Experiments with Steady-State Evoked Responses from Speech and Music

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Thank you for this opportunity to come to Cuba.

In my Ph.D. study on speech audiometry at the Norwegian University of Science and Technology (NTNU) I needed to make some obligatory study points, and I am using this talk as a part of this. This was also an opportunity to use some time on ideas I wanted to check.

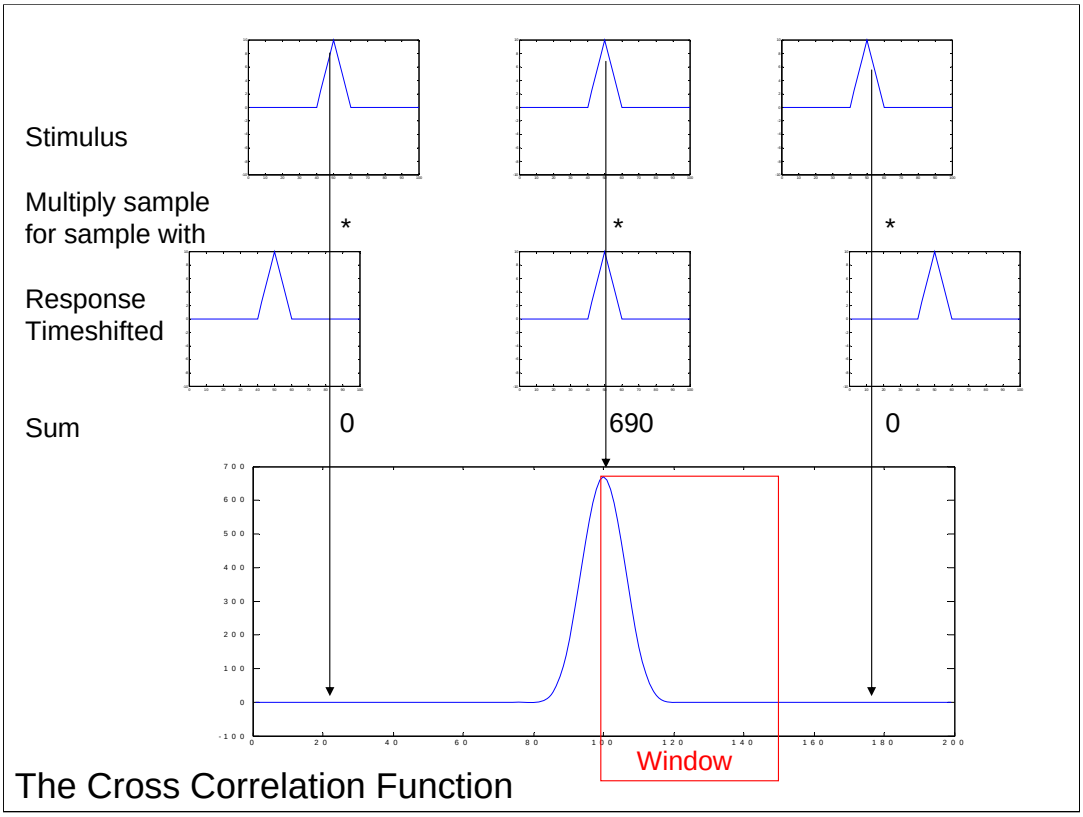
- Cross Correlation Method
- Equipment
- Signal
  music
  speech
  clicks
  modulated tones
- Results
  music
  speech
  clicks
  modulated tones
  total signal
- Discussion

Here is an outline of my talk

- **The Journal of the Acoustical Society of America -- November 1984 -- Volume 76, Issue 5, pp. 1411-1421**
- **Short-latency auditory responses obtained by cross correlation**
- **Robert A. Dobie and Michael J. Wilson**
- Pseudorandom white noise

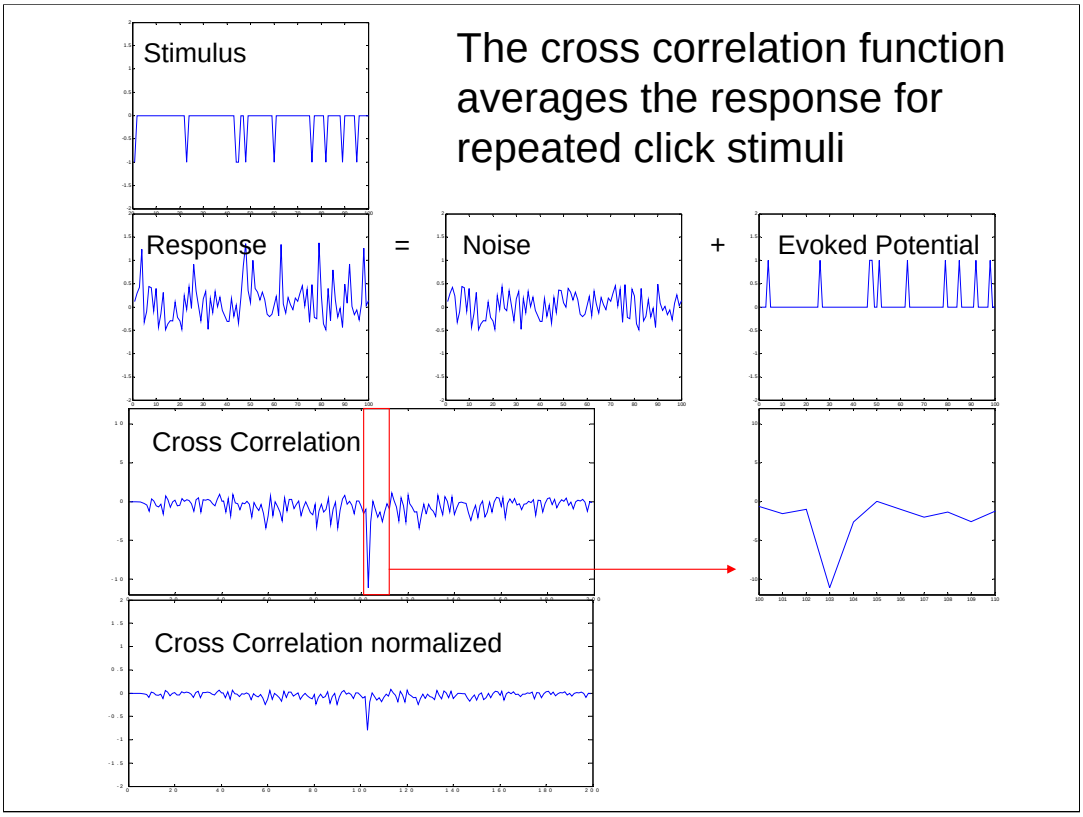
- **The Journal of the Acoustical Society of America -- September 1991 -- Volume 90, Issue 3, pp. 1398-1404**
- **Human brain-stem auditory evoked responses obtained by cross correlation to trains of clicks, noise bursts, and tone bursts**
- **Robert Burkard**
- MLS

The Cross Correlation method has been used before with evoked potentials. Dobie and Wilson have used it with pseudorandom noise, and Burkhard have used it with MLS signals of clicks, noise bursts, and tone bursts.

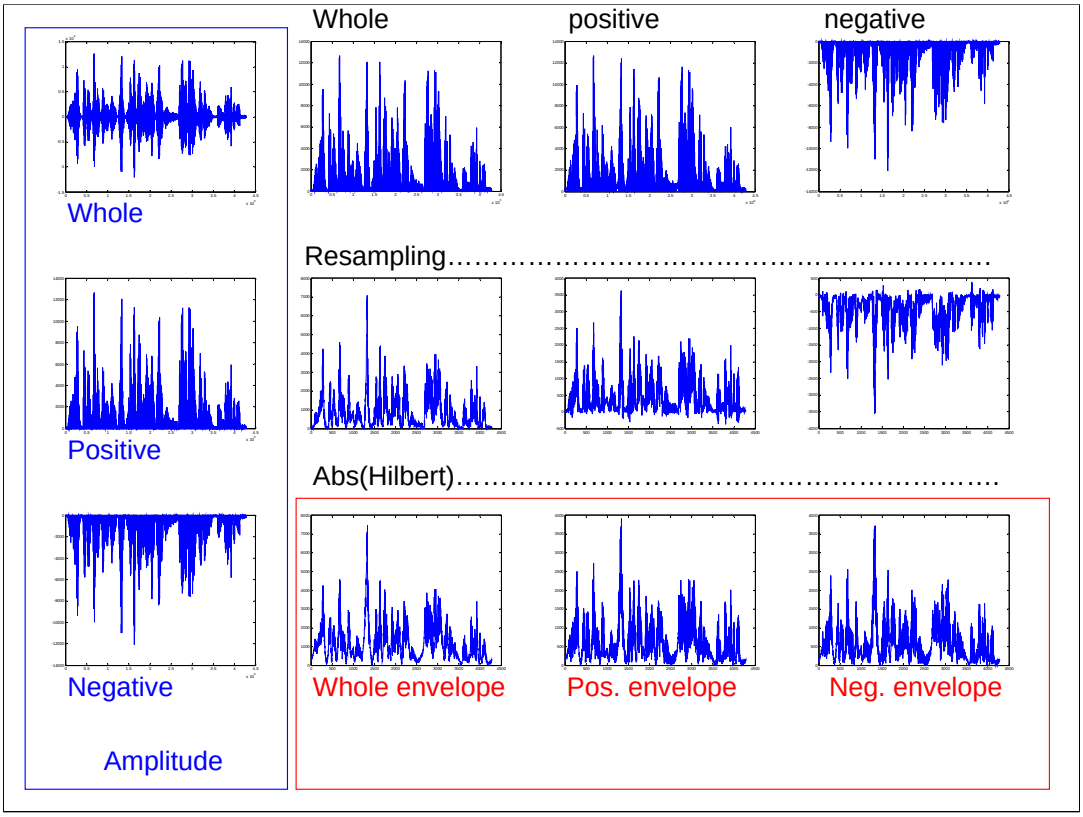


The Cross Correlation Function

If we have a signal that evokes a response (here shown just like the stimulus), we can get the cross correlation by gradually shift the response to the stimulus, multiply them together and sum. If we are only interested in parts of the response we can limit the calculation to those parts that have an effect on our window. Often the cross correlation are calculated in the frequency domain, but I have done my calculations in the time domain.



The cross correlation function averages the response for repeated click stimuli and will give the same improvement in signal to noise ratio as standard averaging. We can also notice that since our stimulus is a negative pulse it changes the polarity of the evoked potential seen in the cross correlation window.



During my analysis of results I have used the cross correlation between some variants of the part of the stimulus I wanted to check and the eeg. The variants of the stimulus have been the amplitude: full wave, positive or negative and the envelope full wave rectified, positive or negative.

- Cross Correlation Method
- Equipment:
  Circumaural headphone: Sennheiser HD530
  Montage: Fpz-Oz
  Common: chin
- Signal
  music
  speech
  clicks
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  music
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I had made some preliminary test with the MASTER equipment and other stimuli. The main problem was that I did not get synchronization between the sound I used as stimulus and the eeg-response I measured. I needed this to do a good analysis of the results.


Roken brengt
u en anderen rondom u
ernstige schade toe
KLEINE
TUDUNAK
P.G.C. HAJENIUS
AMSTERDAM
25 CIGARS 100% TOBACCO


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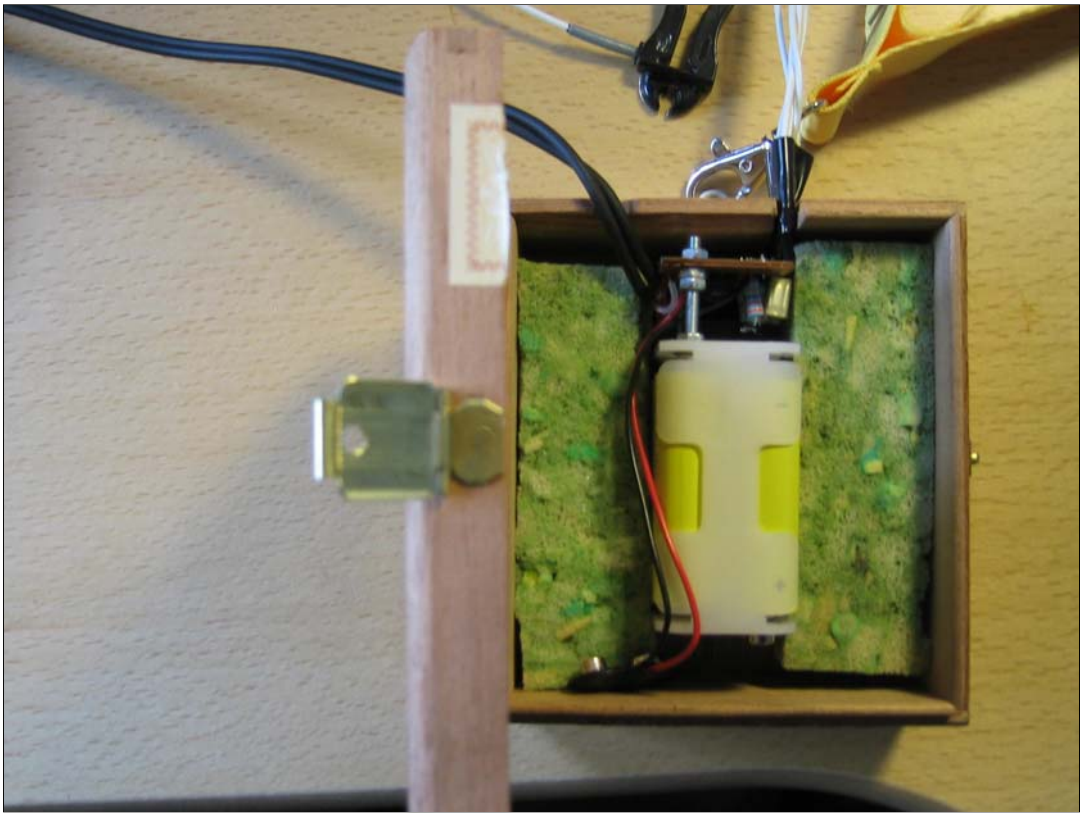
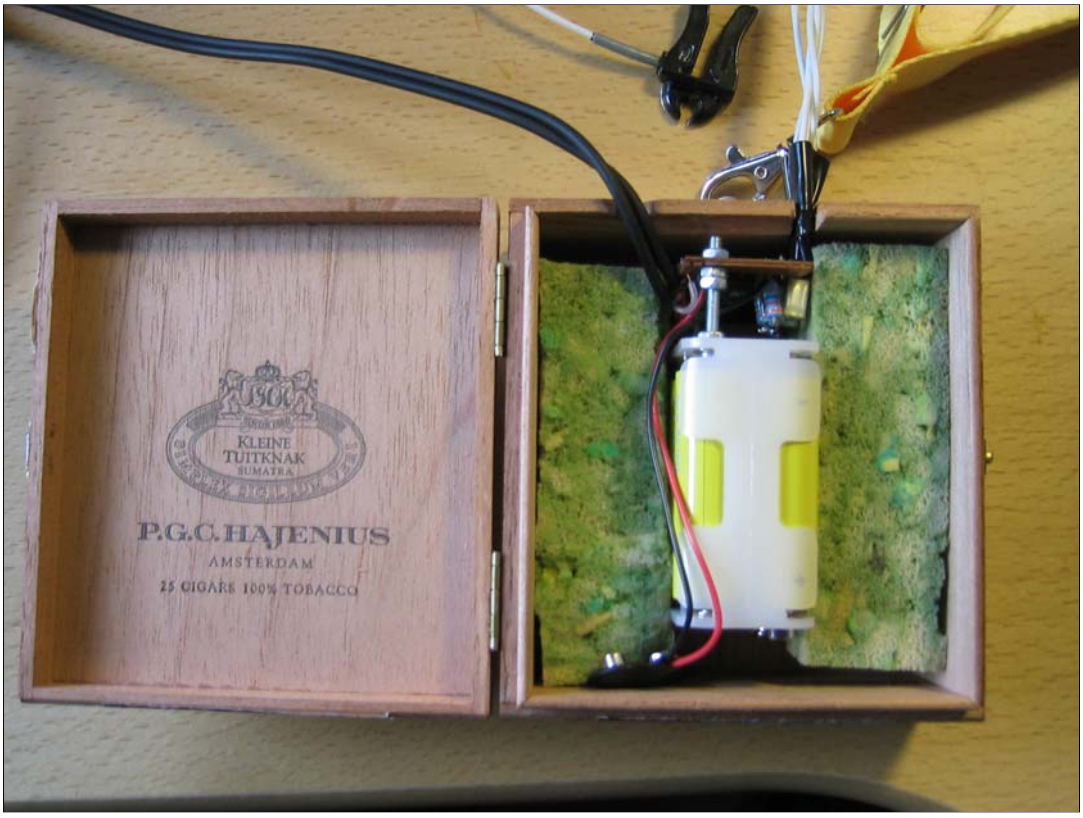
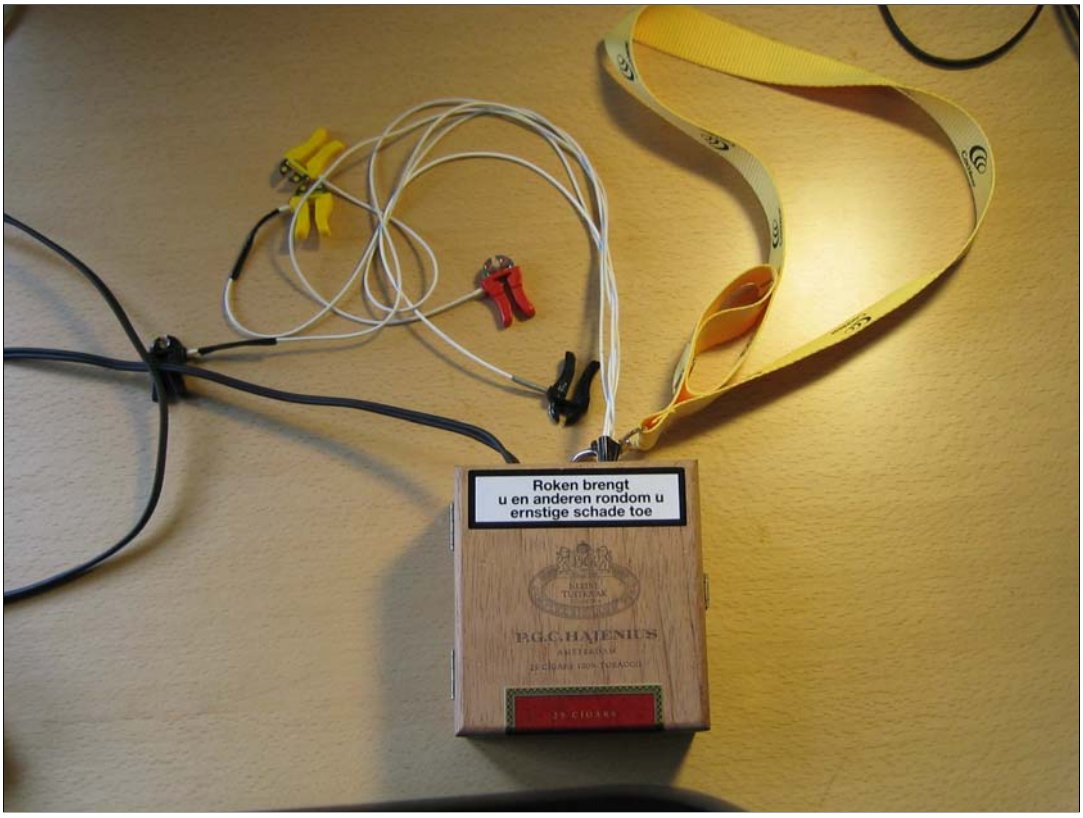



KLEINE
TUITENAK
P.G.C.HAJENIUS
AMSTERDAM



I decided to build an eeg-amplifier. The 2-channel eeg-amplifier was built with Analog Devices AD620 instrumentation amplifier, and put into this cigar case with a battery pack. I am sorry I did not have any Cuban cases that were suitable, but this Dutch case fitted perfectly.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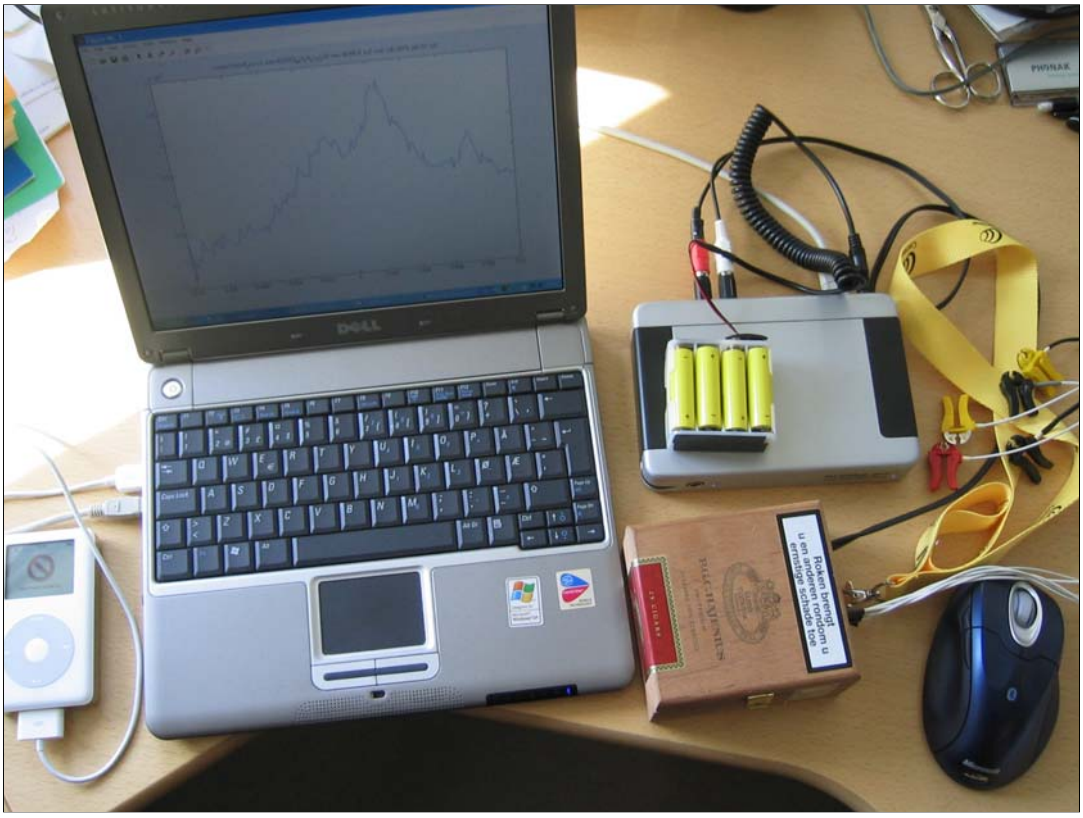

The signal from the eeg-amplifier was led to a Terratec Phase 24 firewire soundcard. I also made a battery pack for this sound card.

I would record the results from this 24-bit soundcard as 32-bit wav-files. The recordings would last for almost an hour so I needed lots of disk space for generating the sound stimuli, for recording of the eeg-signals and for analysis of the results. For patient safety reasons I wanted all my equipment to be battery powered. The Apple iPod photo with a 60GB hard disk was a good equipment to expand my need for more space and keep the equipment battery operated.

- Cross Correlation Method
- Equipment
- Signal
  - music
  - speech
  - clicks
  - modulated tones
- Results
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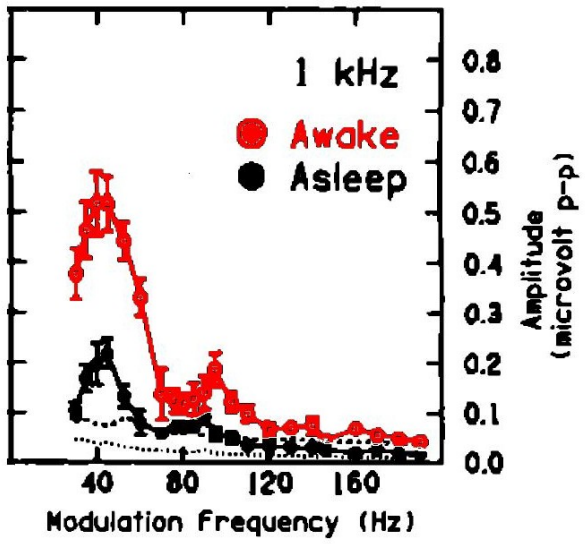
A 50 minute stereo stimulus file was generated.

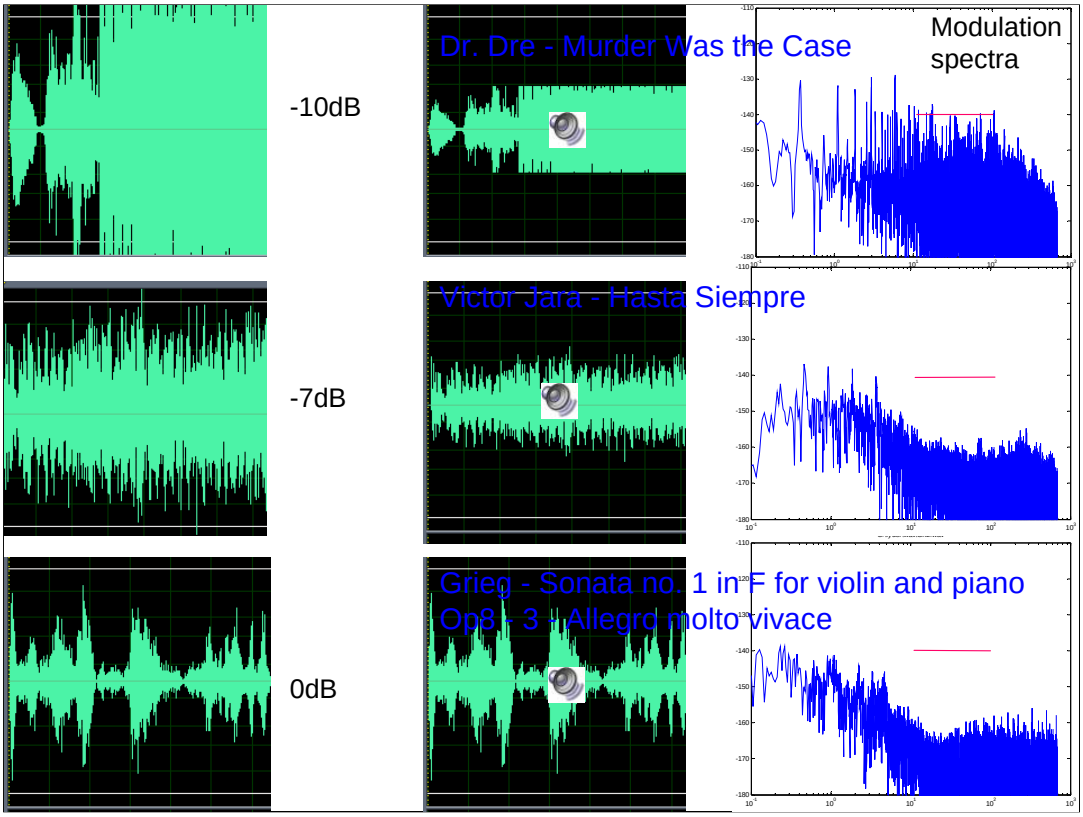


A comparison of steady-state evoked potentials to modulated tones in awake and sleeping humans

Lawrence T. Cohen, Field W. Rickards, and Graeme M. Clark
Human Communication Research Centre, The University of Melbourne, Department of Otolaryngology, Parkville 3052, Australia

J. Acoust. Soc. Am. **90** (5), November 1991

From the experience with ASSR measurements we know that the modulation frequency has a great impact on how good responses we get. I wanted music that had much modulation in the 40Hz and 80Hz regions as we use in ASSR measurements.



I made a MATLAB routine to calculate the modulation spectrum of the first 90 seconds of sound files, and searched through many songs in my mp3 collection. On the right we see some modulation spectra. I have marked the 10-100Hz region with the red line, and we see great differences between different types of music.

Rap music were what I found have the highest levels, rock and folk music was lower and the lowest levels of modulation spectra did I find on classical music. Here I have chosen one melody from each group.

I used Adobe Audition to adjust the loudness level equal for those melodies. We see that it was necessary to reduce the first melody 10dB and the second 7dB to get equal loudness.

Here can we hear some excerpts of the music used:

Dr. Dre - Murder Was the Case

This is an example of music with the highest modulation spectra.

Victor Jara - Hasta Siempre

I selected this in honour of Che Guevara who would have had his birthday yesterday.

Grieg - Sonata no. 1 in F for violin and piano op8 - 3 - Allegro molto vivace

This is an example of music with the lowest modulation spectra.

- Cross Correlation Method
- Equipment
- Signal
  music
  speech
  A radio play from Norwegian Broadcasting of suitable length. The play was written by John Dickson Carr
- clicks
  modulated tones
- Results
  music
  speech
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- Discussion

I tried to find some good binaural sources with little correlation between left and right channel. But I did not succeed in the limited time span I have been working with this. So I ended up with using a radio play from Norwegian Broadcasting of suitable length. The play was written by John Dickson Carr.

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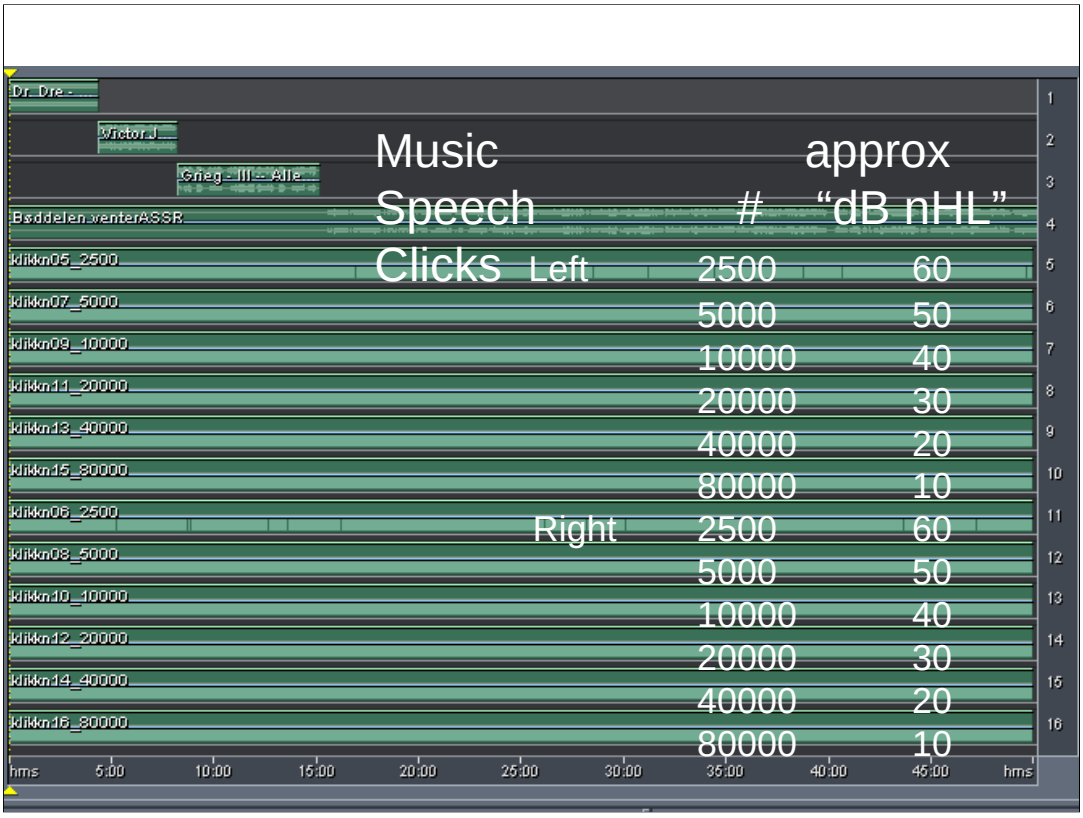

Here are some parts of the stimuli as seen Adobe Audition. The three top lines show the stereo tracks of music used. The fourth track shows the stereo tracks of the radio play with speech. Below are several mono tracks with clicks. Several files were generated with MATLAB with 90.7 microsecond negative width (electrical, not checked acoustically if they really are rarefaction). The clicks are randomly spaced over 50 minutes:

2500 clicks at approx. 60 dBnHL

5000 clicks at approx. 50 dBnHL

10000 clicks at approx. 40 dBnHL

20000 clicks at approx. 30 dBnHL

40000 clicks at approx. 20 dBnHL

80000 clicks at approx 10 dBnHL

Different files are generated for each ear.

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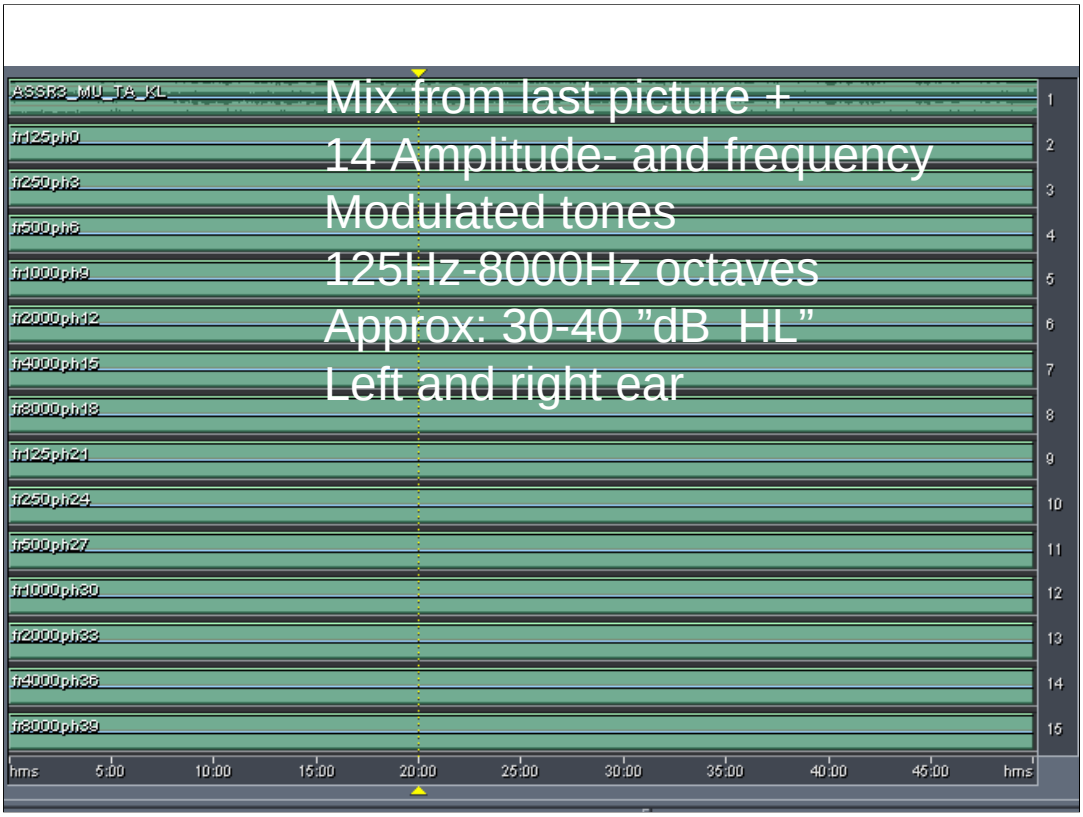
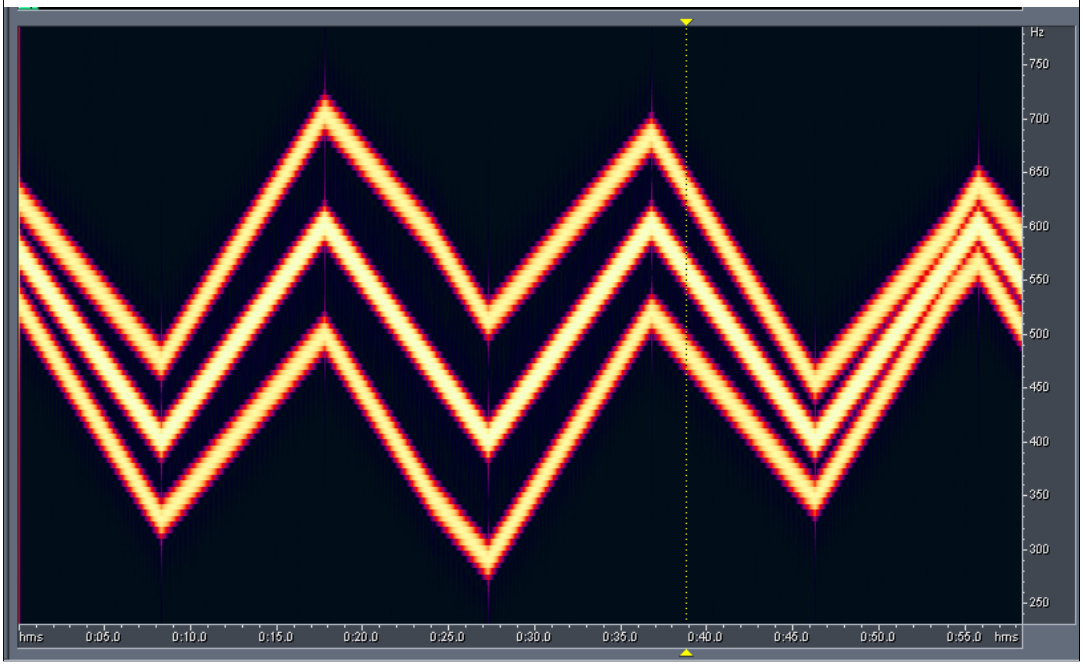


On the top track are the mix from last picture with music, speech and clicks.

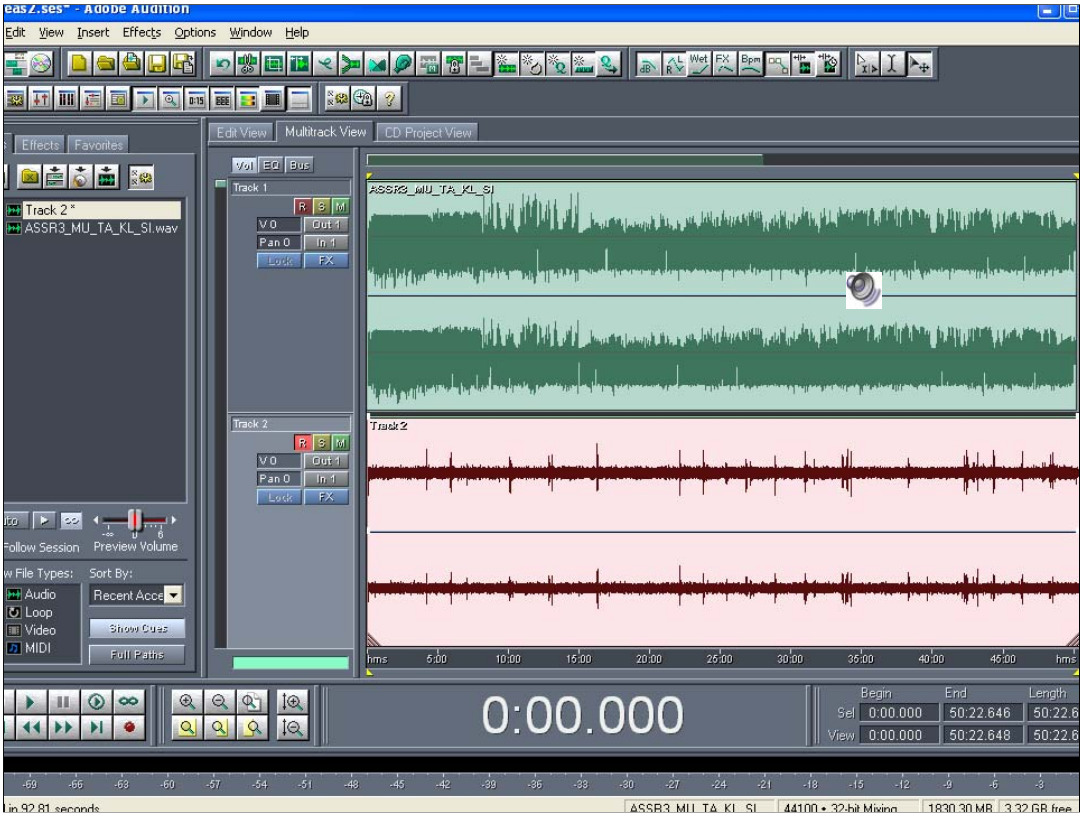
Here have I added AM and FM tones of all the octaves from 125Hz to 8000Hz at approximately 30 and 40 dBHL.

Different files were generated for each ear wtith MATLAB.

Spectrogram of 500Hz tone left ear
Frequency modulation +- 20% 19s period
Amplitude modulation 30 -120Hz 60s period
Different modulation phases for all tones



Here we see a spectrogram generated by Adobe Audition of the start of the 500 Hz tone from left ear as an example. The central zigzag shows the +-20% FM modulation with a period of 19 seconds. The varying distance to the upper and lower sidebands shows the AM modulation between 30-120Hz with a period of 60 seconds. The other tones have different phases on the amplitude and frequency modulation with 3 seconds increments. This will give each tone a different modulation pattern that should be possible to detect during the analysis.



Adobe Audition 1.5 was used both to mix together the recording stimuli and to record the eeg-response.

Here can we hear a passage of the speech with the clicks and tones in the background.

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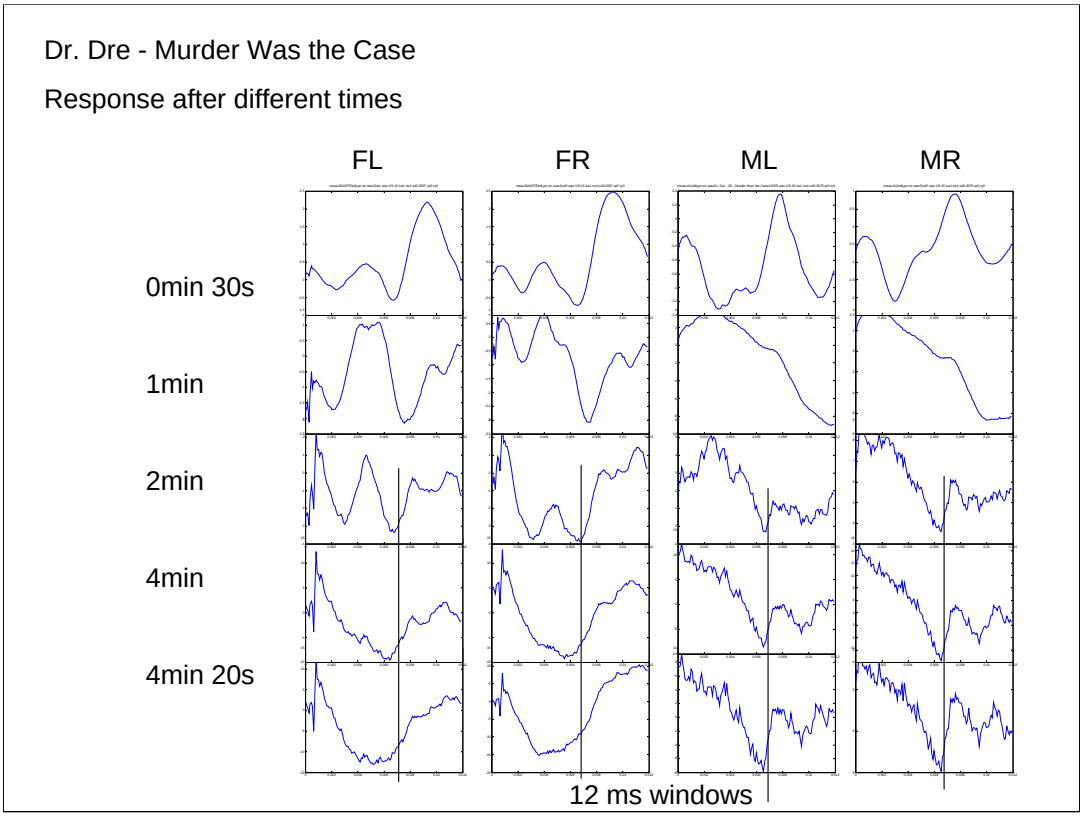
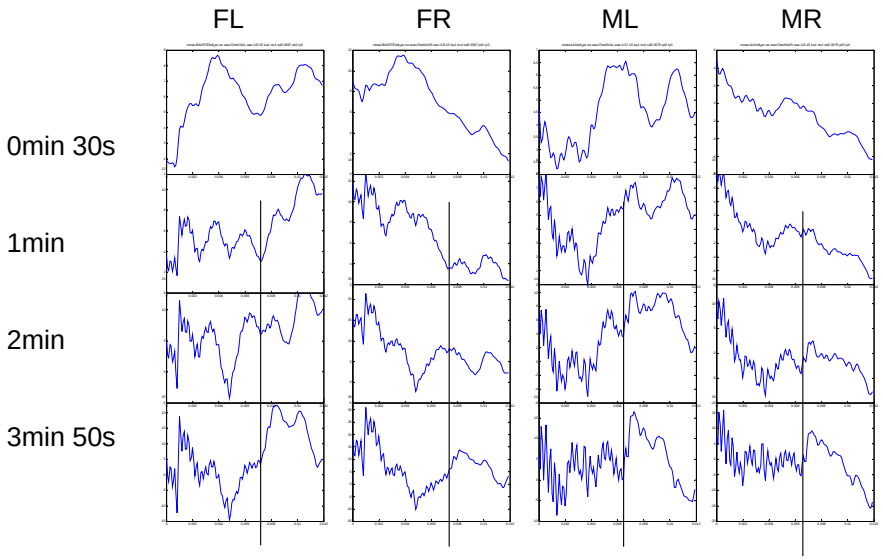
I have only tested two young adults with this technique; one male and one female test person.



To see the results we use the cross correlation function between one channel of the original music and the eeg-response. Here is shown the results in 12ms windows. We see how the response was built up during the recording session. The vertical lines show what could be Jewett V waves at 6ms.

Victor Jara - Hasta Siempre

Response after different times

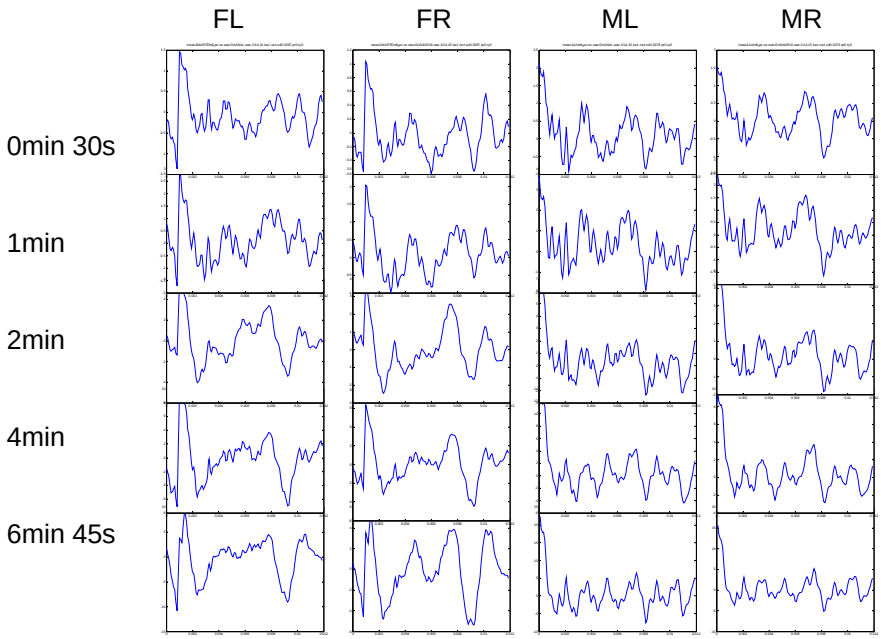


12 ms windows

Here are similar results from the second melody.

Grieg - Sonata no. 1 in F for violin and piano op8 - 3 - Allegro molto vivace

Response after different times



On the classical music the timings of the waves are a little different; the most pronounced negative peak is at 8ms.

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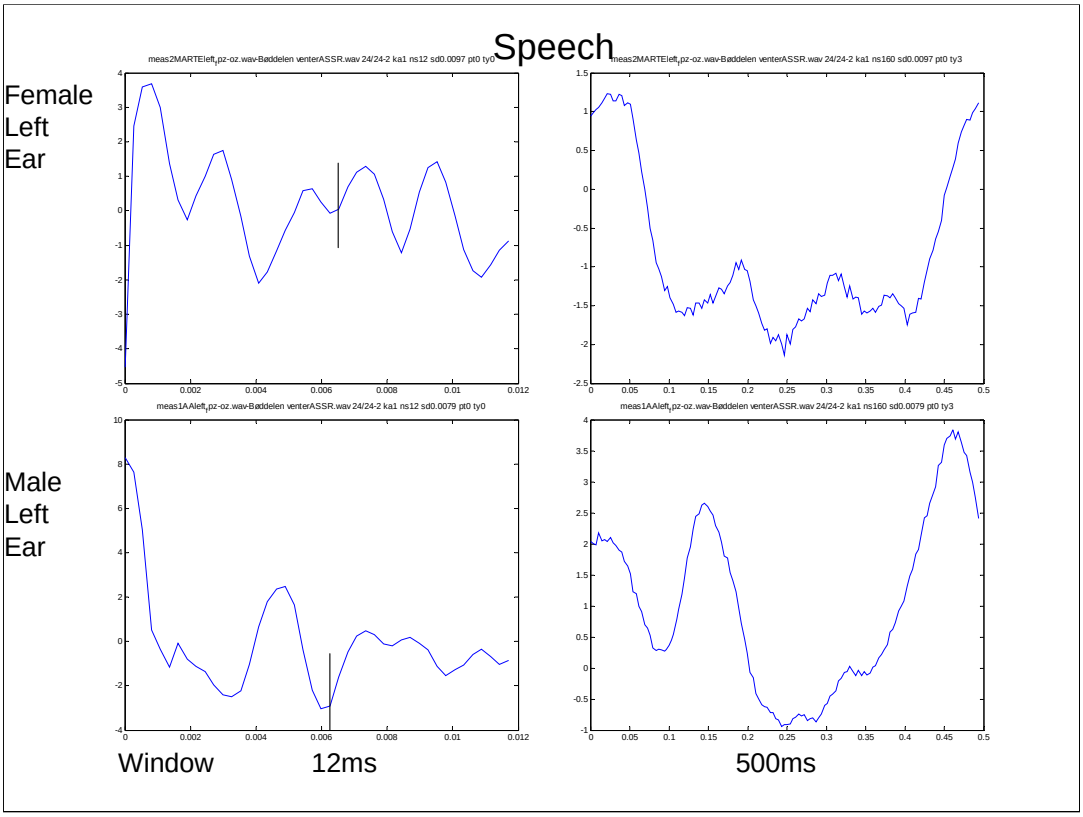

Results with a 12ms and a 500ms window are shown. We have perhaps a Jewett V at approx 6ms on the left? I am not sure about the slow waves at the right.

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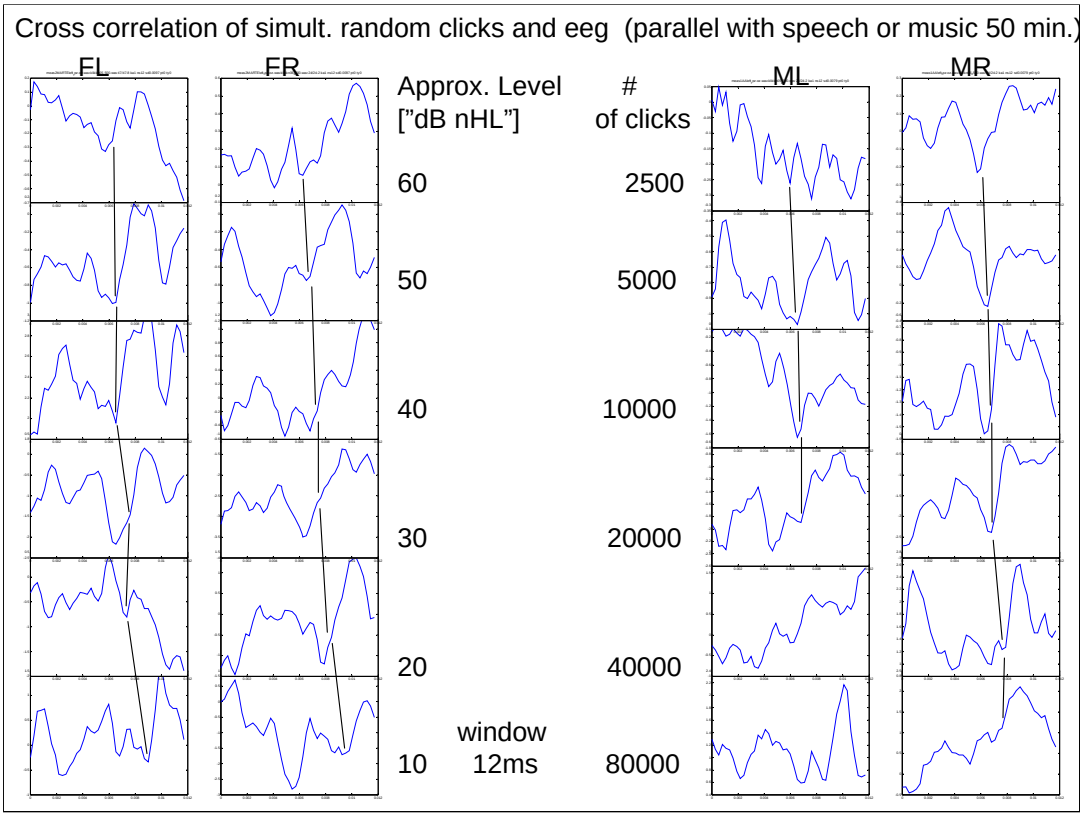

It seems that we can follow some waves with increasing latencies down to low levels?

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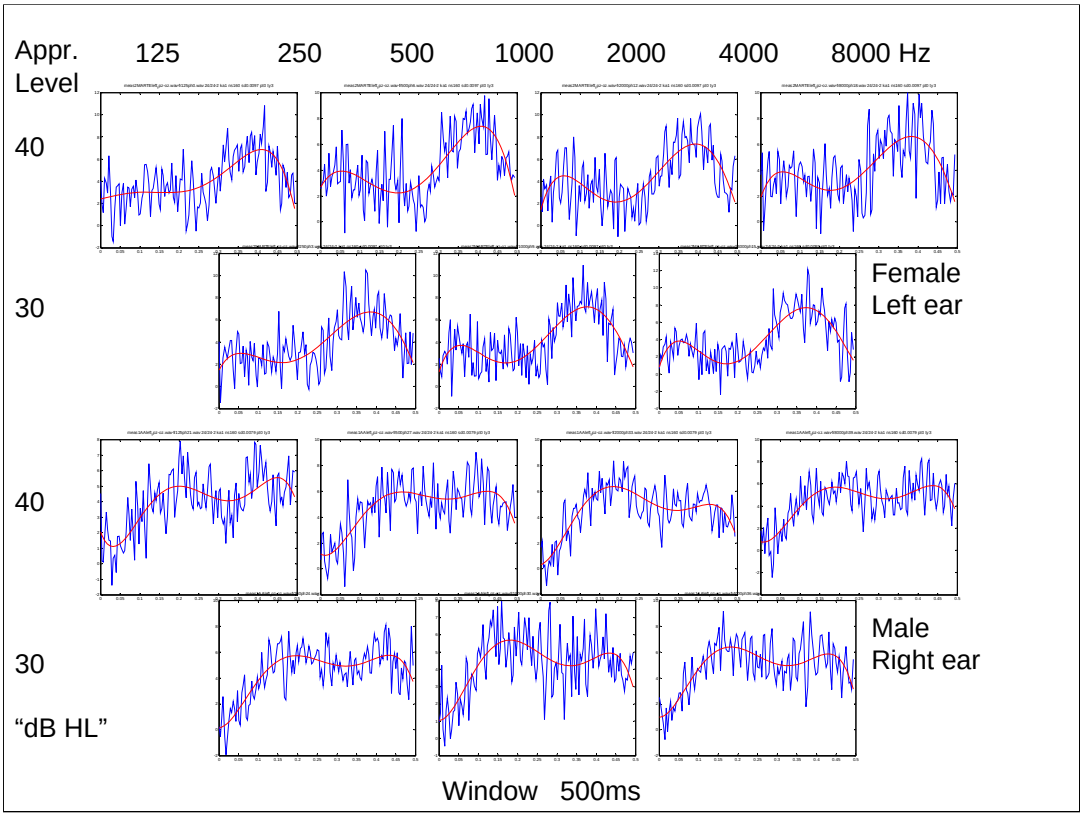

I have had some problems to find results from the modulated tones in the short windows. Here are shown some results from a longer window of 500ms. The cross correlation have been calculated between the full wave rectified envelope of the tone and the eeg. Because of the ripple from the analysis (blue) I have overlaid a polynomial of degree 5 (red). Then it is possible to find some common characteristics from these curves.

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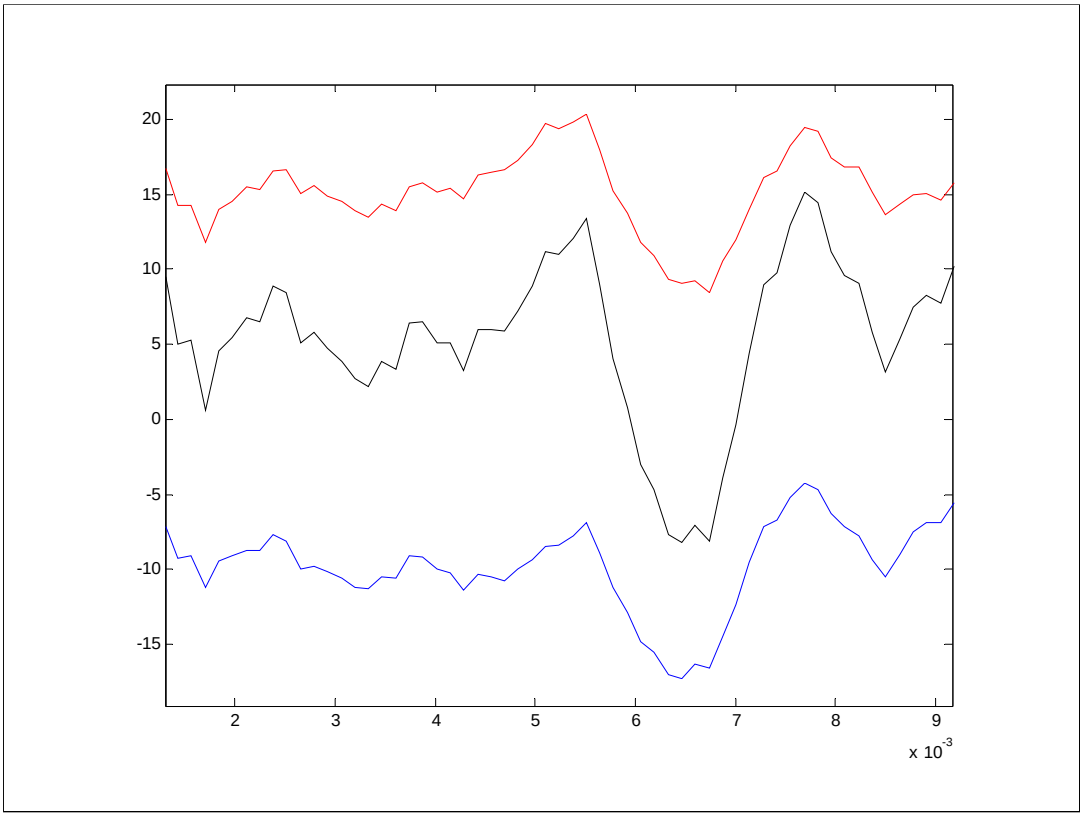
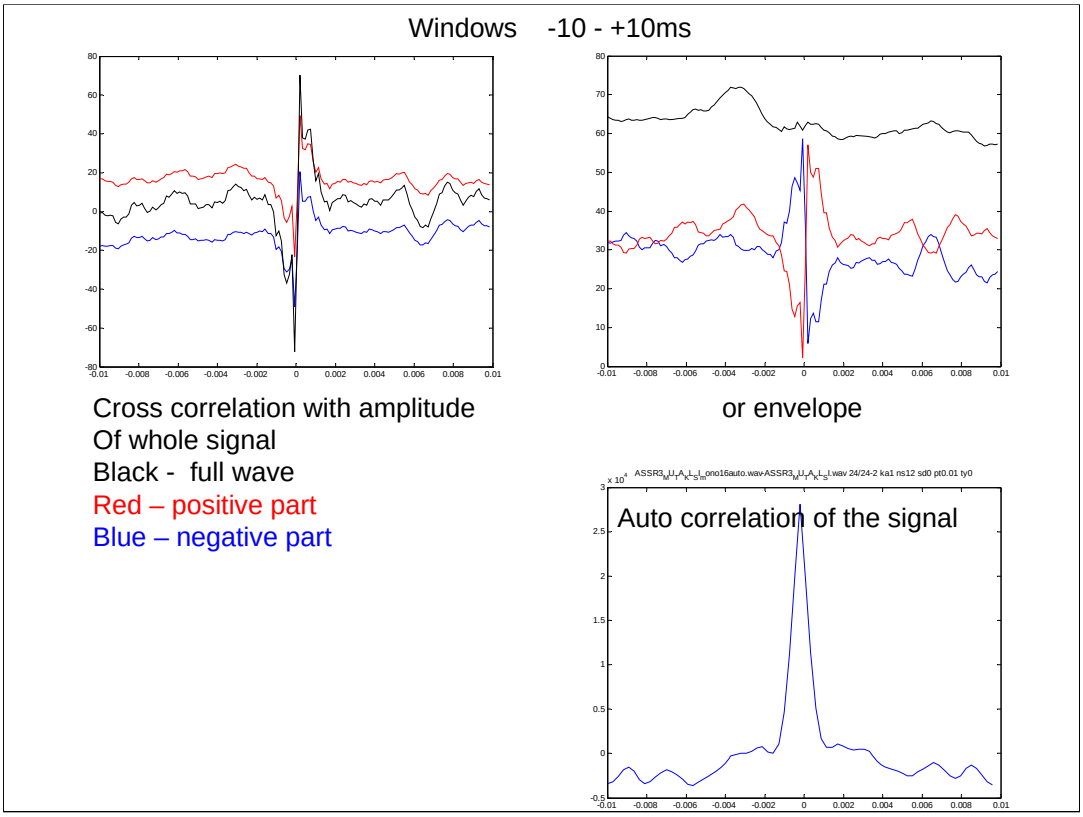
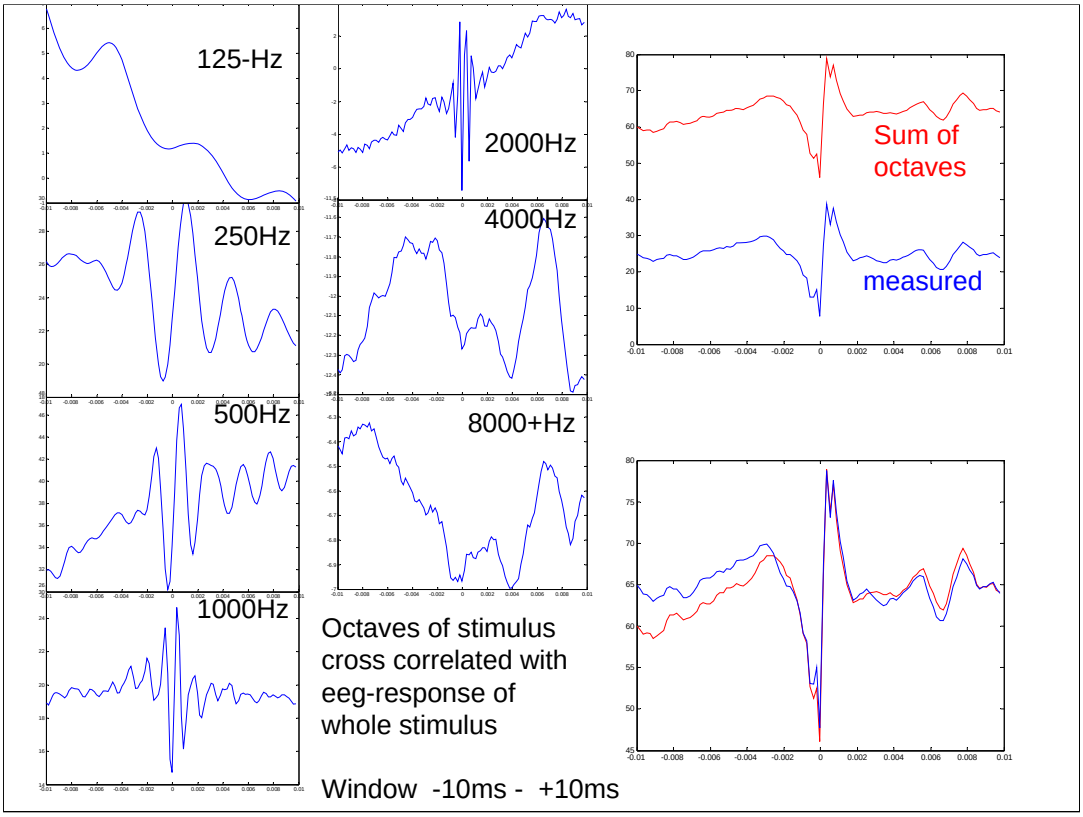


Here are results were we have used the total signal (music+speech+clicks+tones) during our analysis. First approx 10ms window with cross correlation with full wave (black), positive (red) or negative (blue) amplitudes and the eeg.



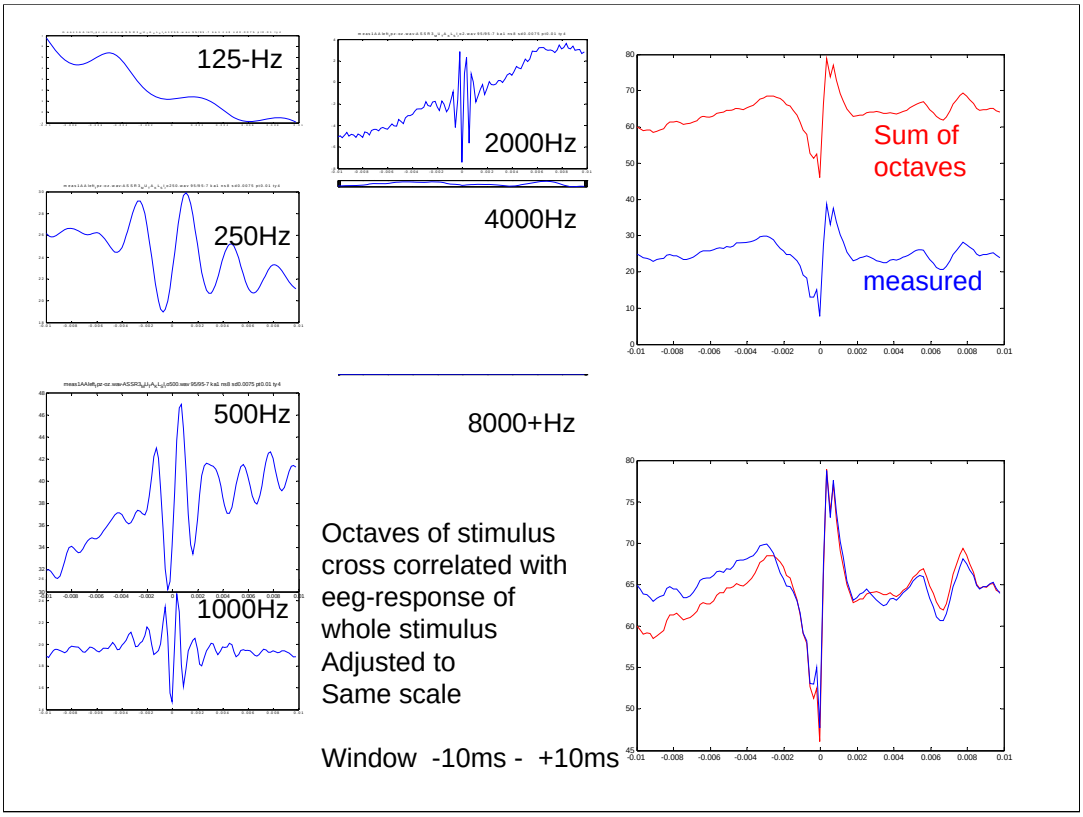
Here on the left the same as previous picture but in a -10ms - +10ms window. On the right are results if use the envelope in the cross correlation in stead of the amplitude. Remember that all my calculation of the envelope was positive. But we see that the responses from the positive envelope (red) have opposite polarity compared to the response from negative envelope (blue). If this response was purely neural I would have expected the same polarity. Because of this polarity differences we see that the full wave result have much smaller amplitude. On the bottom called the auto correlation is the cross correlation between a mono mix of the signal and the right channel of the signal. We can here find waves with similar latencies as above. These results show that parts of the results I have shown can be artefacts from the measurement signal I have been using.



(Octaves…

Did not have time to say anything about these slides in the presentation)

Here are shown the results if we take cross correlation of different octave bands of the stimulus and the eeg. I don't know if it is possible to use these results? Since MATLAB shows these curves with auto scaling, I have adjusted the vertical scale of the windows on the next slide so we can see how much each of the octaves contributes to the sum.



The calculated sum is reasonably close to the measured response. The differences could be because of inaccuracies with the octave band filtering which was done with Adobe Audition.

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The bottom line is here the most important; more research needs to be done to make sure we are studying neural responses and not measurement artefacts. I think this method could evolve into something very useful.

Discussion/conclusion

- Artifacts from the signal?
- Clicks can be mixed with steady state signals?
- Speech or music can be used as test signals, or to make the measurement session more pleasant, or to give instructions?
- Cross correlation method gives more opportunities in selection of test signals?
- More research needs to be done.