Auditory Cortical Responses at 100ms Post Onset Are Modulated by Figure/Ground Status of the Stimulus

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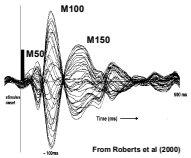
INTRODUCTION

The earliest auditory evoked responses in auditory cortex (AC) peak near 20, 30 and 50 ms. These responses are followed by a deflection at about 100 ms (M100/N1m) which is the most prominent and robust response across listeners and stimuli. The source of the M100 response is localized to Planum Temporale [1]. Its amplitude and latency vary with certain physical and temporal aspects of stimuli. Investigations of the M100 typically employ clicks, tones, or speech stimuli, which almost always elicit the response, leading to a commonly held hypothesis that the M100 reflects the process of detecting changes in sensory input, although the underlying mechanisms remain ambiguous. Specifically, it is not clear why an onset detector would operate so late (100 ms post onset) in the processing stream. The earlier and smaller M50 peak is believed to originate in or near the primary auditory cortex (PAC). A recent study found it to activate the antero-lateral portion of Heschl's gyri and Heschl's sulcus [2]. This might reflect activity in the human counterpart of the anterior areas in the core line region or in the antero-lateral belt region described in monkey.



Here we report on the auditory evoked responses to *wide-band noise* stimuli , in several experimental settings and discuss their implications for the functional role of the M50 and M100 auditory evoked fields. The evidence described here indicates that the M100 does not result from a process of detecting changes in sensory input, but reflects later, more specialized, stages in processing, related to figure ground segregation.

EXPERIMENT 1 (N=7)

Stimuli: 400 ms long white noise. In order to create a perceptually diverse stimulus set, five different interaural correlations were used. ISI=900-1600

Task: A target stimulus (not analyzed), which was one of the same stimuli modulated sinusoidally, appeared in 25% of the trials.

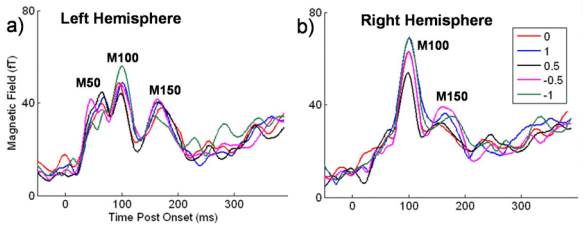


Figure shows the group RMS for the stimuli in Exp1 for all experimental conditions. The response is characterized by a three-peaked (M50, M100 and M150) noise onset response. The M50 response is attenuated in the RH.

This is the classic pattern of activation. Note the prominent M100 response.

REFERENCES AND ACKNOWLEDGEMENTS

[1] Lütkenhöner B, Steinsträter O. High-precision neuromagnetic study of the functional organization of the human auditory cortex. Audiol. Neurootol 1998; 3:191-213.

[2] Yvert B, Crouzeix A, Bertrand O, Seither-Preisler A, Pantev C . Multiple supratemporal sources of magnetic and electric auditory evoked middle latency components in humans. Cereb. Cortex 2001; 11:411-423.

[3] Kubovy M, Van Valkenburg D. Auditory and visual objects. Cognition. 2001; 80:97-126

[4] Nelken I, Fishbach A, Las L, Ulanovsky N, Farkas D. Primary auditory cortex of cats: feature detection or something else? Biol Cybern. 2003;89:397-406.

[5] Chait M, Simon JZ, Poeppel D. Auditory M50 and M100 responses to broadband noise: functional implications. Neuroreport. In press

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EXPERIMENT 2 (N=20) and EXPERIMENT 3 (N=16)

Stimuli: The stimuli were 1500 ms long: 1000 ms of inter-aurally correlated (Exp 1) or uncorrelated (Exp 2) white noise followed by a 500 ms tonal-object (200, 400 600 or 1000Hz) embedded in correlated noise or by 500 ms correlated noise (no tone; control condition) . ISI=500-2000 .

Task: Tone detection task (50% of the stimuli).

Before the beginning of the experiment proper subjects listened to 200 repetitions of 1kHz 50 ms pure tones.

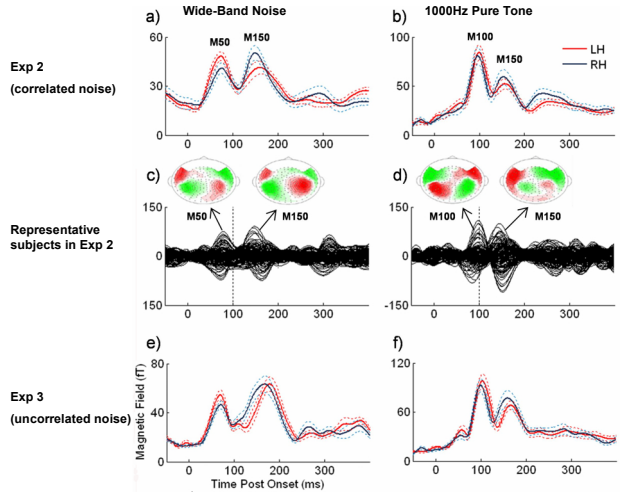
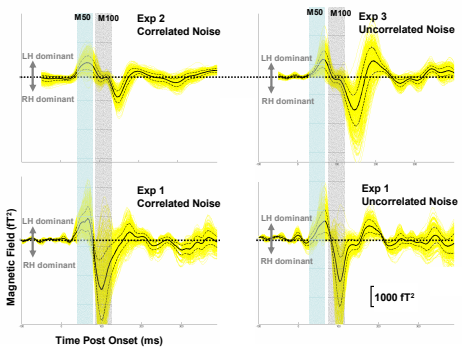


Figure shows the group RMS (RMS of the individual subject RMSs) of the auditory evoked responses to the noise stimuli and the responses to pure tones (in the pre-experiment) for Exp 2 and 3. The pure tone responses (b,f) reveal the classic pattern of activation: a prominent M100 response and much smaller M50 and M150 peaks. The responses to the noise stimuli (a,e) contain a two-peaked 'noise onset response' both with a characteristic M50 spatial distribution (all participants had comparable response trajectories).

M100 response suppressed even though the stimuli (correlated and uncorrelated noise) are physically the same as in Experiment 1 (not what would be expected from an onset response). The M100 response is known to be modulated by attention but reported effects are not as extreme as seen here



Comparison of hemispheric activation. For each subject, in each experiment, the squared RMS value of the RH was subtracted from the squared RMS value of the LH. The resulting difference vectors for each subject were averaged together (dashed lines are 1 stde)

M50 showed significant LH lateralization in all task and experimental conditions tested. M100 lateralization (and amplitude) is task dependent (compare Experiments 2 and 3 to Experiment 1).

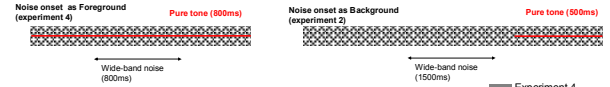
Although no lateralization is observed in the pure tone condition (and Exp 2, 3), a right lateralization is observed in Exp 1 This is attributable to the detection of slow-modulations hypothesized to be sub-served by the right hemisphere. Crucially, modulations appear only in the target stimuli (which are not analyzed)

EXPERIMENT 4 (N=5)

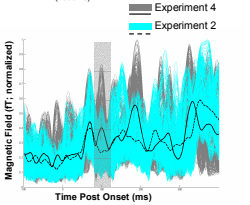
This experiment was designed to investigate the hypothesis that the reduction in M100 amplitude observed in Exps 2, 3 is a result of fact that task demands allowed listeners to treat the initial noise as background.

Stimuli: The stimuli were a 800ms long correlated noise. There was a faint pure tone (200,400, 600 and 800 Hz) embedded in the noise in 25% of the stimuli (not analyzed). ISI=900-1600

Task: Tone detection task (25% of the stimuli)



Data from Experiments 4 and 2 for a representative subject. A running average of length 200 epochs was computed and an RMS was calculated for each window (different lines in plot) in order to show that when noise is perceived as background (exp 2) responses in the M100 time window never reach the amplitude of responses when noise is perceived as foreground (exp 4). There is a significant increase in M100 in Experiment 4 relative to Experiment 2.

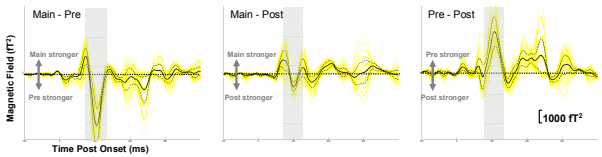


M100 is inhibited when the onset of the noise is perceived as background.

EXPERIMENT 5 (N=5): What if the noise is replaced by a pure tone?

Stimuli: The stimuli were 1500 ms long: 1500 ms of 990Hz pure tone with a faint 500 ms tonal-object (200, 400 600 or 800 Hz) appearing at 1000ms post onset

Task: (1) Pre: subjects are counting 1000ms 990Hz Tones (200 tones)
(2) Main: faint tone detection task (50% of trials)
(3) Post: subjects are counting 1000ms 990Hz Tones (200 tones)
(1)-(3) are performed sequentially. in (1) and (3) 990Hz tone is treated as an object of attention. In
(2) 990Hz tone onset is background



For each subject, the squared RMS value of each condition was subtracted from the squared RMS value of the other conditions. The resulting difference vectors for each subject were averaged together (dashed lines are 1 stde).

Even though a pure tone is a very un-natural background results are similar to what was shown for noise. M100 value is reduced in the Main part of the experiment (relative to pre) and increases again in the Post part. The Post value is still reduced relative to Pre, possibly indicating a slow return to normal after task induced persistent inhibition.

M50 value is equal in the 'Pre' and 'Post' parts and *increases* during the 'Main' part

DISCUSSION

•Experiments with wide-band noise stimuli show that, *for the same stimuli*, the strength and lateralization of the M100 response are task modulated. The M50 is consistently lateralized to the LH and its amplitude appears to be task independent, as long as wide-band noise stimuli are used

•We have demonstrated that task induced (top down) effects significantly modify auditory cortical onset responses in the M100 window.

•The current experiments differ from classic selective attention experiments because in all cases the onset of the noise was within the focus of attention.

• These findings may be interpreted as evidence for a mechanism similar to the one suggested by Kubovy &Van Valkenburg [3]:

"Early processing produces elements that require grouping….. grouping produces perceptual organizations, which are putative perceptual objects. Attention selects one putative object (or a small set of them) to become figure and relegate all other information to ground, The putative objects that become figure are perceptual objects, whereas the ground remains undifferentiated information" (pp 102).

This interpretation of our data would suggest that the processes underling the generation of M100 are responsible for coding 'perceptual objects'.

• These findings are also related to a recent suggestion by Nelken [4]. Together, the M50 and M100 might reflect the processes of feature analysis and grouping in A1 (M50) and the assignment of identity, such as pitch, phonemic quality, or location to these objects in higher auditory centers (M100)