trials i.e. day → gay Vs de → ge, it was not always possible to determine in which trial the response first occurred.

TABLE 4.5. Models in the Plane ∼ Trials Appraisal

	MMN Trials	
Model	*day → gay Vs de → ge*	*de → day Vs day → de*
Bayesian Hierarchical	*day → gay has later activity onset than de → ge*	*day → de has later activity onset than de → day*
Kriging	*Comparison of activity onset is indeterminable*	*day → de has later activity onset than de → day*
Log-Normal Kriging	*Comparison of activity onset is indeterminable*	*Comparison of activity onset is indeterminable*

4.3. A Spherical Consideration

We have data from the standard 10–20 skull cap system and have previously used a simple planar view (from above) to project the electrode positions in a perpendicular manner(by hand) to form Cartesian co-ordinates. If we consider the head to be a sphere, we may consider other projection methods. In this instance we may use a co-ordinate system similar to latitude and longitude. As the 10–20 system has previously been mapped into spherical co-ordinates, see Misic, ***(2009)*** *where an overview of the 10–20 skull cap electrode placement is outlined, we may quickly convert these spherical co-ordinates into rectangular co-ordinates, by using the standard rectangular transforms. This projection system should provide better accuracy in regards the actual electrode positioning as well as provide a more precise representation of the true distance distance separating the electrodes.*

Let θ = latitude, ϕ = longitude and for simplicity our radius, $\rho = 1$. Then our rectangular coordinates are

- $x = \rho \cos\theta \sin\phi$
- $y = \rho \sin\theta \sin\phi$
- $z = \rho \cos\theta$

Our plan view of this representation is shown in Figure 4.22

We now have a set of planar co-ordinates (x, y) which provides a representation of the true distance between the electrodes. We then combine this with the energies as from

FIGURE 4.22. A Polar Representation

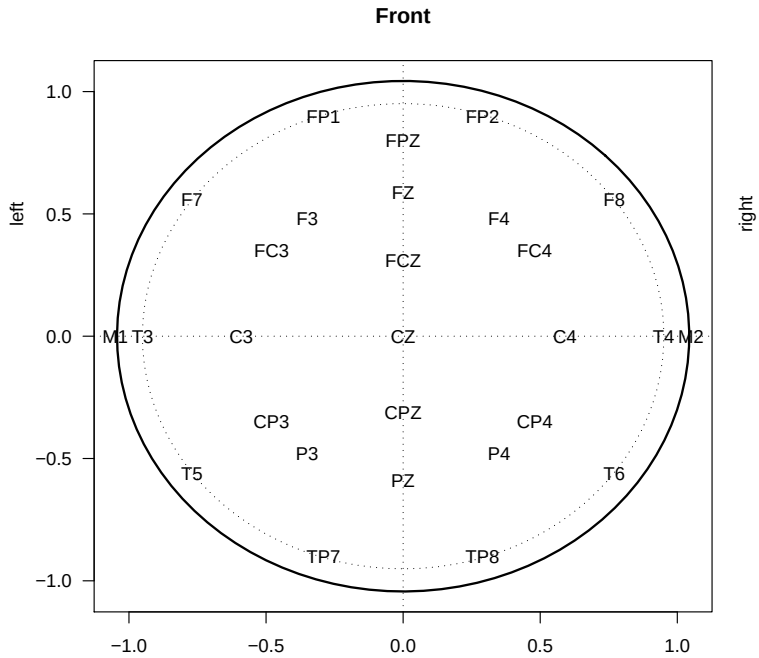


Table 4.1 on page 32 to build a spatial model. Here we build a Hierarchical model[10] *similar to previously shown in Section 4.2.1.1 (page 34), this time with our new co-ordinates.*

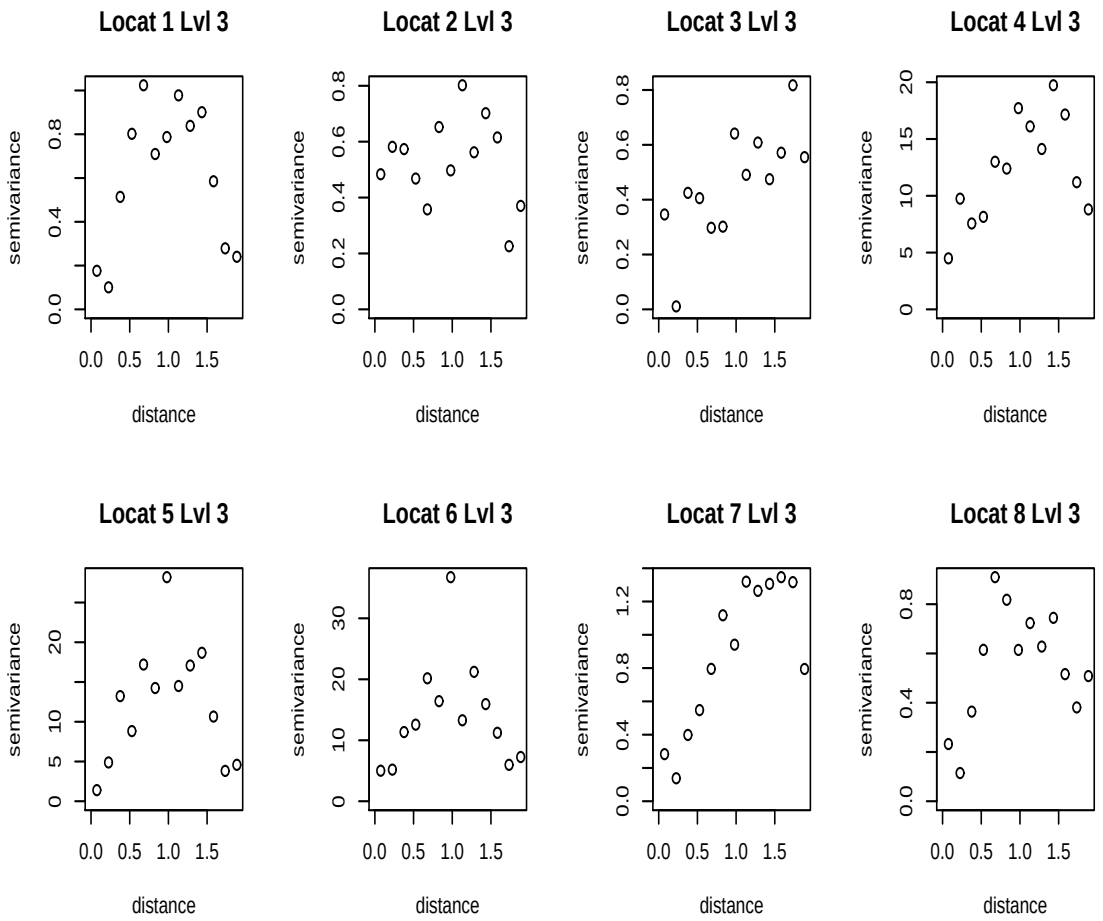
4.3.1. The Bayesian Modeling approach. *Depending upon which energy level we consider, we have a corresponding number of time locations. At each time location we may develop a specific model with the individual spatial parameters for that time location.*

We consider the day → gay trial and construct empirical variograms at each of the 8 time locations, at energy level 3. Using the geoR package from R we obtain variograms, from these we obtain our general spatial parameters, (values and priors) for the model. We need to do this again as having changed the scale and placement of the x and y co-ordinates. Hence the distances[11] *and spatial effects may alter.*

[10]We choose the spatial Bayesian hierarchical model as the results shown in Table 4.5 indicate that such a model provides finer discrimination in determining the onset of activity when comparing these trials.

[11]These changes can be noticed by comparing Figure 4.23, page 55 to Figure 4.2, page 27.

FIGURE 4.23. Empirical Variogram: day → gay

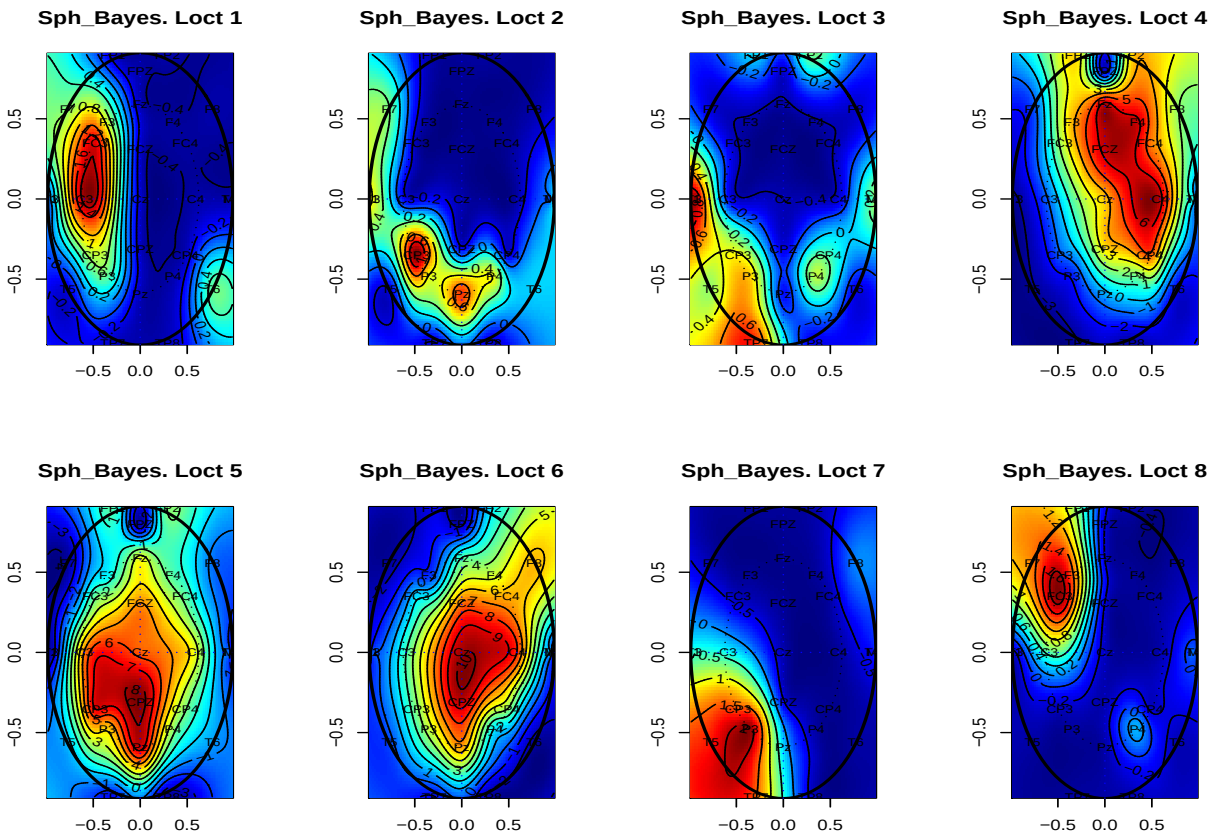


With the time locations for the trial in question, we may begin to construct our model. These empirical variograms help define the prior hyperparameters that we will use in our Hierarchical model. From each variogram, we obtain estimates[12] *for* σ^2 , τ^2 *and* ϕ.

Equipped with these values, we have initial values for our hyperparameters. The priors we used are those as suggested in the the spBayes vignette [**Finley, 2007**]. *Therefore adjusting each of the values accordingly, (hyperparameters, initial starting values) for each location in time we obtain a graphic representation, Figure 4.24.*

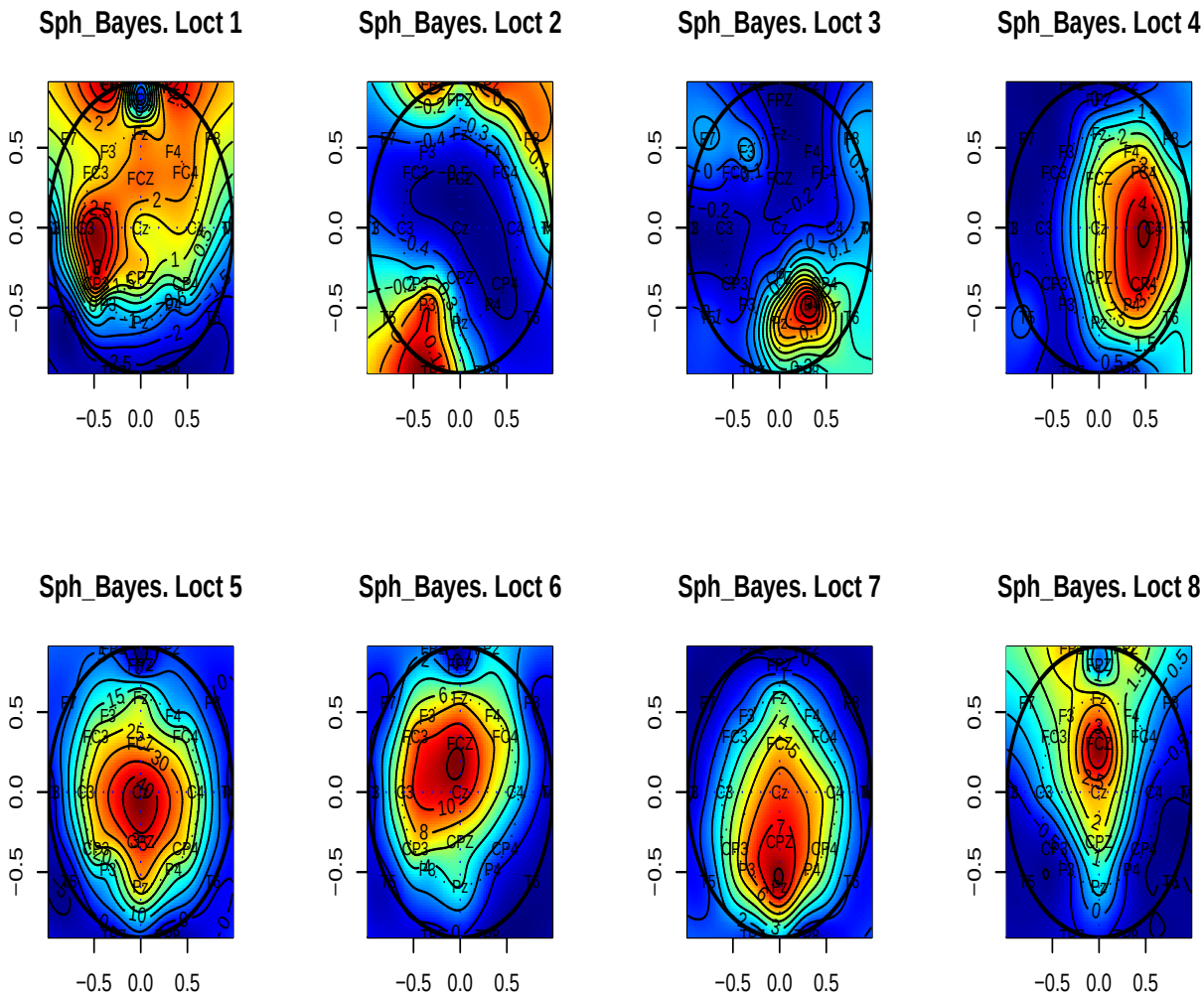
[12]For both σ^2 and τ^2, 2 is chosen as the shape parameter as this suggests that the Inverse gamma distribution has infinite variance.

FIGURE 4.24. Bayesian Hierarchical: day → gay at level 3



Similarly we may generate de → ge Figure 4.25, where we adjust the parameters individually at each time location, according to the results of obtained from the respective variogram (not shown).

FIGURE 4.25. Bayesian Hierarchical: de → ge at level 3



In both these Figures (4.24 and 4.25), we note an obvious increase in energy beginning to become evident around time locations 4 and 5. In an attempt to differentiate the latency of the onset of such energy buildup, again we attempt to explore this further by moving to a higher level of resolution, i.e. energy level 4 (Figures 4.26 and 4.27).

FIGURE 4.26. Bayesian Hierarchical: day → gay at level 4

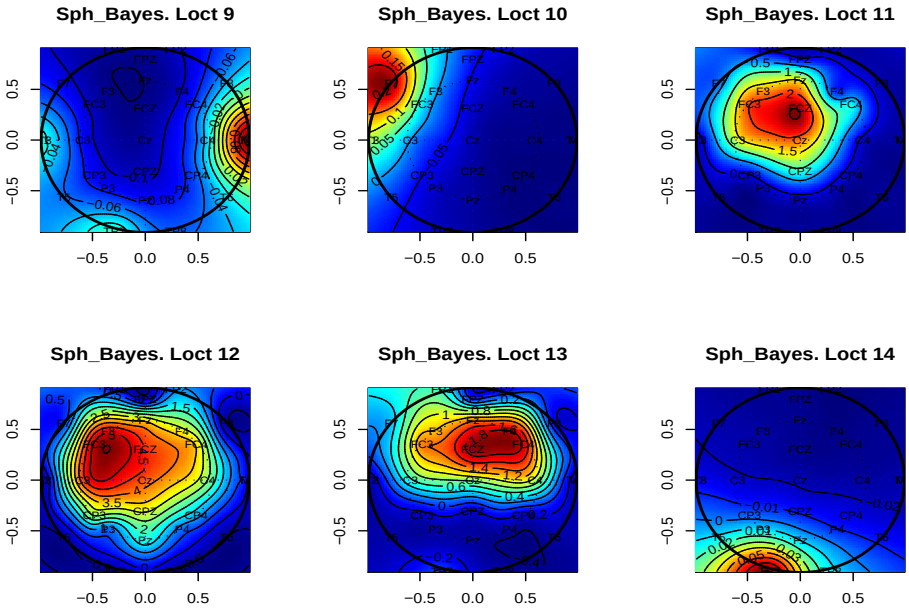
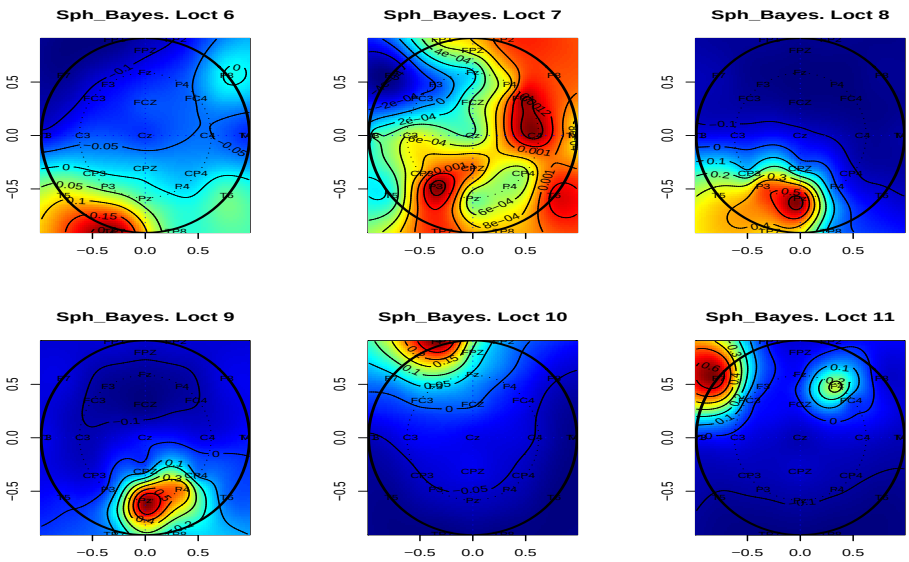


FIGURE 4.27. Bayesian Hierarchical: de → ge at level 4



In Figure 4.26, we note the increase in activity beginning at time location 11 while in Figure 4.27 a sharp increase in activity is shown at time location 7. This highlights that we have further approximated the initial onset of energy by moving to a finer resolution, i.e. from level 3 to 4.

de $\rightleftharpoons$ **day** trials.

Similar to that previously undertaken, we construct models in an attempt to detect MMN latency in the de $\rightleftharpoons$ day trials.

The following graphics (Figures 4.28 and 4.29) highlight that MMN activity begins to increase at around time location 3 or 4 (out of 8) in either trial.

FIGURE 4.28. Bayesian Hierarchical: de $\rightarrow$ day at level 3

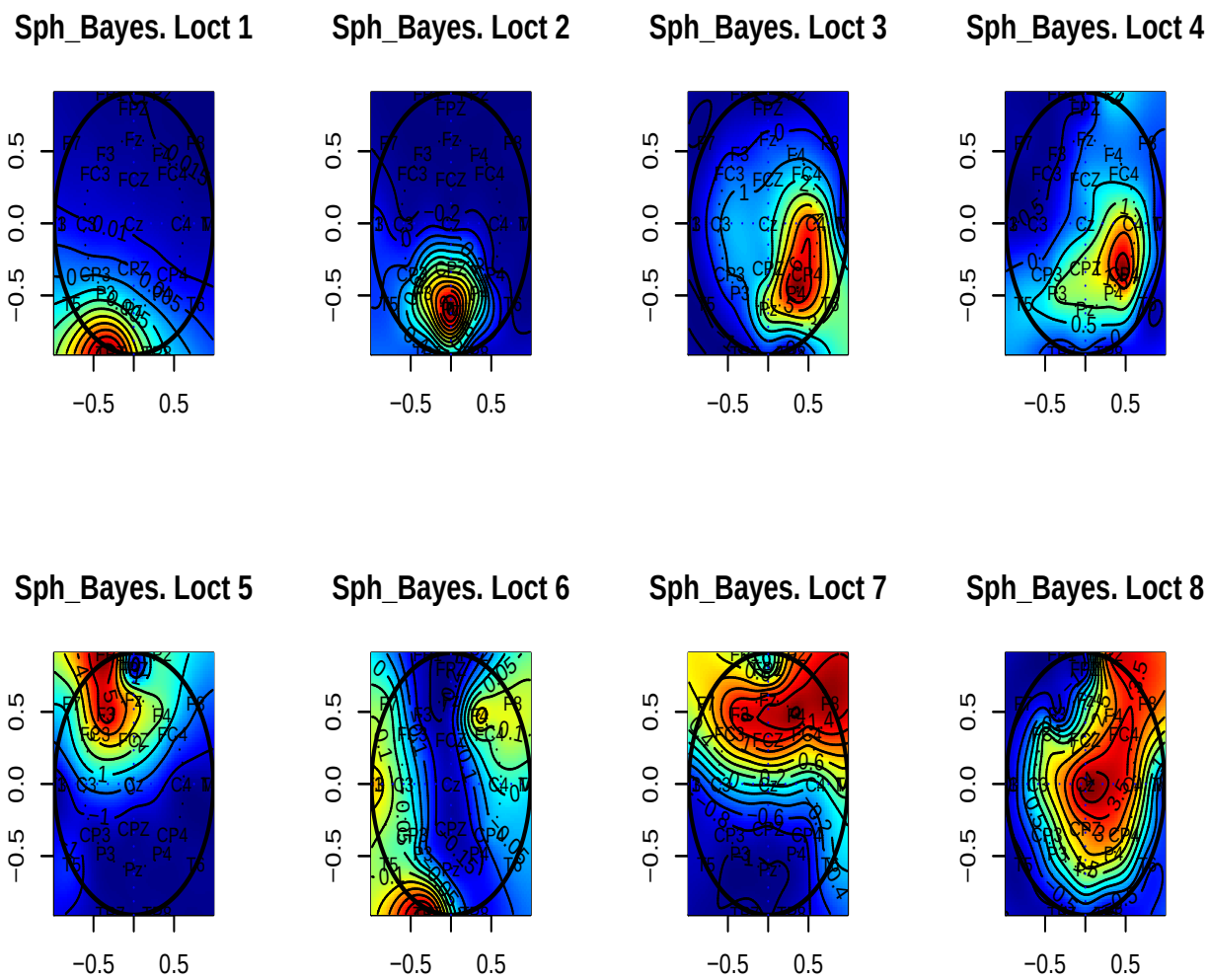
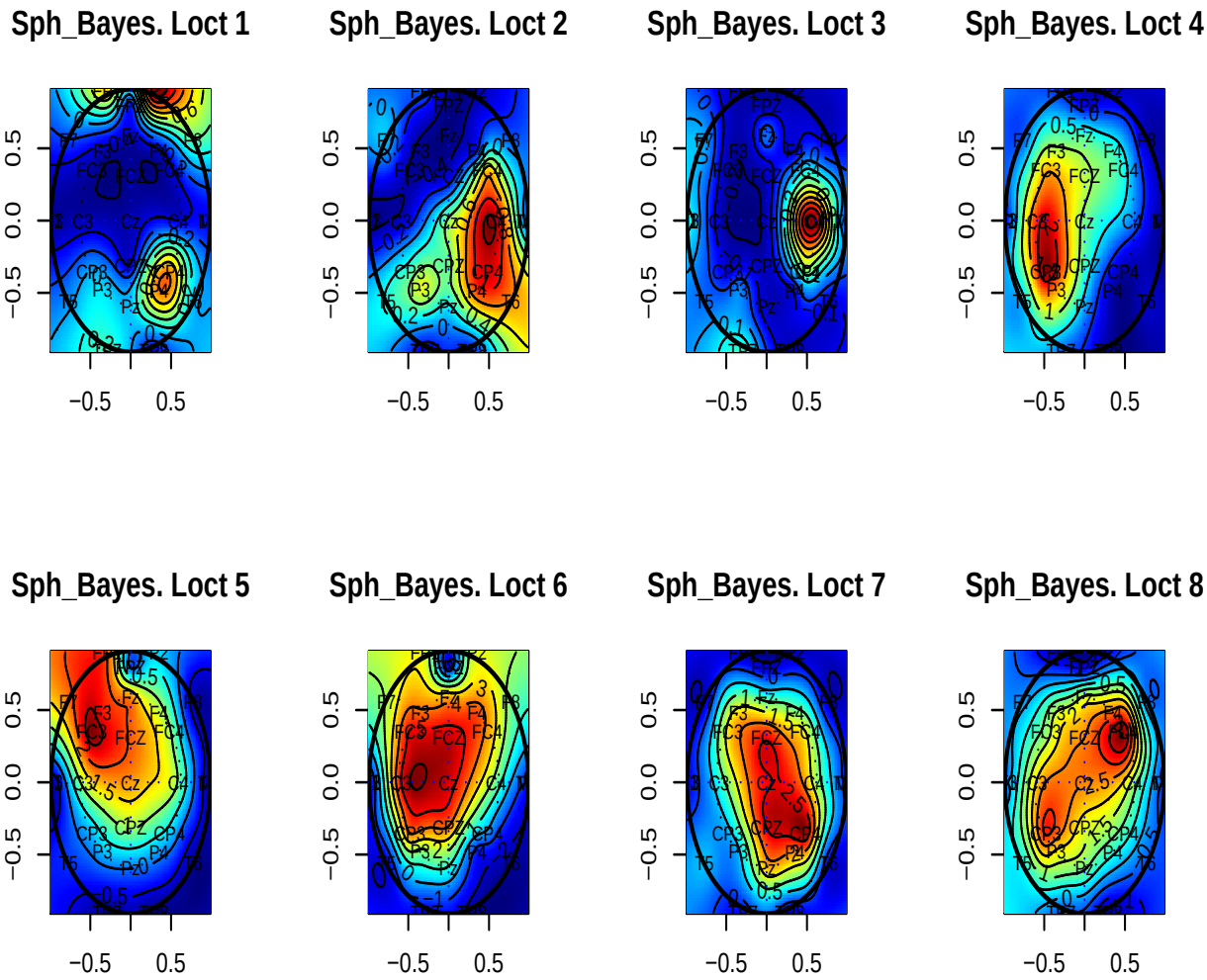


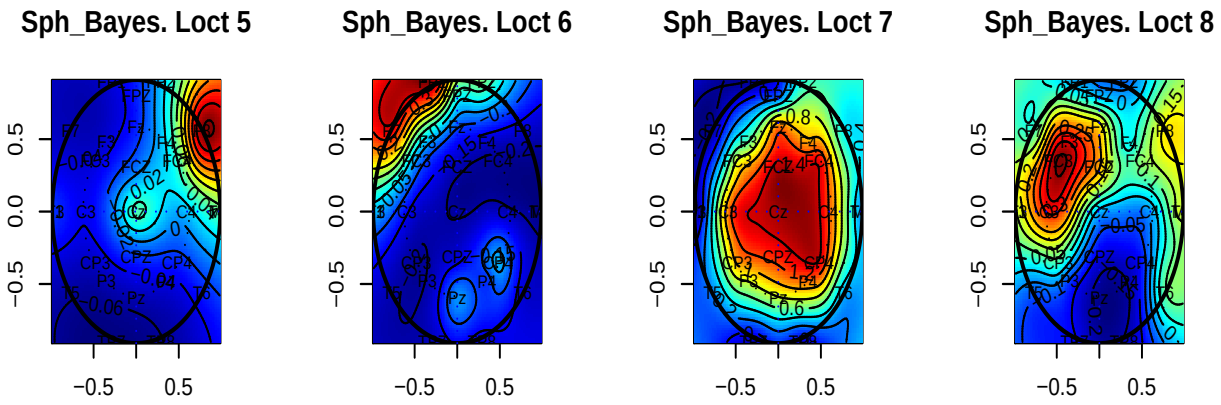
FIGURE 4.29. Bayesian Hierarchical: day → de at level 3



We maybe able investigate this further by moving to a higher energy level for finer resolution across time, i.e. 16 time locations. Again we need to build variograms at this higher resolution level to extract parameters for the Bayesian model.

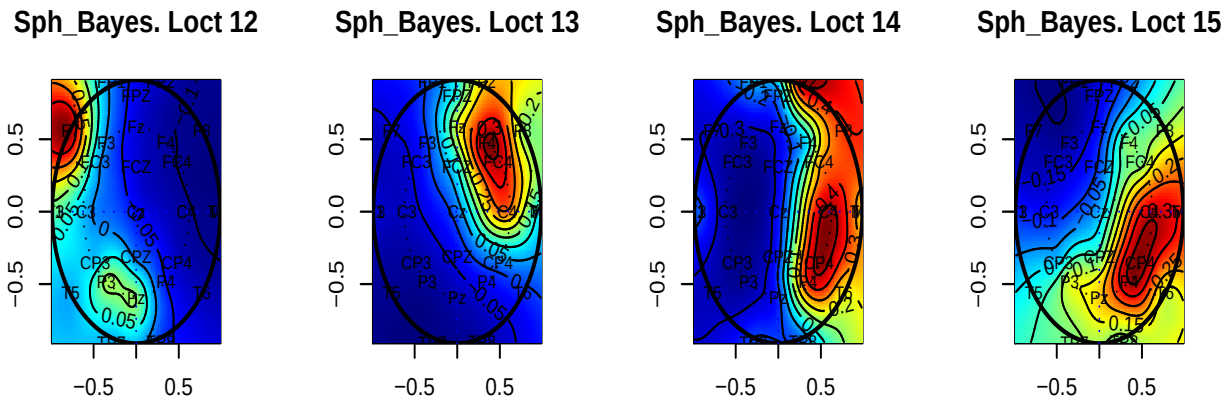
With this higher resolution we attempt to highlight the MMN energy increase and the location in time at which it begins.

FIGURE 4.30. Bayesian Hierarchical: de → day at level 4



For the de → day trial at level 4 (Figure 4.30), we may note a considerable increase in activity at time location 7 (out of 16). While in the day → de trial, the energy values of the EGG signal returned at time locations 7 and 8 are negligible (not shown). Hence we look at later time locations in the trial to notice any significant increase in activity, which appears to begin at time location 13 (out of 16), see Figure 4.31.

FIGURE 4.31. Bayesian Hierarchical: day → de at level 4



From these graphics (Figures 4.28, 4.29, 4.30 and 4.31) we observe that the actual onset of increase in activity occurs at an earlier latency in the de → day trial in comparison to day → de trial, which is consistent with the hypothesis and results in Pettigrew, ***(2004)****.*

Here we have applied the Bayesian hierarchical model to compare specific trials and have been able to show, not only when in time the activity from a MMN response increases for a specific trial but also to be able to compare trials containing "fine acoustic speech contrast" for the onset of such activity, i.e. day → gay Vs de → ge.

TABLE 4.6. Spherical projection ∼ Trials Appraisal

	MMN Trials	
Model	*day → gay Vs de → ge*	*de → day Vs day → de*
Spherical Bayesian Hierarchical	*day → gay has later activity onset than de → ge*	*day → de has later activity onset than de → day*