Understanding Concussion

Collaborators:

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Paul Shepard (Physics)

The Referee Consensus Solver
1. Properties

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We record the magnetoencephalogram (MEG) during a variety of tasks.

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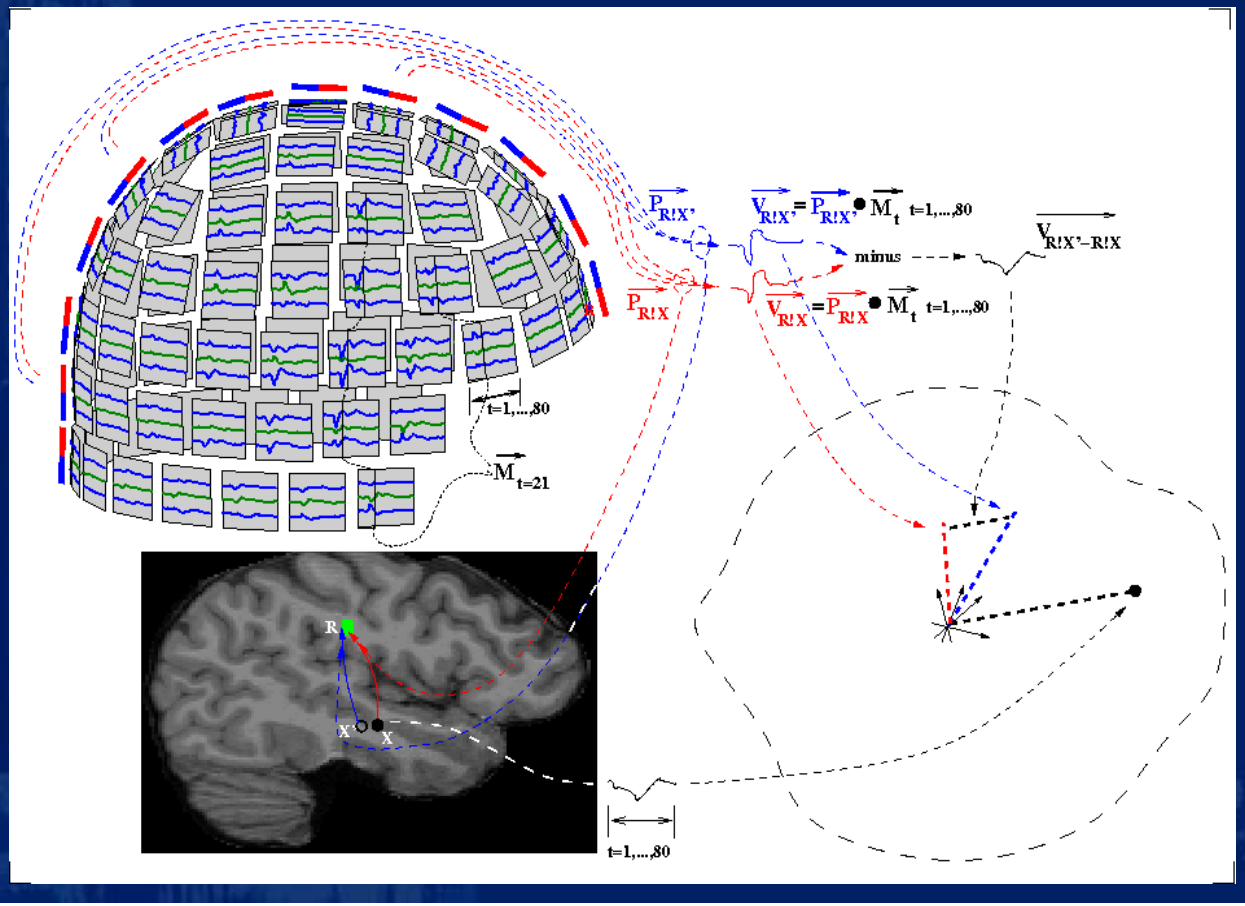
We have discovered a new way to extract localized high fidelity neuroelectric recordings from the MEG, referee consensus processing.



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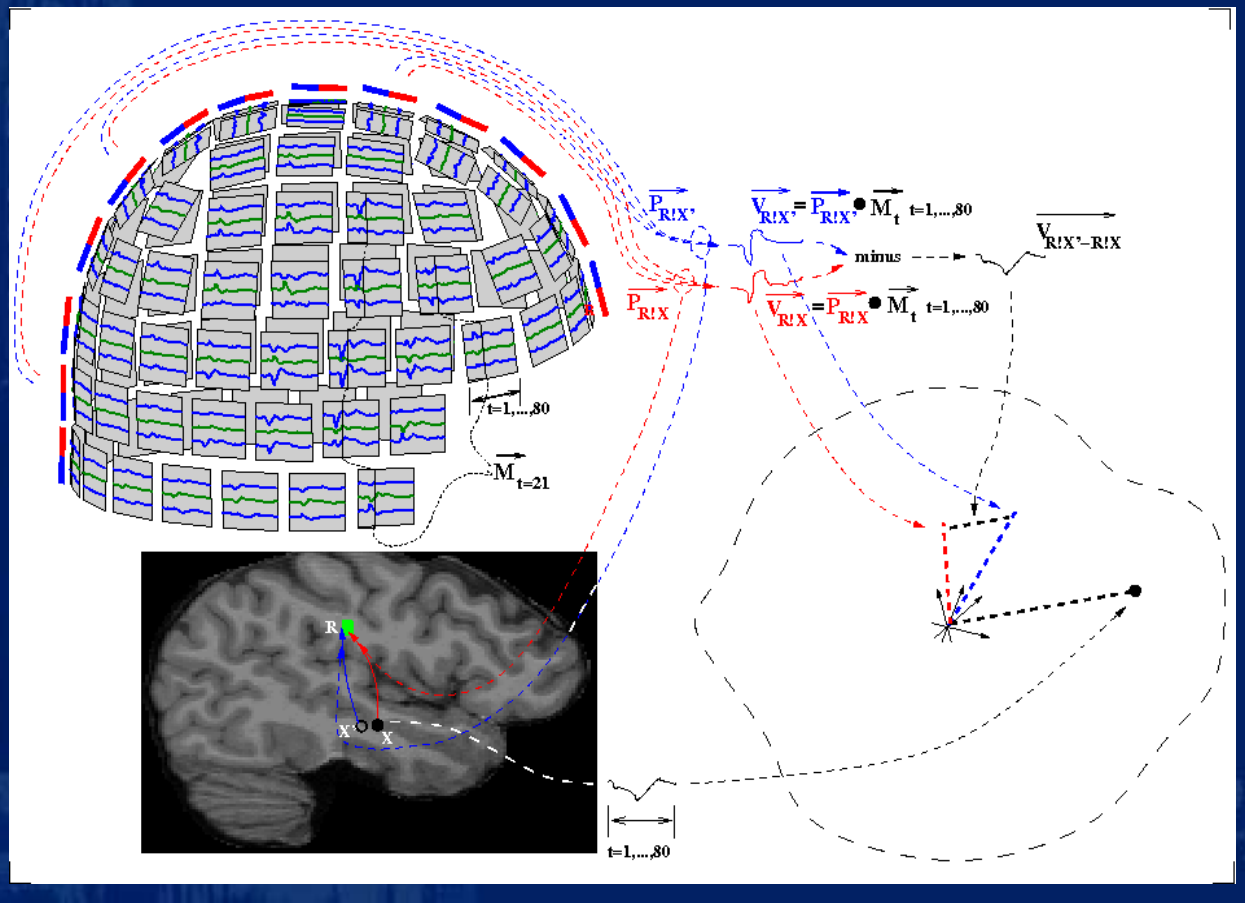
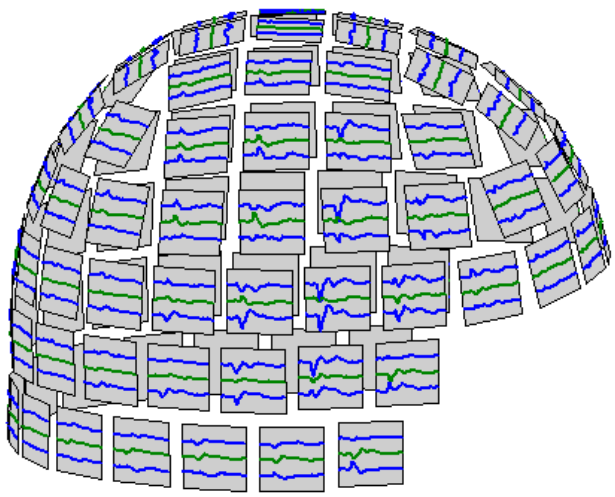
The processing requires ≈50 cpuHours per second of recorded MEG data.



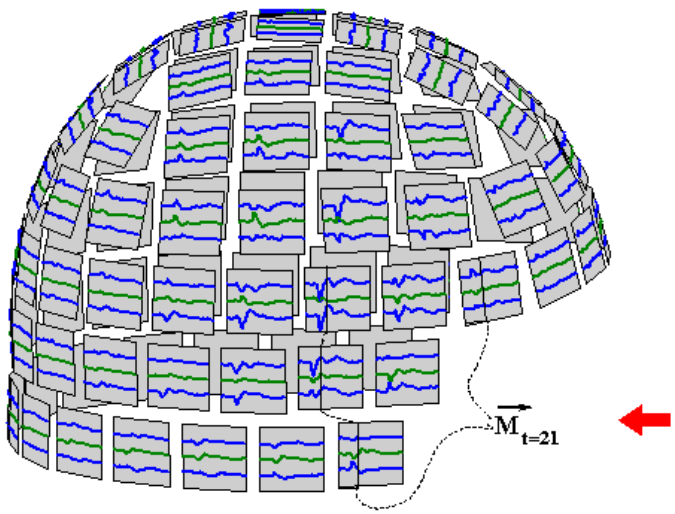
Inside the liquid helium dewar is an array of 102 1”x1” chips, each with 3 magnetic field sensors.

Hence the 3D “shape” of the magnetic field around the head is sampled at 102 points .



This 3D snapshot of the “shape” of the magnetic field is obtained 1000 times per second.

Each snapshot is a set of 306 measurements at a particular time and is designated: $\mathbf{M}_t$



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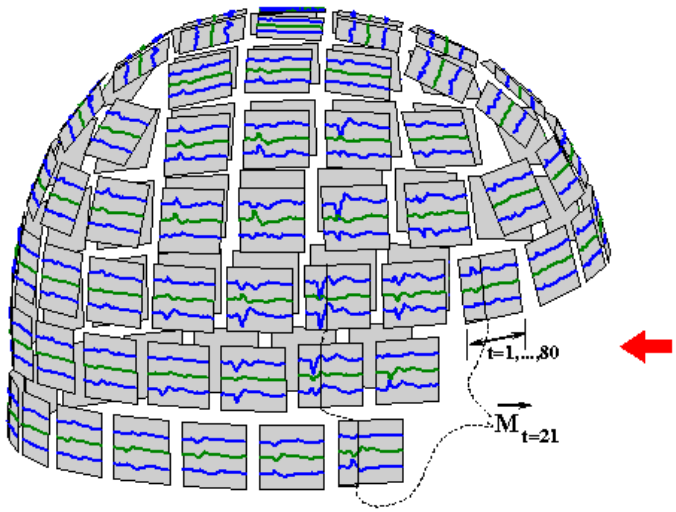
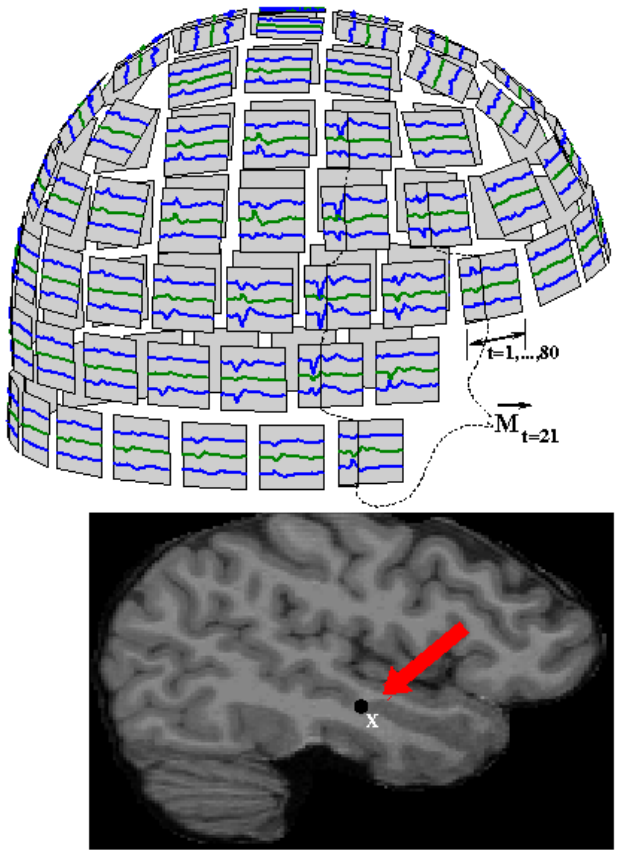
The referee consensus solver uses 80 snapshots at a time.

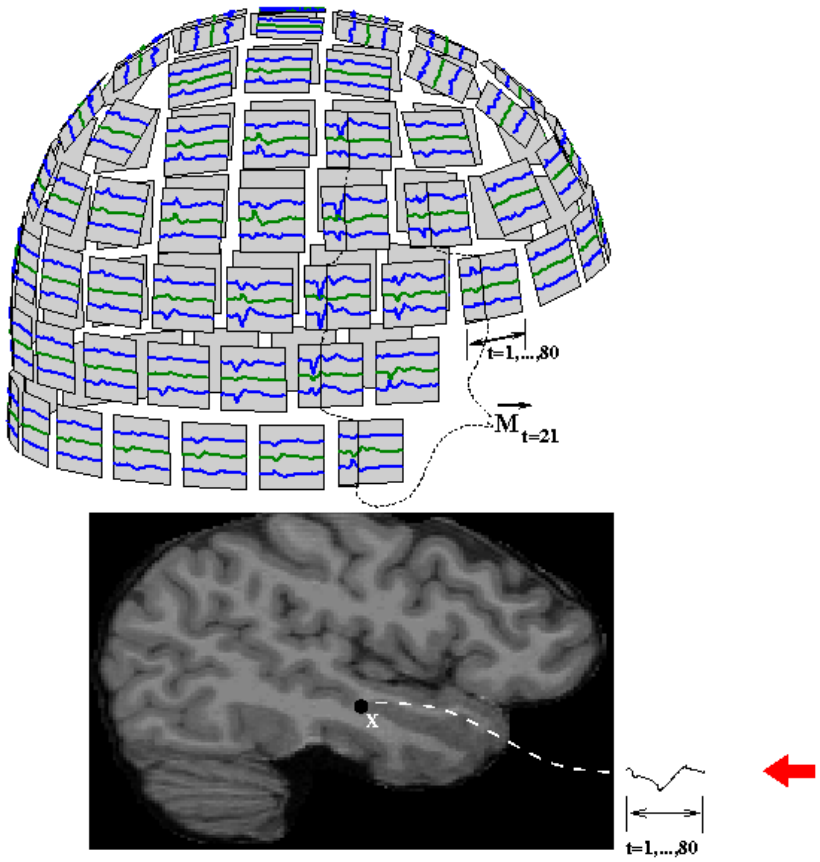


Given a specific location in the brain, **X,** the referee consensus cost function is used to determine if an electric current at **X** is contributing significantly to the shape of the magnetic field.

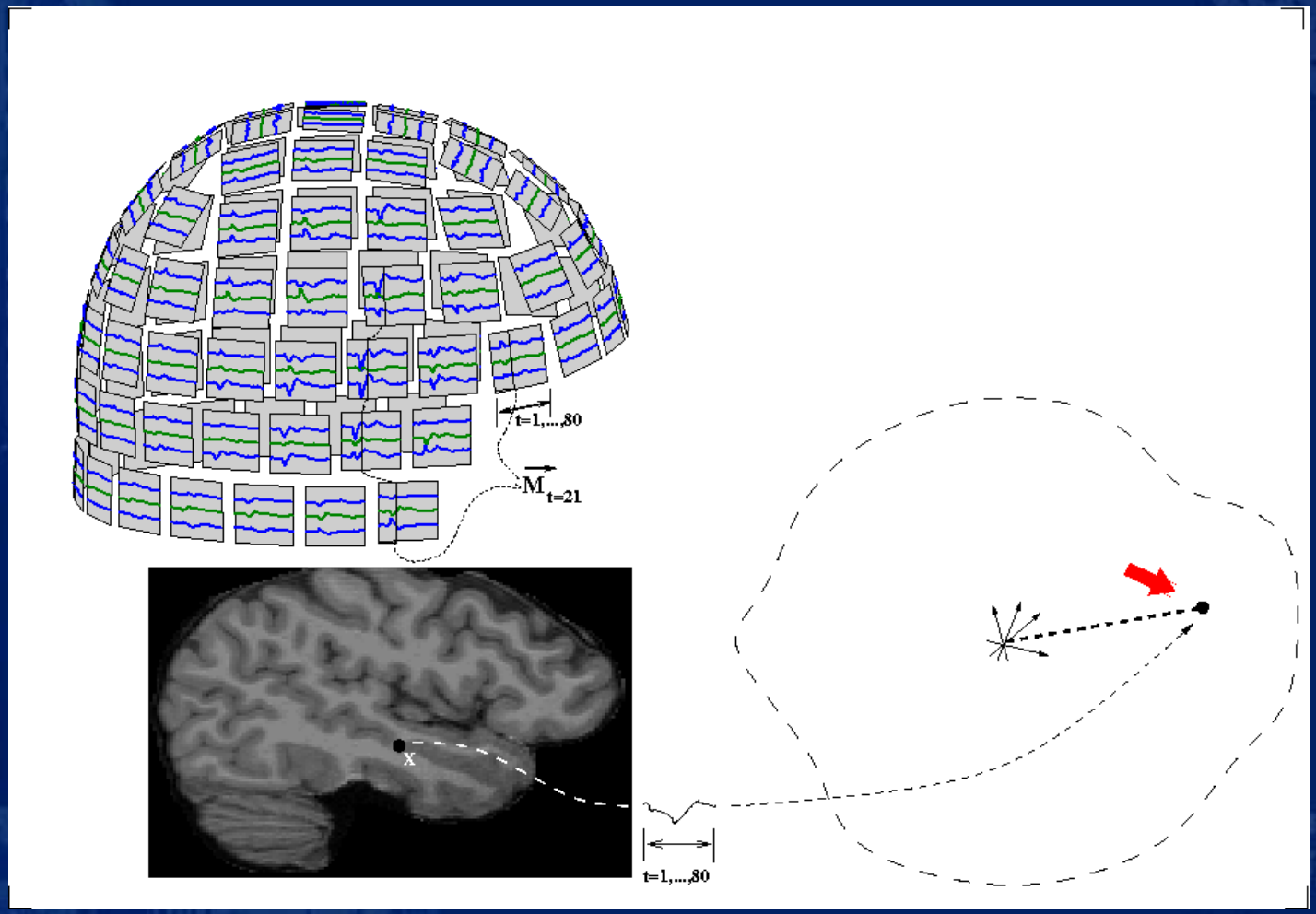


Given a specific location in the brain, **X,** the referee consensus cost function is used to determine if an electric current at **X** is contributing significantly to the shape of the magnetic field.

As part of this determination the procedure produces a high fidelity estimate of the time course of the electric current at **X**.

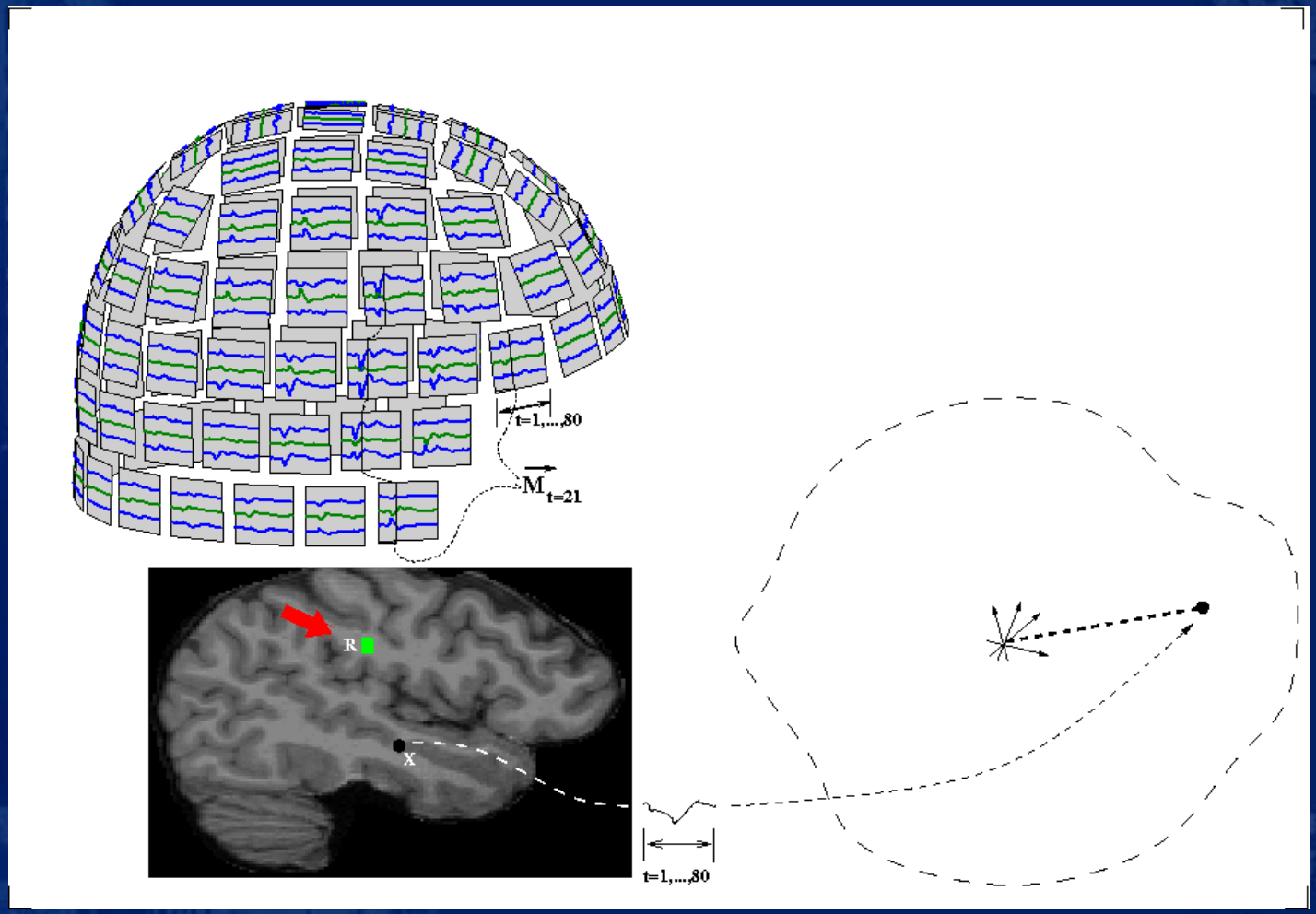


We can represent the true 80-point time course of the current at **X** as a vector in an 80-dimensional space.

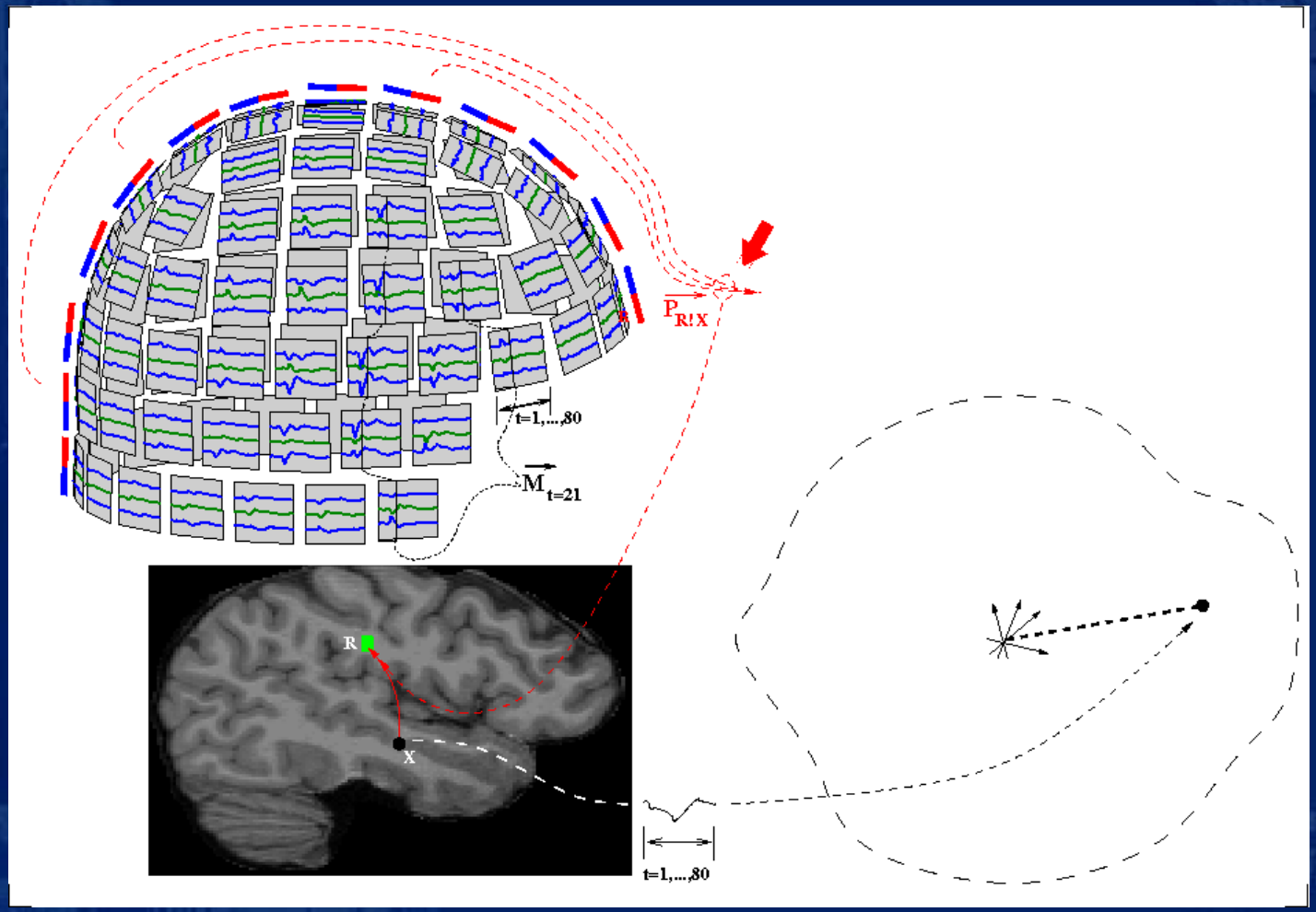


We obtain an estimate of that time course from the “point of view” of **R**, a location at a distance from **X,** a “referee.”

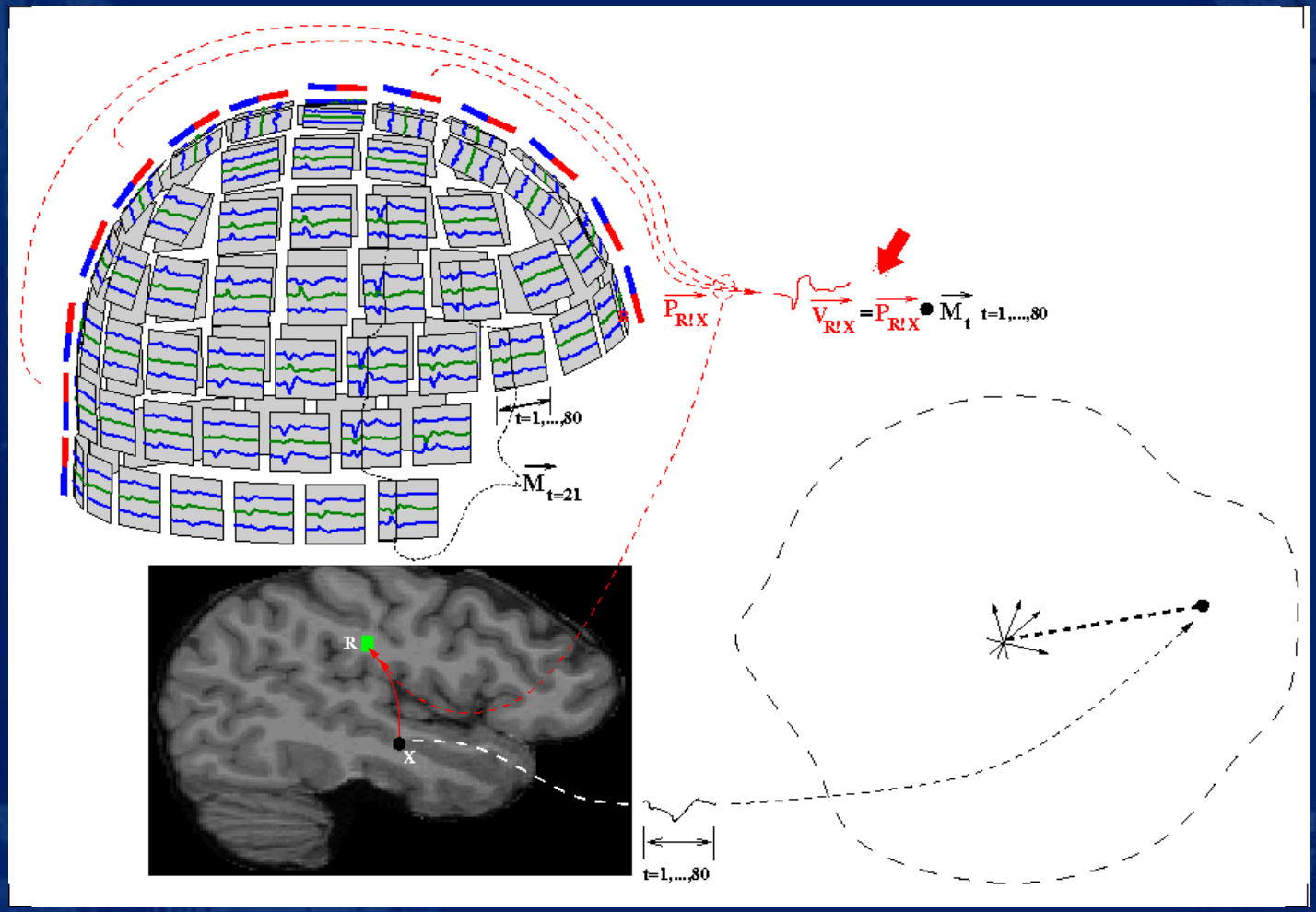
We will combine estimates from many referees to (1) decide if a non-zero current is present and (2) what its time course is, hence the name: “referee consensus.”



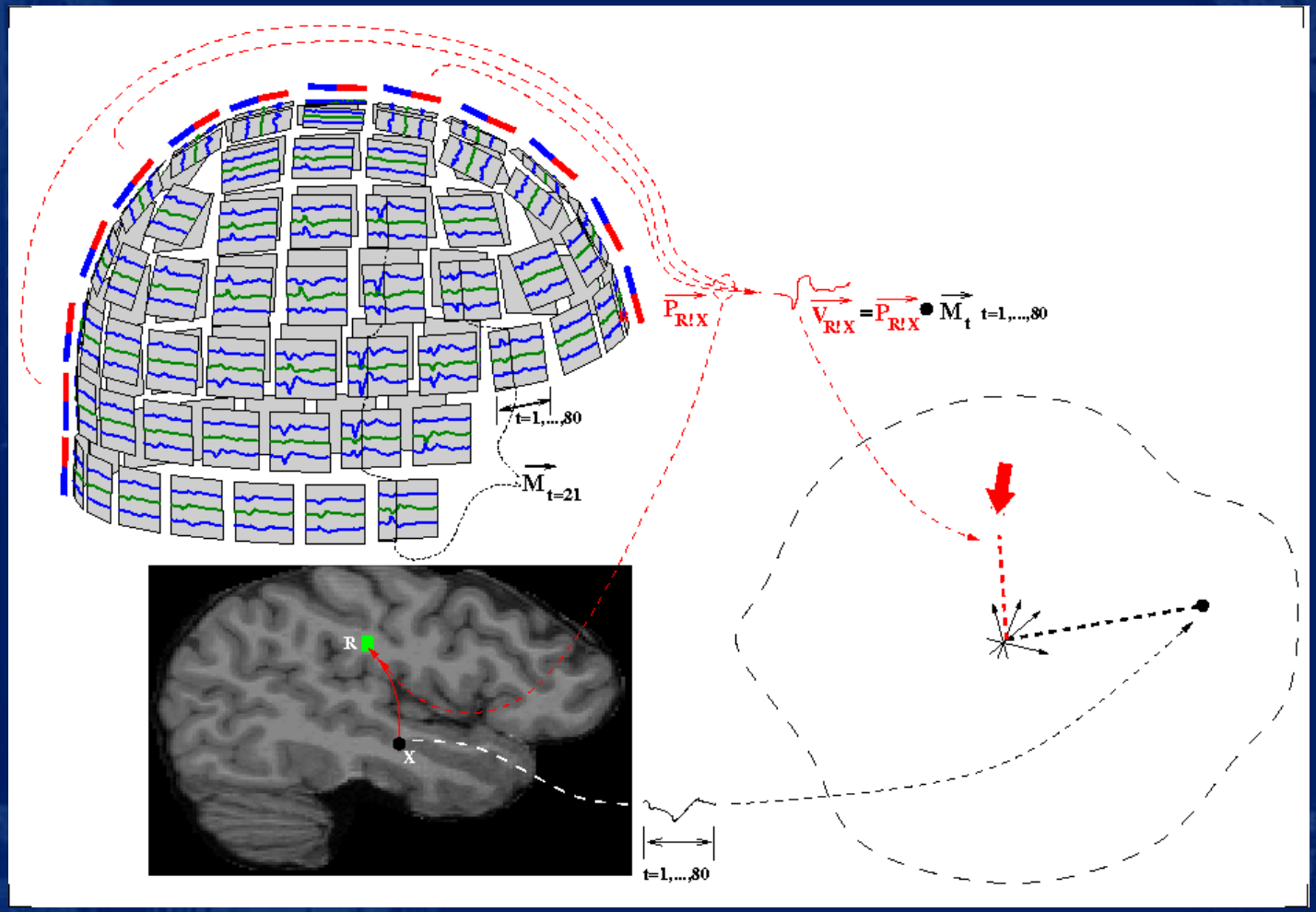
First we generate a projection operator, a filter, which produces an estimate of the current at **R**. We choose a filter which excludes any contribution to the estimate by the current at **X**. The filter is represented by the symbol, $\overrightarrow{P_{R!X}}$, where "R!X" reads "**R** not **X**."



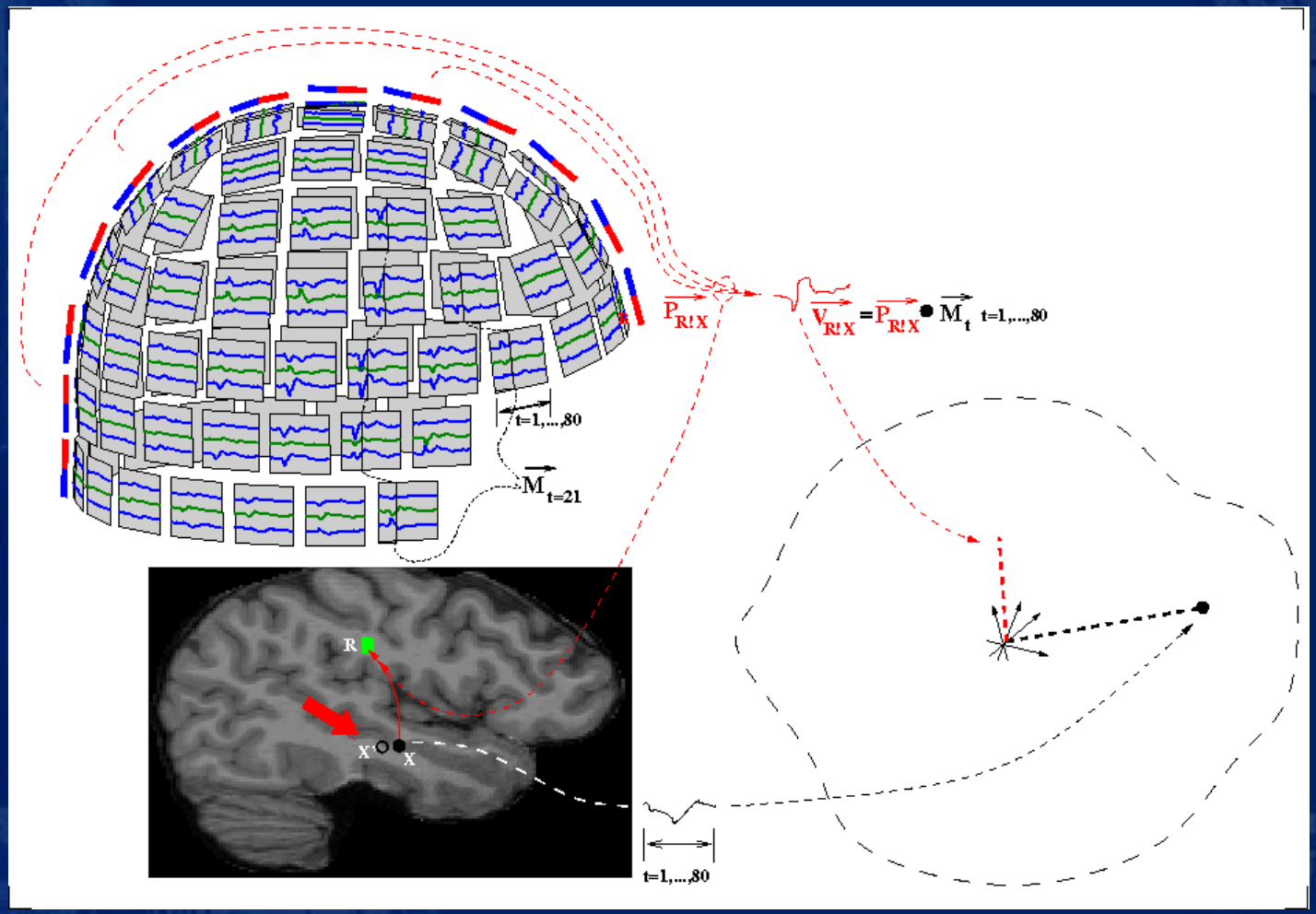
When we apply the filter to a sequence of 80 magnetic field snapshots we obtain $\overrightarrow{V_{R!X}}$, an estimate of the current waveform at **R** with no contribution from the waveform at **X**.



The vector, $\overrightarrow{V_{R!X}}$, may fall at any angle to the true waveform at **X**, i.e. they may be correlated. Here it is shown near the ideal angle of 90°.

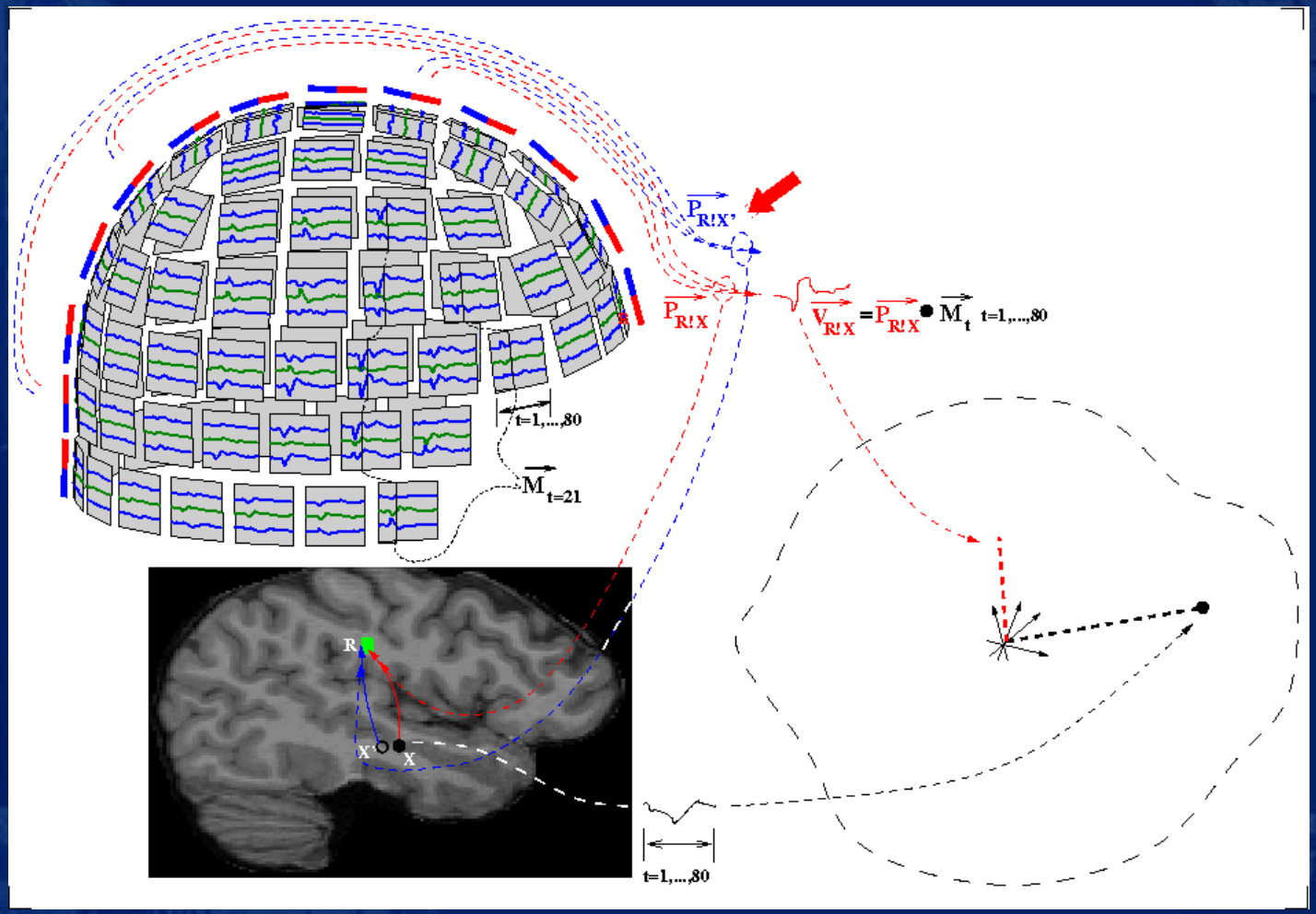


We now pick **X'**, a point which is at 1 mm distance from **X**.

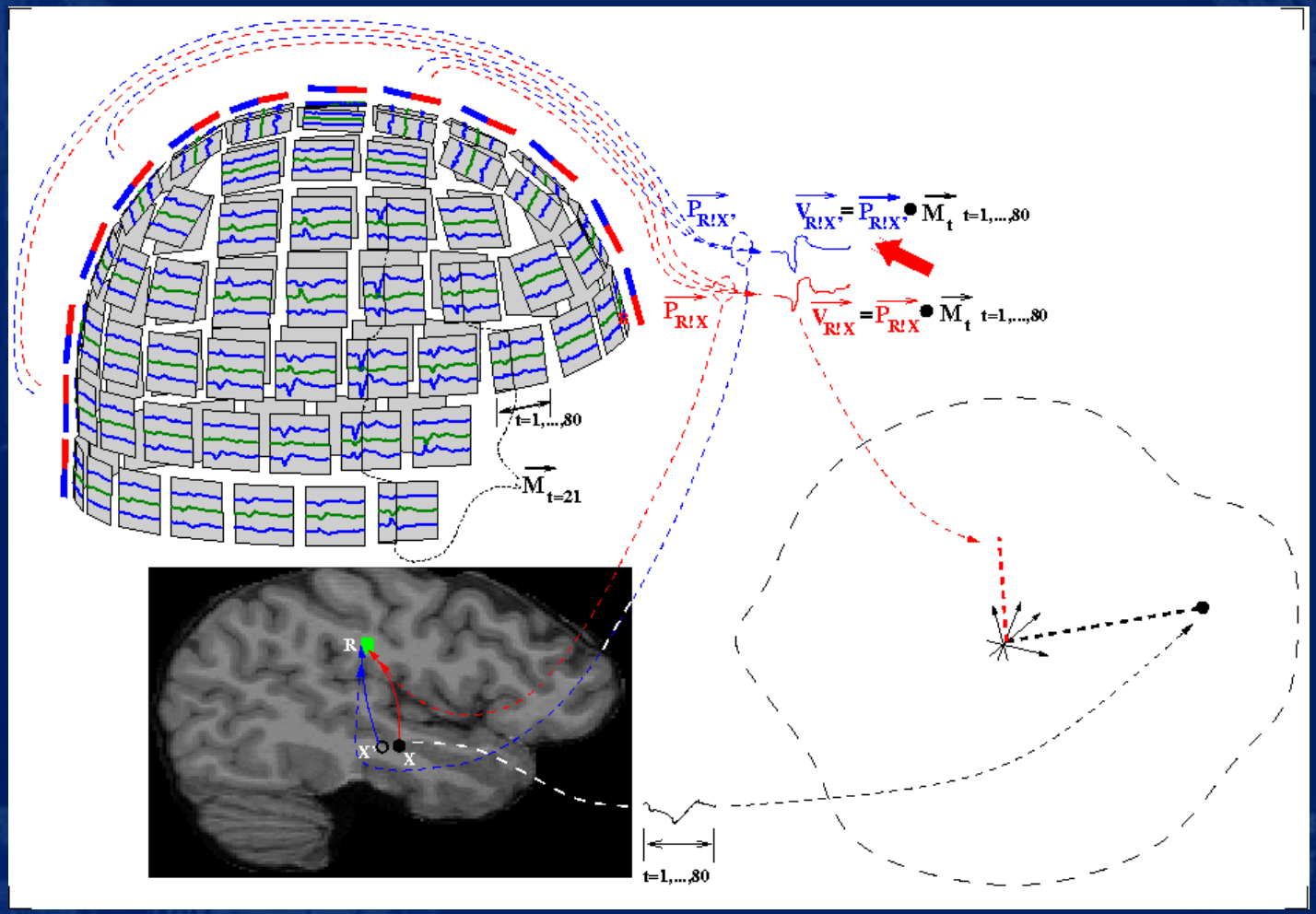


We now pick **X'**, a point which is at a distance of 1 mm from **X**.

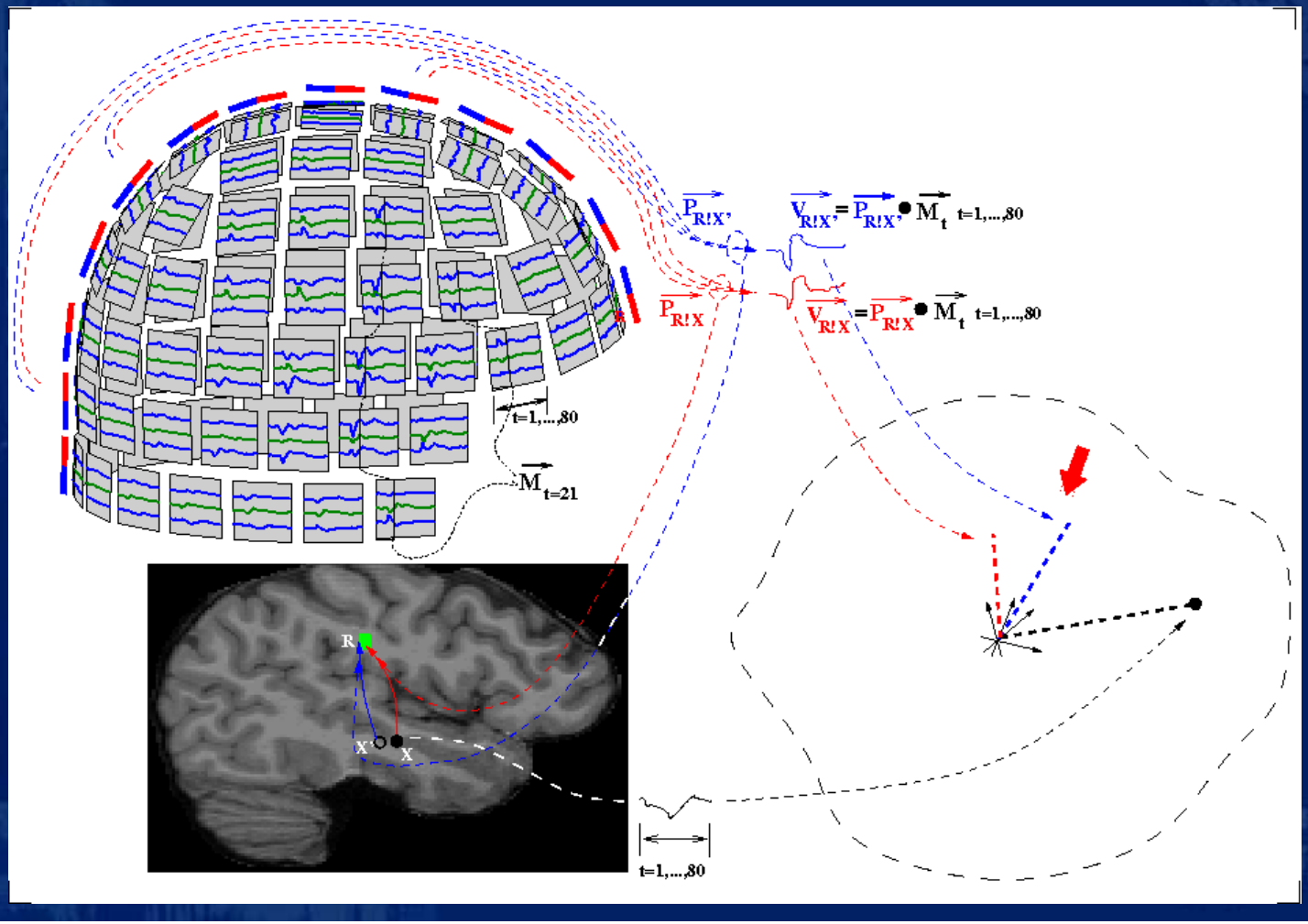
We generate a 2nd filter to produce an estimate of the current at **R**. This time the filter, $\overrightarrow{P_{R!X'}}$, is chosen to exclude any contribution to the estimate by the current at **X'**.



Again we apply the filter to the sequence of 80 magnetic field snapshots. This time we obtain $\overrightarrow{V_{R!X'}}$, an estimate of the current waveform at **R** with no contribution from the waveform at **X'**.

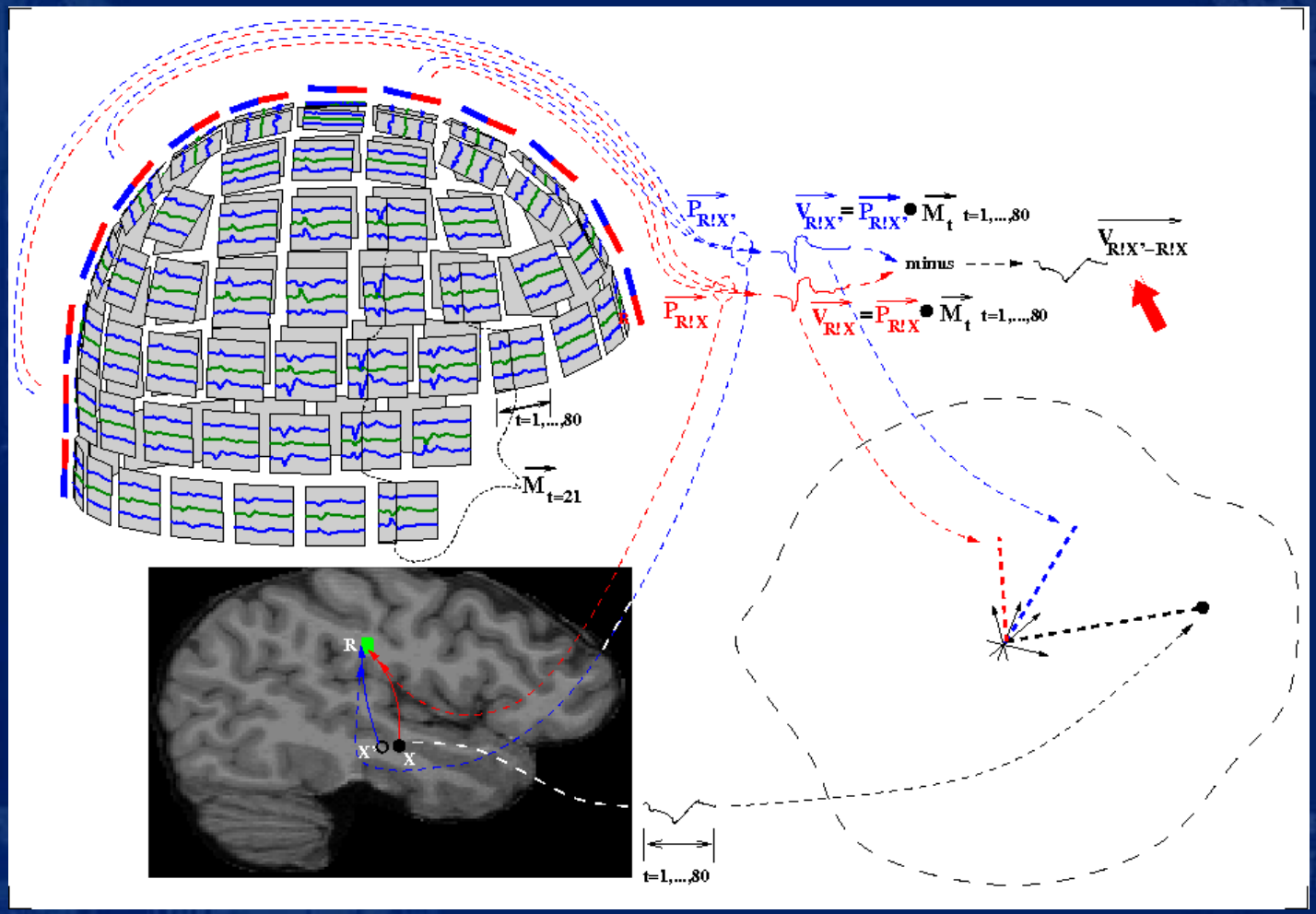


The $\overrightarrow{V_{R!X'}}$ vector falls between the $\overrightarrow{V_{R!X}}$ vector and the true waveform at **X** because the signal at **X** was not excluded by the 2nd filter, $\overrightarrow{P_{R!X'}}$. Another way to put this is that $\overrightarrow{V_{R!X'}}$ must include a component which is proportional to the true waveform at **X** whereas $\overrightarrow{V_{R!X}}$ need not.

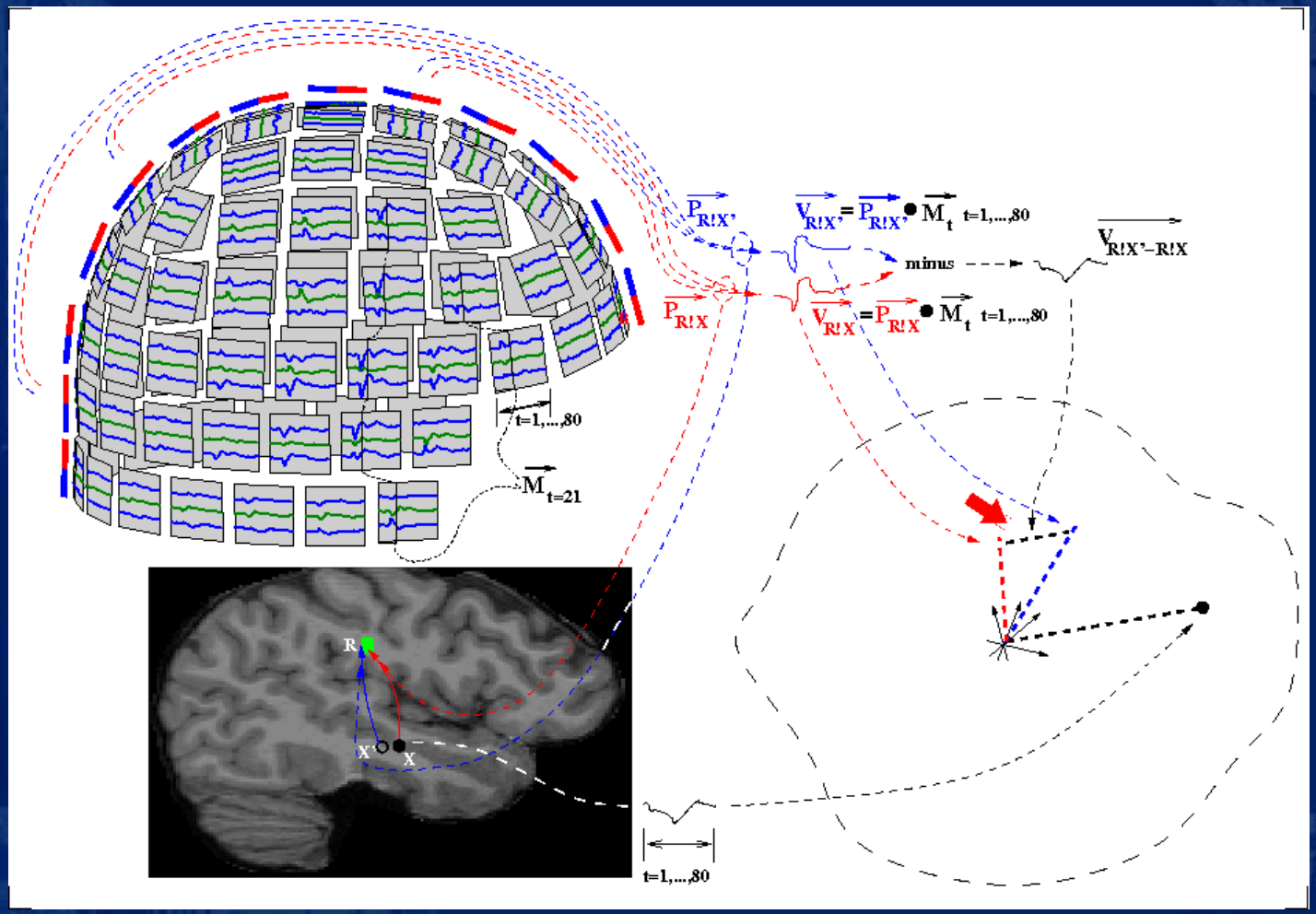


Finally we take the difference between $\overrightarrow{V_{R!X'}}$ and $\overrightarrow{V_{R!X}}$ to obtain an estimate of true waveform at **X** from the "point of view" of **R** but with the estimates of the current at **R** now subtracted away.

This also attenuates contributions to $\overrightarrow{V_{R!X'}}$ and $\overrightarrow{V_{R!X}}$ from all other sources both inside and outside the brain.

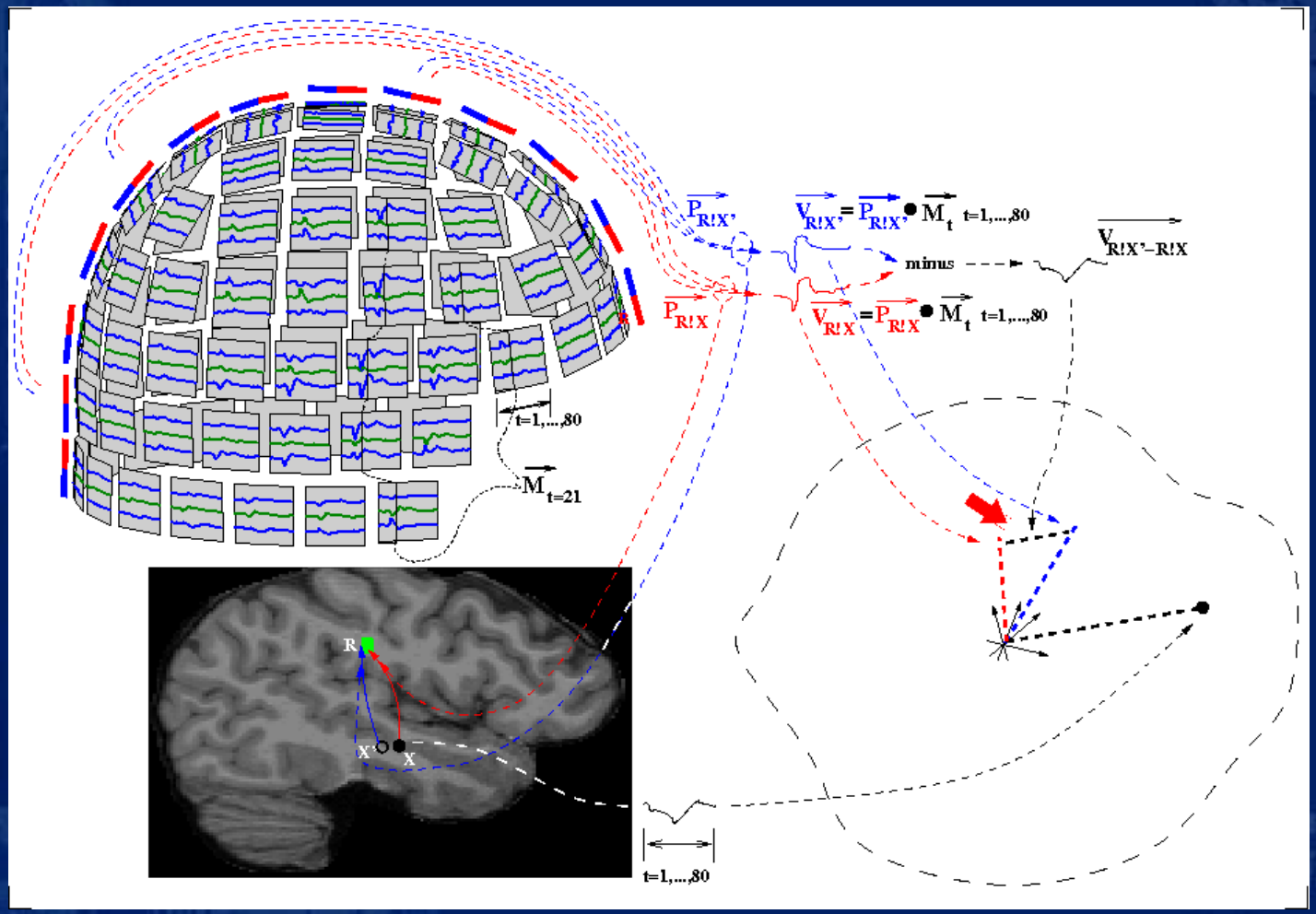


The difference vector, $\overrightarrow{V_{R!X'-R!X}}$, falls nearly parallel to the true signal at **X**. It is a "similar" waveform in that their shapes are nearly the same, i.e. they are highly correlated. Another way to put it is that this difference must include a simile of the true waveform at **X** and little else.



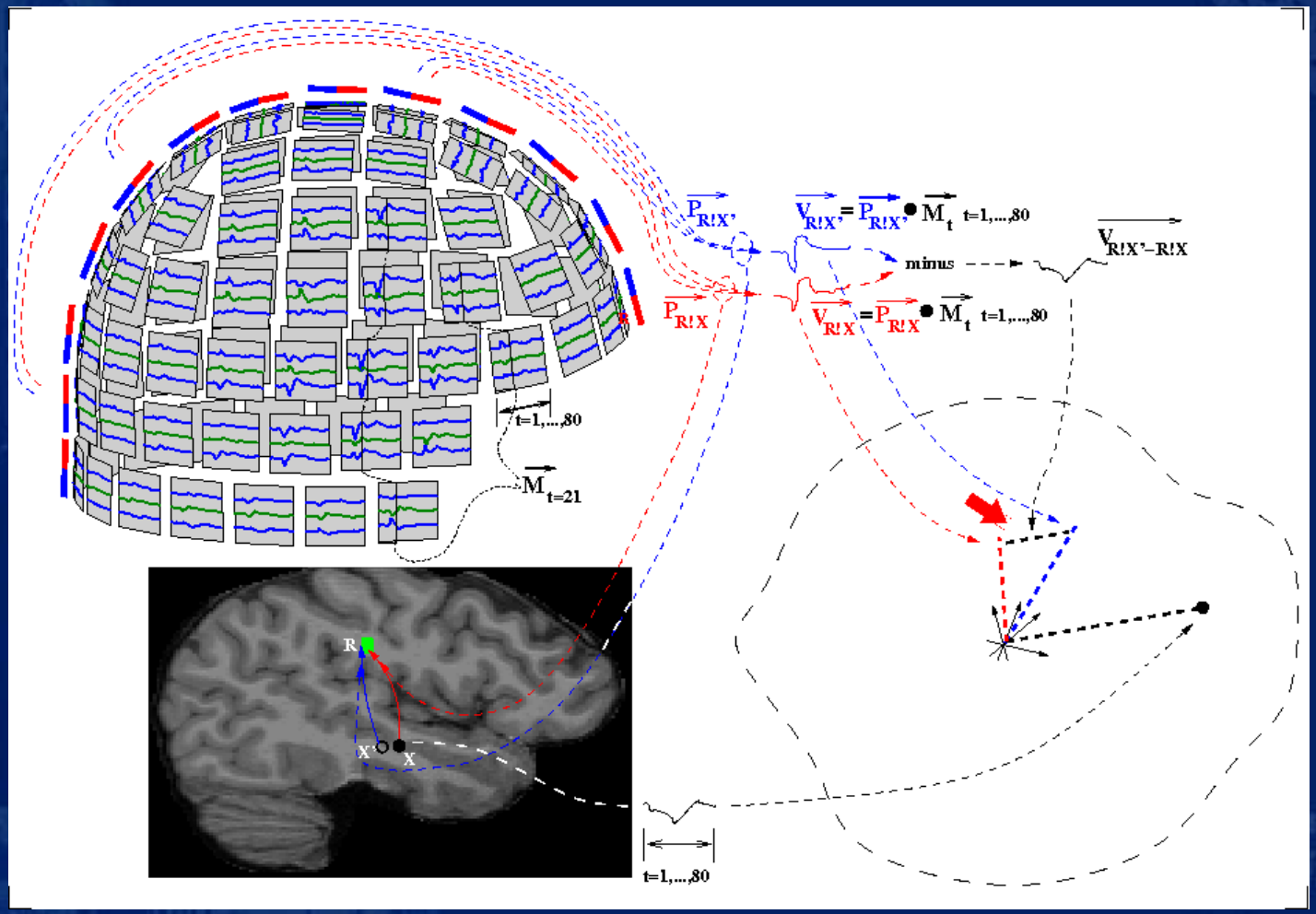
The referee consensus cost function calculation …

… provides a statistically powerful “goodness of fit” measure.



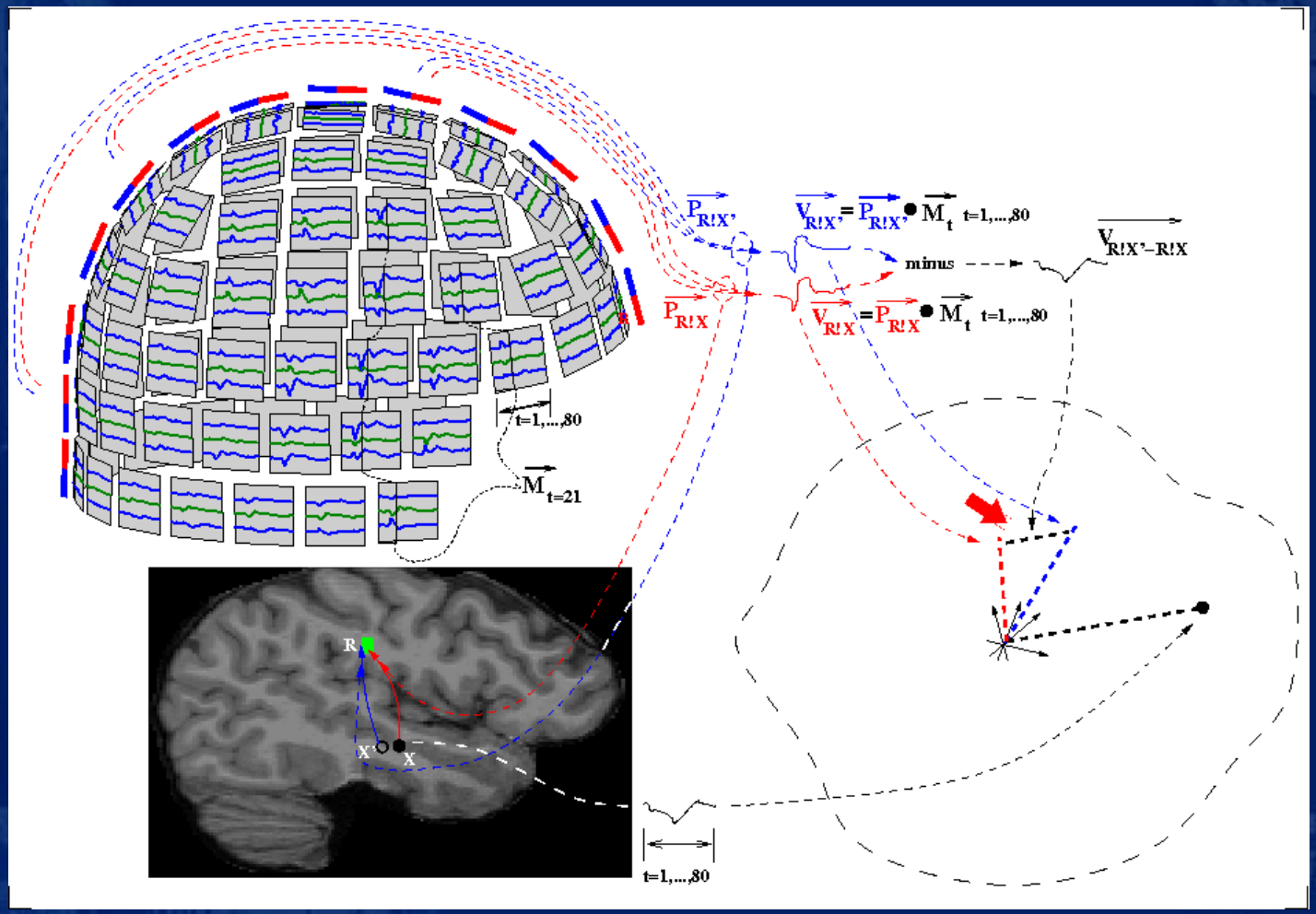
The referee consensus cost function calculation …

… produces sufficient signal/noise enhancement to enable source identification and accurate time course measurement from single trial data.



The referee consensus cost function calculation …

… isolates one source from all others, enabling identification and time course measurement of one source at a time …



The referee consensus cost function calculation …

… isolates one source from all others, enabling identification and time course measurement of one source at a time …

… this makes the method most similar functionally to Equivalent Dipole Source Localization.