Improving Practices and Inferences in Developmental Cognitive Neuroscience

Open Science Tools for Research Design, Analysis, and Publication

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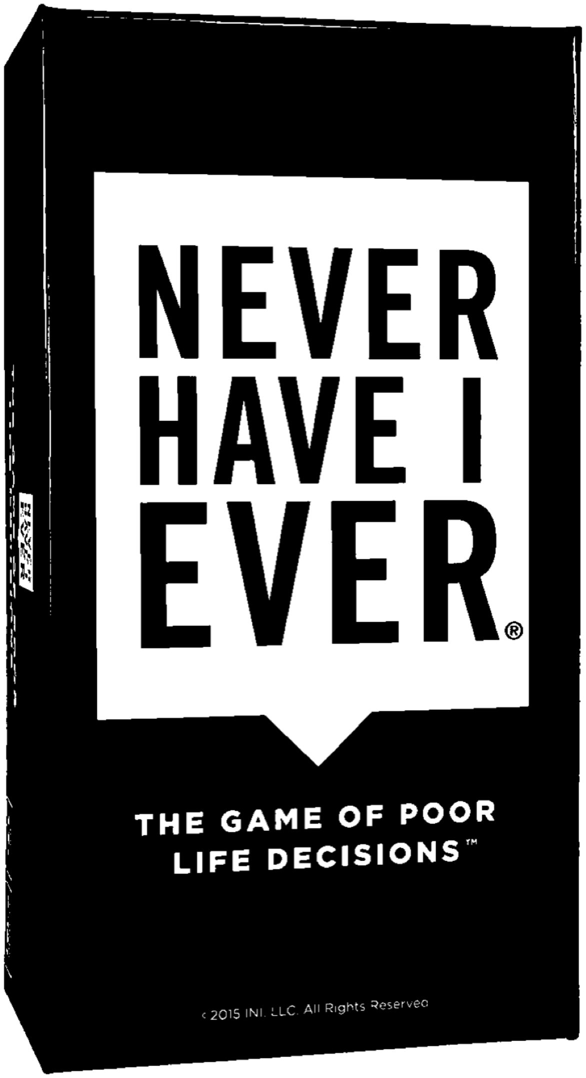
CENTER FOR TRANSLATIONAL NEUROSCIENCE



Ice breaker!

- Run analyses to understand the impact of different analytical/processing decisions
- Changed modeling strategies when you realized your initial plan was not feasible
- Supplemented whole-brain with ROI analyses (or vice versa) when your initial results were null
- Realized that neuroanatomical labeling schemes or developmental age-bins can be annoyingly flexible

Transformative and accessible changes in:

- Analytical strategies
- Publication standards and formats
- (Future goal: system-wide incentives)

Two complementary frameworks for data analysis

Confirmatory	Exploratory
• Null hypothesis significance testing (NHST) • Logical requirements need to be met for p-values to be valid	• Absence of hypothesis testing • Exploration invalidates p-values

Confirmatory Analyses

Correcting for many researcher decisions

(Simmons, Nelson, & Simonsohn, 2011; Hong, Yoo, Wager, & Woo, 2019)

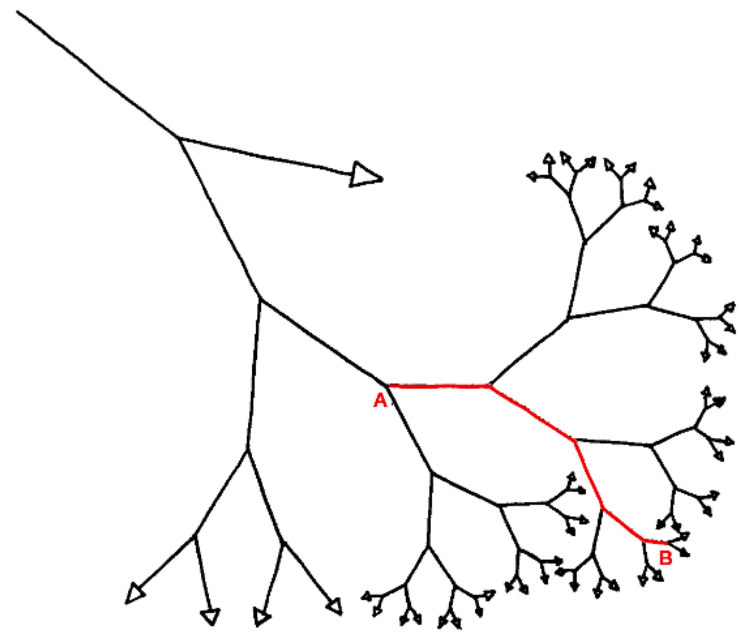
- Researcher degrees of freedom = analytical decisions made after data has been observed
- Proliferation of analytical pathways, especially in Big Data studies

> “ ***Researcher degrees of freedom*** *do not feel like degrees of freedom because, conditional on the data, each choice appears to be deterministic. But if we average over all possible data that could have occurred, we need to look at the entire* ***garden of forking paths*** *and recognize how each path can lead to statistical significance in its own way. (Gelman & Loken, 2013)* ”

The “garden of forking paths” in neuroimaging

(Carp, 2012)

- Myriad decisions from DICOMS → results
- Each data-contingent decision increases need for correction
- If you don’t know how many possible tests you could perform, you can’t know or control your probability of false positives
- Investigating the effects of different parameters/pipelines typically results in inadequate correction for Type I error *in traditional confirmatory methods*



Correcting for many voxels

Cluster
-Flux

- FWE (family-wise error) vs FDR (false discovery rate)
- Two flavors of FWE correction:
  - Bonferroni correction at voxel level
  - Joint magnitude and spatial extent at cluster level
  - To do this using SPM+AFNI, see https://uoregonctn.atlassian.net/wiki/spaces/FSS/pages/208175249/Thresholding+using+3dClustSim
- **Important note: cluster-correction techniques move inference and error control from voxel to cluster**
  - Cannot make within-cluster inferences (Woo et al., 2014)

Limitations of p-values: rejecting the null

- You can fail to reject the null even when there is a true effect, if the size of effect is too small to be detected given the:
  - Methods, due to imprecise measurement, and/or
  - Sample size
- Can only use p-value to infer there **is** some effect in certain voxels -- everywhere else there may be a difference we were just too underpowered to detect
  - Retaining the null hypothesis requires an appeal to power
  - Big Data will be useful here!

Limitations of p-values: obscuring effect sizes

(Orben & Pryzbilski, 2019)

- What is the smallest effect we may be interested in?
- P-values can distract us from effect sizes
- In Big Data studies, be mindful of the relationship between power and p-values – very small associations (r's < 0.05) produce 'compelling evidence' to psychologists and cognitive neuroscientists for rejecting the null hypothesis (p's < 0.05)

Two tools to protect confirmatory analysis

- Preregistration
- Registered Reports

Preregistration

(Nosek, Ebersole, DeHaven, & Mellor, 2018)

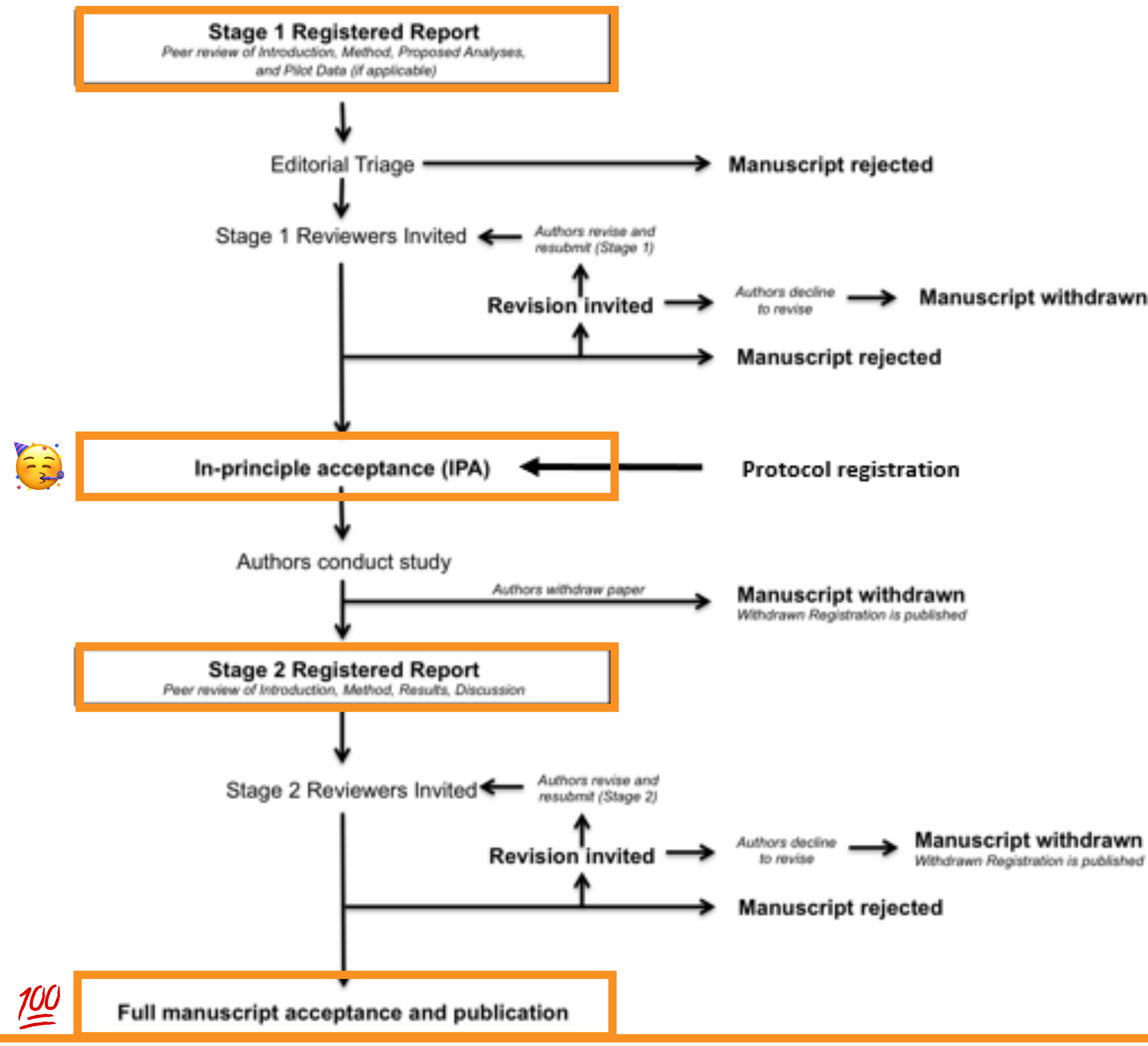
- Useful *throughout* the scientific process
- Use OSF (https://cos.io/prereg/), can embargo and update over the duration of a project (time-stamped amendments)
- Can refer out to standard operating procedures, study protocols
- Facilitates a more straightforward analysis, writing, and review process – helps identify your unknowns
- Increases transparency and reproducibility!

TIP: Too many unknowns? Maybe an exploratory approach would be better!

Registered Reports (RRs)

(Chambers, 2013; Hardwicke & Ioannidis, 2018)

- Project undergoes peer review prior to data collection ('primary') or data analysis ('secondary')
- **Available at *Developmental Cognitive Neuroscience* this fall!**


Stage 1 Registered Report
Peer review of Introduction, Method, Proposed Analyses, and Pilot Data (if applicable)
Editorial Triage
Manuscript rejected
Stage 1 Reviewers Invited
Authors revise and resubmit (Stage 1)
Revision invited
Authors decline to revise
Manuscript withdrawn
Manuscript rejected
In-principle acceptance (IPA)
Protocol registration
Authors conduct study
Authors withdraw paper
Manuscript withdrawn
Withdrawn Registration is published
Stage 2 Registered Report
Peer review of Introduction, Method, Results, Discussion
Stage 2 Reviewers Invited
Authors revise and resubmit (Stage 2)
Revision invited
Authors decline to revise
Manuscript withdrawn
Withdrawn Registration is published
Manuscript rejected
Full manuscript acceptance and publication

Nuances of RRs at *DCN*

- Secondary RRs are submitted for peer review after data collection has taken place, but before data analysis (example: ABCD)
- Secondary RRs are ***fully welcomed*** at DCN
- Registered Replication Reports (RRRs) are also welcomed
- Some open questions:
  - Secondary RRs are strongest when you can provide evidence the data have not been observed (e.g., access to data has been controlled)
  - Knowledge of baseline data, cumulative changes from landmark large-scale studies will soon permeate the literature
  - How do we track what is known and weight its impact on analysis plans?

Exploratory Analyses

An exploratory data analysis framework

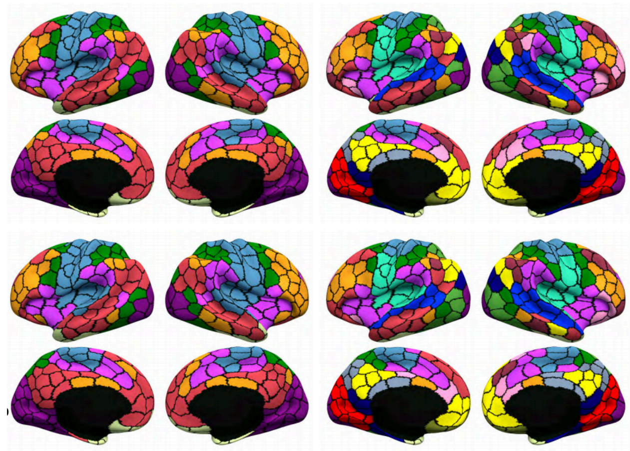
- Absence of hypothesis testing
- Can range from model-free graphical visualizations to characterizations of ways in which fitted models depart from data
- Open science tools make it easier than ever to exhaustively explore one's data (e.g. using R, BIDS apps)

Focus on estimation, comprehensive reporting

- Maps from group-level analyses are just like any other set of variables (can provide summary statistics on them)
- NeuroVault (https://neurovault.org)
  - Can upload any statistic (t, F, beta, percent signal change)
  - Supports future power calculations and meta-analyses
  - Developmental community!
- Clearly scaled map of standardized effect sizes

Parcellations

- A principled way to select ROIs that is both *a priori* and facilitates reproducibility
- Reduces number of comparisons, increases ease of interpretation
- Structural
- Connectivity-Based Parcellation techniques
  - Homogeneity of timecourses at rest



Choosing and using parcellations

- There are many parcellation schemes (Eickhoff, Yeo, & Genon, 2018)
- Factors to consider: number of parcels, standard vs. native space, cortical vs. subcortical…
- Can be applied to data at different levels (group, individual, trial)
- One important current limitation: parcellations have not been created from developmental populations

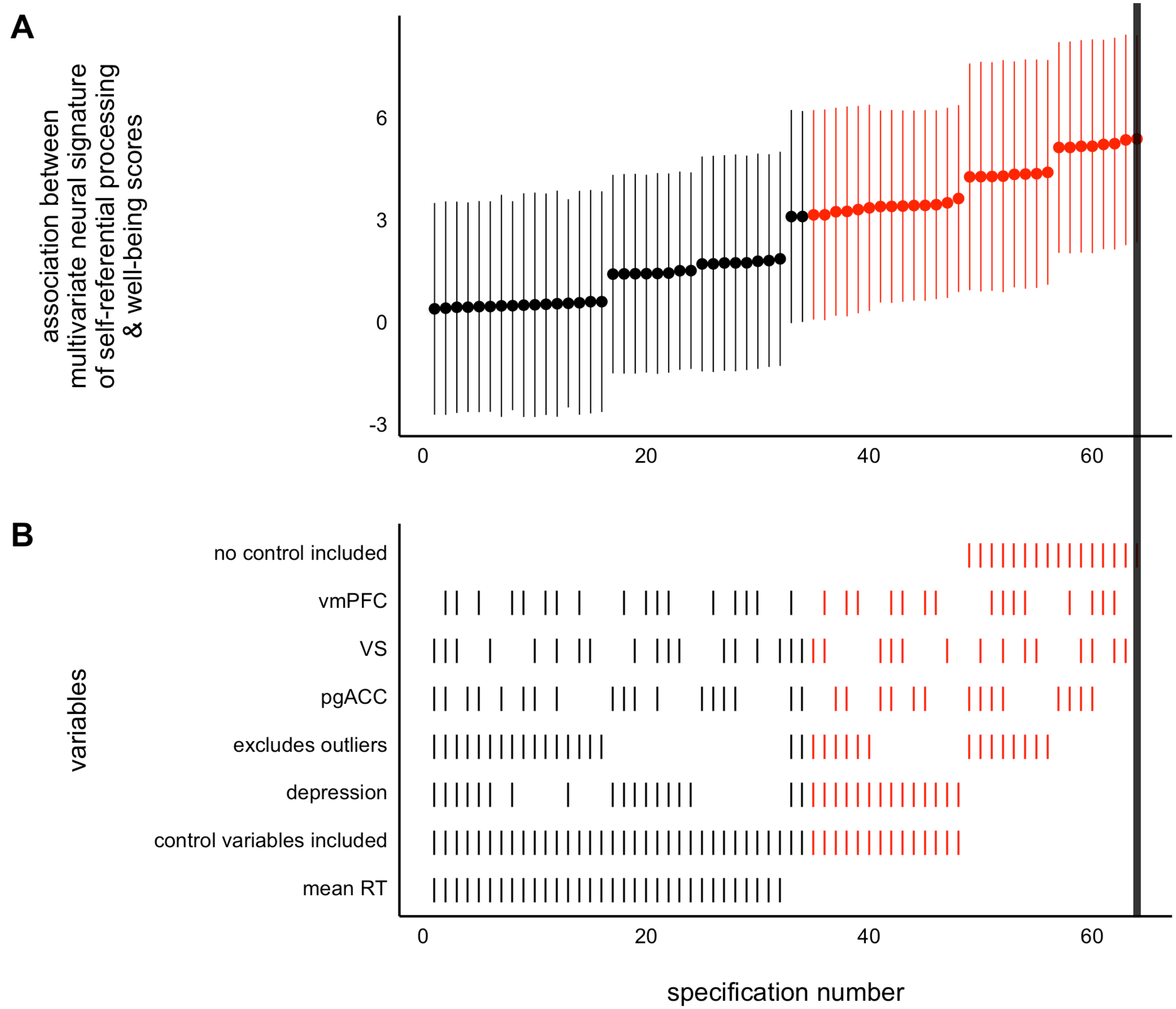
Specification Curve Analysis (a.k.a. Multiverse Analysis)

Simonsohn, Simmons, & Nelson, 2015; Steegen, Tuerlinckx, Gelman, & Vanpaemel, 2016)

- Addresses researcher degrees of freedom problem (many ways to test the same research question)
- In Big Data studies with many variables and researchers, this problem snowballs
- SCA lets you quantify and visualize the stability of observed effects across many possible models – a kind of sensitivity analysis

For a tutorial, see https://github.com/dcosme/specification-curves/

Check out Dani's poster at 2-O-104!



Next-Gen Tools at *DCN*

- New article type and virtual collection to continue prioritizing development and dissemination of best practices in our field acknowledges early career leadership in this area
- **Available at *Developmental Cognitive Neuroscience* this fall!**
- Expands on 2018 special issue of *DCN* on Methodological Challenges in Developmental Cognitive Neuroscience: Contemporary Approaches and Solutions https://www.sciencedirect.com/journal/developmental-cognitive-neuroscience/vol/33

Conclusion: Both/And, not Either/Or

- We need ***both*** more rigor in confirmatory analyses, ***and*** more value accorded to exploratory analyses
- Use preregistration/RRs to constrain researcher degrees of freedom and increase transparency, reproducibility
- Learn how to conduct and review exploratory work on its own merits (which are vast)



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NIH National Institute of Mental Health

NIH National Institute on Drug Abuse

John Flournoy (Harvard); Nandi Vijayakumar (Deakin University, AUS); and Dani Cosme, Theresa Cheng, Jessica Flannery, and Kate Mills (U of O)

Preprint expanding on these topics: https://psyarxiv.com/ez5sf