### Study Information

1. Title:
2. Authors:
3. Description:

Please give a brief description of your study, including some background, the purpose of the of the study, or broad research questions.

1. Hypotheses:
   1. List specific, concise, and testable hypotheses. Please state if the hypotheses are directional or non-directional. If directional, state the direction. A predicted effect is also appropriate here. If a specific interaction or moderation is important to your research, you can list that as a separate hypothesis.

### Design Plan

In this section, you will be asked to describe the overall design of your study. Remember that this research plan is designed to register a single study, so if you have multiple experimental designs, please complete a separate preregistration.

1. Study type:
   1. Experiment - A researcher randomly assigns treatments to study subjects, this includes field or lab experiments. This is also known as an intervention experiment and includes randomized controlled trials.
   2. Observational Study - Data is collected from study subjects that are not randomly assigned to a treatment. This includes surveys, natural experiments, and regression discontinuity designs.
   3. Meta-Analysis - A systematic review of published studies.
   4. Other
2. Blinding:
   1. Blinding describes who is aware of the experimental manipulations within a study. Mark all that apply.
      1. No blinding is involved in this study.
      2. For studies that involve human subjects, they will not know the treatment group to which they have been assigned.
      3. Personnel who interact directly with the study subjects (either human or non-human subjects) will not be aware of the assigned treatments. (Commonly known as “double blind”)
      4. Personnel who analyze the data collected from the study are not aware of the treatment applied to any given group.
3. Is there any additional blinding in this study?
4. Study design
   1. Describe your study design. Examples include two-group, factorial, randomized block, and repeated measures. Is it a between (unpaired), within-subject (paired), or mixed design? Describe any counterbalancing required. Typical study designs for observation studies include cohort, cross sectional, and case-control studies.
   2. Example: We have a between subjects design with 1 factor (sugar by mass) with 4 levels.
   3. More info: This question has a variety of possible answers. The key is for a researcher to be as detailed as is necessary given the specifics of their design. Be careful to determine if every parameter has been specified in the description of the study design. There may be some overlap between this question and the following questions. That is OK, as long as sufficient detail is given in one of the areas to provide all of the requested information. For example, if the study design describes a complete factorial, 2 X 3 design and the treatments and levels are specified previously, you do not have to repeat that information.
5. Randomization
   1. If you are doing a randomized study, how will you randomize, and at what level? We used simple randomization, where each participant was randomly assigned to one of eight conditions.

### Sampling Plan

In this section we’ll ask you to describe how you plan to collect samples, as well as the number of samples you plan to collect and your rationale for this decision. Please keep in mind that the data described in this section should be the actual data used for analysis, so if you are using a subset of a larger dataset, please describe the subset that will actually be used in your study.

1. Existing data:

10.1 Preregistration is designed to make clear the distinction between confirmatory tests, specified prior to seeing the data, and exploratory analyses conducted after observing the data. Therefore, creating a research plan in which existing data will be used presents unique challenges. Please select the description that best describes your situation.

* + 1. Registration prior to creation of data: As of the date of submission of this research plan for preregistration, the data have not yet been collected, created, or realized.
    2. Registration prior to any human observation of the data: As of the date of submission, the data exist but have not yet been quantified, constructed, observed, or reported by anyone - including individuals that are not associated with the proposed study. Examples include museum specimens that have not been measured and data that have been collected by non-human collectors and are inaccessible.
    3. Registration prior to accessing the data: As of the date of submission, the data exist, but have not been accessed by you or your collaborators. Commonly, this includes data that has been collected by another researcher or institution.
    4. Registration prior to analysis of the data: As of the date of submission, the data exist and you have accessed it, though no analysis has been conducted related to the research plan (including calculation of summary statistics). A common situation for this scenario when a large dataset exists that is used for many different studies over time, or when a data set is randomly split into a sample for exploratory analyses, and the other section of data is reserved for later confirmatory data analysis.
    5. Registration following analysis of the data: As of the date of submission, you have accessed and analyzed some of the data relevant to the research plan. This includes preliminary analysis of variables, calculation of descriptive statistics, and observation of data distributions. Please see cos.io/prereg for more information.

1. Explanation of existing data:

11.1 If you indicate that you will be using some data that already exist in this study, please describe the steps you have taken to assure that you are unaware of any patterns or summary statistics in the data. This may include an explanation of how access to the data has been limited, who has observed the data, or how you have avoided observing any analysis of the specific data you will use in your study.

1. Data collection procedures:
   1. Please describe the process by which you will collect your data. If you are using human subjects, this should include the population from which you obtain subjects, recruitment efforts, payment for participation, how subjects will be selected for eligibility from the initial pool (e.g. inclusion and exclusion rules), and your study timeline. For studies that don’t include human subjects, include information about how you will collect samples, duration of data gathering efforts, source or location of samples, or batch numbers you will use.
2. Sample size:
   1. Describe the sample size of your study. How many units will be analyzed in the study? This could be the number of people, birds, classrooms, plots, interactions, or countries included. If the units are not individuals, then describe the size requirements for each unit. If you are using a clustered or multilevel design, how many units are you collecting at each level of the analysis? We have a sample size of 21 younger adults. Size for each unit?

### Variables

In this section you can describe all variables (both manipulated and measured variables) that will later be used in your confirmatory analysis plan. In your analysis plan, you will have the opportunity to describe how each variable will be used. If you have variables which you are measuring for exploratory analyses, you are not required to list them, though you are permitted to do so.

1. Manipulated variables
   1. Describe all variables you plan to manipulate and the levels or treatment arms of each variable. This is not applicable to any observational study.
2. Measured variables
   1. Describe each variable that you will measure. This will include outcome measures, as well as any predictors or covariates that you will measure. You do not need to include any variables that you plan on collecting if they are not going to be included in the confirmatory analyses of this study.

### Analysis Plan

You may describe one or more confirmatory analysis in this preregistration. Please remember that all analyses specified below must be reported in the final article, and any additional analyses must be noted as exploratory or hypothesis generating.

A confirmatory analysis plan must state up front which variables are predictors (independent) and which are the outcomes (dependent), otherwise it is an exploratory analysis. You are allowed to describe any exploratory work here, but a clear confirmatory analysis is required.

1. Statistical models
   1. What statistical model will you use to test each hypothesis? Please include the type of model (e.g. ANOVA, multiple regression, SEM, etc) and the specification of the model (this includes each variable that will be included as predictors, outcomes, or covariates). Please specify any interactions, subgroup analyses, pairwise or complex contrasts, or follow-up tests from omnibus tests. If you plan on using any positive controls, negative controls, or manipulation checks you may mention that here. Remember that any test not included here must be noted as an exploratory test in your final article. We will use regression to analyze our results (need more details).
2. Transformations
   1. If you plan on transforming, centering, recoding the data, or will require a coding scheme for categorical variables, please describe that process.
   2. Example: The “Effect of sugar on brownie tastiness” does not require any additional transformations. However, if it were using a regression analysis and each level of sweet had been categorically described (e.g. not sweet, somewhat sweet, sweet, and very sweet), ‘sweet’ could be dummy coded with ‘not sweet’ as the reference category.
   3. More information: If any categorical predictors are included in a regression, indicate how those variables will be coded (e.g. dummy coding, summation coding, etc.) and what the reference category will be.
3. Inference criteria
   1. What criteria will you use to make inferences? Please describe the information you’ll use (e.g. p-values, bayes factors, specific model fit indices), as well as cut-off criterion, where appropriate. Will you be using one or two tailed tests for each of your analyses? If you are comparing multiple conditions or testing multiple hypotheses, will you account for this?
4. Data exclusion
   1. How will you determine what data or samples, if any, to exclude from your analyses? How will outliers be handled? Will you use any awareness check?
5. Missing data
   1. How will you deal with incomplete or missing data
6. Exploratory analysis
   1. If you plan to explore your data set to look for unexpected differences or relationships, you may describe those tests here. An exploratory test is any test where a prediction is not made up front, or there are multiple possible tests that you are going to use. A statistically significant finding in an exploratory test is a great way to form a new confirmatory hypothesis, which could be registered at a later time.
   2. Example: We expect that certain demographic traits may be related to taste preferences. Therefore, we will look for relationships between demographic variables (age, gender, income, and marital status) and the primary outcome measures of taste preferences.

Other (Optional)

If there is any additional information that you feel needs to be included in your preregistration, please enter it here. Literature cited, disclosures of any related work such as replications or work that uses the same data, or other context that will be helpful for future readers would be appropriate here.

Analyses

Statistical Analysis Backup Plan

Describe what you will do should your data violate assumptions, your model not converge, or some other analytic problem arise? (One text box for each hypothesis)

Example: If out multilevel model with random variables A, B, and C predicting Y using X, we will utilize smaller models (A and B only/B and C/A and C) and remove random variables that are unnecessary (i.e. with close to 0 variance) according to these smaller models in order to choose the optimal model.

*Extended fMRI Information*

The goal of this template is to provide sufficient information in preregistration for fMRI data design to increase reproducible reporting practices.

*Experimental Design*

Design Specifications

|  |  |
| --- | --- |
| Design type (task, rest; event-related, block) – |  |
| Conditions & Stimuli (detailed as possible, pictures encouraged) – |  |
| Number of blocks, trials or experimental units per session and/or subject – |  |
| Timing and Duration (length of each trial and interval between trials) – |  |
| Length of experiment (length of full scan and each run) – |  |
| Was the design optimized for efficiency, and if so, how? – |  |
| Presentation software (name, version, operating system; code if possible) |  |

Task Specification

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| --- | --- |
| Instructions to subjects (what were they asked to do?) – |  |
| Stimuli (what were they; how many were there; did it repeat across trials?) |  |
| Stimuli presentation & response collection – |  |
| Randomization/pseudo-randomized (why/why not done & how) – |  |
| Run order (of tasks within scanner) – |  |

*Data acquisition*

Subject Preparation

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| --- | --- |
| Mock scanning (Report type of mock scanner and protocol; i.e. duration, types of simulated scans, experiments). – |  |
| Specific accommodations (e.g., pediatric, parent present? Asleep?) – |  |
| Experimental personnel (number of planned personnel to interact with subjects) – |  |

MRI system

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| --- | --- |
| Manufacturer, field strength (in Tesla), model name – |  |

MRI acquisition

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| --- | --- |
| Pulse sequence (gradient/spin echo etc.) |  |
| Image type (EPI, spiral, 3D etc.) |  |
| Essential sequence & imaging parameters.  For all acquisitions:  ● Echo time (TE).  ● Repetition time (TR).  o For multi­shot acquisitions, additionally the time per volume.  ● Flip angle (FA).  ● Acquisition time (duration of acquisition).  Functional MRI:  ● Number of volumes.  ● Sparse sampling delay (delay in TR) if used.  Inversion recovery sequences:  ● Inversion time (TI).  B0 field maps:  ● Echo time difference (dTE). Diffusion MRI:  ● Number of directions.  o Direction optimization, if used and type.  ● b-values.  ● Number of b=0 images.  ● Number of averages (if any).  ● Single shell, multi­shell (specify equal or unequal spacing).  ● Single­ or dual­spin­echo, gradient mode (serial or parallel).  ● If cardiac gating used.  Imaging parameters:  ● Field of view.  ● In­plane matrix size, slice thickness and interslice gap, for 2D acquisitions. ● Slice orientation:  ○ Axial, sagittal, coronal or oblique.  ○ Angulation: If acquistion not aligned with scanner axes, specify  angulation to AC­PC line (see Slice position procedure).  ● 3D matrix size, for 3D acquisitions. |  |
| Phase encoding |  |
| Parallel imaging method & parameters |  |
| Multiband parameters |  |
| Readout parameters |  |
| Fat suppression (for anatomical, state if used) |  |
| Shimming |  |
| Slice order & timing |  |
| Brain coverage (e.g., whole brain, was cerebellum, brain stem included) |  |
| Scanner-side preprocessing (e.g., Including: Reconstruction matrix size differing from acquisition matrix size; Prospective-motion correction (including details of any optical tracking, and how motion parameters are used); Signal inhomogeneity correction; Distortion-correction.) |  |
| Scan duration (in seconds) |  |
| Other non-standard procedures |  |
| T1 stabilization (discarded “dummy” scans acquired discarded by scanner) |  |
| Diffusion MRI gradient table (Also referred to as the b­matrix, but not to be confused with the 3×3 matrix that describes diffusion weighting for a single diffusion weighted measurement) |  |

*Preprocessing*

Preliminary quality control

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| --- | --- |
| Motion monitoring (For functional or diffusion acquisitions, any visual or quantitative checks for severe motion; likewise, for structural images, checks on motion or general image quality.) |  |
| Incidental findings (Protocol for review of any incidental findings, and how they are handled in particular with respect to possible exclusion of a subject’s data.) |  |

Pre-processing: general

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| Specify order of preprocessing operations |  |
| Describe any data quality control measures |  |
| Unwarping of B0 distortions |  |
| Slice timing correction |  |
| Reference slice and type of interpolation used (e.g., “Slice timing correction to the first slice as performed, using SPM5's Fourier phase shift interpolation”) |  |
| Motion correction |  |
| Reference scan, image similarity metric, type of interpolation used, degrees-of-freedom (if not rigid body) and, ideally, optimization method, e.g., “Head motion corrected with FSL's MCFLIRT by maximizing the correlation ratio between each timepoint and the middle volume, using linear interpolation.” |  |
| Motion susceptibility correction used |  |
| Smoothing  Size and type of smoothing kernel (provide justification for size; e.g., for a group study, “12 mm FHWM Gaussian smoothing applied to ameliorate differences in intersubject localization”; for single subject fMRI “6 mm FWHM Gaussian smoothing used to reduce noise”) |  |

*Intersubject Registrstion*

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| Intersubject registration method used |  |
| Illustration of the voxels present in all subjects (“mask image”) can be helpful, particularly for restricted fields of view (to illustrate overlap of slices across all subjects). Better still would be an indication of average BOLD sensitivity within each voxel in the mask |  |
| Transformation model and optimization |  |
| Transformation model (linear/affine, nonlinear), type of any non-linear transformations (polynomial, discrete cosine basis), number of parameters (e.g., 12 parameter affine, 3 × 2 × 3 DCT basis), regularization, image-similarity metric, and interpolation method |  |
| Object image information (image used to determine transformation to atlas) |  |
| Anatomical MRI? Image properties (see above) |  |
| Co-planar with functional acquisition? |  |
| Functional acquisition co-registered to anatomical? if so, how? |  |
| Segmented gray image? |  |
| Functional image (single or mean) |  |
| Atlas/target information |  |
| Brain image template space, name, modality and resolution (e.g., “FSL's MNI Avg152, T1 2 × 2 × 2 mm”; “SPM2's MNI gray matter template 2 × 2 × 2 mm”) |  |
| Coordinate space  (Typically MNI, Talairach, or MNI converted to Talairach  If MNI converted to Talairach, what method? e.g., Brett's mni2tal?  How were anatomical locations (e.g., gyral anatomy, Brodmann areas) determined? (e.g., paper atlas, Talairach Daemon, manual inspection of individuals' anatomy, etc.) |  |
| Smoothing  Size and type of smoothing kernel (provide justification for size; e.g., for a group study, “12 mm FHWM Gaussian smoothing applied to ameliorate differences in intersubject localization”; for single subject fMRI “6 mm FWHM Gaussian smoothing used to reduce noise”) |  |

*Statistical modeling*

Planned comparison

If the experiment has multiple conditions, what are the specific planned comparisons?

First level (fx) modeling

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| --- | --- |
| Event­related design predictors.  ○ Modeled duration, if other than zero.  ○ Parametric modulation. |  |
| Block Design predictors.  (Note whether baseline was explicitly modeled.) |  |
| HRF basis, typically one of:  Canonical only.  Canonical plus temporal derivative.  Canonical plus temporal and dispersion derivative. Smooth basis (e.g. SPM “informed” or Fourier basis; FSL’s FLOBS).  Finite Impulse Response model. |  |
| Drift regressors (e.g. DCT basis in SPM, with specified cut­off). |  |
| Movement regressors; specify if squares and/or temporal derivative used. |  |
| Any other nuisance regressors, and whether they were entered as interactions (e.g. with a task effect in 1st level fMRI, or with group effect). |  |
| Any orthogonalization of regressors, and set of other regressors used to orthogonalize against. |  |
| Contrast construction (Exactly what terms are subtracted from what? Define these in terms of task or stimulus conditions (e.g., using abstract names such as AUDSTIM, VISSTIM) instead of underlying psychological concepts. |  |
| Autocorrelation model type (e.g., AR(1), AR(1) + WN, or arbitrary autocorrelation function), and whether global or local.  (e.g., for SPM2/SPM5, ‘Approximate AR(1) autocorrelation model estimated at omnibus F-significant voxels (P < 0.001), used globally over the whole brain’; for FSL, ‘Autocorrelation function estimated locally at each voxel, tapered and regularized in space.’). |  |

Second level (group) modeling

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| Statistical model and estimation method, inference type (mixed/random effects or fixed), e.g., “Mixed effects inference with one sample t-test on summary statistic” (SPM2/SPM5), e.g., “Mixed effects inference with Bayesian 2-level model with fast approximation to posterior probability of activation.” (FSL)  If fixed effects inference used, justify |  |
| If more than 2-levels, describe the levels and assumptions of the model (e.g., are variances assumed equal between groups) |  |
| Repeated measures?  If multiple measurements per subject, list method to account for within subject correlation, exact assumptions made about correlation/variance  e.g., SPM: “Within-subject correlation estimated at F-significant voxels (P <0.001), then used globally over whole brain”; or, if variances for each measure are allowed to vary, “Within-subject correlation and relative variance estimated…” |  |
| For group model with repeated measures, specify:  ● How condition effects are modeled (e.g. as factors, or as linear trends).  ● Whether subject effects are modeled (i.e. as regressors, as opposed to  with a covariance structure). |  |
| For group effects: clearly state whether or not covariates are split by group (i.e. fit as a group­by­covariate interaction). |  |
| Model type  (Some suggested terms include:  ● “Mass Univariate”.  ● “Multivariate” (e.g. ICA on whole brain data).  ● “Mass Multivariate” (e.g. MANOVA on diffusion or morphometry tensor  data).  ● “Local Multivariate” (e.g. “searchlight”).  ● “Multivariate, intra­subject predictive” (e.g. classify individual trials in  event­related fMRI).  ● “Multivariate inter­subject predictive” (e.g. classify subjects as patient vs.  control).  ● “Representational Similarity Analysis”.) |  |
| Model settings (The essential details of the model. For mass­univariate, first level fMRI, these include:  ● Drift model, if not already specified as a dependent variable (e.g. locally linear detrending of data & regressors, as in FSL).  ● Autocorrelation model (e.g. global approximate AR(1) in SPM; locally regularized autocorrelation function in FSL).  For mass­univariate second level fMRI these include:  ● Fixed effects (all subjects’ data in one model).  ● Random or mixed­effects model, implemented with:  ○ Ordinary least squares (OLS, aka unweighted summary statistics approach; SPM default, FSL FEAT’s “Simple OLS”).  ○ weighted least squares (i.e. FSL FEAT’s “FLAME 1”), using voxel­wise estimate of between subject variance.  ○ Global weighted least squares (i.e. SPM’s MFX).  With any group (multi­subject) model, indicate any specific variance structure, e.g.  ● Un­equal variance between groups (and if globally pooled, as in SPM).  ● If repeated measures, the specific covariance structure assumed (e.g.  compound symmetric, or arbitrary; if globally pooled).  For local­multivariate report:  ● The number of voxels in the local model.  ● Local model used (e.g. Canonical Correlation Analysis) with any  constraints (e.g. positive weights only). |  |

ROI analysis

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| How were ROIs defined  (e.g., functional, anatomical, parcel localizer)? |  |
| How was signal extracted within ROI?  (e.g., average parameter estimates, FIR deconvolution?) |  |
| If percent signal change reported, how was scaling factor determined  (e.g., height of block regressor or height of isolated event regressor)? |  |
| Is change relative to voxel-mean, or whole-brain mean? |  |
| Justify definition of ROI and analysis conducted with it: (e.g., if your ROI is defined based on the cluster; how will you ensure your ROI analyses are not circular?) |  |

*Statistical inference*

Inference on statistic image (thresholding)

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| --- | --- |
| Search region (Type of search region for analysis, and the volume in voxels or CC)    If not whole brain, state how region was determined; method for constructing region should be independent of present statistic image   * Whole brain or “small volume”; carefully describe any small volume correction used for each contrast.   ● If a small-volume correction mask is defined anatomically, provide named anatomical regions from a publicly available ROI atlas.  ● If small-volume correction mask is functionally defined, clearly describe the functional task and identify any risk of circularity.  ● All small-volume corrections should be fully described in the methods section, not just mentioned in passing in the results. |  |
| Statistical type (Typically one of:  ● Voxel­wise (aka peak­wise in SPM).  ● Cluster-wise.  ○ Cluster size.  ○ Cluster mass.  ○ Threshold­free Cluster Enhancement (TFCE).  For cluster size or mass, report:  ● Cluster-forming threshold.  For all cluster­wise methods, report:  ● Neighborhood size used to form clusters (e.g. 6, 18 or 26).  For TFCE, report:  ● Use of non­default TFCE parameters.) |  |
| P value computation (Report if anything but standard parametric inference used to obtain (uncorrected) P­values. If nonparametric method was used, report method (e.g. permutation or bootstrap) and number of permutations/samples used.) |  |
| Multiple test correction (For mass­univariate, specify the type of correction and how it is obtained, especially if not the typical usage.)  Usually one of:  ● Familywise Error.  ○ Random Field Theory (typical).  ○ Permutation.  ○ Monte Carlo.  ○ Bonferroni.  ● False Discovery Rate.  ○ Benjamini & Hochberg FDR (typical).  ○ Positive FDR.  ○ Local FDR.  ○ Cluster­level FDR.  ● None/Uncorrected.  If permutation or Monte Carlo, report the number of permutations/samples. If Monte Carlo, note the brain mask and smoothness used, and how smoothness was estimated.  If correction is limited to a small volume, the method for selecting the region should be stated explicitly.  If no formal multiple comparisons method is used, the inference must be explicitly labeled “uncorrected.”  If FWE found by random field theory list the smoothness in mm FWHM and the RESEL count  If FWE found by simulation (e.g., AFNI AlphaSim), provide details of parameters for simulation  If not a standard method, specify the method for finding significance (e.g., “Custom in-lab software was used to construct statistic maps and thresholded at FDR< 0.05 (Benjamini and Hochberg, 1995)”  If cluster-wise significance, state cluster-defining threshold (e.g., P = 0.001) |  |
| False negative discussion  Any discussion of failure to reject the null hypothesis (e.g., lack of activation in a particular region) should be accompanied by SNR or effect size of the actually observed effect (allows reader to infer power to estimate an effect) |  |

*Functional connectivity*

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| Confound adjustment & filtering  Report:  ● Method for detecting movement artifacts, movement-related variation, and remediation (e.g. ‘scrubbing’, ‘despiking’, etc).  ● Use of global signal regression, exact type of global signal used and how it  was computed.  ● Whether a high or lowpass temporal filtering is applied to data, and at which point in the analysis pipeline. Note, any temporal regression model using filtered data should have its regressors likewise filtered. |  |
| Multivariate method: Independent Component Analysis  Report:  ● Algorithm to estimate components. ● Number of components (if fixed), or algorithm for estimating number of  components. ● If used, method to synthesize multiple runs. ● Sorting method of IC’s, if any. ● Detailed description of how components were chosen for further analysis. |  |
| Dependent variable definition  For seed­-based analyses report:  ●  Definition of the seed region(s).  ●  Rationale for choosing these regions.  For region-­based analyses report: ● Number of ROIs. ● How the ROI’s are defined (e.g. citable anatomical atlas; auxiliary fMRI  experiments); note if ROIs overlap. ● Assignment of signals to regions (i.e. how a time series is obtained from  each region, e.g. averaging or first singular vector) ● Note if considering only bilateral (L+R) merged regions.  ● Note if considering only interhemispheric homotopic connectivity. |  |
| Functional connectivity measure/ model  Report:  ●  Measure of dependence used, e.g. Pearson’s (full) correlation, partial  correlation, mutual information, etc; also specify:  ○  Use of Fisher’s Z-transform (Yes/No) and, if standardised, effective  N is used to compute standard error (to account for any filtering  operations on the data).  ○  Estimator used for partial correlation.  ○  Estimator used for mutual information.  ●  Regression model used to remove confounding effects (Pearson or partial correlation). |  |
| Effectivity connectivity  Report: ● Model.  ● Algorithm used to fit model. ● If per­ subject model, method used to generalize inferences to population. ● Itemize models considered, and method used for model comparison. |  |
|  |  |