

# Off-response to pure tone burst is affected by the previous pure tone intensity

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## 1 Introduction

The auditory magnetic brain response, N1m, which is defined as a magnetic deflection occurring about 100 ms after the tone onset, varies depending on the stimulus interval. Hari et al. [1] measured the N1m responses to the onset of a 0.55-s white noise burst with four Stimulus Onset Asynchrony (SOA: 1.1, 2.2, 4.4, and 8.8 s) in different blocks. The results of their experiments indicated that the amplitude of the N1m response to the tone onset (on-N1m) increases as the SOA increases. They also showed that the N1m response to the tone cessation (off-N1m) increases as the Stimulus Cessation Asynchrony increases. Both the on- and off-N1m responses are affected by the stimulus intervals.

We showed that the on-N1m response varies depending on the immediately preceding SOA when there were more than one SOA in the same block [2]. We compared the on-N1m responses to five 1-kHz pure tone bursts with different durations (0.05, 0.5, 1.0, 1.5, and 2.0 s) and with five immediately preceding SOAs (0.5, 1.0, 1.5, 2.0, and 2.5 s). The result showed that the on-N1m amplitude increases as the immediately preceding SOA increases, indicating that the N1m response varies locally in the measurement block.

In another experiment, we showed the significant effect of the immediately preceding tone on the off-N1m responses to the current tone. We recorded the off-N1m responses to a random sequence of 1-kHz pure tones with two durations; one was 0.2 s (presentation probability: 0.5) and the other was either 0.2, 1.2, or 2.2 s in different blocks. The off-N1m peak amplitude in response to the 0.2-s pure tone significantly increases as the preceding tone duration increases. The off-N1m peak amplitude is significantly larger when the 0.2-s tone is preceded by the 2.2-s tone than when preceded by the 0.2-s tone (off-response enhancement) [3].

We also recorded the off-N1m responses in a random sequence of 0.2- and 2.2-s pure tones with two frequencies; one was 1 kHz (presentation probability: 0.5) and the other was either 0.5, 1, or 2 kHz in different blocks. The off-N1m peak

amplitude in response to the 0.2-s pure tone significantly increased as the preceding tone was different. The off-N1m peak amplitude is significantly larger when the 0.2-s tone is preceded by the 1-kHz tone (2.2 s) than when preceded by both the 0.5-kHz and 2-kHz tones (off-response enhancement) [4].

## 2 Methods

### 2.1 Subjects and stimulus

Eight right-handed subjects (6 females; 19-28 years old) with normal hearing were studied.

We used three long pure tones (L-tones; duration: 2.2 s; intensity: 70, 74, and 78 dB Sound Pressure Level (SPL), each in a different block) and one short pure tone (S-tone; 0.2 s; 78 dB SPL), which were 1-kHz pure tone bursts with 10-ms rise and decay times.

As shown in Figure 1, in each block, the S-tone (78 dB) and one of the L-tones (70, 74, or 78 dB) were presented, in random order, with a constant 1-s cessation-to-onset interstimulus interval to the subject's left ear through a plastic tube and an ear piece.

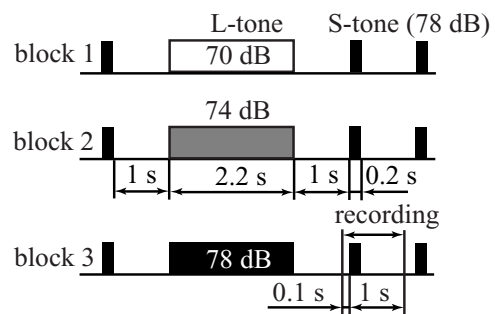


Figure 1: Stimulus sequence. The L-tone (2.2 s) and the S-tone (0.2 s) were presented in random order with the same presentation probability (0.5). The intensities of the L-tones were 70, 74, and 78 dB SPL in blocks 1, 2, and 3, respectively. The intensity of the S-tone was constant at 78 dB SPL throughout all blocks. Response was recorded between 0.1 s before and 1.0 s after the onset of the S-tone.

The subjects were instructed to read a book of their own choice and to pay no attention to the stimuli during the measurement.

The subjects took a 3-minute rest between the blocks, but were instructed not to move their head throughout all blocks including the rest time. The order of the 3 blocks was randomized for each subject.

## 2.2 Recording and analysis

We recorded the magnetic response from  $-0.1$  s to  $1.0$  s (onset of S-tone =  $0$  ms) using a 122-channel whole-head neuromagnetometer (Neuromag-122; Neuromag Ltd., Finland) in a magnetically shielded room. Epochs with a magnetic response amplitude exceeding  $3000$  fT/cm or with a vertical electro-oculogram exceeding  $150$   $\mu$ V were rejected from further analyses. More than 50 responses were averaged after being filtered ( $0.1$ - $170$  Hz) and digitized at  $0.5$  kHz. Only the responses to the S-tone in each block were averaged separately depending on the preceding tones; the response to the S-tone immediately after the L-tone (LS-response) and that immediately after the S-tone (SS-response). The averages were digitally low-pass filtered at  $40$  Hz. We removed DC component that was present in the  $100$ -ms prestimulus baseline. Neuromag-122 has 2 pickup coils in each sensor position, which measure 2 tangential derivatives,  $\partial B_z/\partial x$  and  $\partial B_z/\partial y$ , where the field component  $B_z$  is normal to the coil surface. The value  $B'$  in the following equation (1) was defined here as the amplitude of the response at each sensor position.

$$B' = \sqrt{(\partial B_z/\partial x)^2 + (\partial B_z/\partial y)^2} \quad (1)$$

The maximum on-N1m peak, denoted by the max-on-N1m peak, was determined in the following way. First, we calculated the amplitude of all the peaks found between  $50$  and  $150$  ms after the onset of the S-tone, and then we determined the maximum amplitude among these peaks over the right temporal area as the max-on-N1m peak amplitude.

These max-on-N1m peak amplitudes were normalized in each subject with respect to the individual's maximum value across all blocks. We undertook an analysis of variance (ANOVA) and a post-hoc analysis of these normalized max-on-N1m peak amplitudes and the latencies to determine the effect of the preceding tone intensity. We performed a paired t-test within the same block between these normalized max-on-N1m peak amplitudes and latencies preceded by the L- and S-

tones. The maximum off-N1m peak (max-off-N1m peak) was analyzed in the same manner.

## 3 Results

### 3.1 On-response

Figure 2 shows the response waveforms of subject 1 in blocks 1, 2, and 3. The max-on-N1m peak amplitudes (latencies: the length in time from the onset of the S-tone) of the LS-response in blocks 1, 2, and 3 were  $70$  fT/cm ( $116$  ms),  $79$  fT/cm ( $126$  ms), and  $84$  fT/cm ( $105$  ms), respectively.

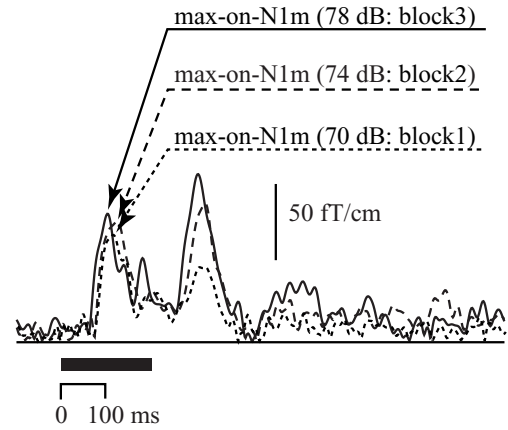


Figure 2: Typical waveforms (subject 1) in response to the S-tone preceded by the 70-, 74-, and 78-dB L-tones (LS-response). The arrows indicate the max-on-N1m peaks. A horizontal thick bar shows stimulus.

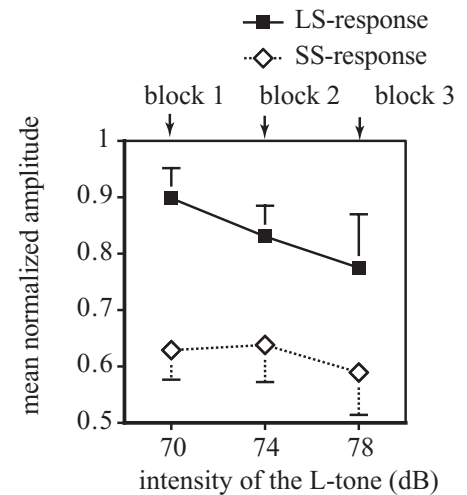


Figure 3: The mean normalized max-on-N1m amplitudes in blocks 1, 2, and 3 averaged across 8 subjects are shown as a function of the stimulus intensity of the L-tone. A vertical bar indicates S.E.M.

Figure 3 shows the mean normalized max-on-N1m peak amplitudes with the standard error of the mean (S.E.M.) for the LS-response and the SS-response as a function of the intensity of the L-tone.

The ANOVA showed that there was no significant difference in the max-on-N1m peak amplitudes between the 3 blocks either for the LS-response or for the SS-response. The paired t-test showed that the max-on-N1m peak amplitude was significantly larger for the LS-response than for the SS-response by 47 % ( $t = 5.79$ ,  $p < 0.01$ ), by 30 % ( $t = 2.68$ ,  $p < 0.05$ ), and by 31 % ( $t = 3.38$ ,  $p < 0.05$ ) in blocks 1, 2, and 3, respectively.

The mean latencies of the max-on-N1m for the LS-response (SS-response) were 92 ms (91 ms), 96 ms (88 ms), and 90 ms (91 ms), in blocks 1, 2, and 3, respectively. There was no significant difference in the max-on-N1m peak latencies between the 3 blocks either for the LS-response or for the SS-response.

### 3.2 Off-response

Figure 4 shows the response waveforms of subject 1 in blocks 1, 2, and 3. The max-off-N1m peak amplitudes (latencies: the length in time from the cessation of the S-tone) of the LS-response in blocks 1, 2, and 3 were 51 fT/cm (105 ms), 91 fT/cm (124 ms), and 110 fT/cm (108 ms), respectively. The max-off-N1m peak amplitude of the LS-response increased as the intensity of the preceding tone (L-tone) increased.

Figure 5 shows the mean normalized max-off-N1m peak amplitudes with the S.E.M. for the LS-response and the SS-response as a function of the intensity of the L-tone.

The ANOVA showed that the max-off-N1m peak amplitude of the LS-response significantly increased as the intensity of the preceding tone increased ( $F(2, 21) = 4.82$ ,  $p < 0.05$ ). The post-hoc analysis showed that the max-off-N1m peak amplitude of the LS-response in block 3 was 45 % larger ( $p < 0.05$ ) than that in block 1. There was, however, no significant difference in the max-off-N1m peak amplitudes of the SS-response between the 3 blocks. The paired t-test showed that the max-off-N1m peak amplitude was significantly larger for the LS-response than for the SS-response by 45 % ( $t = 4.24$ ,  $p < 0.01$ ) in block 3. In blocks 1 and 2, there was no significant difference between the max-off-N1m peak amplitudes of the LS- and SS-responses.

The mean latencies of the LS-response (SS-response) were 99 ms (90 ms), 96 ms (89 ms), and 97 ms (110 ms), in blocks 1, 2, and 3, respectively. There was no significant difference in the max-off-

N1m peak latencies between the 3 blocks either for the LS-response or for the SS-response.

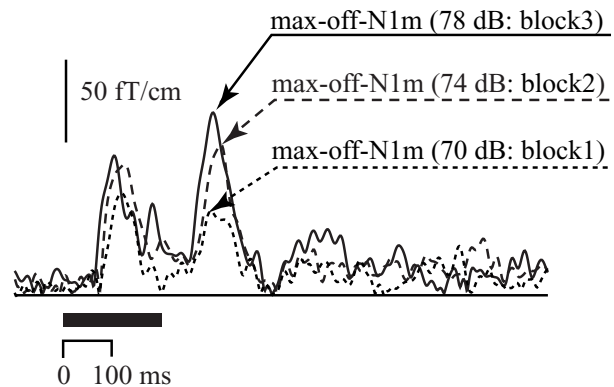


Figure 4: Typical waveforms (subject 1) in response to the S-tone preceded by the 70-, 74-, and 78-dB L-tones (LS-response). The arrows indicate the max-off-N1m peaks. A horizontal thick bar shows stimulus.

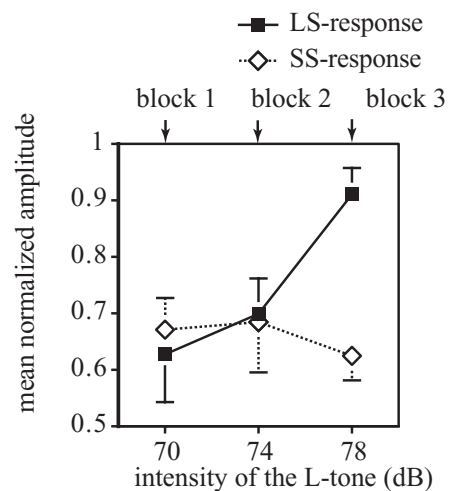


Figure 5: The mean normalized max-off-N1m amplitudes in blocks 1, 2, and 3 averaged across 8 subjects are shown as a function of the stimulus intensity of the L-tone. A vertical bar indicates S.E.M.

## 4 Discussion

### 4.1 On-response

Between the blocks, there was no significant difference in the max-on-N1m peak amplitudes for the LS-response although there was a tendency that the larger the difference in intensity between the L- and S-tones, the larger the amplitudes. In our experiment, the max-on-N1m peak amplitude seems to be not affected by the intensity of the immediately preceding tone.

Within each block, the max-on-N1m peak amplitude of the LS-response was significantly

larger than that of the SS-response. The immediately preceding SOA of the S-tone was longer when it was preceded by the L-tone than when preceded by the S-tone in all blocks. Therefore, it seems that the max-on-N1m peak amplitude was affected by the immediately preceding SOA. These results agree with the previous result, which indicated that the on-N1m amplitude increases as the immediately preceding SOA increases [2].

#### 4.2 Off-response

Between the blocks, the max-off-N1m peak amplitude of the LS-response in block 3 was significantly larger than that in block 1, suggesting that the enhancement of the max-off-N1m response was intensity specific. However, the max-off-N1m peak amplitude of the SS-response did not differ significantly between the blocks.

In block 3, the max-off-N1m peak amplitude of the LS-response was significantly larger than that of the SS-response. This is consistent with the previous study [3, 4], where the intensity of the preceding tone was also the same as that of the current tone. In blocks 1 and 2, the max-off-N1m peak amplitude showed no significant difference between the LS-response and the SS-response. These results imply that the preceding tone with different intensity did not show the off-response enhancement.

It seems difficult to explain the mechanism of the max-off-N1m peak amplitude enhancement only by the release of spontaneous activity from the inhibition [1, 6], because the off-response enhancement was strongly affected by the intensity of the preceding tone rather than that of the current tone.

As we reported in our previous study [3, 4], the enhancement of the max-off-N1m peak amplitude of the LS-response in block 3 may include a mismatch response to the difference in duration and intensity.

In the present study, however, the intensity mismatch was detected at the onset of the S-tone, whereas, the duration mismatch was detected at the cessation of the S-tone. Therefore, if the off-response enhancement includes the mismatch component, it is caused only by duration difference. However, the duration difference and the presentation probability of the L- and S-tones were the same throughout the blocks. Therefore, the off-response enhancement seems to be due to factors other than mismatch responses.

#### References

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