

Ignoring a moment in time – an auditory MEG study

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ATTENDING VS. IGNORING

Most studies of auditory attention employ a dichotic presentation task, similar to visual studies of spatial attention, where different signals are presented to left and right ears and listeners are instructed to attend to one ear while ignoring the other, or tasks where subjects are presented with auditory and visual stimuli and are instructed to attend to one of the modalities. The difficulty with such tasks is the fact that it is not clear, from the comparison of brain activation to attended and non-attended stimuli whether the effects are due to amplification of responses to attended stimuli, attenuation of responses to non-attended (ignored) stimuli, or both. In the present experiment we use stimuli that allow the dissociation of the effects of attending and ignoring in order to examine whether there is an attenuation of brain responses to ignored stimuli in addition to amplification of responses to attended signals. Specifically, we investigate the temporal dynamics of early brain activity while subjects attempt to ignore (or prepare to ignore) a moment in time.

STIMULI AND EXPERIMENTAL CONDITIONS

The stimuli were triplets of 100ms pure tones (A, B, C) with a 600ms inter-onset-interval. In half of the trials, the initial and final tones (A and C) were equal in frequency; In the other half they differed by the subject's discrimination threshold. Tone B was an octave above or below. The stimulus set also included a proportion (25%) of noise bursts interspersed at random between the triplets.

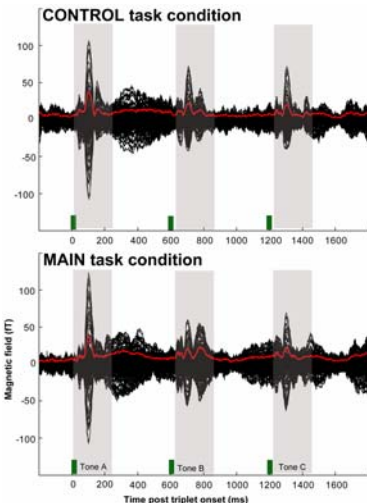
Two tasks were performed on these stimuli.

MAIN task: subjects disregarded the noise bursts and responded when tones A and C were of same frequency.

CONTROL task: subjects responded as fast as possible to noise bursts.

The task-order was counter-balanced across subjects. Stimuli were identical for both tasks, so differences in response can be attributed to the task-induced perceptual state of the listeners.

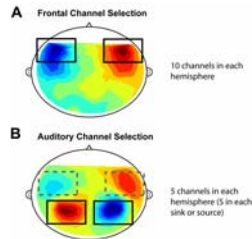
MEG DATA (N=13)



The figure presents the data for one triplet condition in the CONTROL (top) and MAIN (bottom) task conditions. Tone onsets are marked with green bars. Plotted in black are the responses for each of the 156 channels averaged over subjects. The root mean square (RMS) over all channels is plotted in red. The M100 onset responses to A, B and C tones are clearly seen at 100, 700 and 1300ms. Below we quantify and discuss the difference between MAIN and CONTROL in the way the tones are processed (shaded areas) and in the brain activity leading to and after the appearance of the tones.

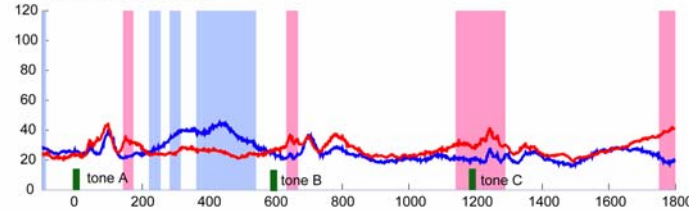
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COMPARISON OF ACTIVATION TIME COURSE

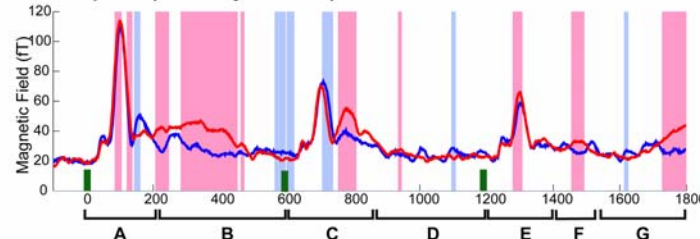


The figure below presents the time course of composite (combined across triplet conditions and hemispheres) MAIN and CONTROL amplitudes recorded from frontal (top) and auditory (bottom) channels while subjects were listening to the tone triplets (green bars). Significant differences between MAIN and CONTROL amplitudes are marked with pink (MAIN> CONTROL) or blue (CONTROL>MAIN) shading.

Frontal channels

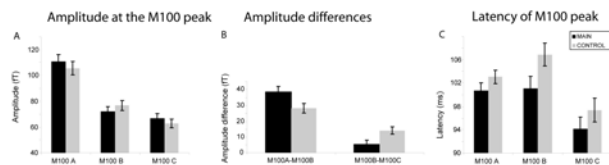


Temporal (Auditory Cortical) channels



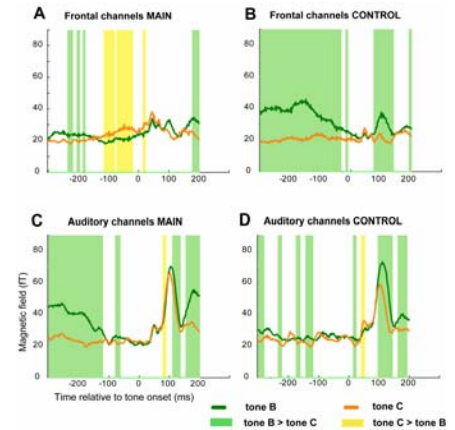
■ CONTROL ■ MAIN
 ■ CONTROL > MAIN ■ MAIN > CONTROL

ATTENTION EFFECTS ON THE AUDITORY CORTICAL M100 RESPONSE



A repeated measures ANOVA on peak amplitudes revealed a main effect of tone ($F(2,206)=158.38$ $p < 0.0001$) and an interaction between task condition \times tone ($F(2,206)=5.322$ $p=0.006$). The main effect is due to the fact that in both task-conditions the M100 amplitude progressively declines from tone A to tone C. This is known in the MEG literature as 'response habituation'. However, the interaction between task condition and tone stems from a reversal in amplitude dominance between conditions: whereas the MAIN task condition dominates for A and C tones, this dominance reverses for the B tone. Indeed, when performing the ANOVA only on A and C tones, the interaction disappears ($F(1,103)=0.7$ $p=0.78$) and instead there emerges a main effect of task ($F(1,103)=7.18$ $p=0.009$) in addition to the main effect of tone ($F(1,103)=255.37$ $p < 0.001$).

COMPARISON OF THE PROCESSING OF TONES B AND C IN THE MAIN TASK



Differences between B and C related activation in the CONTROL task condition (right) are attributable to general order effects and attention un-related aspects of the stimulus. In order to find effects that are specifically related to attention we therefore look for differences between tones C and B that emerge in the MAIN task condition (left) relative to the CONTROL condition (right). An inspection of the auditory channel data (bottom) reveals no qualitative differences between B and C related activation in MAIN and CONTROL tasks. However, activity in frontal channels (top) reveals a difference between B and C that does not appear in the CONTROL condition (compare panels A and C). Specifically, at about 100 ms before the onset of tone C, there is an increase in frontal channel amplitudes relative to the same time period before tone B (yellow shading in panel 5A).

SUMMARY– EFFECTS OF ATTENTION

The earliest auditory cortical effects related to attention are measured at the level of the M100 response. These effects, although consistent, are very small. What does that imply about processing?

Effects related to attending:

- In auditory cortex, the first effect of attention emerges at the buildup or the peak of the M100 response which originates from non-primary auditory cortex.
- In frontal cortex, when preparing to attend to an expected stimulus, there is increased activation before the onset of the tone that persists during the presentation of the tone. This is similar to the Stimulus Preceding Negativity (SPN) discussed in the literature.

Effects related to ignoring:

- In auditory cortex the first effect of ignoring emerges at the peak of the M100 response whose generators are thought to lie in planum temporale. We also see a progressive decrease in auditory cortical activity before the onset of tone B (blue shading before 600ms post onset in temporal channels) that may indicate preparatory decrease in activation.
- In frontal cortex, there is no preparatory increase in activation, such as the one observed for tone C.
- A striking effect of ignoring (or trying to ignore) is an increased positive (M150-like) response occurring after the M100 response for tone B. The comparison of frontal and auditory activity indicates that this effect is primarily generated in auditory cortex.