Applying Transparent Thresholding to Visualize Data and Highlight Results in SUMA

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Introduction

AFNI's [1] 3D visualization tool, SUMA [2], allows information to be displayed on brain surfaces in many ways. It is common to overlay some kind of physiological information and apply a threshold, T, so that only the information with sufficient magnitude is displayed; note that the threshold dataset can be different than the overlay one. However, there may be times when the user wants to highlight above-threshold values while also showing information just below T, as well as simultaneously getting a sense of how far below T the information is (without needing to adjust T).

Indeed, known problems with hiding information just below the threshold include: step function segmentation of continuously distributed data, over-dependence on sample size, information loss, hiding noise contributions, hiding potentially interesting features, arbitrariness in results, reproducibility issues, p-hacking, hiding of artifacts and poor modelling, and hidden uncertainty [3,4]. It may, therefore, be desirable to blend multiple overlays based upon how close the respective surface values are to the thresholds set for different displayed datasets. SUMA can now apply such transparent thresholding to the data, where the opacity of sub-threshold data is proportional to the proximity of the threshold value to T. This allows the overlay colors to still be visible but "fade away" for sub-threshold locations, rather than disappear, carrying more information.

Methods

An “A” checkbox has been added to the SUMA surface control menu, and its behavior is described as follows. Consider a surface note is assigned a gray color, G. If “A” is *un*checked, then standard thresholding applies: the displayed overlay value, y, is the overlay color, c, if the local threshold data value x >= T, or otherwise it is G. If “A” is checked, then the new transparent thresholding is applied: as before, y=c if x>=T; but now, for cases where x<T, y=oc+tG, where o=(x/T)^D is the opacity, t=(1-o) is the transparency, and D is a parameter called the degree of the ratio function, which determines the fading rate. D can be any positive, real number, but is 2 (quadratic) by default. If there are multiple overlaid datasets, each is processed in the same way, starting with the overlay closest to the surface. When a given overlay is being processed, G is replaced by the value of y for o=0, t=1 for that overlay.

Results

The figure at right shows an application of the “A” checkbox. The overlay represents the F-statistic of the surface at a given point, and the same F-statistic dataset is applied as the threshold here (again, a separate dataset could be applied).

When no threshold is applied (**A**), the parts of the cerebral cortex in yellow/magenta appear to be more active than most. When the threshold is set to 130, and the “A” box remains unchecked (**B**), only the parts of the overlay at or above the threshold are shown. However, even near-threshold regions now appear to be inactive, hiding potentially useful information. When the “A” box is checked (**C**), the overlay coloration is thresholded transparently: its coloration can still be shown, proportional to ratio of local F-statistic to the threshold value. Thus, locations close to the threshold, and appearing active in the unthresholded surface, can still be seen.

This enables thresholded displays to be carry more information, decreasing sensitivity of results to the choice of arbitrary threshold. On a practical note, this reduces need to adjust thresholds to interpret data (AKA p-hacking), which can occur with all-or-nothing thresholding. When comparing the two hemispheres, there are seemingly active regions, at the same locations in both hemispheres, suggesting potentially real neuronal activity. Some of these can be seen as active with the “A” box checked but not with strict thresholding. Active regions, seen in one hemisphere but not in the other, may be noise but this is not clear if they are hidden by strict thresholding.

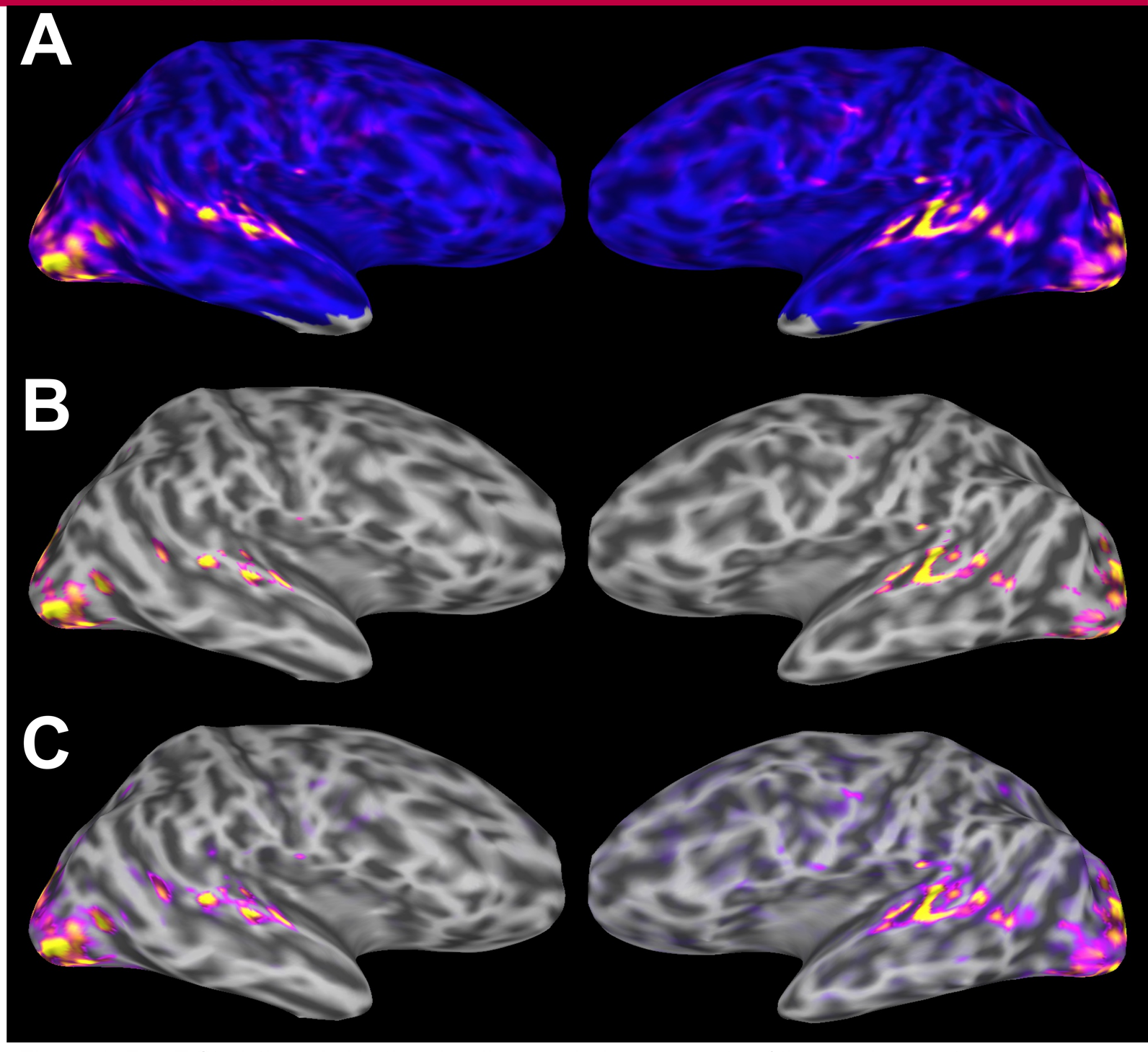

Figure 1: Full-F Statistics. A: No thresholding applied: some parts of the cerebral cortex seem clearly more active than most. B: Strict thresholding applied: supra-threshold regions are clearly seen but parts that are only marginally below that value appear totally inactive. C: Transparent thresholding applied with linear fading: all active areas are accentuated by being opaque, while subthreshold regions still appear, and the exact choice of statistical threshold is much less important.

Conclusion

A new option has been added to SUMA. It allows varying transparency of the displayed data so that:
- Supra-threshold regions are highlighted (opaque) while subthreshold regions show progressively fading colors as the threshold value value falls below T.
- Multiple overlays can be blended.

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