001***	***0.00001***	***0.00001***	***0.00001***	***0.00001***	***0.00001***	***0.00001***	***0.00001***	***0.00001***	***0.00001***
ONSET	***0.00001***		0.34239	0.67469	***0.01327***	0.59508	0.55697	***0.00840***	***0.00001***	***0.00010***	***0.00001***
I 20	***0.00001***	0.34239		0.17236	0.11944	0.67469	0.12609	0.08518	***0.00044***	***0.00246***	***0.00001***
I 40	***0.00001***	0.67469	0.17236		***0.00408***	0.34239	0.86662	***0.00246***	***0.00001***	***0.00001***	***0.00001***
I 80	***0.00001***	***0.01327***	0.11944	***0.00408***		***0.04927***	***0.00246***	0.86662	***0.04061***	0.12609	***0.00025***
B 20	***0.00001***	0.59508	0.67469	0.34239	***0.04927***		0.26445	***0.03330***	***0.00010***	***0.00064***	***0.00001***
B 40	***0.00001***	0.55698	0.12609	0.34239	***0.00246***	0.26445		***0.00146***	***0.00001***	***0.00001***	***0.00001***
B 80	***0.00001***	***0.00840***	0.08518	0.86662	0.86662	***0.03330***	***0.00146***		0.05945	0.17236	***0.00044***
C 20	***0.00001***	***0.00001***	***0.00044***	***0.00246***	***0.04061***	***0.00010***	***0.00001***	0.05945		0.59507	0.08518
C 40	***0.00001***	***0.00010***	***0.00246***	***0.00001***	0.12609	***0.00064***	***0.00001***	0.17236	0.59507		***0.02535***
C 80	***0.00001***	***0.00001***	***0.00001***	***0.00002***	***0.00025***	***0.00001***	***0.00001***	***0.00044***	0.08518	***0.02535***	

I 20=Ipsilateral 20 msec B 20=Bilateral 20 msec C 20=Contralateral 20 msec

I 40-Ipsilateral 40 msec B 40=Bilateral 40 msec C 40=Contralateral 40 msec

I 80=Ipsilateral 80 msec B 80=Bilateral 80 msec C 80=Contralateral 80 msec

significant main effects of primer type and primer-masker gaps, but not a significant primer X gap interaction. This two-way analysis of variance is presented in Table 4.13. Subject 4 is the only subject who demonstrated no significant primer X gap interaction.

TABLE 4.13 Two-way analysis of variance for subject #4 with primer and gap length as the two variables at 3 levels. There were significant main effects of primer and gap length, but not a significant interaction between the two variables.

Effect	df effect	MS effect	df error	MS error	F	p-level
Primer	2	130.62	18	4.20	31.12	<0.0005
Gap length	2	49.13	18	3.01	16.31	<0.0005
Primer x Gap length	4	0.72	36	2.97	0.24	0.9132

Subject 5

Subject 5 demonstrated significant overshoot and significant masking release at the ipsilateral 20, 40 and 80, bilateral 20, and contralateral 20 msec gaps. The masking release was complete for the ipsilateral 40 and 80 and contralateral 20 msec gaps. Like subject 3, she showed no significant masking enhancement for any condition. She is the only subject demonstrating masking release (which is complete) with a contralateral primer. Threshold for each primer as a function of primer-masker gap is presented in Figure 4.3.

Post-hoc results, presented in Table 4.14, revealed significant differences across primers, most particularly between the ipsilateral and bilateral primers which

TABLE 4.14. Least Significant Difference Post-hoc analysis for Subject 5 with condition as the sole variable at 11 levels. Numbers in bold italics indicate significant effects at the 5% level of confidence.

COND.	CENTER	ONSET	I 20	I 40	I 80	B 20	B 40	B 80	C 20	C 40	C 80
CENTER		***0.00001***	***0.03772***	0.89918	0.16569	***0.00002***	***0.00001***	***0.00010***	0.07064	***0.00001***	***0.00001***
ONSET	***0.00001***		***0.00002***	***0.00001***	***0.00001***	***0.04003***	0.85923	***0.01114***	***0.00001***	0.95958	0.87917
I 20	***0.03772***	***0.00002***		***0.02782***	0.47863	***0.01561***	***0.00001***	0.05350	0.78050	***0.00002***	***0.00003***
1 40	0.89918	***0.00001***	***0.02782***		0.13087	***0.00001***	***0.00001***	***0.00006***	0.05650	***0.00001***	***0.00001***
1 80	0.16569	***0.00001***	0.47863	0.13087		***0.00204***	***0.00001***	***0.00905***	0.66680	***0.00001***	***0.00001***
B 20	***0.00002***	***0.04003***	***0.01561***	***0.00001***	***0.00204***		***0.02614***	0.61256	***0.00732***	***0.04502***	0.05661
B 40	***0.00001***	0.85923	***0.00001***	***0.00001***	***0.00001***	***0.02614***		***0.00682***	***0.00001***	0.81963	0.74192
B 80	***0.00010***	***0.01114***	0.05350	***0.00006***	***0.00905***	0.61256	***0.00682***		***0.02782***	***0.01277***	***0.01668***
C 20	0.07064	***0.00001***	0.78050	0.05350	0.66680	***0.00762***	***0.00001***	***0.02782***		***0.00001***	***0.00001***
C 40	***0.00001***	0.95958	***0.00002***	***0.00001***	***0.00001***	***0.04502***	0.81963	***0.01277***	***0.00001***		0.91927
C 80	***0.00001***	0.87917	***0.00003***	***0.00001***	***0.00001***	0.05661	0.74192	***0.01668***	***0.00001***	0.91727	

I 20=Ipsilateral 20 msec B 20=Bilateral 20 msec C 20=Contralateral 20 msec

I 40-Ipsilateral 40 msec B 40=Bilateral 40 msec C 40=Contralateral 40 msec

I 80=Ipsilateral 80 msec B 80=Bilateral 80 msec C 80=Contralateral 80 msec

were significantly different from one another at all primer-masker gaps. There were no significant differences between the ipsilateral and contralateral primers for the 20 msec gap and between the bilateral and contralateral primers for the 40 msec gap. Subject 5 is the only subject exhibiting essentially identical results with a contralateral and ipsilateral primer (at 20 msec).

With respect to differences across gap lengths for each of the priming conditions, the 20 and 40 msec gap lengths were significantly different from one another ipsilaterally. There were significant differences between the 20 and 40 msec gap lengths and between the 40 and 80 msec gap lengths bilaterally. Finally, contralateral priming revealed significant differences between the 20 and 40 msec gap lengths and between the 20 and 80 msec gap lengths.

A two-way analysis of variance with primer (at 3 levels) and primer-masker gap (at 3 levels) revealed significant main effects of primer type and primer-masker gaps and a significant interaction between these two variables. This analysis of variance is shown in Table 4.15.

TABLE 4.15 Two-way analysis of variance for subject #5 with primer and gap length as the two variables at 3 levels. There were significant main effects of primer and gap length and a significant primer x gap length interaction.

Effect	df effect	MS effect	df error	MS error	F	p-level
Primer	2	150.71	18	7.72	19.53	<0.0005
Gap length	2	19.80	18	3.98	4.98	<0.0005
Primer x Gap length	4	42.99	36	4.34	9.91	<0.0005

Summary of results

The individual subject results with respect to masking release and enhancement for each primer and gap length are summarized in Table 4.16.

While the five subjects exhibited different patterns, several characteristics were common to all. They are as follows:

1. The ipsilateral 20 and 40 msec gap conditions produced no masking enhancement in any subject. While subject 4 did not exhibit masking release, neither did she exhibit masking enhancement. Her ipsilateral 20 and 40 msec gap conditions were not significantly different from those for the unprimed overshoot.

2. The bilateral 20 msec condition produced no masking enhancement in any subject.

3. The contralateral 40 and 80 msec condition produced no masking release in any subject and the contralateral 20 msec condition produced masking release in only one subject (#5).

4. As with the group results, there was a trend for poorer thresholds with increasing primer-masker gap for all primers. While there were several instances in which the 40 msec primer-masker gap produced better thresholds than the 20 msec primer-masker gap, this difference was usually not significant.

5. Also, as with the group results, there was a tendency for poorer threshold with further perceived distance of the primer from the masker. Therefore, masked thresholds in the presence of ipsilateral priming were better than masked threshold in the presence of bilateral priming and masked thresholds in the presence of bilateral priming were better than masked threshold in the presence of contralateral priming.

In summary, the ipsilateral 20 and 40 msec gap primer produced masking release or had no significant effect on the probe threshold. In no instance did it produce masking enhancement in any subject. Conversely, the contralateral 40 and 80 msec primer produced no masking release in any subject and only one subject (#5) exhibited masking release with the contralateral 20 msec gap primer. Lastly, the bilateral 20 msec gap condition produced no extra masking in any subject and only one subject (#2) exhibited extra masking with the bilateral

40 msec primer and one subject (#4) with the bilateral 80 msec primer.

Table 4.16 Summary of the post-hoc result for each subject. The first column shows masking release (an improvement in primed over unprimed threshold), while the second column shows masking enhancement (a deterioration in primed over unprimed threshold).

SUBJECT	MASKING RELEASE	MASKING ENHANCEMENT
1*	Ipsilateral 20 and 40 msec Bilateral 40 msec	contralateral 80 msec
2	Ipsilateral 20 and 40 msec	bilateral 40 msec Contralateral 20, 40 and 80 msec,
3	Ipsilateral 20, 40 and 80 Bilateral 20 msec	none
4	none	Ipsilateral 80 msec, Bilateral 80 msec Contralateral 20,40 and 80 msec
5	Ipsilateral 20, 40 and 80 msec Bilateral 20 and 80 msec, Contralateral 20 msec	none

* The only subject exhibiting no overshoot.

CHAPTER 5
DISCUSSION

The general purpose of this study was to determine the relative contributions of peripheral and central processes to the masking overshoot phenomenon.

As stated in the introduction, masking overshoot is the phenomenon, whereby the threshold for a probe located at the onset of a broadband noise is poorer than when the probe is located at the temporal center of a broadband noise. The difference between these two thresholds is the amount of masking overshoot.

Masking release (improvement in the "probe at onset" threshold) has been found when an ipsilateral priming noise is presented before the masker containing a probe tone. Researchers have theorized that there is peripheral, neural adaptation to the primer, hence the improvement in the threshold of the probe at onset. However, recent studies have found that this same phenomenon exists when the primer is presented to the contralateral ear. Peripheral adaptation cannot be responsible for this phenomenon since the opposite cochlea is stimulated by the primer. Turner and Doherty (1995) have theorized that the efferent system has an effect on the active process of the cochlea, such that the contralateral primer also provides masking release.

In an attempt to discover whether this phenomenon is due to peripheral factors, central factors or a combination of the two, this experiment was concerned with the different effects of ipsilateral, contralateral and bilateral priming on the masking overshoot effect. It was hypothesized that if there was no statistically significant difference between the ipsilateral and bilateral priming conditions, and if the contralateral priming condition produced results which were not significantly different from the unprimed "probe-at-onset" threshold, then a peripheral basis would account for the masking overshoot effect. Any other combination of results would not support a purely peripheral basis for masking overshoot and its release. If thresholds in the presence of contralateral priming are significantly different from the unprimed "probe-at-onset" threshold, then processes above the periphery are exerting an effect on masking overshoot.

Peripheral explanation for overshoot and its release

If peripheral factors were responsible for masking overshoot and its release, then when the probe is at temporal center of the masker, neural fibers in the cochlea, auditory nerve or cochlear nucleus will adapt to the masker. After the peripheral mechanism has been

stimulated by the masker for 200 msecs, some degree of adaptation may occur, so when a probe tone is presented at this point in the masker, the peripheral mechanism is more able to detect the change. As single auditory nerve fibers are characterized by a large onset response to auditory stimuli, with a decrease in response thereafter, a change in stimulus in the form of a probe tone occurring 200 msecs *after* the onset of the masker (rather than *at* the onset of the masker) would be more likely to result in a response. Conversely, when the probe occurs at the onset of the masker, no adaptation to the masker has occurred, so the probe at onset is less detectable than the probe at center.

When an ipsilateral primer is presented before the masker, the primer serves to "pre-adapt" the peripheral mechanism, so that when the masker containing the probe located at onset follows, threshold for the probe is better than it was in the unprimed condition.

Therefore, if this peripheral adaptation was the sole factor underlying overshoot, ipsilateral and bilateral priming would not be significantly different from one another, because both primers would be directly stimulating the peripheral mechanism and masking release

would occur. In this instance, masking release would vanish for contralateral priming.

"Central" explanation for overshoot and its release

If masking overshoot was determined by centrally-mediated processes, then when the probe is both preceded and followed by a masker, the central mechanism is most able to differentiate masker alone from masker plus probe. However, when the probe is preceded by silence and followed by masker, the central mechanism is less capable of distinguishing between "silence followed by masker" and "silence followed by probe plus masker", hence the overshoot. Providing a sample of the noise in the form of a primer before the probe gives the central mechanism a "masker-alone" reference against which to compare the "probe and masker" or "masker alone" signals, hence the release from overshoot.

If this explanation is correct, a contralateral primer might be expected to produce overshoot release, though perhaps less effectively than ipsilateral priming, because it is in the opposite ear. Because the synchronous bilateral primer is perceived between the ears, any masking release would be expected to fall between the ipsilateral and contralateral release.

Pickles (1993) reports that auditory cortical neurons are more responsive to change than to ongoing stimulation and auditory cortical neurons tend to respond to stimulus onset and/or offset.

Alternative "peripheral" explanation

While differences between ipsilateral and bilateral priming would not support a purely peripheral basis for masking overshoot and its release, a small caveat is necessary at this point. It is possible that ipsilateral and bilateral primers would produce different results, while masking overshoot may still be the result of peripheral adaptation. The introduction of a primer, either bilaterally or contralaterally excites auditory areas at the superior olivary complex and beyond up to the primary auditory cortex and cerebral cortex. This excitation may cause the efferent system to interfere with the peripheral response to the probe tone in the masker. In this case, masking overshoot and its release may truly be a peripheral phenomenon, but prior activation of the efferent system precludes the peripheral mechanism from acting as it normally would. So, while differences between ipsilateral and bilateral priming would not support a purely peripheral basis for masking overshoot and its release, it also cannot be

concluded that masking overshoot and its release are not partly a peripheral phenomena.

General areas for discussion

This discussion will attempt to answer several questions. They are:

1) Are these results representative of the psychophysical capabilities of these subjects?

2) Do these subjects manifest overshoot?

3) What inferences can we draw about the psychophysical manifestations of overshoot with respect to the general population?

4) What are the effects of the different primers and the different primer-masker gaps?

5) What inferences can we draw about the psychophysical manifestations of masking release and masking enhancement with respect to the general population?

6) Do the results support a purely peripheral theory of masking overshoot and masking overshoot release or is there evidence of contributions from a central mechanism?

The discussion will deal with each of these questions separately.

Are these results representative of the psychophysical capabilities of these subjects?

While all of the subjects employed in this study had some degree of experience with psychophysical experiments, some subjects had more experience than others. Unprimed thresholds for "probe at onset" and "probe at center" were obtained both before and after the primed thresholds. It was expected that the initial unprimed thresholds would serve as a training period so that thresholds would be more stable at the start of data collection for the primed conditions. The group standard deviation across all conditions, ranged from 2.77 dB for the unprimed "probe-at-center" condition to 5.48 dB for the contralateral 20 msec primer-masker gap. Individual standard deviations were smaller. While subjects were significantly different from one another with respect to absolute threshold across both the unprimed and primed conditions, standard deviations were similar across the five subjects. Largest and smallest standard deviations for the five subjects along with the largest and smallest group standard deviation are presented in Table 5.1. As the table shows, individual subject variability was similar across subjects and greater or lesser variability was not peculiar to any one condition. Therefore,

although subjects demonstrated different absolute thresholds across the 11 conditions, with respect to variability the group appeared to homogenous.

Table 5.1 Smallest and largest standard deviations and conditions for individual subjects and for the group.

S#	Smallest S.D. and condition	Largest S.D. and condition
1	0.53dB-unprimed probe at center	3.31dB-bilateral 40 msec
2	0.76dB-ipsilateral 20 msec	2.67dB-contralateral 40 msec
3	0.44dB-contralateral 40 msec	2.35dB-ipsilateral 40 msec
4	1.09dB-ipsilateral 80 msec	3.28dB-unprimed probe at onset
5	0.72dB-bilateral 40 msec	3.48dB-ipsilateral 40 msec
group	2.77dB-unprimed probe at center	5.48dB-contralateral 20 msec

As was stated previously, data for the unprimed conditions were obtained both before and after data collection for the primed conditions. It was the final unprimed threshold measurements (obtained after the data collection for the primed condition) which were included in the final analysis. This raises the question of whether or not there were significant differences in the initial and final unprimed threshold measurements and whether these differences would lead to different conclusions.

Appendix C.1 contains figures comparing the means for the initial and final unprimed thresholds for probe at center and probe at onset. As stated previously, unprimed thresholds were obtained before data collection for the primed conditions (replication 1), and after data collection for the primed conditions (replication 2).

Appendix C.1 illustrates mean thresholds for the first and second replication for the unprimed probe-at-center (top graph) and unprimed probe-at-onset for individual subjects and for the group. While it is evident that there are differences between the first and second replications for both the unprimed probe-at-center and unprimed probe-at-onset, in some cases thresholds improved, while in other instances thresholds became poorer. With respect to the unprimed probe-at-center threshold, 4 out of the 5 subjects exhibited better thresholds with the second replication. For the unprimed probe-at-onset, only 2 of the 4 subjects showed improvement with the second replication.

Appendix C.2 shows the mean overshoot for individual subjects and for the group for the first and second replications of the unprimed conditions. Overshoot magnitude increased for 3 of the 5 subjects, declined for 2 of the 5 subjects and remained unchanged for the group.

One-way analyses of variance with replication as the sole variable at 2 levels for the unprimed probe-at-center condition for the group and for individual subjects are presented in Appendices C3.1 and C3.2 respectively. For the group analysis, subject-to-subject differences provided the error variance, while for

individual subjects, trial-to-trial differences provided the error variance. The group analysis showed no significant difference for the two replications for the probe-at-center condition. For the individual analyses, two subjects (# 3 and 5) exhibited significant differences between the two replications.

One-way analyses of variance with replication as the sole variable at two levels for the unprimed probe-at-onset for the group and for individual subjects are presented in Appendices C3.3 and C3.4 respectively. The group analysis showed no significant difference for the two replications. The unprimed probe-at-onset threshold was significantly different across the two replications for subjects 4 and 5.

While significant differences are noted between the two replications for the unprimed probe-at-onset and unprimed-probe at center thresholds for some subjects, it is hard to ascribe these changes to learning. These changes may be indicative of different listening strategies employed by the subjects during the study. These different listening strategies may have varied from subject to subject and from test session to test session for the same subject. Subjects 3 and 4 showed significant differences with respect to overshoot across the two

replications. For subject 3, an overshoot value of 0.7dB was obtained with the first replication, while an overshoot value of 3.63dB was obtained with the second replication. For subject 4, overshoot values of 8.96 and 5.68 were obtained for the first and second replications, respectively. This significant increase in overshoot is due primarily to the significant improvement in the unprimed probe-at-onset threshold for the second replication (6.98dB for replication 1 vs. 2.93dB for replication 2). It should be noted that subjects had more exposure to the probe at onset, as this was the threshold tested in the primed conditions.

If the initial unprimed threshold values were employed for data analysis for these two subjects, subject 4 may have exhibited some degree of masking release with the ipsilateral and bilateral 20 and 40 msec primers, but masking enhancement would still be evident with the contralateral 80 msec primer. In this respect, subject 4's data would appear more consistent with the rest of the group. Subject 3 would likely not demonstrate significant overshoot and would not have significant masking release with the bilateral 20 msec primer. For the remaining three subjects, using the unprimed thresholds from the first replication would not alter the

results. Therefore, use of the last 10 thresholds of the unprimed conditions from the second replication seems justifiable. It should be noted that inter- and intra-subject variability is common in experiments of overshoot. This has been reported frequently in prior experiments (Zwicker, 1965, Fastl, 1976a, 1976b, 1979, Bacon and Viemeister, 1985, Bacon and Moore, 1986, Bacon 1990).

Do these subjects manifest overshoot?

As will be recalled, all subjects demonstrated significant overshoot in the group analysis. The subjects' overshoot ranged from 1.6 to 6.6 dB with a mean of 4.3dB. The subjects were significantly different from one another, but all demonstrated significant overshoot. These findings are consistent with other studies (Zwicker, 1965, Fastl, 1976a, 1976b, 1979, Bacon and Viemeister, 1985, Bacon and Moore, 1986, Bacon and Moore, 1986b and Bacon, 1990), where great individual differences were found within and across overshoot studies with overshoot ranging from 2-20dB. It should be noted that these studies differed from the present study with respect to noise bandwidth, frequency, temporal location, duration and frequency of the probe, intensity of the probe and masker and sample size. The differences

in these variables could account for the smaller range of overshoot observed among the subjects in the present study.

With respect to individual subjects, it should be noted that subject 1 did not demonstrate significant overshoot at the 5% level of confidence, but did have significant overshoot at the 10% level of confidence. However, when only the unprimed data were examined, the overshoot effect reached the 5% level of significance for this subject. In other words, the chances that the difference between measured thresholds at onset and center was attributable to test-retest variability was less than 5%. The fact that the same difference did not reach the 5% level when all data were used to estimate test-retest variability tells us that this subject had more consistent thresholds in the umprimed conditions. In Turner's and Doherty's (1995) study, two subjects did not exhibit significant overshoot. Their study used parameters which were close to those used in the present study (i.e. same probe frequency and same probe and masker duration).

What inferences can we draw about the psychophysical manifestations of overshoot with respect to the general population?

All of the subjects in the present study exhibited overshoot. While the range of overshoot magnitude was not as large as seen in previous studies, great individual variability was present. This variability is common to studies of overshoot. Previous studies (Turner and Doherty, 1995) have reported subjects who have exhibited no overshoot. For the means of the population represented by these subjects, and under the conditions of this experiment, significant overshoot is present and the results obtained with this group of subjects appears to be consistent with other studies of overshoot.

What are the effects of the different primers and the different primer-masker gaps?

With respect to the group data, ipsilateral priming (at the 20 and 40 msec primer-masker gaps) produced masking release, bilateral priming had no significant effect on thresholds and contralateral priming (at the 80 msec primer-masker gap) produced masking enhancement. Additionally, there tended to be poorer threshold with increased primer-masker gap for all primers. While the 20 and 40 msec primer-masker gaps were not always

significantly different from one another, there were significant differences found between the 20 and 80 msec primer-masker gaps and the 40 and 80 msec primer-masker gaps. The ipsilateral findings in the present study are similar to those of Bacon and Smith (1991). In their study, priming reduced the threshold at onset by about 3dB. In the present study ispilateral priming reduced threshold by 2.8, 3.3 and 1dB for the 20, 40 and 80 msec primer-masker gaps respectively. In the present study, there was significant masking release with the ipsilateral 20 and 40 msec primer-masker gaps and no significant difference between the ipsilateral 80 msec gap and the unprimed "probe-at-onset" threshold. However, it should be noted that Bacon and Smith (1991) used a notched noise masker, a primer with varying bandwidths and a probe of only 10 msec duration. In addition the primer and the masker were continuous. In a later experiment within the same study, Bacon and Smith examined the same effect with primer-masker gaps of 1, 25, 50, 100 and 200 msec. For the 1 msec gap, threshold at onset was not significantly different from the unprimed probe-at-center threshold, but threshold increased as primer-masker gap increased. These findings are consistent with the present study, where the

ipsilateral 80 msec threshold was poorer than the 20 and 40 msec gap thresholds. With respect to differences with increasing primer-masker gap, a similar pattern was found with the contralateral and bilateral primers.

The effects of contralateral priming are contrary to those found by Turner and Doherty, (1995). In the present study, thresholds in the presence of contralateral priming became poorer by 0.3, 1.5 and 2.7dB for the 20, 40 and 80 msec primer-masker gaps respectively. While the decline at 20 and 40 msec was not significantly different from the unprimed probe-at-onset condition, the 80 msec primer-masker gap resulted in significant masking enhancement. In Turner's and Doherty's study, contralateral priming reduced overshoot by about 5dB with reductions as great as 10dB. Turner's and Doherty's study used a primer-masker gap of 10 msec, while the smallest primer-masker gap in the present study was 20 msec. As there were decreased effects of contralateral priming with shorter primer-masker gaps in the present study, it is possible that masking release may have occurred had a smaller primer-masker gap been used. The results in the present study are more similar to those of Kidd and Wright who found no masking release when a 150 msec contralateral forward fringe was added to

a 22 msec broadband noise. However, the stimuli used in Kidd's and Wright's study were quite different from the stimuli used in the present study. Kidd and Wright used a lower frequency probe (1khz.) and a shorter duration probe and masker.

Bilateral priming reduced the probe-at-onset threshold by 0.8, 0.3, and 0.1dB for the 20, 40 and 80 msec primer-masker gaps. As these thresholds were not significantly different from the unprimed "probe-at-onset" threshold, it cannot be concluded that the bilateral primer produced masking release or masking enhancement. This finding is contrary to that of Kidd's and Wright's study where bilateral forward masker fringes produced masking release, although not as great as that found with the ipsilateral forward masker fringes. However, as was stated previously the stimuli used in Kidd's and Wright's study was quite different from the stimuli used in the present study.

Looking at the effects of ipsilateral priming alone would support a peripheral theory of masking overshoot and its release. Threshold improves in the presence of an ipsilateral primer and the effect declines as primer-masker gap increases. However, bilateral priming has no effect on threshold (there is neither masking release nor

masking enhancement), indicating that the contralateral portion of the bilateral primer is exerting an effect on the probe threshold. Additionally, the ipsilateral and bilateral primers are significantly different from one another. Therefore, the results do not support a purely peripheral theory of masking overshoot and its release. Given the fact that ipsilateral and bilateral priming produced significantly different results, a theory based at least partly on central processes is more likely. Contralateral priming produced masking enhancement, which would also not support a purely peripheral theory of masking overshoot and its release.

While there were significant subject-to-subject differences, the trend of poorer threshold with perceived distance of the primer from the test ear and poorer threshold with increasing primer-masker gap holds true for individual subjects as well. While some subjects did not exhibit significant masking enhancement (subjects 3 and 5), one subject did not exhibit significant masking release (subject 4), and one subject (subject 1) exhibited undershoot (a primed threshold that was significantly better than the unprimed "probe-at-center" threshold), the general pattern is the same across subjects. That is; ipsilateral priming produced better

thresholds than bilateral priming and bilateral priming produced better thresholds than contralateral priming. There is also a trend towards poorer thresholds with increasing primer masker-gap. While there are instances in which the 40 msec primer-masker gap produced better thresholds than the 20 msec primer-masker gap (subjects 3 and 5 exhibited poorer thresholds with the ipsilateral 20 msec primer-masker gap than with the 40 msec primer-masker gap and subject 1 exhibited poorer thresholds with the bilateral 20 msec than the bilateral 40 msec primer-masker gap), the differences were not significant.

The reason for the phenomenon of undershoot noted for subject 1, may be that the original assumption of priming having no effect on the "probe at center" threshold is erroneous. If a peripheral theory of masking overshoot and its release were certain, then the primer would not be expected to have an effect on the "probe-at center" threshold. However, if processes at the level of the superior olivary complex and beyond are responsible for masking overshoot and its release or if processes at the level of the superior olivary complex and beyond interfere with masking overshoot and its release, it might be expected to have an effect or interfere with the "probe-at-center" threshold as well as the "probe-at-

onset" threshold. Follow-up studies should examine the possibility that "probe-at-center-" thresholds are sensitive to priming.

Overall, for 4 of the 5 subjects, ipsilateral and bilateral priming were significantly different from one another. This finding would not support a purely peripheral theory for masking overshoot and its release. One of the subjects (#4) exhibited bilateral and ipsilateral thresholds which were not significantly different from one another. This finding would tend to support a peripheral theory of masking overshoot and its release, at least for this subject. However, this subject exhibited significant masking enhancement with all of the contralateral primers indicating that processes at the superior olivary complex and beyond are exerting an effect on the cochlea of the opposite ear. As stated previously two explanations for this outcome are possible:

1) Masking overshoot is a peripheral phenomenon (as evidenced by the identical results with bilateral and ipsilateral priming). The ipsilateral primer and the ipsilateral portion of the bilateral primer "pre-adapt" the neurons in the cochlea, auditory nerve or cochlea nucleus. Any effect the contralateral portion of the

bilateral primer would have on cochlear mechanics is offset by the presence of the ipsilateral portion of the bilateral primer. When only the contralateral primer is present, no "pre-adaptation" takes place as the primer is in the ear opposite to the masker and probe. Stimulation of the superior olivary complex or processes higher in the auditory system, possibly as high as the cerebral cortex exert an effect on the active process of the cochlea, such that it interferes with the traveling wave along the basilar membrane, precluding "pre-adaptation" of neurons in the cochlea, auditory nerve or cochlea nucleus. Consequently, threshold becomes poorer. Evidence for such a phenomenon has been provided by Buno (1978), who showed that stimulation of one ear reduced the response of auditory nerve fibers arising from the other ear.

2) Masking overshoot is a purely central phenomenon. Stimulation of the superior olivary complex or centers higher up in the auditory system to the level of the auditory cortex stimulates the opposite cochlea. Therefore, presenting a contralateral primer to one ear will stimulate neurons at the level of the superior olivary complex or beyond and reduce the response to stimuli at the opposite ear. In the case of an

ipsilateral primer which would also stimulate neurons in the opposite ear, no reduction in response to the probe in masker will occur because the masker and the probe are in the same ear. In this case, bilateral priming produces the same result because the stimulation of both sides of the superior olivary complex or higher auditory centers up to the auditory cortex will cancel each other out, hence masking release with a bilateral primer. Evidence for such a phenomenon comes from Cranford (1975) who trained cats to detect the occurrence of 1kHz tones at one ear, while continuous noise pulses were presented to the opposite ear. After unilateral auditory cortex ablation, the cats exhibited an asymmetry between the ears with respect to detection of the tones. That is, there was an increase in threshold for detection of tones at the ear contralateral to the damaged hemisphere. Subsequent ablation of the auditory cortex on the other side resulted in a cancellation of the unilateral effect (i.e. thresholds improved).

What inferences can we draw about the psychophysical manifestations of masking release and masking enhancement with respect to the general population?

For the means of the population represented by this group and under the conditions of this experiment, there

is significant masking release with ipsilateral priming at least at the 20 and 40 msec primer-masker gaps. The masking is possibly complete at the 20 msec primer-masker gap. There is significant masking enhancement with contralateral priming at least at the 80 msec primer-masker gap and essentially no significant effect with bilateral priming. For all primers, there is a tendency for poorer threshold with increasing primer-masker gap.

Do the results support a peripheral theory of masking overshoot and masking overshoot release or is there evidence of contributions from a central mechanism?

Overall, the results do not support a purely peripheral theory of masking overshoot and its release as evidenced by the differences between ipsilateral and bilateral priming. In fact there is evidence that central mechanisms may affect masking overshoot and/or masking release, as evidenced by masking enhancement with contralateral priming.

However, as stated previously an important caveat is necessary. While the results do not support a purely peripheral basis for masking overshoot and its release, neither do the results discount a peripheral contribution to masking overshoot and its release. It is possible that the contralateral primer and the contralateral portion of

the bilateral primer exert an effect on auditory processes at the level of the superior olivary complex and above, up to and possibly including the cerebral cortex. If this is the case, stimulation of these areas (at the superior olivary complex and above) may interfere with the peripheral adaptation processes of the cochlea, auditory nerve or cochlea nucleus, so that masking release is hindered. In the case of the bilateral primer, while the ipsilateral portion may provide masking release, the contralateral portion is exerting an inhibitive effect, such that the combined effects of the two components of the bilateral primer tend to cancel each other. While the masking release effects observed with ipsilateral priming diminish with increasing primer-masker gap (lending support to a peripheral adaptation process for masking overshoot and its release), the masking enhancement effects observed with contralateral priming become more pronounced with increasing primer-masker gap, suggesting central or efferent mechanisms with very long latencies. It is possible that both peripheral and central mechanisms are responsible for masking overshoot and its release and the relative contributions of the two may be subject-dependent.

Summary and conclusions

In conclusion, the results of this study do not support or disprove a peripheral basis for masking overshoot and its release. There is evidence that masking overshoot and/or its release are effected by processes at the superior olivary complex and above, possibly as high as the auditory cortex and cerebral cortex. The effect produced by these areas may be one of inhibiting the peripheral adaptation which may indeed underlie overshoot, or areas of the superior olivary complex and above, up to the auditory and cerebral cortex may actually govern the overshoot and overshoot release phenomena.

Areas for future research

The bilateral primer used in this study was synchronous. The exact same waveform was presented to each ear at the same time. It is possible that there would have been different effects had the bilateral primer been asynchronous (i.e. different waveforms at the two ears). If the perceived distance of the primer from the test ear governs the degree of masking release and/or enhancement, as it appeared to do in the present study, the use of an asynchronous primer may provide more information about the contributions of peripheral and

central factors to masking overshoot and its release. If identical effects are found with the synchronous and asynchronous bilateral primers, then it would not alter the conclusions made in the present study. However, if the synchronous and asynchronous bilateral primers produced statistically different results, there would be more support for a central mechanism for masking overshoot and its release.

The assumption that there would be no significant difference between the unprimed and primed "probe-at-center" thresholds may be erroneous. It is necessary to examine the effects of ipsilateral, bilateral and contralateral primers on the probe-at-center threshold. If significant differences were found between the unprimed and primed probe-at-center thresholds, it would certainly alter the conclusions made here.

APPENDICES

Appendix A.1: DADISP WORKSHEET CALCULATIONS FOR GENERATING STIMULI FOR THE IPSILATERAL AND CONTRALATERAL PRIMER CONDITIONS

W1: Gline(int(22.05*640),1/22050,1,0)
This expression generates a line with a specified number of points (22.05) whose integer value is calculated (int) and then multiplied by the interval between the first noise (primer) and the following noise (masker). The next value in the expression (1/22050) denotes the spacing of the points of the waveform, followed by the slope of the line (1) and the point of intersection with the y-axis (0).

W2: (gcos(220,1/22050,22050/440)+1)/2
This expression generates a cosine curve (fall time). The first number (220) refers to the number of points in the curve, followed by the spacing of the points measured in seconds (1/22050), the frequency and the phase. The expression is divided by two to create one half of the cosine curve (fall time).

W3: Reverse(W2)
This reverses the function of W2 so that the rise time of the curve is created.

W4: -(Concat(W2,extract(W3,-4410+440,4410-220))-1)
The concat function creates a new series by concatenating input series together. It creates a new series by appending a series in one or more windows. The extract function forms a new series by extracting a portion of another series. In this expression, the fall time is concatenated, while the rise time(W3) is extracted beginning at 4410 points before the start of the waveform and extending 440 points after the beginning of the waveform.

W5: -(Concat(W2,extract(W3,-8820+440,8820-220))-1)

W6: -(Concat(W2,W3)-1)
The concat function creates a new series by concatenating input series together. In this case it takes the cosine curves (rise/fall times) generated in windows 2 and 3 and generates a cosine wave end-to-end.

W7: extract(Gnormal(4410,1/22050)*length(W1)/length(W1), 1,4410+length(W1)+8820)
The extract function forms a new series by extracting a portion of another series, while the Gnormal function creates a normally distributed random

series. In this expression, 4410 refers to the number of points in the waveform, followed by the spacing (1/22050) and then multiplied by the length of window 1. This creates a 200 msec noise (primer) followed by a 640 msec silence. This same function is also carried out in windows 8, 9, 10 and 11 so that random noises will be generated. This is done to prevent a frozen noise primer from providing a possible alternative cue.

```
W8: extract(Gnormal(4410,1/22050)*length(W1)/length(W1),
    1,4410+length(W1)+8820)

W9: extract(Gnormal(4410,1/22050)*length(W1)/length(W1),
    1,4410+length(W1)+8820)

W10: extract(Gnormal(4410,1/22050)*length(W1)/length(W1),
    1,4410+length(W1)+8820)

W11: extract(Gnormal(4410,1/22050)*length(W1)/length(W1),
    1,4410+length(W1)+8820)

W12: extract(W6*Gsin(440,1/22050,4000),-length(W1)-
    4410,4410+length(W1)+8820)
```

In this expression, the cosined end-to-end curve is extracted. The Gsin function generates a sine wave, with a specific number of points (440), spacing (1/22050) and frequency (4000 Hz). The remainder of the expression refers to the start (-length (W1)-4410 and the length (4410+length (W1)+8820). This insures that the probe will start at the beginning of the masking noise.

```
W13: extract(Gnormal(8820,1/22050)*length(W1)/length(W1),
    -4410-length(W1),4410+length(W1)+8820)
```

As with the primer, the Gnormal function creates a normally distributed random series. The number of points in this waveform is 8820, with spacing of 1/22050. The start and the length of the waveform are then calculated. This insures that there will be an 840 msec interval before that start of the masking noise (200 msec primer followed by a 640 msec silent interval). This same function is also carried out in windows 14, 15, 16 and 17. As with the primer, the goal is to prevent any alternative cues that might be present when using frozen noise.

```
W14: extract(Gnormal(8820,1/22050)*length(W1)/length(W1),
    -4410-length(W1),4410+length(W1)+8820)
```

```
W15:extract(Gnormal(8820,1/22050)*length(W1)/length(W1),
    -4410-length(W1),4410+length(W1)+8820)

W16:extract(Gnormal(8820,1/22050)*length(W1)/length(W1),
    -4410-length(W1),4410+length(W1)+8820)

W17: extract(Gnormal(8820,1/22050)*length(W1)/length(W1),
    -4410-length(W1),4410+length(W1)+8820)

W18: Gline(6,1,1,1)
```

The Gline function generates a line in accordance with the specified parameters. In this expression, the line has 6 points with a spacing of 1 between each point, measured in seconds, a slope of 1 and the point at which it intersects the y-axis is 1.

```
W19: merge(W13+W12/10^(2/20*(length(W18)-
    16+1)),W7)*length(W24)
```

The merge function creates a new series by splicing input series together. In this expression, W13, the first random masking noise is merged with W12 , the probe. This is divided by 10 raised to the power of 2/20, multiplied by the length of W18. A constant factor of 16 is subtracted form this series and 1 is added and then merged with W7, the priming noise. This is then multiplied by W24 (See specifics below). This same function is carried out in Windows 20-23, 25-29, 31-35 and 37-41. The only difference is that in each subsequent series, one higher value is added before merging with W7. This governs the signal to noise ratio, so that the signal to noise ratio decreases with each subsequent stimulus generation. Therefore the signal in W19 is more easily heard because of a more favorable signal to noise ratio than the signal in W47, where the signal to noise ratio is very poor.

```
W20: merge(W14+W12/10^(2/20*(length(W18)-
    16+2)),W8)*length(W24)

W21: merge(W15+W12/10^(2/20*(length(W18)-
    16+3)),W9)*length(W24)

W22: merge(W16+W12/10^(2/20*(length(W18)-
    16+4)),W10)*length(W24)

W23: merge(W17+W12/10^(2/20*(length(W18)-
    16+5)),W11)*length(W24)
```

```
W24: Gline(5000,1,1,1)
```
This generates a line with 5000 points, with spacing of 1 between each point measured in seconds, a slope of 1, which intercepts the y-axis at 1. This governs the overall intensity of the entire stimulus (primer+signal+masker).

```
W25: merge(W13+W12/10^(2/20*(length(W18)-
    16+6)),W7)*length(W24)

W26: merge(W14+W12/10^(2/20*(length(W18)-
    16+7)),W8)*length(W24)

W27: merge(W15+W12/10^(2/20*(length(W18)-
    16+8)),W9)*length(W24)

W28: merge(W16+W12/10^(2/20*(length(W18)-
    16+9)),W10)*length(W24)

W29: merge(W17+W12/10^(2/20*(length(W18)-
    16+10)),W11)*length(W24)

W30:

W31: merge(W13+W12/10^(2/20*(length(W18)-
    16+11)),W7)*length(W24)

W32: merge(W14+W12/10^(2/20*(length(W18)-
    16+12)),W8)*length(W24)

W33: merge(W15+W12/10^(2/20*(length(W18)-
    16+13)),W9)*length(W24)

W34: merge(W16+W12/10^(2/20*(length(W18)-
    16+14)),W10)*length(W24)

W35: merge(W17+W12/10^(2/20*(length(W18)-
    16+15)),W11)*length(W24)

W36:

W37: merge(W13+W12/10^(2/20*(length(W18)-
    16+16)),W7)*length(W24)

W38: merge(W14+W12/10^(2/20*(length(W18)-
    16+17)),W8)*length(W24)

W39: merge(W15+W12/10^(2/20*(length(W18)-
    16+18)),W9)*length(W24)
```

```
W40: merge(W16+W12/10^(2/20*(length(W18)-
    16+19)),W10)*length(W24)

W41: merge(W17+W12/10^(2/20*(length(W18)-
    16+20)),W11)*length(W24)

W42:

W43: merge(W13,W7)*length(W24)
    This merges the masker and primer and multiplies it
    by the length of W24 so that a noise only stimulus is
    created.  This same function is carried out in
    windows 44-47.

W44: merge(W14,W8)*length(W24)

W45: merge(W15,W9)*length(W24)

W46: merge(W16,W10)*length(W24)

W47: merge(W17,W11)*length(W24)

W48:
```

APPENDIX A.2: DADISP WORKSHEET CALCULATIONS USED FOR GENERATING STIMULI FOR THE BILATERAL PRIMER CONDITION

W1: Gline(int(22.05*40),1/22050,1,0)

This expression generates a lineand calculates the integer value of the expression (int) according to specific parameters. The first number (22.05) refers to the number of point in the waveform followed by the spacing between each poInt on the x-axis measured in seconds (1/22050) the slope of the line (1) and the point at which the line intercepts the y-axis (0).

W2: (gcos(220,1/22050,22050/440)+1)/2

This expression generates a cosine curve (fall time). The first number (220) refers to the number of points in the curve, followed by the spacing of the points measured in second (1/22050), the frequency and the phase. The expression is divided by two to create one half of the cosine curve (fall time).

W3: Reverse(W2)

This reverses the function of W2 so that the rise time of the curve is created.

W4: concat(gline(4410,1/22050,0,1),extract(Gline(8820,1/22050,0,1),-length(w1),length(w1)+8820))

The concat function creates a new series by concatenating input series together. The extract function forms a new series by extracting a portion of another series. In this expression, a line with 8820 points, spacing of 1/22050 with a slope of 0 that intersects the y-axis at 1 is extracted. This is concatenated with a line of 4410 points with a spacing of 1/22050, a slope of 1 which intersects the y-axis at 1. From this equation, the length of W1 is subtracted and then concatenated with the length of W1 + a gap of 8820 (equivalent to 640 msec).

W5: extract(Gline(4410,1/22050,0,1),1,4410+length(w1)+8820)

The extract function forms a new series by extracting a portion of another series. In this expression a line is generated with 4410 points, spacing of 1/22050, a slope of 0, which intercepts the y-axis at 1. This is the input series for extraction. The next part of the expression refers to the starting point (1) and the length which is 4410 + the length of W1 +8820.

W6: -(Concat(W2,W3)-1)

This concatenates the input series of W2 and W3 and subtracts 1. Essentially, this takes the cosined curves generated in windows 2 and 3 and concatenates them to form a sine wave.

W7: W13*w5

This multiplies W13 (see specifics above) by W5 (see specifics below) to create a 200 msec random noise followed by a 640 msec silence. This same function is performed in windows 8-11 using different random noises.

W8: W14*w5

W9: W15*w5

W10: W5*w16

W11: W5*w17

W12: extract(W6*Gsin(440,1/22050,4000),-length(W1)
-4410,4410+length(W1)+8820)

This expression generates a sine wave with 440 points, spacing of 1/22050 and frequency of 4000 Hz. This is multiplied by W6 to provide the appropriate rise/fall times for the sine wave and extracted beginning at a point before the length of W1- 4410 points (200 msec), whose length is 200 msecs + length of W1 + 8820 points (400 msec). This places the probe at the appropriate point in space to be later merged with the 400 msec masking noise.

W13: Gnormal(4410+length(w1)+8820,1/22050)*w4

The Gnormal function generates a normally distributed random series with specified parameters. In this expression, it creates a random noise of 4410 points (200 msec), inserts an interval the length of W1 and then adds another random noise with 8820 points (400 msec), spacing of 1/22050 and multiplies it by the W4 which creates the correct spacing for the placement of the noises (A 200 msec noise, followed by a 640 msec silence and a 400 msec random noise. The same functions are carried out in windows 14-17 with different random noise. This is done to prevent the presence of alternative cues which may exist when using frozen noise.

W14: Gnormal(4410+length(w1)+8820,1/22050)*w4

W15: Gnormal(4410+length(w1)+8820,1/22050)*w4

W16: Gnormal(4410+length(w1)+8820,1/22050)*w4

W17: Gnormal(4410+length(w1)+8820,1/22050)*w4

W18: Gline(6,1,1,1)

The gline function creates a line in accordance with the specified parameters. In this expression, the line has 6 points with a spacing of 1 between each point, measured in seconds and a slope of 1. It intersects the y-axis at 1.

W19: merge(W13+W12/10^(2/20*(length(W18)-16+1)),W7)*length(W24)

The merge function creates a new series by splicing input series together. In this expression W13, the first random primer, silence and random masking noise is merged with W12, the probe. This is divided by 10, raised to the power of 2/20 and multiplied by the length of W18. A constant factor of 16 is subtracted from this series and 1 is added and then merged with W7, the first random priming noise. This is then multiplied by the length of W24 (see specifics below). Not that in this expression, unlike the ipsilateral and contralateral calculations which involved simply merging a single primer and masking noise, here a primer + masking noise is merged with another primer noise. This in effect creates a stereo file which enables the presentation of a bilateral primer. The same function for this expression is carried out in Windows 20-23, 25-29, 31-35 and 37-41. The only difference is that in each subsequent series, one higher value is added before merging with W7. This governs the overall signal to noise ratio, so that the signal to noise ratio decreases with each subsequent stimulus generation.

W20: merge(W14+W12/10^(2/20*(length(W18)-16+2)),W8)*length(W24)

W21: merge(W15+W12/10^(2/20*(length(W18)-16+3)),W9)*length(W24)

W22: merge(W16+W12/10^(2/20*(length(W18)-16+4)),W10)*length(W24)

W23: merge(W17+W12/10^(2/20*(length(W18)-16+5)),W11)*length(W24)

W24: Gline(5000,1,1,1)

This generates a line with 5000 points, with spacing of 1 between each point measured in seconds, a slope of 1, which intercepts the y-axis at 1. This governs the overall intensity of the entire stimulus (primer+signal+masker).

```
W25: merge(W13+W12/10^(2/20*(length(W18)-
     16+6)),W7)*length(W24)

W26: merge(W14+W12/10^(2/20*(length(W18)-
     16+7)),W8)*length(W24)

W27: merge(W15+W12/10^(2/20*(length(W18)-
     16+8)),W9)*length(W24)

W28: merge(W16+W12/10^(2/20*(length(W18)-
     16+9)),W10)*length(W24)

W29: merge(W17+W12/10^(2/20*(length(W18)-
     16+10)),W11)*length(W24)

W30:

W31: merge(W13+W12/10^(2/20*(length(W18)-
     16+11)),W7)*length(W24)

W32: merge(W14+W12/10^(2/20*(length(W18)-
     16+12)),W8)*length(W24)

W33: merge(W15+W12/10^(2/20*(length(W18)-
     16+13)),W9)*length(W24)

W34: merge(W16+W12/10^(2/20*(length(W18)-
     16+14)),W10)*length(W24)

W35: merge(W17+W12/10^(2/20*(length(W18)-
     16+15)),W11)*length(W24)

W36:

W37: merge(W13+W12/10^(2/20*(length(W18)-
     16+16)),W7)*length(W24)

W38: merge(W14+W12/10^(2/20*(length(W18)-
     16+17)),W8)*length(W24)

W39: merge(W15+W12/10^(2/20*(length(W18)-
     16+18)),W9)*length(W24)
```

```
W40: merge(W16+W12/10^(2/20*(length(W18)-
     16+19)),W10)*length(W24)

W41: merge(W17+W12/10^(2/20*(length(W18)-
     16+20)),W11)*length(W24)

W42:

W43: merge(W13,W7)*length(W24)
```

This merges the masker and primer and multiplies it by the length of W24 so that a noise only stimulus is created. This same function is carried out in windows 44-47, using different random noises.

```
W44: merge(W14,W8)*length(W24)

W45: merge(W15,W9)*length(W24)

W46: merge(W16,W10)*length(W24)

W47: merge(W17,W11)*length(W24)
```

APPENDIX B.1 Thresholds for the last 10 replications for 11 conditions (2 unprimed-probe at center and probe at onset) and 9 priming conditions (ipsilateral, bilateral and contralateral at 20, 40 and 80 msec primer-masker gap) for subject 1.

S#	REP	NOPC	NOPO	20I	40I	80I	20B	40B	80B	C20	C40	C80
1	1	-7.50	-5.25	-10.50	-14.25	-5.00	-10.75	-5.75	-7.75	-4.50	-7.00	-1.75
1	2	-7.75	-6.5	-11.50	-10.25	-9.25	-7.25	-5.25	-6.00	-10.0	-10.0	0.00
1	3	-8.50	-5.5	-13.00	-11.75	-5.00	-9.00	-14.5	-6.75	-5.00	-5.25	-1.50
1	4	-8.75	-5.5	-10.75	-10.00	-4.25	-5.25	-7.25	-7.50	-10.25	-7.75	0.00
1	5	-8.50	-5.75	-13.50	-10.25	-10.00	-5.75	-7.25	-5.25	-6.50	-6.75	-2.00
1	6	-7.75	-8.75	-11.00	-9.25	-5.00	-5.75	-8.50	-6.50	-6.50	-4.50	-2.50
1	7	-8.00	-4.25	-5.75	-10.25	-9.25	-5.50	-14.0	-6.00	-6.00	-5.50	0.00
1	8	-8.00	-5.5	-10.25	-5.50	-10.25	-6.00	-6.00	-4.75	-7.00	-5.50	-5.50
1	9	-7.25	-8.25	-8.25	-6.00	-5.25	-6.00	-6.25	-7.00	-10.5	-4.00	-5.75
1	10	-7.25	-7.75	-5.75	-4.75	-4.00	-7.25	-8.00	-5.00	-6.25	-4.25	-2.50
MEAN		-7.93	-6.3	-10.03	-9.23	-6.73	-6.85	-8.23	-6.25	-7.25	-6.05	-2.15
S.D.		0.53	1.47	2.68	2.98	2.59	1.78	3.31	1.03	2.20	1.86	2.08
S.E		0.17	0.47	0.85	0.94	0.82	0.56	1.05	0.33	0.70	0.59	0.66
95% CL		0.54	1.52	1.92	2.13	1.86	1.27	2.37	1.74	1.57	1.33	1.49

S#=Subject number
REP=replication
NOPC=unprimed "probe-at-center" threshold
NOPO=unprimed "probe-at-onset" threshold

20I=ipsilateral 20 msec 20B=bilateral 20 msec 20C=contralateral 20 msec
40I=ipsilateral 40 msec 40B=bilateral 40 msec 40C=contralateral 40 msec
80I=ipsilateral 80 msec 80B=bilateral 80 msec 80C=contralateral 80 msec

APPENDIX B.2 Thresholds for the last 10 replications for 11 conditions (2 unprimed-probe at center and probe at onset) and 9 priming conditions (ipsilateral, bilateral and contralateral at 20, 40 and 80 msec primer offset to masker onset gap) for subject 2.

S#	REP	NOPC	NOPO	20I	40I	80I	20B	40B	80B	C20	C40	C80
2	1	-6.25	-2.75	-6.75	-5.50	-4.50	-8.25	-2.75	-2.00	-1.75	-0.50	2.00
2	2	-7.50	-2.75	-6.50	-3.25	-4.25	-2.00	0.00	-2.00	-2.00	1.00	2.25
2	3	-8.50	-5.50	-6.50	-5.50	-2.25	-2.75	-1.75	-3.25	1.25	2.00	0.00
2	4	-8.00	-3.50	-6.00	-4.50	-1.75	-2.25	-0.75	-3.75	-0.25	-2.75	1.50
2	5	-7.25	-3.50	-5.50	-4.50	-1.00	-5.50	-3.00	-2.75	-0.50	2.00	-1.25
2	6	-6.75	-3.25	-8.00	-5.25	-3.00	-2.00	-0.25	-1.50	-3.25	1.00	3.75
2	7	-6.25	-3.25	-6.00	-6.50	-2.50	-4.75	0.00	-3.50	-3.75	0.50	-0.50
2	8	-6.00	-3.25	-6.00	-6.00	-0.50	-2.50	-3.75	-3.25	2.00	-3.75	-1.75
2	9	-8.50	-1.75	-6.25	-6.00	-5.00	-2.00	0.00	-3.25	2.25	-4.25	-1.00
2	10	-6.75	-1.75	-5.25	-6.00	-1.00	-2.00	-3.25	-3.50	1.50	3.75	-1.75
MEAN		-7.18	-3.13	-6.28	-5.30	-2.58	-3.40	-1.55	-2.88	-0.45	-0.10	0.33
S.D.		0.93	1.06	0.76	0.97	1.59	2.11	1.52	0.78	2.18	2.67	1.92
S.E.		0.29	0.33	0.24	0.31	0.50	0.67	0.48	0.25	0.69	0.84	0.61
95% CL		0.66	0.76	0.78	1.00	1.63	1.51	1.09	0.55	2.24	1.91	1.38

S#=Subject number
REP=replication
NOPC=unprimed "probe-at-center" threshold
NOPO=unprimed "probe-at-onset" threshold

20I=ipsilateral 20 msec 20B=bilateral 20 msec 20C=contralateral 20 msec
40I=ipsilateral 40 msec 40B=bilateral 40 msec 40C=contralateral 40 msec
80I=ipsilateral 80 msec 80B=bilateral 80 msec 80C=contralateral 80 msec

APPENDIX B.3 Thresholds for the last 10 replications for 11 conditions (2 unprimed-probe at center and probe at onset) and 9 priming conditions (ipsilateral, bilateral and contralateral at 20, 40 and 80 msec primer offset to masker onset gap) for subject 3.

S#	REP	NOPC	NOPO	20I	40I	80I	20B	40B	80B	C20	C40	C80
3	1	-0.25	2.00	-3.25	-4.50	0.25	2.00	0.50	2.00	4.00	2.00	4.25
3	2	-1.50	2.00	-2.75	-4.25	-0.50	0.50	3.00	1.75	3.25	2.25	1.75
3	3	-0.50	2.25	0.00	-3.50	-1.75	1.25	3.00	2.00	1.00	2.25	2.25
3	4	-1.25	1.50	-1.50	-4.00	0.25	0.25	2.00	1.50	4.00	2.75	2.00
3	5	0.25	2.50	-2.00	-4.25	-0.50	0.25	2.00	1.50	3.75	3.00	2.75
3	6	-1.25	2.25	-2.00	-2.00	0.75	0.00	1.75	2.25	1.00	3.25	2.25
3	7	-1.25	2.00	0.75	-3.50	1.00	-0.25	1.00	0.50	2.25	2.00	2.25
3	8	-3.75	3.00	0.50	-0.25	1.00	0.25	0.25	2.25	0.75	3.00	2.00
3	9	-3.00	2.25	0.25	1.50	-1.00	0.00	1.25	1.75	2.25	2.50	3.75
3	10	-2.50	4.00	-0.25	1.25	-0.50	0.25	1.25	2.50	3.25	2.75	1.75
MEAN		-1.50	2.38	-1.03	-2.35	-0.10	0.45	1.60	1.80	2.55	2.58	2.50
S.D.		1.25	0.69	1.45	2.35	0.91	0.68	0.94	0.56	1.29	0.44	0.85
S.E.		0.40	0.22	0.46	0.74	0.29	0.21	0.30	0.18	0.41	0.14	0.27
95% CL		0.90	0.49	1.03	1.68	0.65	0.48	0.67	0.40	0.92	0.32	0.61

S#=Subject number
REP=replication
NOPC=unprimed "probe-at-center" threshold
NOPO=unprimed "probe-at-onset" threshold

20I=ipsilateral 20 msec 20B=bilateral 20 msec 20C=contralateral 20 msec
40I=ipsilateral 40 msec 40B=bilateral 40 msec 40C=contralateral 40 msec
80I=ipsilateral 80 msec 80B=bilateral 80 msec 80C=contralateral 80 msec

APPENDIX B.4 Thresholds for the last 10 replications for 11 conditions (2 unprimed-probe at center and probe at onset) and 9 priming conditions (ipsilateral, bilateral and contralateral at 20, 40 and 80 msec primer offset to masker onset gap) for subject 4.

S#	REP	NOPC	NOPO	20I	40I	80I	20B	40B	80B	C20	C40	C80
4	1	-3.50	8.00	5.50	-0.25	6.25	0.50	-0.50	4.25	6.25	9.00	6.00
4	2	-2.25	6.50	3.50	2.00	6.25	3.00	1.00	2.25	7.50	6.75	9.50
4	3	-2.75	3.25	3.25	-1.50	5.50	7.25	0.75	4.00	7.50	6.50	10.00
4	4	-4.00	2.50	4.75	5.00	5.25	-0.25	3.00	6.75	8.00	6.25	10.50
4	5	-5.00	1.50	4.50	5.50	5.00	-0.25	0.00	6.50	4.50	8.00	9.25
4	6	-2.25	3.50	4.75	3.75	3.75	6.00	1.75	5.50	9.25	6.00	9.50
4	7	-3.25	2.75	1.50	1.00	3.00	6.00	2.75	4.50	6.25	5.50	9.25
4	8	-0.75	2.50	2.75	3.25	4.75	4.00	4.50	4.00	8.00	5.75	6.00
4	9	-1.75	-4.50	4.25	3.25	6.00	3.75	6.25	7.00	7.25	5.00	8.75
4	10	-2.00	3.25	3.00	3.50	6.00	4.00	4.50	8.50	5.75	6.75	7.00
MEAN		-2.75	2.93	3.78	2.55	5.18	3.40	2.40	5.33	7.03	6.55	8.58
S.D.		1.22	3.28	1.19	2.24	1.09	2.68	2.20	1.86	1.36	1.19	1.64
S.E.		0.39	1.04	0.38	0.71	0.35	0.85	0.69	0.59	0.43	0.38	0.52
95% CL		1.88	2.34	0.85	1.60	0.78	1.91	1.57	1.33	0.97	0.85	1.17

S#=Subject number
REP=replication
NOPC=unprimed "probe-at-center" threshold
NOPO=unprimed "probe-at-onset" threshold

20I=ipsilateral 20 msec 20B=bilateral 20 msec 20C=contralateral 20 msec
40I=ipsilateral 40 msec 40B=bilateral 40 msec 40C=contralateral 40 msec
80I=ipsilateral 80 msec 80B=bilateral 80 msec 80C=contralateral 80 msec

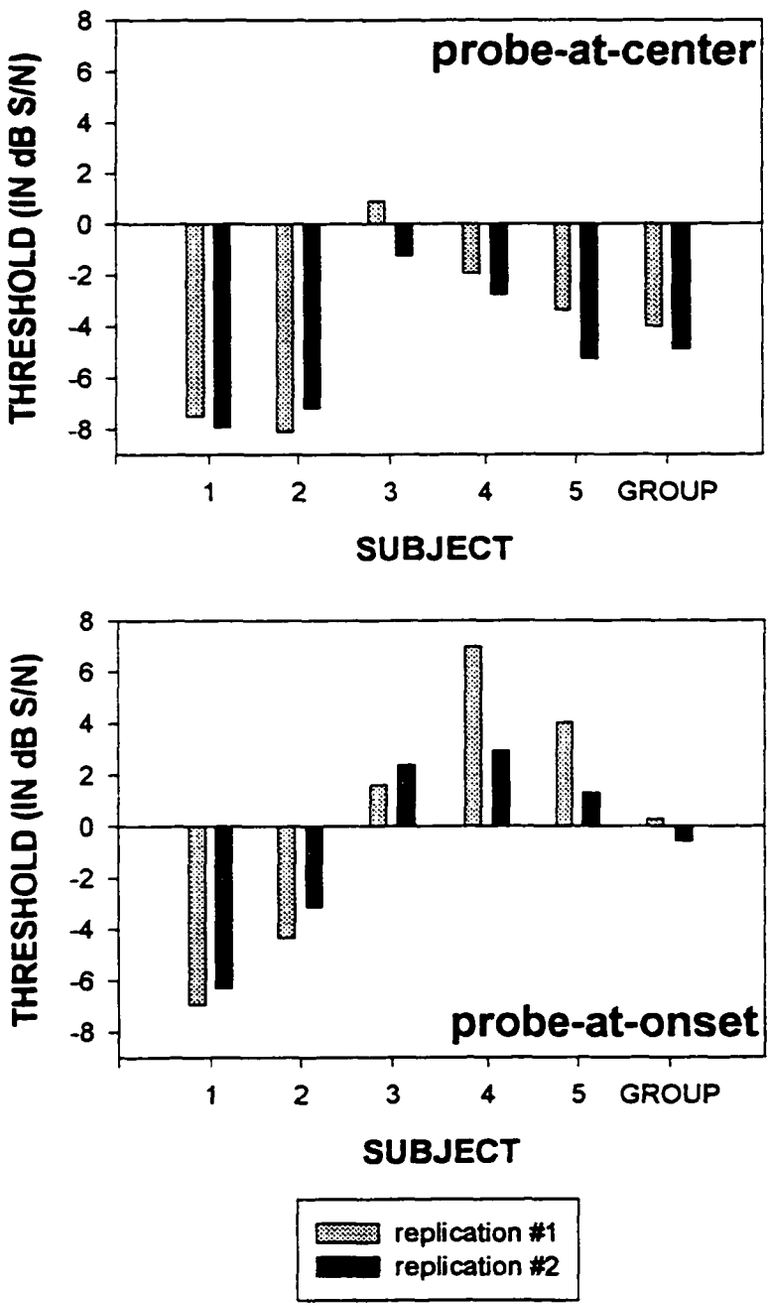
APPENDIX B.5 Thresholds for the last 10 replications for 11 conditions (2 unprimed-probe at center and probe at onset) and 9 priming conditions (ipsilateral, bilateral and contralateral at 20, 40 and 80 msec primer offset to masker onset gap) for subject 5.

S#	REP	NOPC	NOPO	20I	40I	80I	20B	40B	80B	C20	C40	C80
5	1	-6.00	-1.50	5.00	0.00	-3.50	1.75	0.75	1.75	-3.25	-0.50	0.00
5	2	-6.00	4.50	2.00	-2.00	-2.75	0.75	1.00	1.25	-5.75	0.25	3.25
5	3	-3.75	1.25	-4.00	-13.50	-8.00	-2.75	1.75	-3.50	-4.75	0.25	0.00
5	4	-5.75	-0.25	-5.25	-6.25	-4.25	-2.75	2.00	0.00	-7.50	1.75	-0.25
5	5	-6.50	4.50	-5.00	-5.75	-4.25	-2.75	2.25	-2.00	-2.50	0.50	5.00
5	6	-5.50	1.50	-2.50	-5.50	-4.00	-2.50	1.00	0.00	-5.00	0.00	0.00
5	7	-4.25	2.00	-5.50	-5.50	-2.00	2.00	2.25	0.75	-4.25	3.00	3.75
5	8	-5.50	1.00	-5.25	-4.25	-3.25	-0.75	1.25	-9.75	-2.00	2.75	-0.75
5	9	-4.00	-1.25	-6.00	-6.00	-4.50	1.00	2.25	0.00	0.00	2.00	0.00
5	10	-5.25	1.25	-5.25	-5.00	-2.25	-1.50	0.25	-1.00	-2.50	2.50	0.50
MEAN		-5.25	1.30	-3.18	-5.38	-3.88	-0.75	1.48	-1.25	-3.45	1.25	1.15
S.D.		0.94	2.05	3.72	3.48	1.69	1.97	0.72	3.36	1.73	1.29	2.04
S.E.		0.30	0.65	1.18	1.10	0.53	0.62	0.23	1.06	0.55	0.41	0.64
95% CL		0.67	1.47	2.66	2.49	1.21	1.41	0.52	2.41	1.24	0.92	1.46

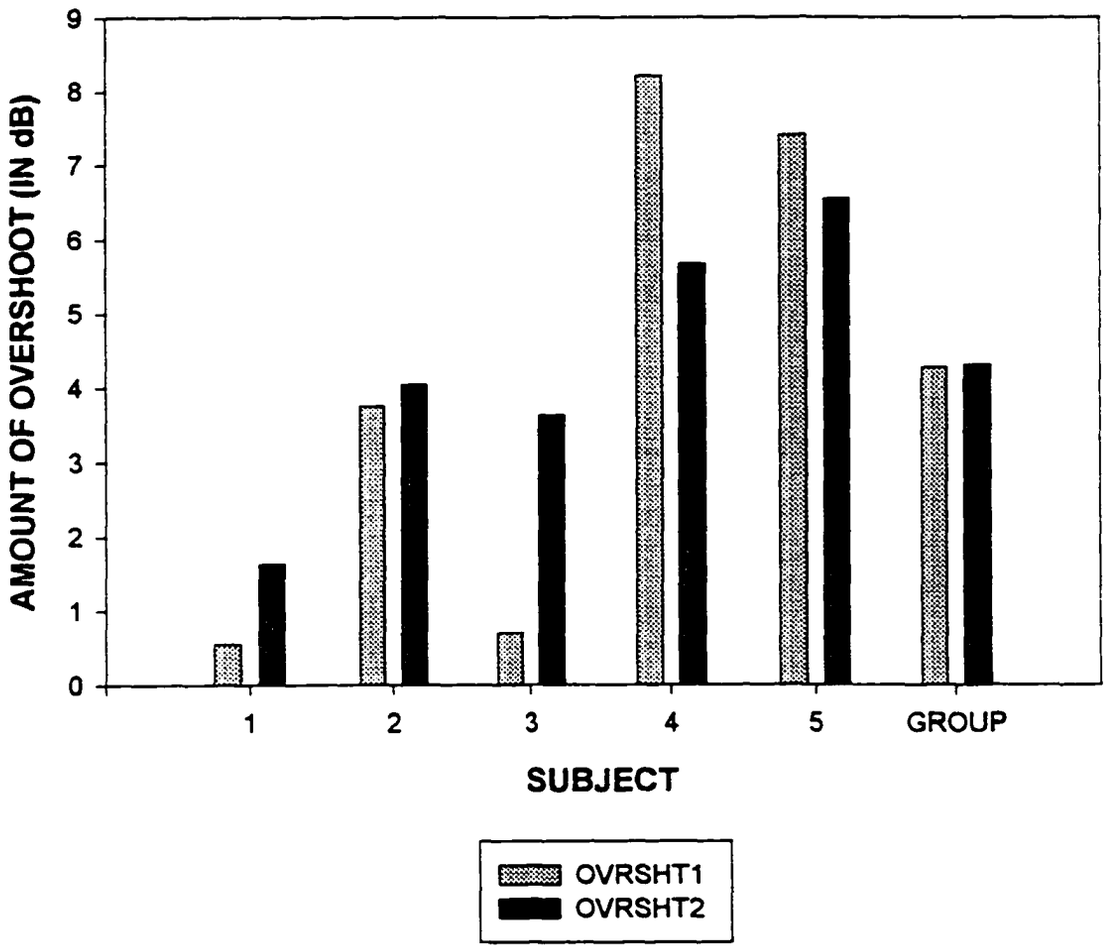
S#=Subject number
REP=replication
NOPC=unprimed "probe-at-center" threshold
NOPO=unprimed "probe-at-onset" threshold

20I=ipsilateral 20 msec 20B=bilateral 20 msec 20C=contralateral 20 msec
40I=ipsilateral 40 msec 40B=bilateral 40 msec 40C=contralateral 40 msec
80I=ipsilateral 80 msec 80B=bilateral 80 msec 80C=contralateral 80 msec

Appendix C.1 Thresholds (in dB S/N) for all subjects and for the group for replication 1 (prior to data collection for the primed conditions) and for replication 2 (after data collection for the primed conditions) for the unprimed "probe at center" (top graph) and unprimed "probe at onset" (bottom graph).



Appendix C.2 Amount of overshoot (in dB HL) for replication 1 (prior to data collection for the primed conditions) and for replication 2 (after data collection for the primed conditions) for all subjects and for the group.



Appendix C3.1 One-way analysis of variance for the group with replication for the unprimed probe-at-center threshold as the sole variable at 2 levels (initial replication-prior to data collection for the primed conditions and final replication-after data collection for the primed conditions). The effect of replication was not significant.

Effect	df effect	MS effect	df error	MS error	F	p-level
replication	1	0.18	4	0.90	0.20	0.68

Appendix C3.2 One-way analyses of variance for individual subjects with replication for the unprimed probe-at-center threshold as the sole variable at 2 levels(initial replication-prior to data collection for the primed conditions and final replication-after data collcetion for the primed conditions). The effect of replication was significant only for subjects 3 and 5.

S#	Effect	df effect	MS effect	df error	MS error	F	p-level
1	replic.	1	0.90	9	0.38	2.41	0.16
2	replic.	1	4.27	9	0.94	4.53	0.06
3	replic.	1	28.8	9	0.88	32.86	<0.05
4	replic.	1	3.40	9	1.88	1.81	0.21
5	replic.	1	17.58	9	0.88	20.05	<0.05

Appendix C3.3 One-way analysis of variance for the group with replication for the unprimed probe-at-onset threshold as the sole variable at 2 levels (initial replication-prior to data collection for the primed conditions and final replication-after data collection for the primed conditions). The effect of replication was not significant.

Effect	df effect	MS effect	df error	MS error	F	p-level
replication	1	1.71	4	2.87	0.59	0.48

Appendix C3.4 One-way analyses of variance for individual subjects with replication for the unprimed probe-at-onset threshold as the sole variable at 2 levels(initial replication-prior to data collection for the primed conditions and final replication-after data collcetion for the primed conditions). The effect of replication was significant only for subjects 4 and 5.

S#	Effect	df effect	MS effect	df error	MS error	F	p-level
1	replic.	1	0.50	9	13.31	0.003	0.95
2	replic.	1	7.50	9	2.58	2.90	0.12
3	replic.	1	3.00	9	6.37	0.47	0.50
4	replic.	1	82.01	9	3.33	24.61	<0.05
5	replic.	1	37.13	9	2.81	13.22	<0.05

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