Go Figure: Keep context in images to meaningfully interpret results

Paul A. Taylor[1], Peter A. Bandettini[2], César Caballero-Gaudes[3], Vince D. Calhoun[4], Jennifer W. Evans[5], Daniel R. Glen[1], Javier Gonzalez-Castillo[2], Omer Faruk Gulban[6], Daniel A. Handwerker[2], Peter D. Lauren[1], David A. Leopold[7], Amanda Mejia[8], Cyril Pernet[9], Luiz Pessoa[10], Justin K. Rajendra[1], Richard C. Reynolds[1], Vinai Roopchansingh[2], Brian E. Russ[11], Salvatore Torrisi[12], Gang Chen[1].

... *in further collaboration with:* Himanshu Aggarwal, Marco Barilari, Molly Bright, Mallar Chakravarty, Gabriel A. Devenyi, Eduardo A. Garza-Villarreal, Jalil Rasgado-Toledo, Rémi Gau, Rainer Goebel, Yaroslav Halchenko, Taylor Hanayik, Jason Lerch, Christian Mathys, Paul McCarthy, Anke McLeod, Stefano Moia, Thomas Nichols, Bettina Pfleiderer, Laura Reyes, Chris Rorden, Benedikt Sundermann, Bertrand Thirion.

[1]SSCC, NIMH, NIH, USA; [2]SFIM, NIMH, NIH, USA; [3]BCBL & Ikerbasque, Spain; [4]TReNDS, Georgia State, Georgia Tech & Emory, USA; [5]ETPB, NIMH, NIH, USA; [6]Maastricht U & Brain Innovation, NL; [7]SNL, NIMH, NIH, USA; [8]Indiana U, USA; [9]NRU, Rigshospitalet, Denmark; [10]U. of Maryland, College Park, USA; [11]NKI, Mount Sinai & NYU, USA; [12]UCSF & SFVA, USA.

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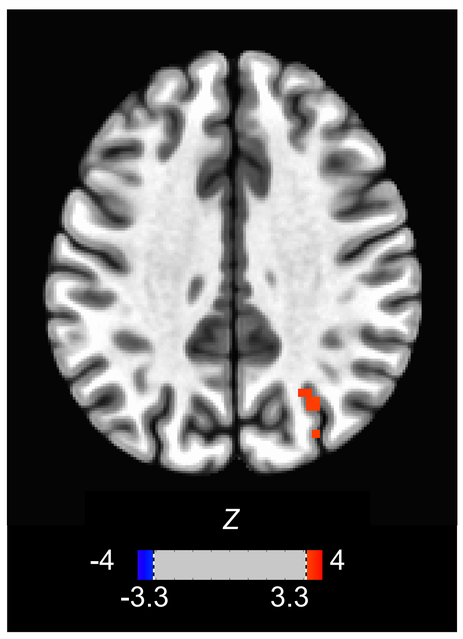
Introduction

Question: What are "the results" of a study to share in figures?
Answer: It depends a lot, based on how you choose to threshold.

Both of the following images *clearly show the same suprathreshold clusters (p=0.001+cluster)*, but they have some important differences:

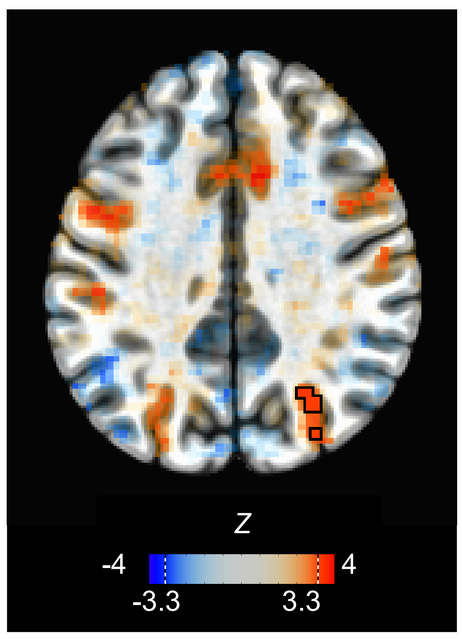
(*old*) All-or-nothing threshold



- Hides results from 99% of brain → treats them like 0 activity
- Removes context around clusters → creates ambiguity
- Biases results → makes results unstable
- Harms reproducibility → can't interpret or compare well

The information loss here leads to misinterpretation and biases towards non-reproducibility.

(*new*) Transparent threshold*



- Shows sub-threshold results → see gradation of effects/stats
- Keeps context around clusters → see networks, extent, etc.
- Appropriately stable results → less sensitive to arbitrariness
- Leads to informed comparisons → more accurate reproducibility

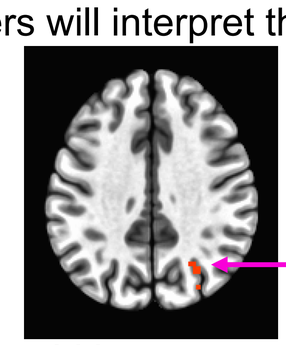
The evidence is presented more scientifically (but still digestibly) for more accurate evaluations.

* Transparent thresholding displays the same above-threshold results as standard "all-or-nothing" thresholds, but it then also presents subthreshold results with increasing transparency. Here, we also put a boundary around the suprathreshold results, to further highlight them (see Allen et al., 2012).

An example of ambiguity from context loss

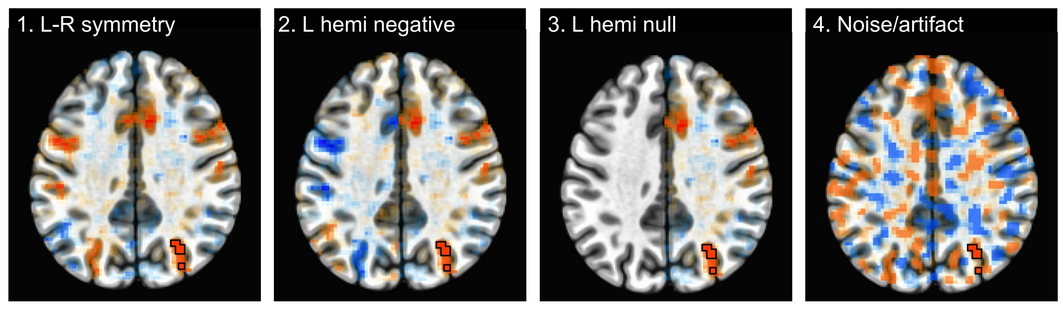
Standard all-or-nothing thresholding removes context around clusters. How does this lead to ambiguity and misinterpretation?

- When results are presented with standard, all-or-nothing thresholding, researchers and readers will interpret these results as "fully lateralized response":



Cluster interpretation
= Lateralized response

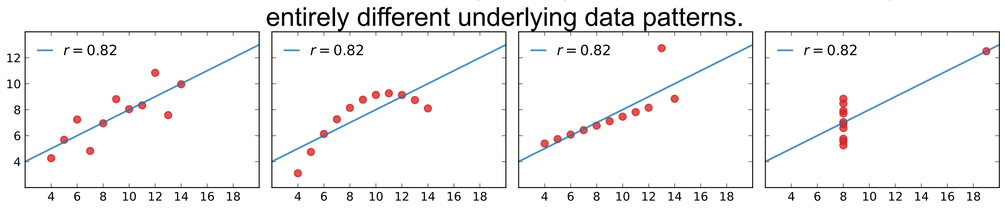
- But that sparse result could have come from *any one of the following* results, which have very different biological interpretations:



- Transparent thresholding shows the context that allows for a more accurate assessment (near left-right symmetry, *not* lateralization).
- All-or-nothing over-reduces results → **ambiguity and misinterpretation**
  Transparency keeps context → **clarity and richer understanding**

***Sidenote*: Statisticians know this same lesson as Anscombe's Quartet (Anscombe, 1973).**

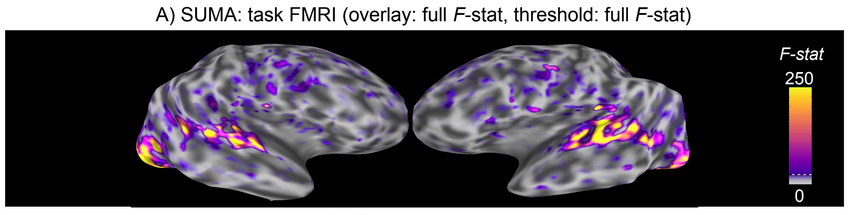
These plots have the same summary stats (mean, stdev and correlation), *but* entirely different underlying data patterns.



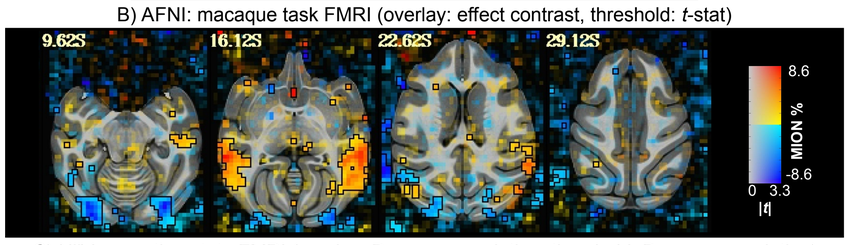
Summary values alone over-reduce results → **ambiguity & misinterpretation.**
Showing the plots provides useful info → **understand & evaluate the data.**

Transparent thresholding: Now available in a software package near you!

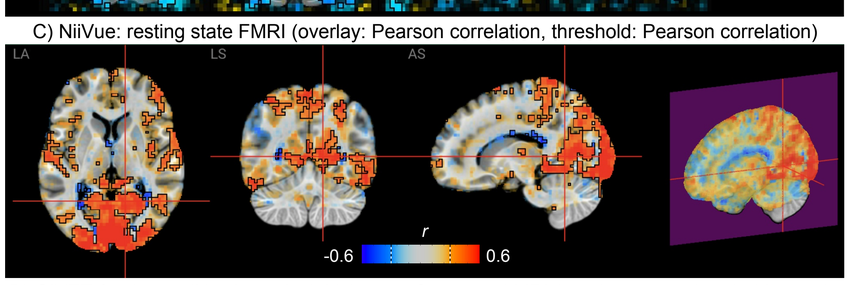
A) SUMA: task FMRI (overlay: full *F*-stat, threshold: full *F*-stat)



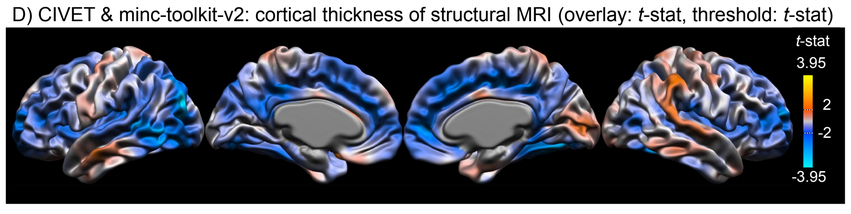
B) AFNI: macaque task FMRI (overlay: effect contrast, threshold: *t*-stat)



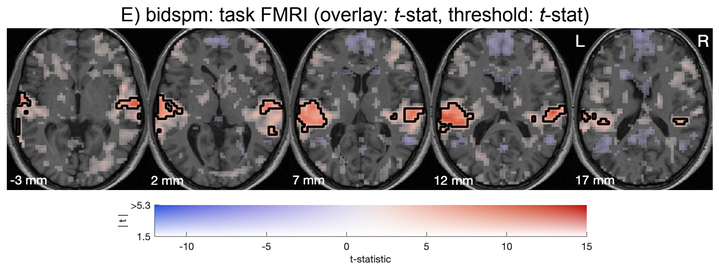
C) NiiVue: resting state FMRI (overlay: Pearson correlation, threshold: Pearson correlation)



D) CIVET & minc-toolkit-v2: cortical thickness of structural MRI (overlay: *t*-stat, threshold: *t*-stat)

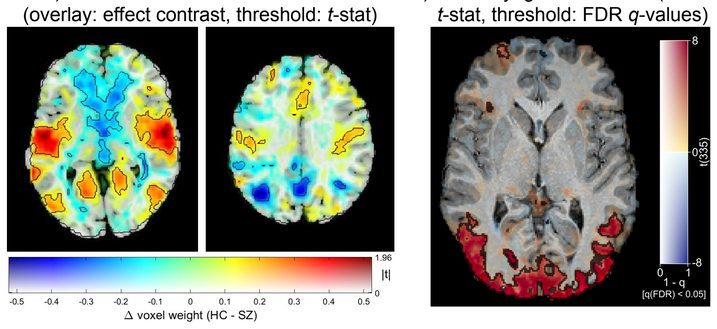


E) bidspm: task FMRI (overlay: *t*-stat, threshold: *t*-stat)

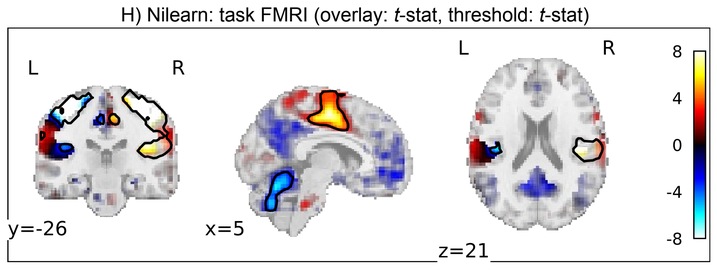


F) Trends-Matlab & GIFT: task FMRI (overlay: effect contrast, threshold: *t*-stat)

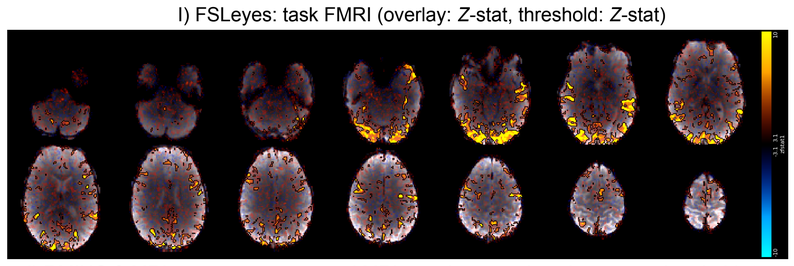
G) BrainVoyager: task FMRI (overlay: *t*-stat, threshold: FDR *q*-values)



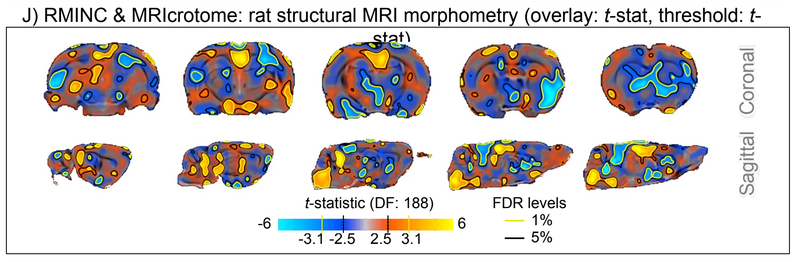
H) Nilearn: task FMRI (overlay: *t*-stat, threshold: *t*-stat)



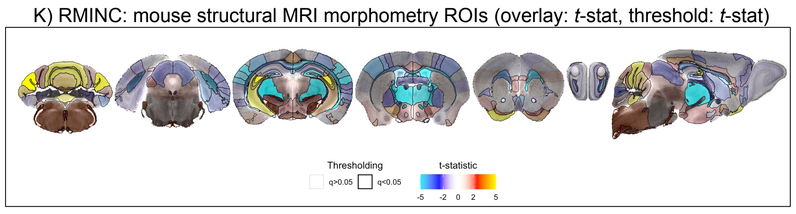
I) FSLeyes: task FMRI (overlay: *Z*-stat, threshold: *Z*-stat)



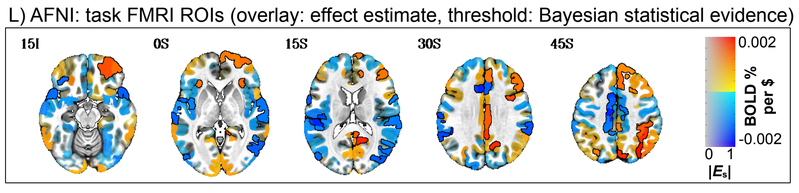
J) RMINC & MRIcrotome: rat structural MRI morphometry (overlay: *t*-stat, threshold: *t*-stat)



K) RMINC: mouse structural MRI morphometry ROIs (overlay: *t*-stat, threshold: *t*-stat)



L) AFNI: task FMRI ROIs (overlay: effect estimate, threshold: Bayesian statistical evidence)



Conclusions

Data visualization is an important analysis step. The method of thresholding is a key processing choice. Modern neuroimaging should use modern thresholding to present results, reducing bias, improving understanding and (of course!) improving reproducibility. For more discussion and examples (including with NARPS and the dead salmon!) please see here:

Go Figure: Transparency in neuroscience images preserves context and clarifies interpretation

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