Speech 2

EEG Research

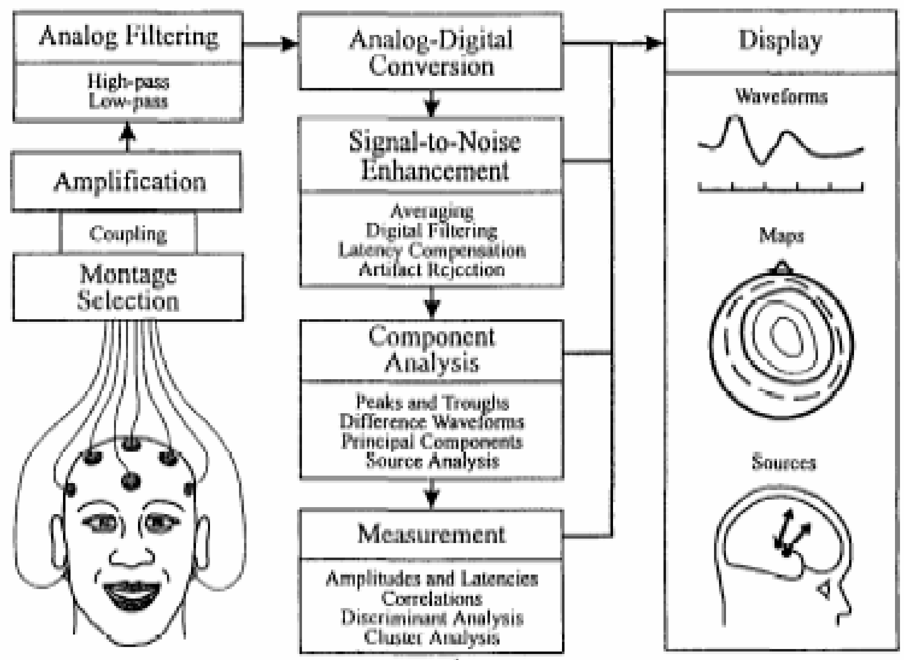


Fig. 1. Overview. This figure illustrates the different procedures involved in recording human ERPs. The left column shows the procedures involved in recording the electrical activity from the scalp. The middle column shows the procedures for analyzing these signals in a digital computer. The amplified analog activity is initially converted into digital format. Various techniques are then used to enhance the signal-to-noise ratio to determine the components of the recorded wave forms and to measure these waveforms or components. The right hand section of the figure shows different means for displaying the activity during and after its analysis.

Voltage Maps

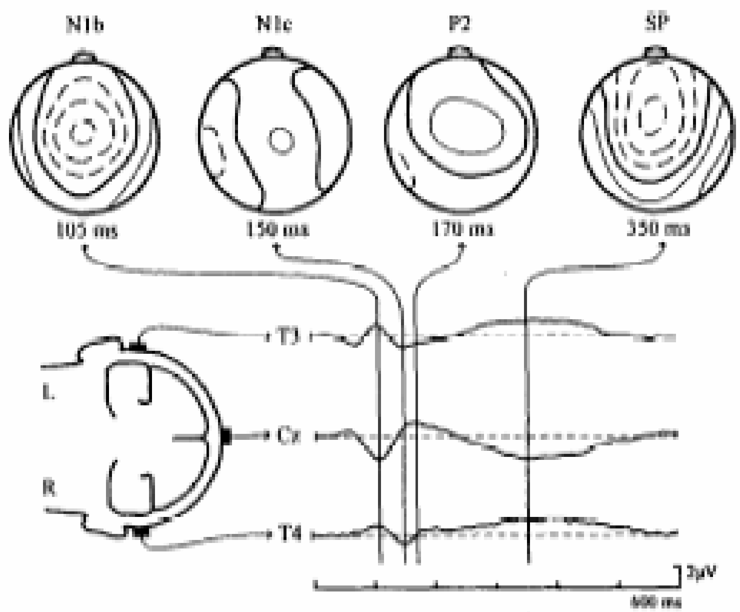


Fig. 19. Scalp distribution maps for the auditory evoked potential. These maps present the scalp distributions at selected latencies during the waveforms plotted in Fig. 4. The maps are based upon the average reference recordings and are plotted using an azimuthal equidistance projection extending down below the Fpz-T7-Oz-T8 equator to about the level of the mastoid electrodes. The thick line in the maps represents zero voltage. The dashed lines represent contours for negative voltages and the thin lines represent contours for positive voltages, both plotted at intervals of 1 μV. At 105 ms there is negative wave (N1b) recorded maximally at the vertex whereas a later negative (N1c) occurs maximally in the left temporal region. The P2 wave is maximally recorded from the vertex. The sustained potential (SP) is maximally recorded from frontocentral regions with a scalp distribution somewhat more anterior than that of the N1b wave.

$$V_x = \sum_{i=1}^{N} (d_i^{-m} V_i) \Big/ \sum_{i=1}^{N} d_i^{-m}$$

- Nearest Neighbor
  - di: distance to electrode i
  - N: number of neighbor electrodes
  - Vi: voltage at electrode i
- Alternative
  - Spline interpolation

Current Source Density

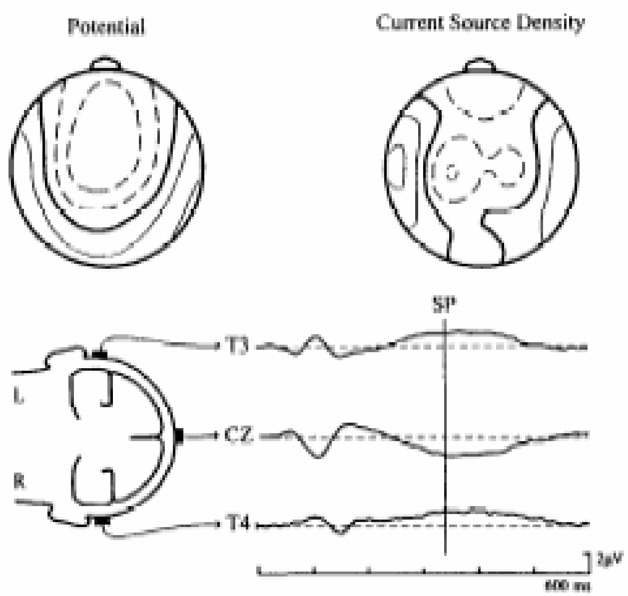


Fig. 22. Current source densities. The upper left of this figure illustrates the scalp distribution of the sustained potential recorded at a latency of 350 ms for the same data as shown in Fig. 19. As in previous maps, contours in region of negative polarity are plotted with dashed lines and contours in the region of positive polarity are plotted with thin lines. Sample waveforms (referred to an average reference) are shown in the lower half of the figure. The current source density is plotted in the upper right of the figure. The distribution of the current source density over the scalp suggests dipole fields originating in the Sylvian fissures, particularly on the left. The stimulus was presented to the right ear.

- 2nd spatial derivative
  - How voltage changes at each point on the scalp differ w/respect to changes at other points
- Estimates sources and sinks of radial current
  - Net current outflow: source
  - Net current inflow: sink
- Highlights activity focused on limited scalp area
- Tends to remove deep sources that show up at many electrodes

Scalp Distribution of Dipole Fields

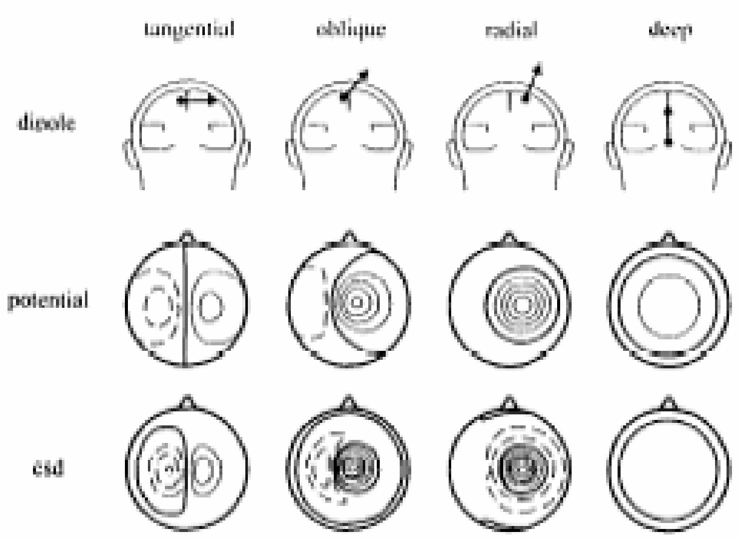
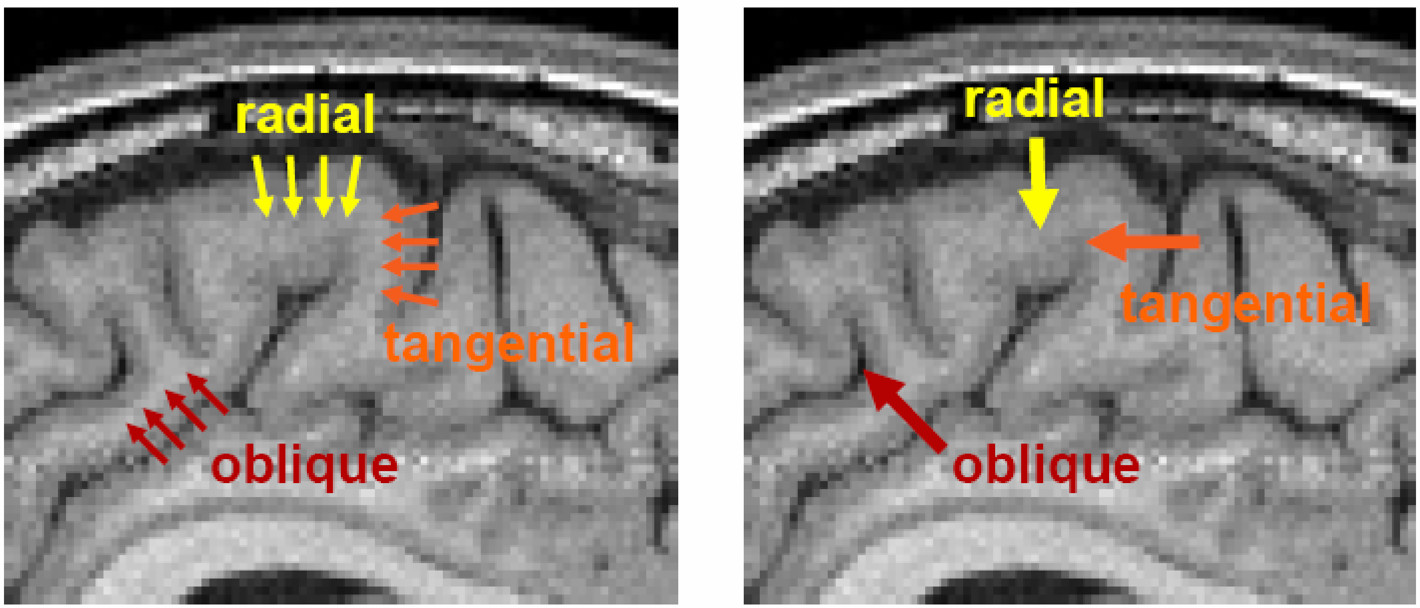


Fig. 21. Scalp distribution of dipole fields. At the top of this figure are shown dipoles located in various regions of the brain. All dipoles are oriented within the coronal plane. The second line of the figure shows the distribution of the scalp potentials associated with these dipoles. The bottom line of the figure estimates the current source density (csd) at the surface of the scalp. Note the similarity between the middle two potential maps and the dissimilarity of the csd maps. Note also the absence of any clear csd map when the dipole is located at the center of the head (rightmost column).

- Oblique & Radial sources yield
  - similar scalp maps
  - different CSDs
- For deep source
  - No clear CSD
  - Deep sources equally distant from all sites
  - Look similar at all sites
  - Hard to detect with derivative measure

Neuronal current flows perpendicular to the cortex and creates dipole fields

net current density * area = equivalent dipole moment



Source Parameters

- Dipoles characterized by 5 parameters
- 3 location parameters
  - Eccentricity – distance to center of head
  - Theta – angle w/vertical axis
  - Phi – angle from coronal plane
- 2 orientation parameters
  - Theta – angle w/vertical axis
    - Positive: right
    - Negative: left
  - Phi – degrees from the coronal plane
    - Positive: counterclockwise
    - Negative: clockwise

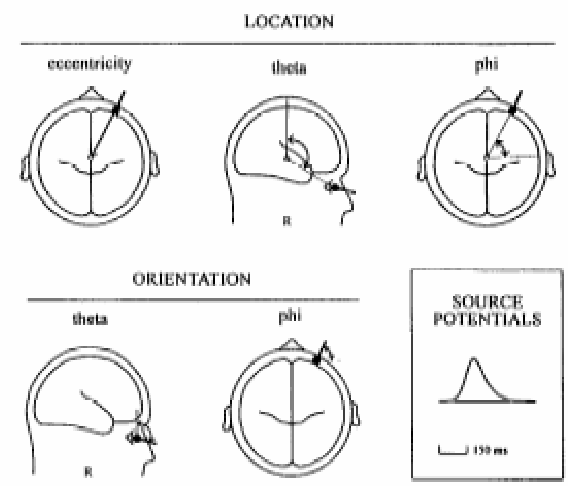


Fig. 38. Source parameters. This figure illustrates how source analysis can describe the parameters of a dipole source. For simplicity, only one dipole is shown (a blink dipole). A source dipole is defined by its location, orientation and strength. Location is expressed by three parameters: eccentricity, azimuth (theta) and longitude (phi). Eccentricity is the distance from the source to the center of the head model. It is often expressed as a percentage of the radius of the head model used. Theta is the angle formed with the vertical axis by the line joining the source location to the center of the head. Phi is the angle formed with the coronal plane by a line joining the source and the center of the head. Orientation is expressed by two parameters: theta and phi. These are measured using the same references as the angles used to express location. The sign convention for theta is that a positive sign indicates right-sided location or right-going orientation and a negative sign indicates left-sided location or left-going orientation. For phi, a negative sign means clockwise rotation and a positive sign means anti-clockwise rotation from the coronal plane. The strength of the dipole as a function of time is given by the dipole source potentials.

Source Analysis

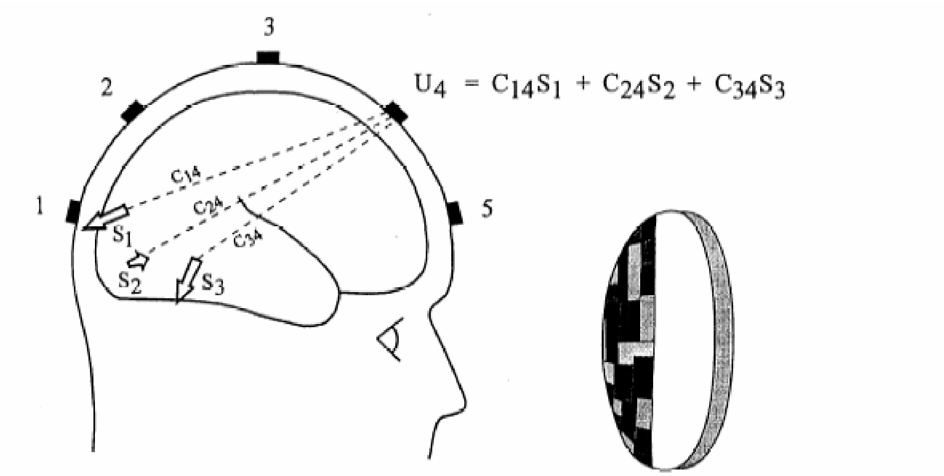


Fig. 39. Basic principles of source analysis. During an ERP waveform several sources (s_n) may generate electrical fields that can be recorded from the scalp. The electrical activity recorded at a scalp electrode (u_k) is the sum of the activities from all the sources. The voltage generated at the scalp by these sources will depend on the location and orientation of the sources and upon the geometry and impedance of the head. These factors can be combined into a coefficient (c_{nk}) specific to the source and the electrode. The diagram illustrates these principles using the main sources that are active during the ERP evoked by a half-field patterned visual stimulus (Plendl et al., 1993). The posteriorly oriented first source represents activity in the striate cortex; the laterally oriented second source represents activity in the peristriate cortex; and the inferiorally oriented third source represents activity in the medial inferior surface of the occipital lobe.

- Activity at each site linear combination of sources
- C here is coefficient that determines value of source at electrode u based on
  - Source Location
  - Source Orientation
  - Conductivity of brain, skull, and scalp

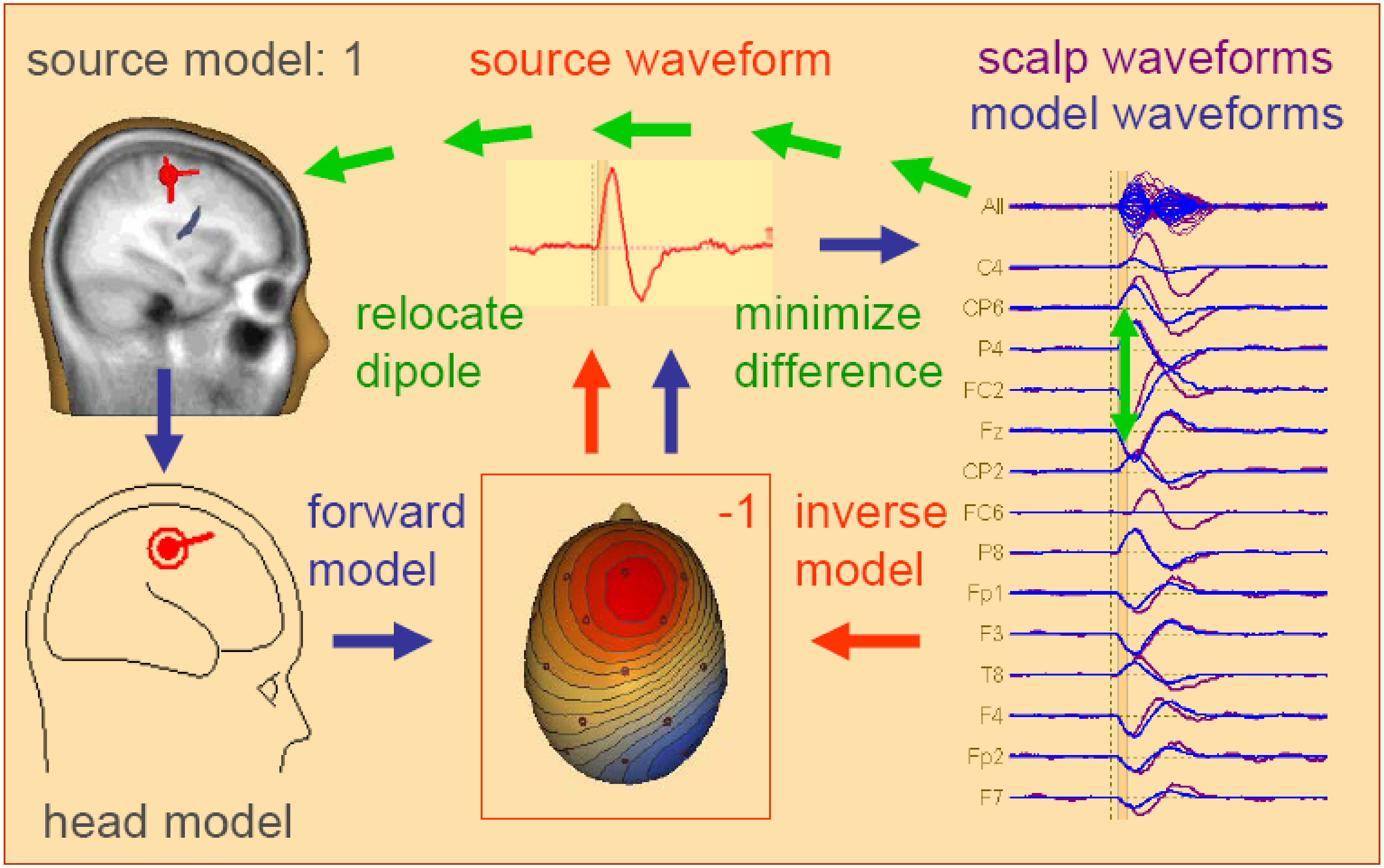
General Idea

- Forward Model
  - Postulate N dipolar sources with particular locations and orientations
  - Coefficient matrix C: N sources x K electrodes (values based on head model)
  - Run source magnitudes through C to yield predicted scalp voltage at each electrode: Vector U’
- Inverse Model
  - Invert matrix C
  - Multiply by actual scalp voltage matrix U
  - Yields S
- Reduce Residual Variance
  - Difference between U and U’
  - Change dipoles so as to minimize difference between U and U’
- Rinse and Repeat

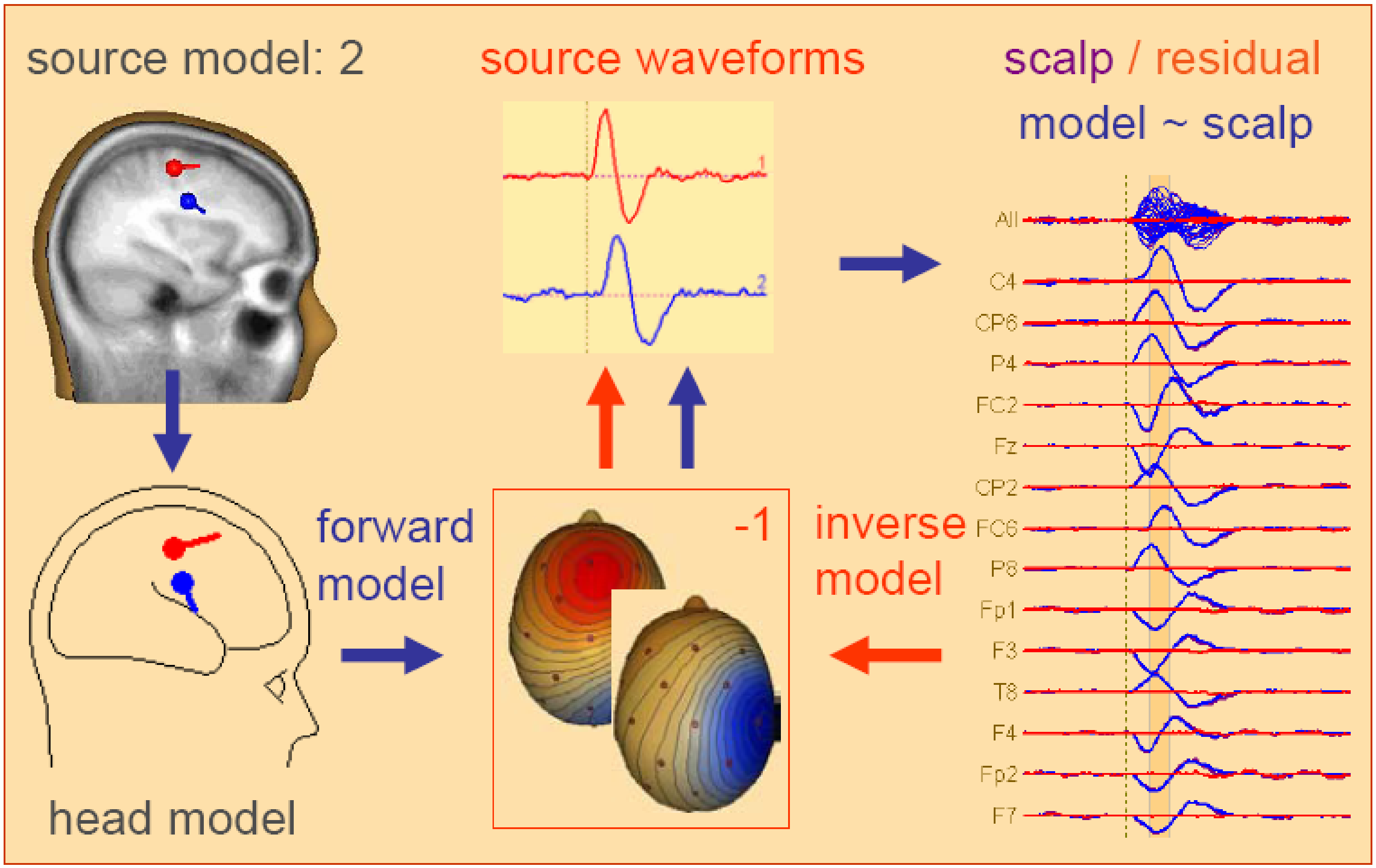
DIPOLE SOURCE MODELING

- There are more unknowns (dipole sources) than knowns (electrodes)
- This results in infinite number of possible solutions.
- Usually done as an iterative forward algorithm with a small number of equivalent source dipoles.
  - A starting point is chosen based upon additional information -fMRI etc.
  - A forward solution of the scalp map is calculated.
  - An iteration is chosen holding some factors constant.
    - Orientation
    - Location
    - Magnitude
  - The process is repeated until a satisfactory fit of the scalp map is obtained.

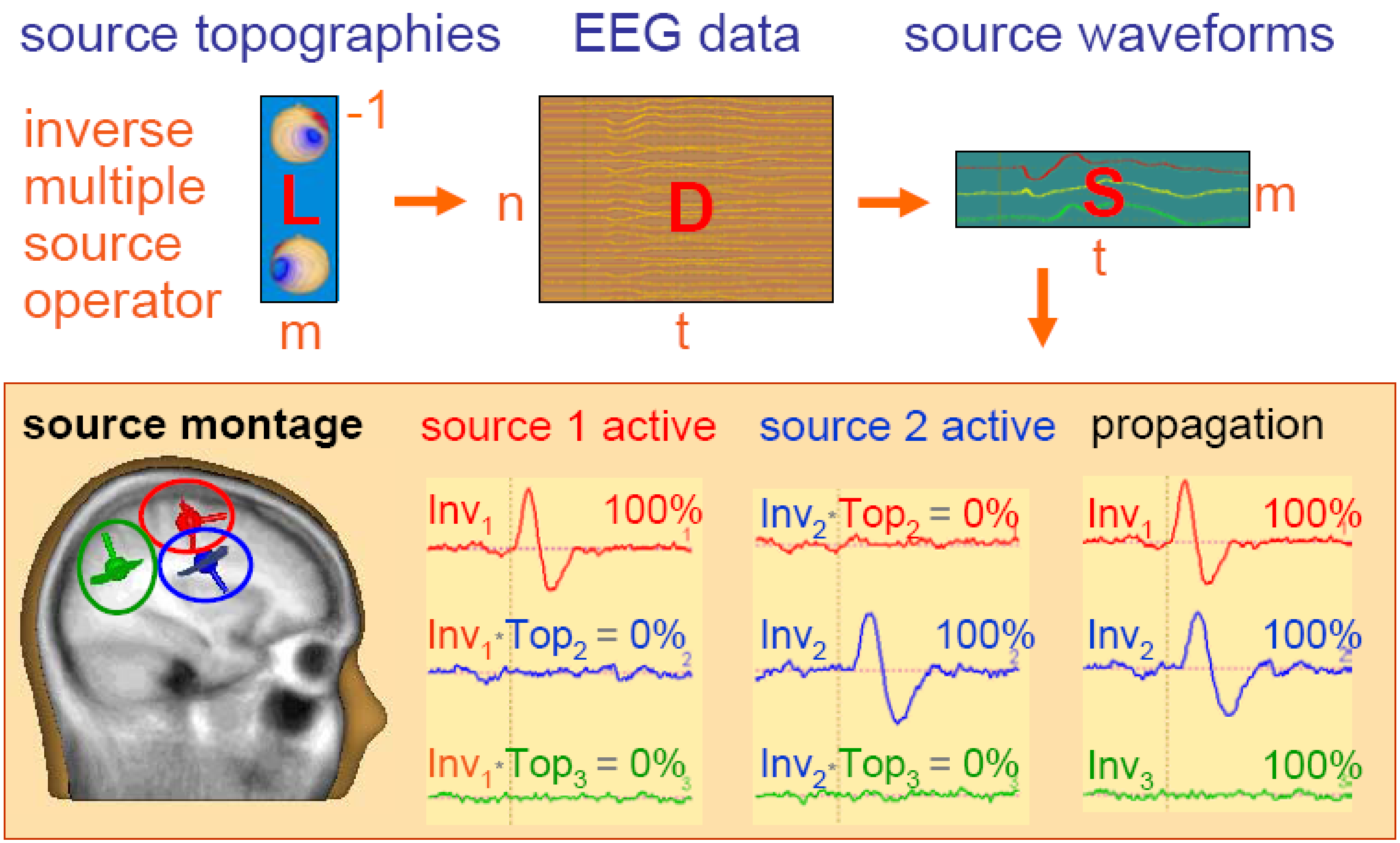
Source modeling of a propagating spike (step 1)



Source modeling of a propagating spike (step 2)



Multiple sources separate activities from different brain regions



Opitz et al.

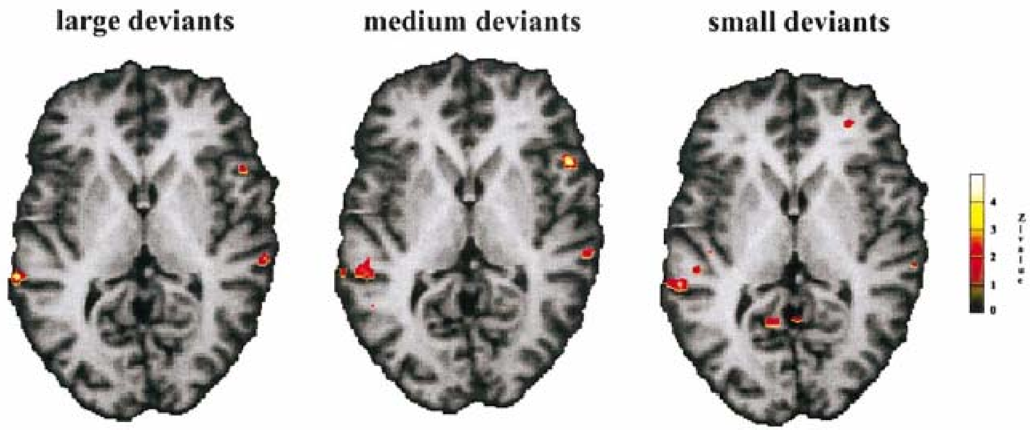


FIG. 2. Brain areas that showed significant fMRI activation to the three deviant stimuli were superimposed on an individual structural magnetic resonance image in Talairach space. Images were thresholded at $P < 0.01$. While all deviant types induced activation in the superior temporal gyri bilaterally (left: −61, −31, 9; right: 58, −23, 9), the opercular part of the right inferior frontal gyrus (46, 20, 6) was found active only for large and medium deviants.

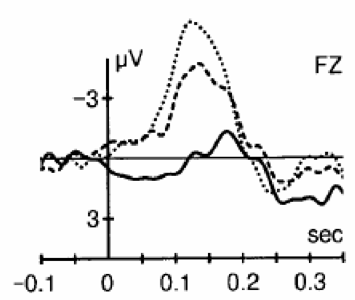


FIG. 3. MMN component elicited by large, medium, and small deviants when scanner noise is present. Difference waveforms were obtained by subtracting the ERPs to standard tones from those to all deviant tones separately. Note that no statistically significant MMN was observed for small deviants. For details see Fig. 1.

Conclusions?

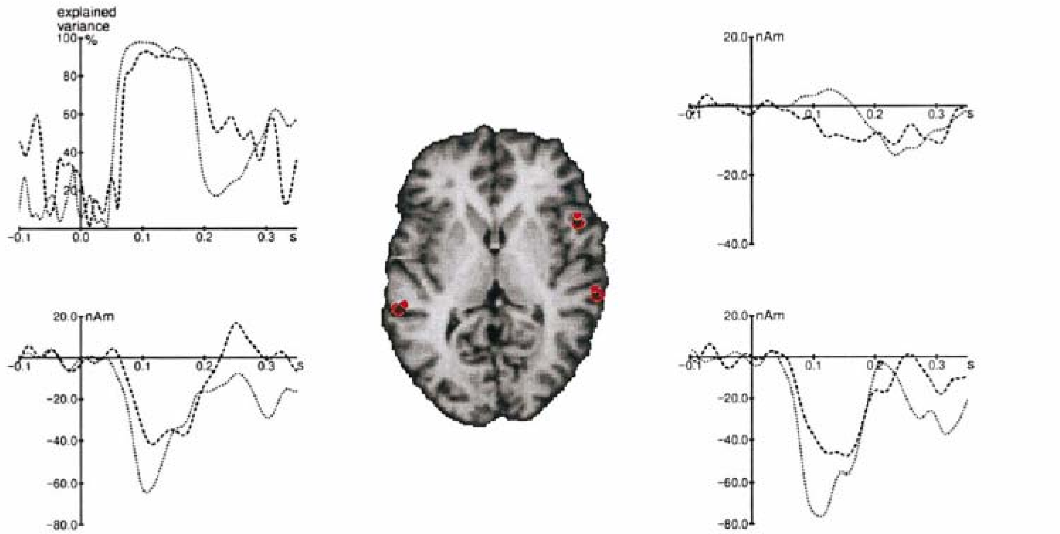


FIG. 4. Dipole locations (middle panel), explained variance (top left), and time course of dipole strength at left temporal (bottom left), right temporal (bottom right), and right frontal (top right) cortices for large and medium devants. For details see Fig. 1.

- Their claim: early MMN temporal lobe sources, late MMN frontal source
  - Plausible a priori
- BUT: Model explains variance from .1 to .2 seconds
- Frontal source most active *after* that period
- Authors making big claims about the least solid aspect of their data…

Consonants

- Place of Articulation
  - Which part of mouth constricts to make consonant?
- Manner of Articulation
  - How is the sound made?
- Voicing
  - Are vocal cords vibrating or relaxed?

Consonants

- Place of Articulation

Bilabial	p	b
Labiodental	f	v
Dental	th	
Alveolar	t	d
Velar	k	g
Glottal	ch in Bach	

- Manner of Articulation

Stops	b		
Fricatives	s	f	v
th			
Affricates	ch	j	
Nasals	m	n	
Laterals	m	n	
Semivowels	w	r	

- Voicing

Voiced	b
Voiceless	s

Why Distinctive Features

- Phonemes described as combo of distinctive features
- Distinctive because they allow us to discriminate between phonemes
  - Voicing t vs d
  - Manner of Articulation n vs d
  - Place of Articulation b vs d

McGurk Effect

Animated McGurk Effect

01_2.mov

McGurk & MacDonald (1977)

- Interested in whether babies attend more to face or to sound
- Plan:
  - Make sound/face mismatch video
  - Habituate babies to video
  - Then give them choice between new video that matched sound vs. new video that matched face movements
- Discovery by technician
  - Mismatch /ba/ /ga/ videos sounded like /da/!!!

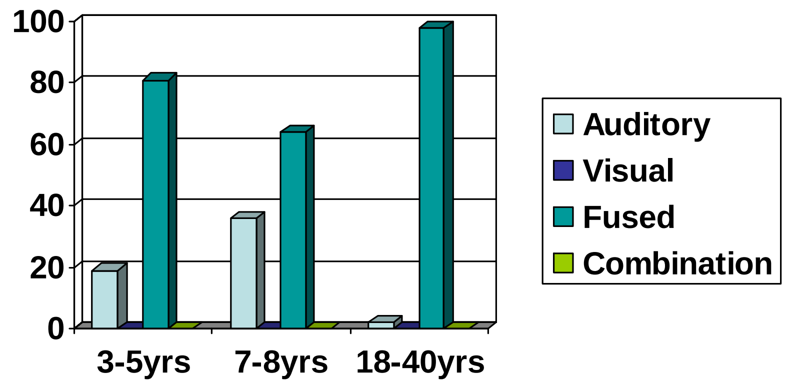
Task

- Watch video and repeat sounds
- Listen to video repeat sounds
- Response Categories
- Auditory /ba-ba/ Visual /ga-ga/
  - Auditory: ba-ba
  - Visual: ga-ga
  - Fused: da-da
  - Combination: --
- Auditory /ga-ga/ Visual /ba-ba/
  - Auditory: ga-ga
  - Visual: ba-ba
  - Fused: da-da
  - Combination: gabga, bagba, baga, gaba

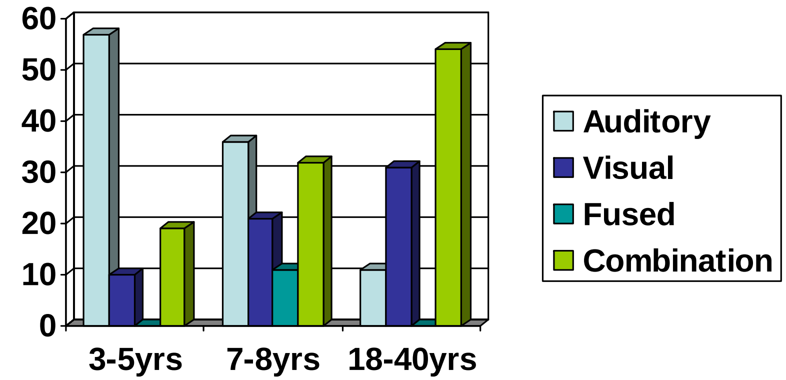
Results

- Auditory (% Correct)
  - Pre-school: 91%
  - School-age: 97%
  - Adults: 99%
- AudioVisual (% Wrong)
  - Pre-school: 59%
  - School-age: 52%
  - Adults: 92%
- How and why do adults and children differ here?

Aud: ba-ba Vis: ga-ga



Aud: ga-ga Vis: ba-ba



Hear-ba/See-ga vs. Hear-ga/See-ba

- Acoustically /ba/ and /da/ similar, /ba/ /ga/ not
- Visually /ba/ confused with /pa/
  - Not with /ga/, /da/, /ka/, or /ta/
- Visually /ga/ confused with /da/
- Hear-ba/See-ga
  - Auditory info compatible with /da/ and /ba/
  - Visual info compatible with /ga/ and /da/
  - /da/ common to both modalities (Fused Response)
- Hear-ga/See-ba
  - Auditory info compatible with /ga/ (not /ba/ or /da/)
  - Visual info compatible with /ba/ (not /ga/ or /da/)
  - Information in conflict (Combination Response)

Sams, et al. (1991)

- McGurk effect reflects a stage of audiovisual integration
- What brain area does this occur in?

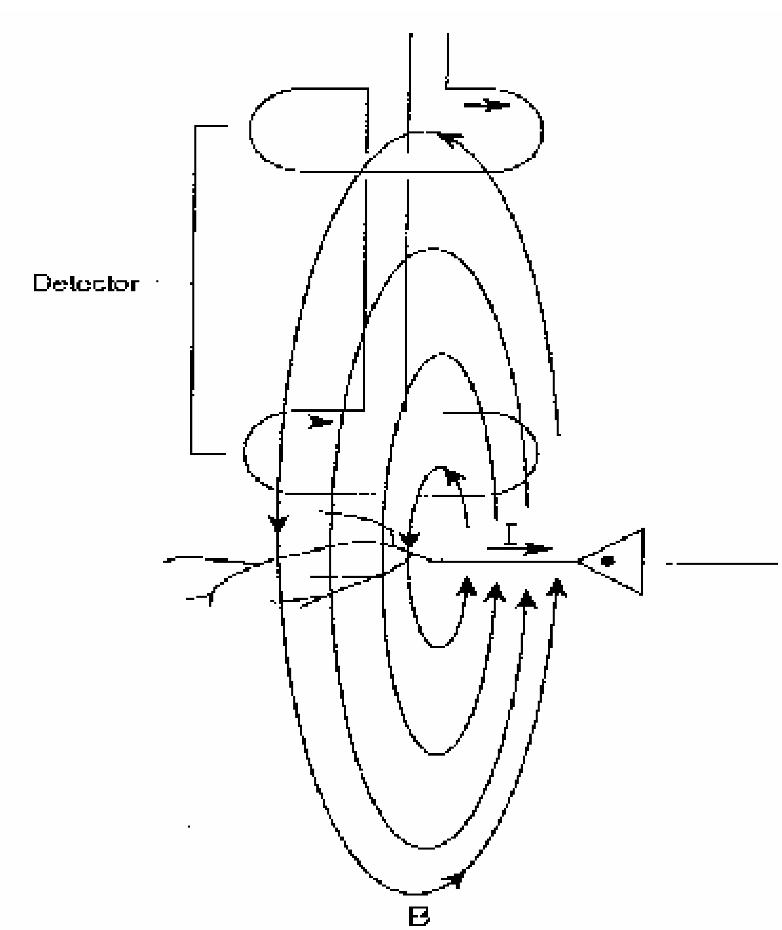
MEG Study

- McGurk Deviant
  - Hear /pa/ See /pa/ 84%
  - Hear /pa/ See /ka/ 16%
- McGurk Standard
  - Hear /pa/ See /ka/ 84%
  - Hear /pa/ See /pa/ 16%
- Control (Face Replaced by)
  - Red light 84%
  - Green light 16%

Magnetoencephalography (MEG)

- Records the *magnetic flux* or the *magnetic fields* that arise from the source current
- A current is always associated with a magnetic field perpendicular to its direction
- Magnetic flux lines are not distorted as they pass through the brain tissue because all biological tissues offer practically no resistance to them

Dipole is a small current source

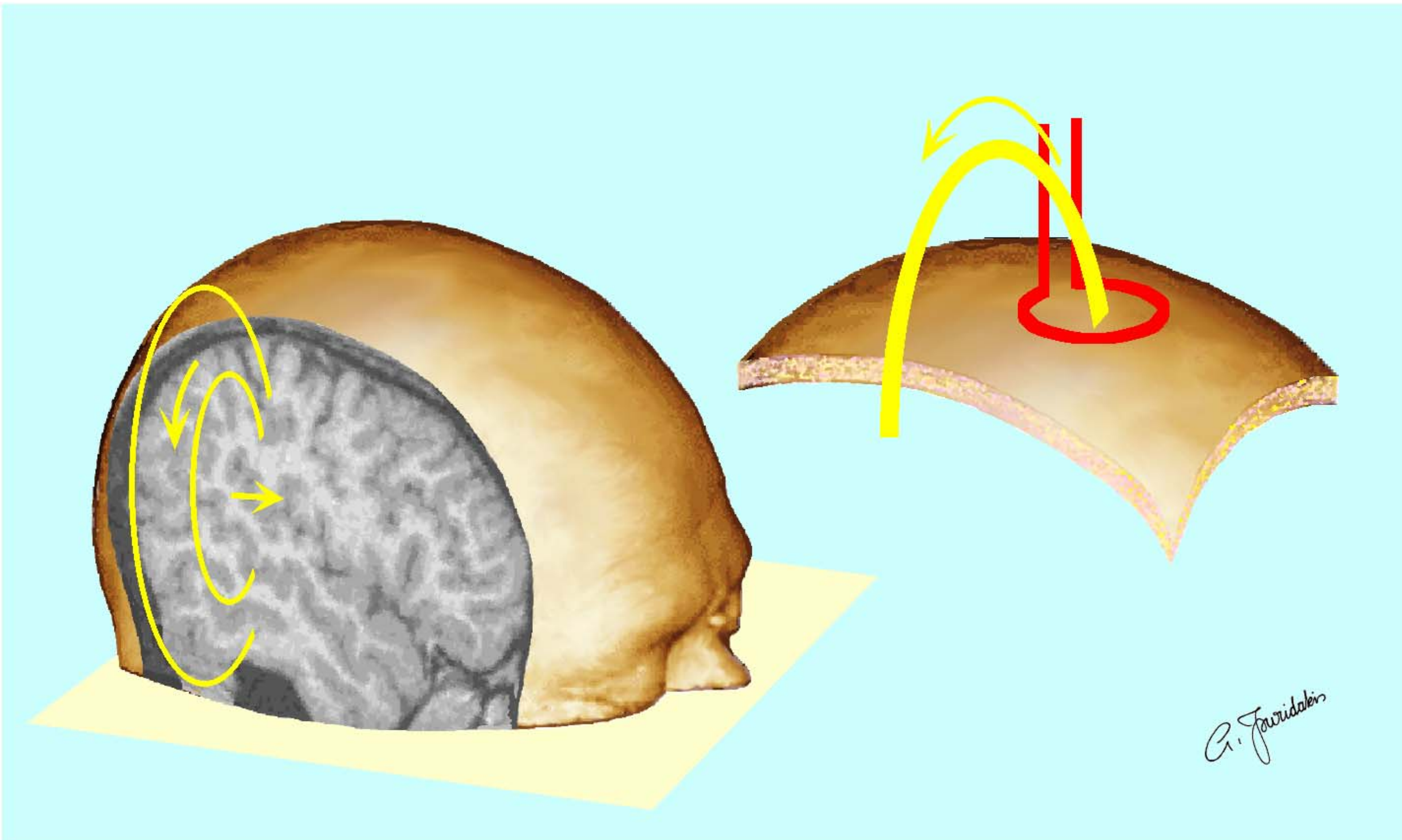


- Dipole generates a magnetic field
- At least 10,000 neurons firing “simultaneously” for MEG to detect
- Dendritic current

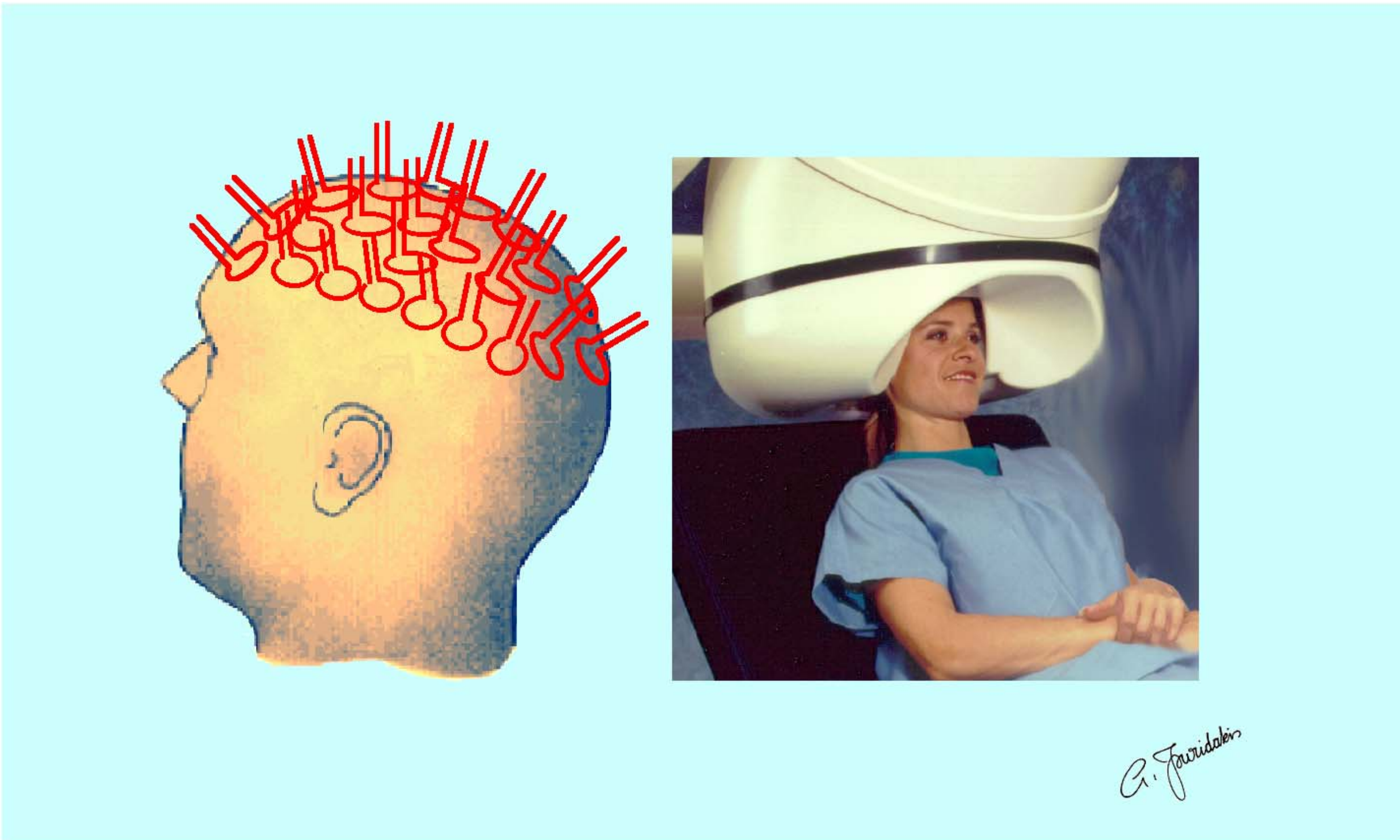
Recording of the Magnetic Flux

- Recorded by special sensors called *magnetometers*
- A magnetometer is a loop of wire placed parallel to the head surface
- The strength (density) of the magnetic flux at a certain point determines the strength of the current produced in the magnetometer
- If a number of magnetometers are placed at regular intervals across the head surface, the shape of the entire distribution by a brain activity source can be determined

Magnetic Flux Associated with Source Currents



Recording of Magnetic Signals




BTi


BTi

Recording of the Magnetic Flux

- 248 magnetometers
- The magnetic fields that reach the head surface are extremely small
- Approximately one million times weaker than the ambient magnetic field of the earth
- Because the magnetic fields are extremely small, the magnetometers must be superconductive (have extremely low resistance)
- Resistance in wires can be lowered when the wires are cooled to extremely low temperatures

Recording of the Magnetic Flux

- When the temperature of the wires approaches absolute zero, the wires become superconductive
- The magnetometer wires are housed in a thermally insulated drum (dewar) filled with liquid helium
- The liquid helium keeps the wires at a temperature of about 4 degrees Kelvin
- The magnetometers are superconductive at this temperature

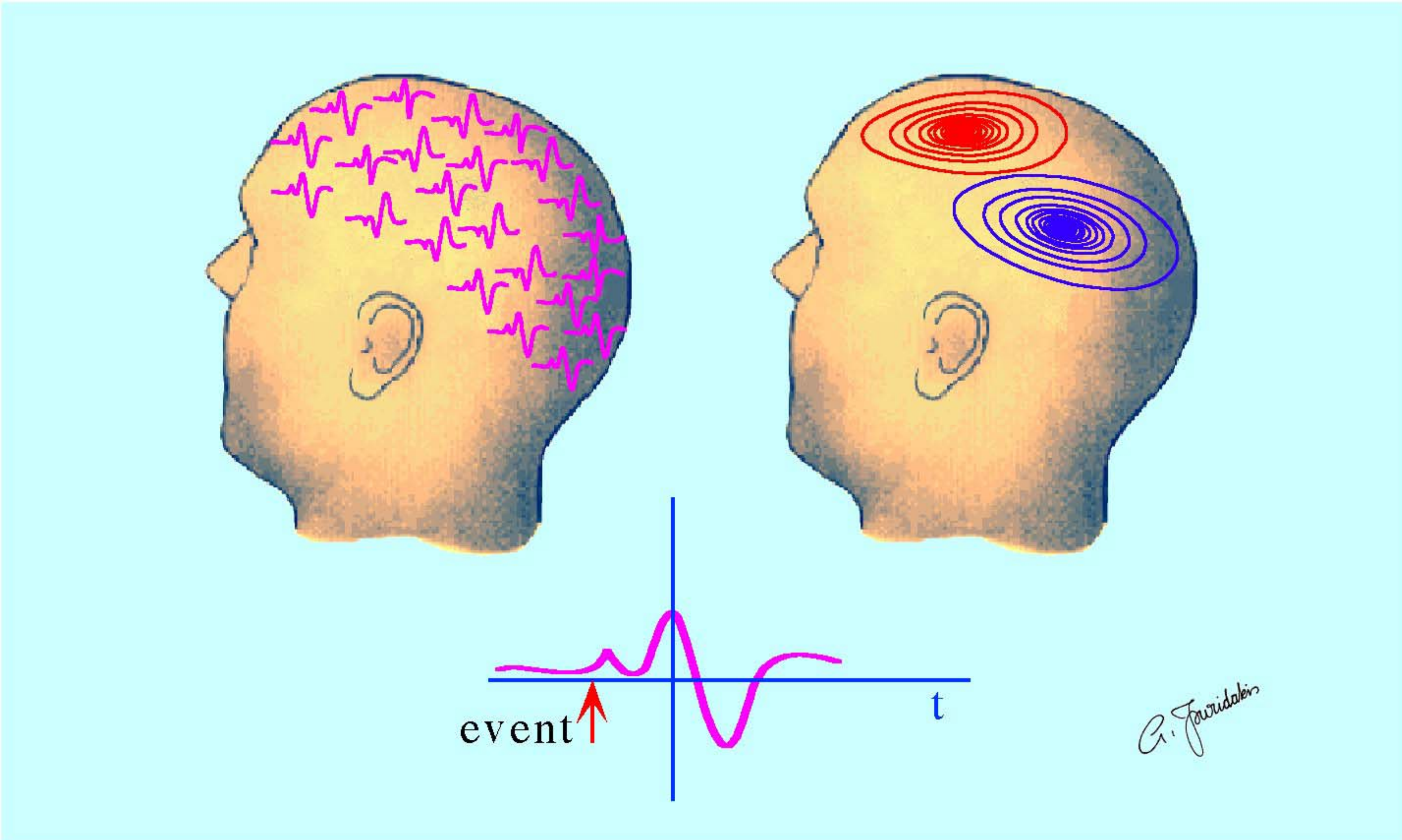
Recording of the Magnetic Flux

- The currents produced in the magnetometers are also extremely weak and must be amplified
- Superconductive Quantum Interference Devices (SQUIDS)
- The magnetometers and their SQUIDS are kept in a dewar, which is filled with liquid helium to keep them at an extremely low temperature

Dipolar Distribution of the Magnetic Flux

- In the following figure, one set of concentric circles represents the magnetic flux exiting the head and the other represents the re-entering flux
- This is called a *dipolar distribution*
- The two points where the recorded flux has the highest value are called *extrema*
- The flux density diminishes progressively, forming *iso-field contours*

Surface Distribution of Magnetic Signals



Dipolar Distribution of the Magnetic Flux

- From the dipolar distributions, we can determine some characteristics of the source

1. The source is below the mid-point between the extrema
2. The source is at a depth proportional to the distance between the extrema
   - Extrema that are close together indicate a source close to the surface of the brain
   - A source deeper in the brain produces extrema that are further apart
3. The source's strength is reflected in the intensity of the recorded flux
4. The orientation of the extrema on the head surface indicates the orientation of the source

Sams, et al. (1991)

- McGurk effect reflects a stage of audiovisual integration
- What brain area does this occur in?

MEG Study

- McGurk Deviant
  - Hear /pa/ See /pa/ 84%
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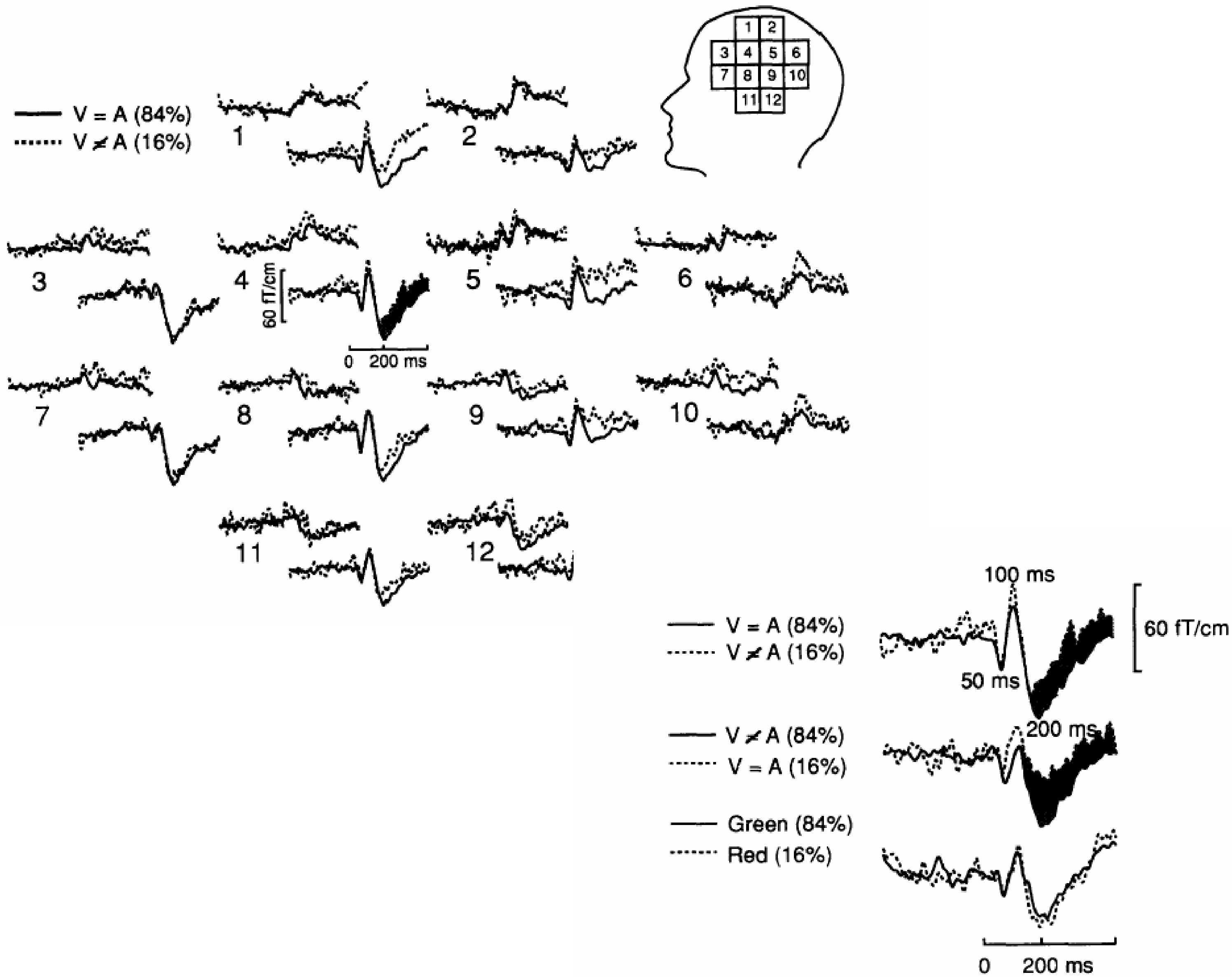
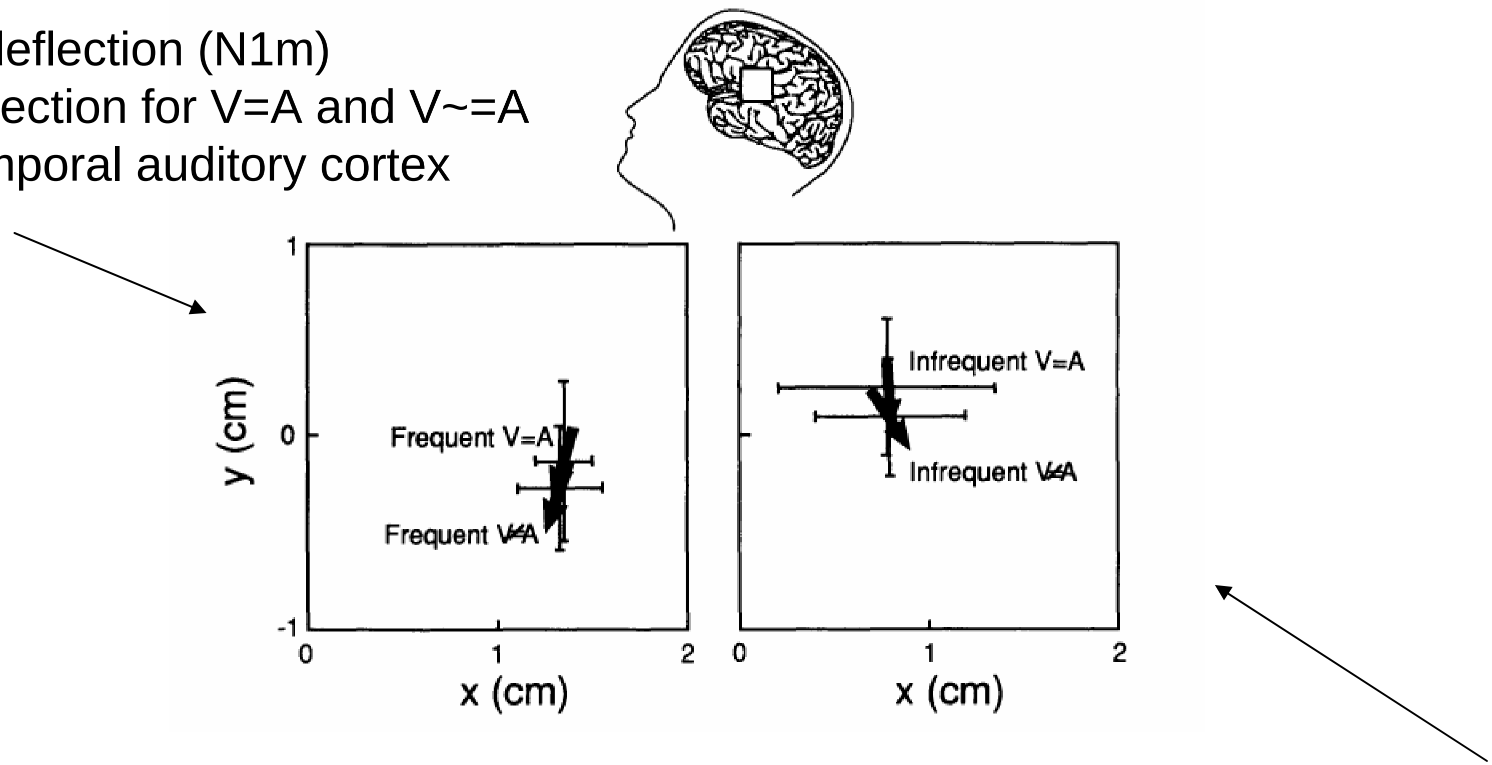


Fig. 1. Magnetic responses of one subject, measured with a 24-SQUID gradiometer over the left hemisphere, are shown in the top part of the figure. The upper traces of each pair show the field gradient in the vertical (y) and the lower one in the horizontal (x) direction. The exact locations and orientations of the gradiometers with respect to the head were determined by passing a current through three small coils, fixed on the scalp, and by analyzing the magnetic field thus produced. The number of averages is 500 for V = A and 80 for V ≠ A. The recording passband was 0.05–100 Hz; the responses have been digitally low-pass filtered at 40 Hz. The visually produced difference between the responses to the V ≠ A and V = A stimuli was largest at locations 1, 4, and 5. The x-responses at location 4 during the 3 measurement conditions are shown enlarged in the bottom part of the figure. The three pairs of traces were recorded over the same area in consecutive measurements.

ECD's

• 100 ms deflection (N1m)
• Same direction for V=A and V~=A
• Supratemporal auditory cortex



• Difference waveform (MMN?)
• More anterior and superior than for N1m
• Similar direction for V=A and V~=A
• Supratemporal auditory cortex

Sams, et al. (1991)

Conclusions

- Visual information during speech affects activity in auditory cortex
- Articulatory movements often precede speech sounds by 100s of milliseconds
- How does Sams propose the brain takes advantage of this?

Colin et al.

- Auditory Theory Speech Perception
  - Speech perception based on acoustic information
- Motor Theory Speech Perception
  - Visual & Auditory Information immediately converted to intended articulatory gestures
  - Percept in McGurk effect is phonetic (not auditory)
- Fuzzy Logic Model of Perception
  - Visual & Auditory Information Processed in Parallel
  - Integrated at a late stage of perception

Colin et al.

- If a McGurk stimulus is the deviant in a passive auditory oddball paradigm, will it evoke an MMN?
- Same acoustic stimulus, different percept

Auditory Alone

Occurrence	Block A	Block B
Frequent	/bi/	/gi/
Rare	/gi/	/bi/

Auditory Alone

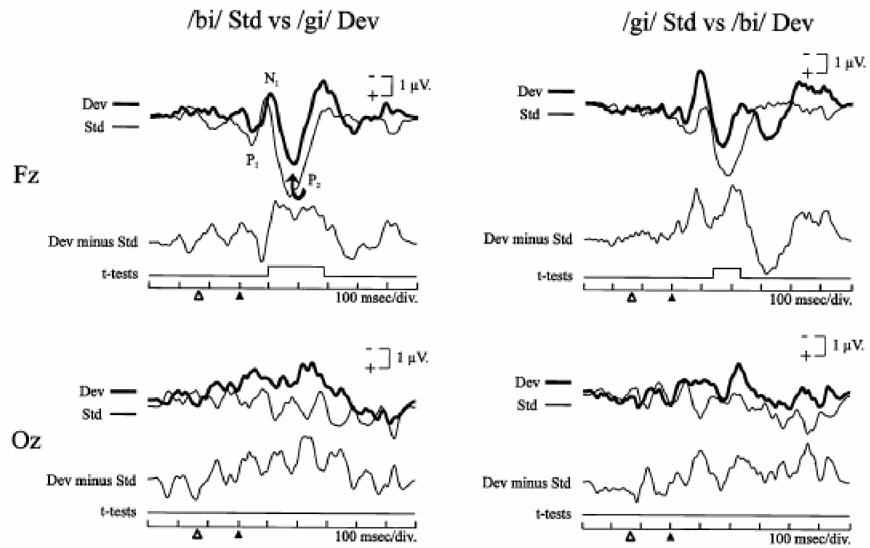


Fig. 1. Auditory alone presentation. In this and subsequent figures, the potentials evoked by the standard (thin line) and deviant (thick line) stimuli are superimposed and represent grand averages across all subjects. The classical exogenous P_1, N_1 and P_2 components are readily identified. The derived waveform obtained by subtracting the standard response from the deviant one is plotted below the exogenous waveforms. The lowest trace illustrates the result of the statistical testing on a binary mode: the level is raised during each period of consecutive significant *t* tests exceeding Guthrie's temporal threshold. The black triangles indicate the temporal position of the deviant consonant burst, the open triangle indicates deviant voicing onset. Both contrasts evoke an MMN at F_z location, whereas none is found at O_z.

Visual Alone

Occurrence	BlockA	BlockB
Frequent	/bi/	/gi/
Rare	/gi/	/bi/

Visual Alone

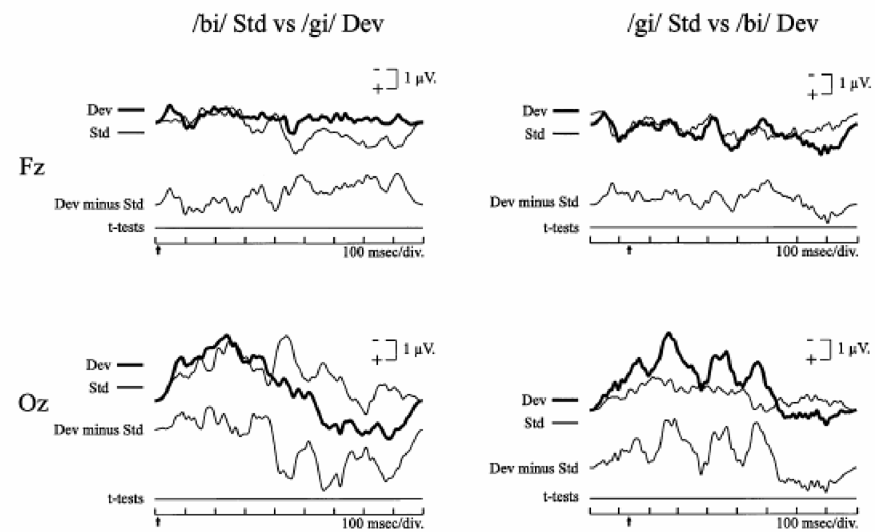


Fig. 3. Visual alone presentation. The arrows indicate the onset of articulatory movement of the deviant stimuli. No MMN can be detected whatever the contrast and the scalp location.

Audiovisual

Occurrence	BlockA	BlockB
Frequent	A/bi/ V/bi/	A/gi/ V/gi/
Rare	A/bi/ V/gi/	A/gi/ V/bi/

Psychophysics Experiment

- Do these stimuli elicit McGurk type effects?
- 74% elicited combination illusions

  bgi or gbi
- 66% elicited fusion illusions

  di

Audiovisual (McGurk Effect)

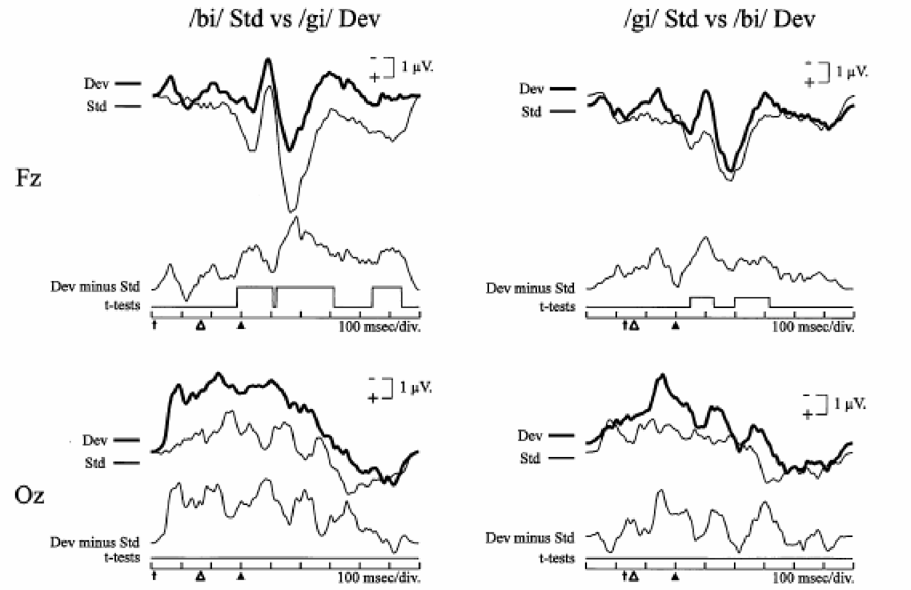


Fig. 4. Audiovisual presentation giving rise to the McGurk illusion. Arrows and triangles indicate the same stimulus temporal features as in previous figures. Both contrasts elicit MMNs at F_z only. When /gi/ is deviant, 3 components are identified. The first two cover most of the exogenous waves, the third one is very late. When /bi/ is deviant, two components are identified: one over the N_1 time slot and the other over the second half of P_2.

Results

- Audio
  - MMN
  - polarity reversal between Fz & M1
- Visual
  - No MMN
- AudioVisual
  - MMN
  - No polarity reversal Fz & M1

Discussion

- McGurk stimuli *do* elicit MMN
- But different topography than auditory MMN
- What does that mean?
  - Generally?
  - For this issue?

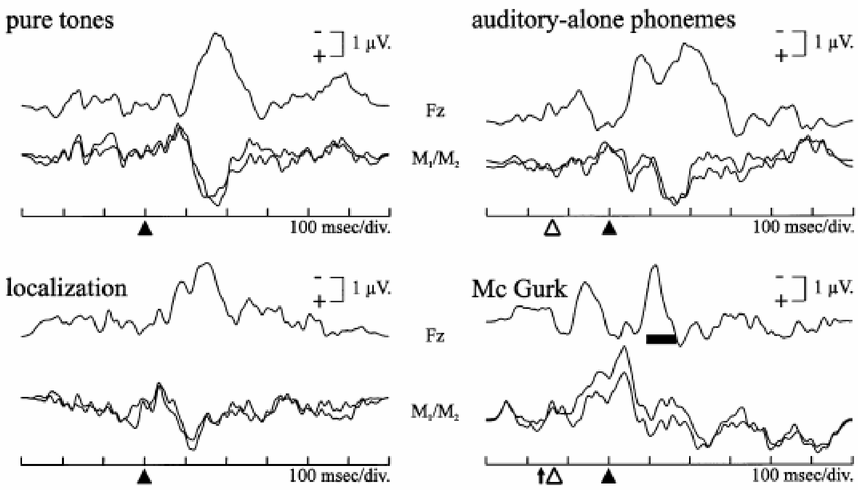
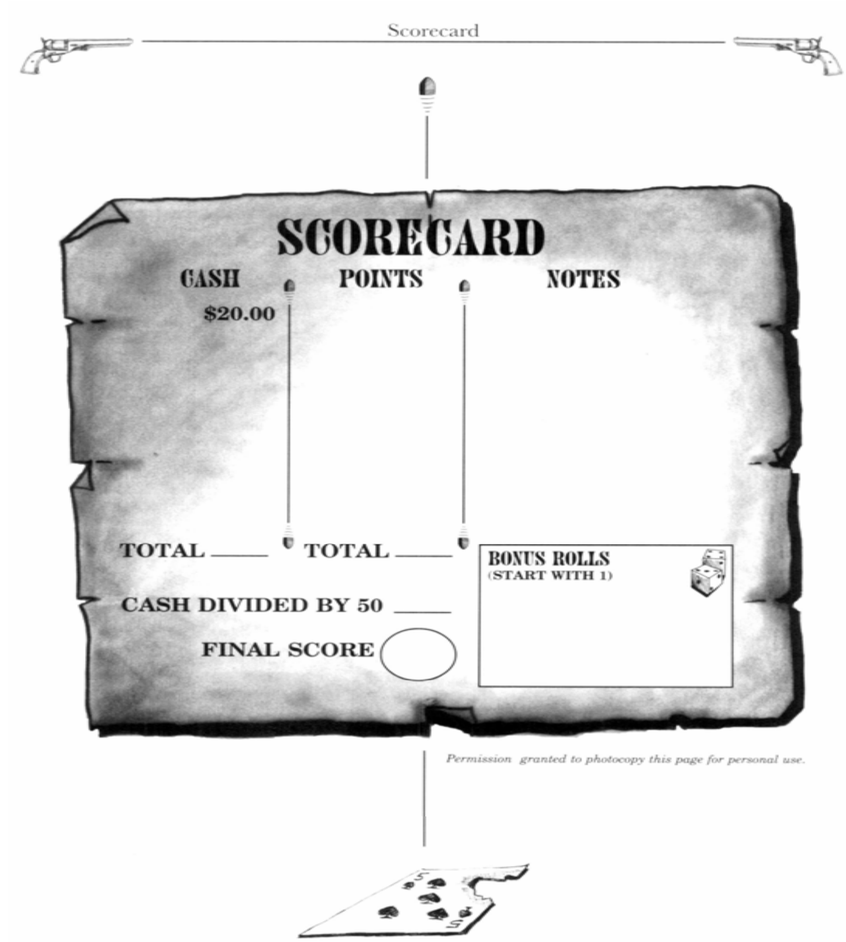


Fig. 5. Comparison of the polarity reversal behavior between F_z and mastoid sites for 3 types of auditory alone contrasts and for the McGurk contrast.

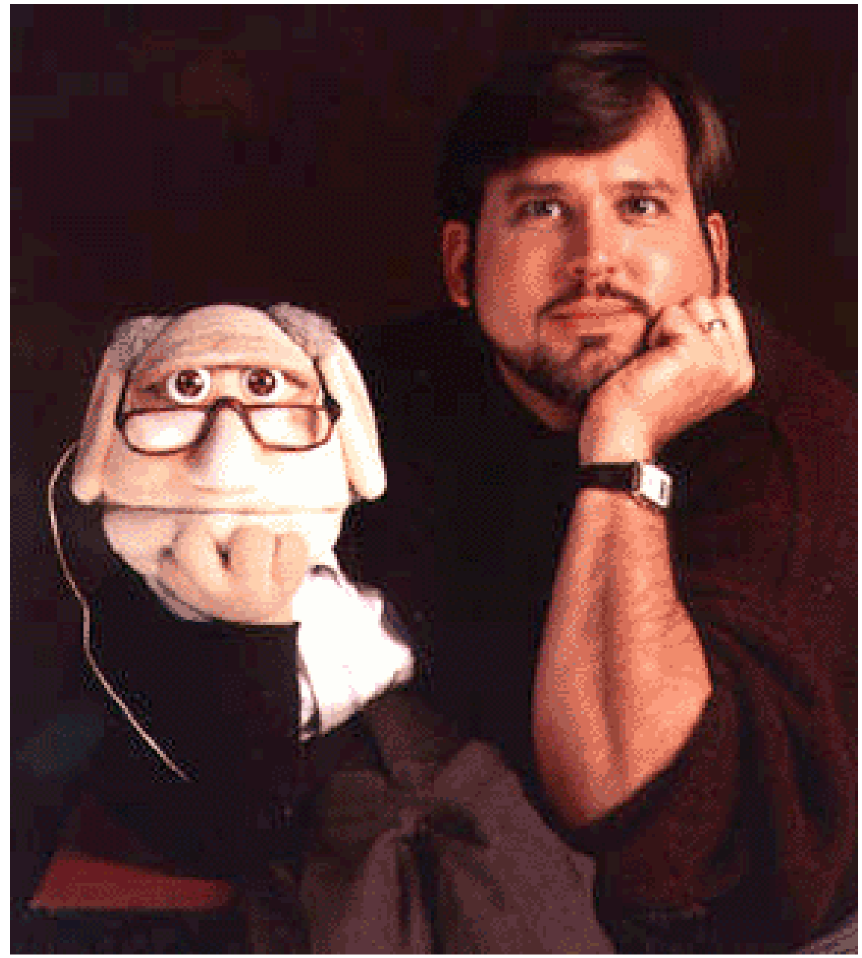
Speech Perception Theories

- Auditory Theory
  - Acoustic
- Fuzzy Logic Model Perception
  - Automatic vs. Controlled
- Motor Theory
  - Phonetic vs. Bimodal



Ventriloquist Illusion

- Speech comes from man, but seems to come from puppet
- When there are synchronized auditory and visual events displaced in space, perceived auditory location shifted in space towards visual event
- Perceptual system integrates discrepant stimuli



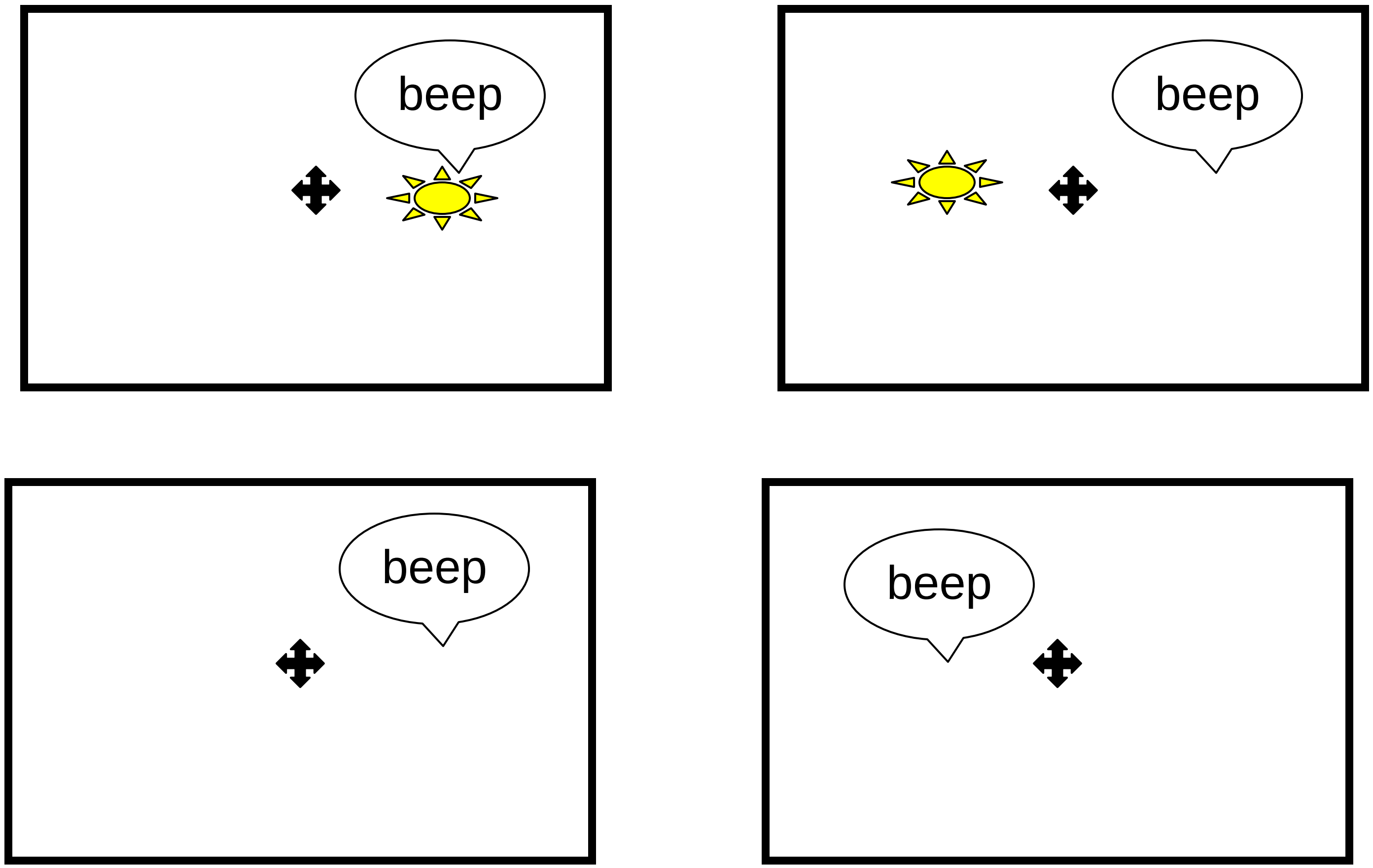
Cross-Modal Integration

Stekelenburg, Vroomen, & de Gelder (2004)

- What is the time course of the cross modal integration in the ventriloquist illusion?
- Is it early enough to elicit a MMN?
  - Spatial displacement of a sound elicits MMN
  - Does *illusory* displacement of a sound elicit MMN?
  - If it did, what would it mean?

Ventriloquist MMN Paradigm

STANDARD DEVIANT



Results

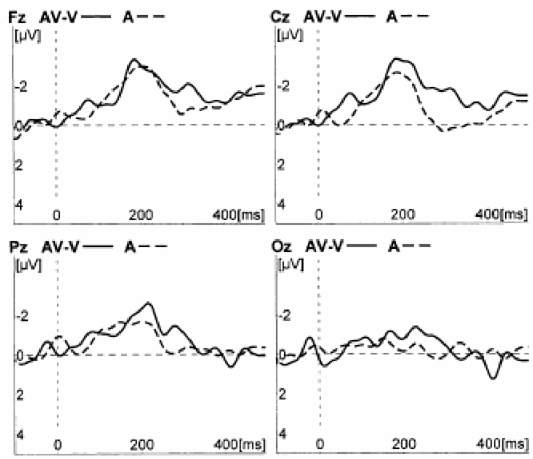


Fig. 2. Grand average difference waves at midline sites for the ventriloquist MMN (AV-V) and the auditory MMN (A).

J.J. Stekelenburg et al. / Neuroscience Letters 357 (2004) 163–166

- MMN auditory condition
  (dashed line)
- MMN AV-V condition
  (solid line)
- Similar amplitude & topography
- What does it mean?