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ARTICLE

Non-Disposable Assignments for Remote Neuroscience Laboratory Teaching Using Analysis of Human Data

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To accomplish discovery learning in a remote educational context, while also addressing disparities in laboratory facility/equipment access, instructors can assign Non-Disposable Assignments (NDA) whereby students design research projects, extract data from public sources, analyze data in a cloud-based environment, and share potentially original findings. Unlike typical course assignments (e.g., lab-reports, tests) that remain in the student-teacher dyad, NDAs (e.g., disseminated presentations, visualizations, manuscripts) are associated with enhanced learning and facilitate the integration of diverse student perspectives in the creation, analysis and dissemination of neuroscience. Illustrating the design of a project-based approach to teaching neuroscience laboratory courses, we provide two example NDAs using neural imaging and physiological information available from public databases. We provide a data set in a directly usable form for teaching with R, and present an overview of two user-friendly tools, RStudio and R-Markdown, for remote teaching and learning through data analysis.

Key words: reproducible data analysis, meta-analysis, psychophysiology, functional magnetic resonance imaging (fMRI), non-disposable assignments (NDA), RStudio Cloud, R-Markdown

OVERVIEW

Whether formative or summative in nature, regular *disposable* course assignments (DAs: e.g., exams, lab-reports or term papers) remain in the confines of the instructor-student dyad and ultimately end up in the wastebasket when a course concludes. In this way, it has been estimated that two billion hours of academic labor by students is wasted every semester (Wiley et al., 2017; Wiley & Hilton, 2018), as they exert significant cognitive effort on assignments that are graded and eventually discarded. By contrast, non-disposable assignments (NDAs) give meaning or purpose to student work by culminating in the creation of new learning objects (tools for collective knowledge) that can be shared beyond, as well as within, course boundaries. Example NDAs include learning activities that culminate in student classroom presentations, publicly shared podcasts, blogs, infographics or published manuscripts. Thus, as described previously (Seraphin et al., 2019), NDAs extend beyond the course boundary—potentially surpassing DAs in the domains of efficacy, impact and relevance. This is because they include learning activities that generate open educational resources, which have “spatial reach” (beyond the classroom), “temporal longevity” (beyond the semester) and “gravity” (or real-world relevance).

NDAs help students learn important disciplinary principles while working through problems and finding solutions that ultimately benefit greater understanding in their peers, in the academy, and potential stakeholders in their community or, more generally, society. Since they typically require students to reconcile information from multiple levels of analysis, NDAs could also boost interdisciplinary and integrative thinking. In addition to fostering self-efficacy and deeper learning, NDAs are described as being more enjoyable and purpose-driven by students. In keeping with the principles of the Open Pedagogy Movement (Ehlers, 2011; Hegarty, 2015; Wiley, 2013), NDAs incorporate: information collaboration and exchange, communication with peers and the instructor throughout the educational process, communal assembly of information resources, scholarly advancement through cooperative critique and chance innovation.

When NDAs stem from applications with an engaging context that makes use of real-world data, they foster the development of students’ data-related computing skills, provide opportunity for interdisciplinary collaboration, train appropriate professional conduct, and allow students to refine their communication skills. These are among the key learning objectives and pedagogical considerations endorsed by the American Statistical Association’s [ASA] undergraduate curricular guidelines (ASA, 2014). Moreover, NDAs that demonstrate neuroscience principles through authentic applications and data analysis provide a natural mechanism for achieving the higher-level learning objectives of developing flexible problem-solving skills and the ability to evaluate scientific hypotheses based on quantitative evidence, which resonate with best practices for project based (Lafer-Sousa and Conway, 2009) and interdisciplinary (Wichlinski, 2009) undergraduate teaching in both fields.

In contrast to the textbook-focused classroom, the data-centered classroom is alive in ways that particularly encourage creativity and innovation by a diverse student body. It is also well suited to online courses, because

Figure 1. Non-Disposable Assignments and the Data-Centered Classroom.

students can access data and a computational environment remotely. With the instructor acting as a liaison, students can collectively build understanding through collaborations that ultimately result in the creation of renewable learning objects or "open educational resources" reflecting diverse perspectives and to benefit society (Figure 1).

When combined with data synthesis or computational analysis, NDAs offer unparalleled opportunities to address typical neuroscience course learning objectives. For example, they allow students to apply knowledge of nervous system anatomy or functions, and practice critical thinking skills, statistical analysis, and communication. In this paper, we provide two course assignments using human neuroimaging and psychophysiology data that can be used to advance common neuroscience learning objectives. We further articulate ways these assignments can be adapted for use in freshman, sophomore, and advanced undergraduate courses.

The importance of equipping undergraduate students with foundational skills necessary to approach, analyze, and interpret results from increasingly large and complex data sources has been well established among neuroscience educators (Grisham, 2016). Working in a modern statistical computing environment is central to this goal, and requisite to achieving reproducible data processing and analysis. The development of the R programming language and computational environment over the past decades has dramatically increased the accessibility of statistical computing for students and researchers in many fields. Readers interested in learning R are encouraged to take an introductory course offered by datacamp (http://datacamp.com) or consult the materials and resources produced by Project Mosaic (http://mosiac-web.org). Here we provide an overview of two tools, RStudio and R-Markdown, that make it easy to get started in R and simplify educators' task of scaffolding computing to the level appropriate for a given course. We also highlight features of these tools that make R ideal for remote teaching.

In the context of neuroscience teaching, fluency with fMRI principles is increasingly in demand. Recently, fMRI studies have experienced problems with reproducibility (Stikov et al., 2019). Notwithstanding the lack of equitable access to fMRI facilities for students outside of R1 institutions, the skills required for fMRI data acquisition and pre-processing are not necessarily as transferable to the postgraduate workplace as important take-aways about functional neuroanatomy to be gained from interacting with brain imaging data. Therefore, we also introduce online databases, Neurosynth and EduCortex, that have the power to teach the neuroimaging principles needed for fMRI experimental design and inference through meaningful interactions with real human neuroimaging data in a user-friendly way.

MATERIALS AND METHODS

Statistical Computing in R

RStudio (https://rstudio.com) is an integrated development environment (IDE) that provides an interface allowing the user to edit code, view output, and visualize data in a manner much like privately licensed software. RStudio can be installed and operated either 1) locally, on students' personal computers, 2) virtually, using an institutional server (this requires IT support), or 3) virtually through RStudio Cloud (https://rstudio.cloud). When teaching in person, particularly in courses for which competency in statistical computing is a major learning objective, having students run RStudio on their own personal computer develops transferable skills for independently installing software and setting up a computational environment. For introductory courses, or courses with limited capacity for covering statistical computing, a virtual platform eliminates the technical challenges associated with software installation and setup, since all computation is performed virtually, and the instructor can pre-load all data and add-on libraries. Further, since all analyses are carried out on a remote server or in the cloud, using RStudio virtually addresses potential computer hardware inequities among students. In a remote teaching context, the virtual platform RStudio Cloud (https://rstudio.cloud) has the additional benefit of allowing instructors to access and edit students' computing environment and revise their code directly, closely mimicking the experience of working together locally.

Another tool that is especially applicable to the creation of NDAs as part of the data centered classroom is R-Markdown (https://rmarkdown.rstudio.com), which is run through the RStudio IDE. R-Markdown is a markup language that combines the code and analysis that one generates in RStudio with report writing in a word processing program. When creating NDAs, R-Markdown naturally facilitates sharing since documents are generated as either a slide deck, word document, pdf, or html file and are thus automatically in a format that is conducive to wide dissemination. A primary benefit of R-Markdown is that it improves reproducibility by eliminating copy & paste errors that could arise from, for example, copying output from R into a separate word processing program (Baumer, 2014). R-Markdown also simplifies and streamlines re-analysis; if data are updated, recompiling the R-Markdown document will automatically update all related analyses and regenerate the document, obviating the need to recopy tables and figures manually.

Neuroimaging Resources

Neurosynth (https://neurosynth.org/), as previously described (Yarkoni et al., 2011), is a web-based tool for the large-scale and automated synthesis of fMRI data. Currently, the database incorporates over 14K studies that are characterized by more than 1,300 terms. In addition to providing functional connectivity and coactivation maps for over 150,000 brain regions, it allows the user to overlay information from human genetics studies. To support use by the readers of this article, we have prepared a brief demonstration video for Neurosynth (https://youtu.be/U2Oc8FmxgAk) that illustrates its important features and can easily be linked to the instructor's Learning Management System (LMS).

A related web-based tool, EduCortex (https://paulscotti.github.io/educortex/#openModal) allows students to manipulate three-dimensional brain visualizations that are derived from the automated synthesis of fMRI data in Neurosynth (Scotti et al., 2020). Its major advantage beyond the capabilities of Neurosynth is its interactivity and color-coded links between brain anatomical and functional terms. For example, upon accessing the site, students are presented with a color-coded brain and connected word cloud. We have also prepared a brief, LMS-friendly demonstration video for EduCortex (https://youtu.be/I0EkJIJbc70).

Additional resources to support student work on these assignments include a word-cloud generator (https://wordclouds.com) and either a paper or online brain atlas. The atlas will support student knowledge of basic neuroanatomy, and their ongoing identification/conversion between Brodmann's Areas and the XYZ coordinates for either Montreal Neurological Institute (MNI) space or the Talairach system (for a discussion of these brain coordinate systems, see Chau & McIntosh, 2005). We recommend the freely accessible online tool BioImage Suite (https://bioimagesuiteweb.github.io/webapp/).

RESULTS

We have created two sample NDAs to demonstrate practical applications of neuroscience concepts using data analysis. Both assignments promote discovery learning and target the neuroscience learning objectives of understanding good experimental design and practice with scientific communication. While allowing students to apply their knowledge of the autonomic nervous system, the psychophysiology assignment also provides students with experience in statistical computing and data analysis. In contrast, the neuroimaging assignment allows students to apply their knowledge of brain anatomy and function while learning the distinction between forward and reverse inference for strong meta-analysis. After their introduction, suggestions are provided for the adaptation of these assignments for 100-300 level courses (1st year - 4th year).

Stressor	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
None	No Stressor	No Stressor	No Stressor	No Stressor	No Stressor
Cognitive	No Stressor	Cognitive Stressor	No Stressor	Cognitive Stressor	No Stressor
Emotional	No Stressor	Emotional Stressor	No Stressor	Emotional Stressor	No Stressor
Sensorimotor	No Stressor	Sensorimotor Stressor	No Stressor	Sensorimotor Stressor	No Stressor

Table 1. Research Conditions for Simulated Driving Data.

Psychophysiology Assignment

The first assignment is based on a study of simulated driving and makes use of data made publicly available by Pavlidis et al. (2016). It can be used to introduce topics related to the autonomic nervous system, attention, emotion and cognitive control, and provides students with an authentic experience analyzing real data. In the original study, researchers examined the effects of various stressors on the reactionary motor response associated with sympathetic arousal, and the error response resulting from higher-order modulation.

Table 1 summarizes aspects of the experimental design relevant to the assignment: 59 subjects completed four computer simulated drives, which were presented in random order, wherein subjects were exposed to cognitive, emotional, and sensorimotor stressors, as well as a control drive with no stressor. Each drive was divided into five phases, with the stressor administered during phases 2 and 4. The cognitive and emotional stressors were administered through a series of oral questions, while the sensorimotor stressor involved texting while driving. Meanwhile, many physiological measurements serving as proxies for sympathetic arousal (e.g., perinasal perspiration, palm EDA, heart rate, breathing rate, and left and right pupillary dilation) were captured by the researchers. The reactionary response was measured by steering angle; and error response was measured by maximum lane departure.

A sample non-disposable assignment appropriate for a 200-level course is provided in Table 2. Students are sorted into three groups that are each assigned a different driver stress challenge (i.e., cognitive, emotional, sensorimotor). The assignment then unfolds in three parts.

Psychophysiology Assignment Part One

In the first stage of the assignment, students evaluate the effect of their group's assigned stressor versus control, upon the physiological measures, by calculating a paired t-test and creating an appropriate data visualization in R. This part of the assignment culminates in students creating a figure or infographic using R-Markdown and sharing their results during an in-class presentation. Through class discussions, students will observe that the three stress stimuli, despite targeting different neural networks, effectively elicit significant sympathetic arousal. Further, students can be prompted to compare the degree of the effects by various stressors across physiological outcomes. This will create an opportunity to deeply examine the integration of the autonomic nervous system with neural systems modulating cognitive, emotion, and sensorimotor functions.

Psychophysiology Assignment Part Two
In the second stage of the assignment, students explore the associations between sympathetic arousal and the reactionary response to their previously assigned stress condition. They do so by creating scatter plots and calculating the correlation between physiological variables and absolute steering angle using R-Markdown.

Psychophysiology Assignment Part Three
In the final stage of the assignment, students evaluate the effect of their assigned stressor on steering angle and lane departure using appropriate data visualizations and calculating paired t-tests in R. This part of the assignment culminates in students creating a figure or infographic using R-Markdown and sharing their results during an in-class presentation. From comparing their results and ensuing class discussions, students will discover that for the cognitive and emotional loaded drives, subjects were able to successfully correct for deviations in steering angle, but not so for the sensorimotor condition (i.e., texting while driving). This finding can lead to further discussions about the disruption of the hand-eye feedback loop in the sensorimotor condition. An important take-away relates to the dangers of texting while driving, which students can then discuss through social media (e.g., Twitter, Facebook, Tik Tok), extending the spatial reach of their NDA learning object.

The psychophysiology assignment can be pared-down for a 100-level course by inviting students to complete Parts One and Two. It can also be adapted for a 300-level course by increasing the complexity of the required data analysis combined with requiring their integration of information about the underlying neural systems through a detailed examination of the primary literature.

The sophistication of the analysis can be tailored to the level appropriate for a given course. For example, one can limit the analysis to data visualizations and summary statistics rather than including statistical inference. Further, the assignment can be customized depending on the level of independence required of students with respect to programming. At the lowest level an instructor can provide a template analysis in an R-Markdown file, so the assignment requires students to change the name of variables and the data set and edit the document to provide an interpretation of their results. At the most advanced level students would create a file using R-Markdown from scratch. A larger class may require more than three groups. Since there are three stressors and 6 physiological variables this assignment could also be divided among 3X6 = 18 groups. A much larger class could even examine issues with reproducibility by carrying out the same steps and exploring differences between their results. This can be accomplished

200 Level Course: 3-Part Non-Disposable Assignment on Psychophysiology Using R			
Student Groups	**Assignment Task**	**Assignment Deliverable (Learning Object)**	**Learning Objectives**
A: Cognitive	Part One: Evaluate the effect of assigned stress condition (versus control) on all physiological outcomes using appropriate data visualizations and paired t-tests in R.	Generate infographics on attention, autonomic nervous system and stress physiology; In-class presentation and discussion of results.	(1) Apply knowledge on attention, the autonomic nervous system and stress physiology . (2) Understand a sophisticated experimental design. (3) Analyze real data in a modern statistical computing environment. (4) Practice scientific communication.
B: Emotional	Part Two: Explore the associations between sympathetic arousal and the reactionary response to assigned stress condition using scatterplots and correlations in R.		
C: Sensorimotor	Part Three: Evaluate the effect of assigned stress condition on steering angle and lane departure using appropriate data visualizations and paired t-tests in R.		

Table 2. Psychophysiology Assignment Steps by Course Level.

200 Level Course: 2-Part Non-Disposable Assignment for Neurosynth				
	Student Groups	**Assignment Task**	**Assignment Deliverable (Learning Object)**	**Learning Objectives**
Part One	A: Pain	Use Functional Term "Pain" ➡ Activation Pattern F ➡ Abstract on subset of underlying studies	In-class presentation of results and discussion of implications of forward/reverse inference.	(1) Develop understanding of functional neuroanatomy (2) Apply knowledge of scientific method
	B: Neuroanatomy	Use Activation Pattern F ➡ Word Cloud (e.g., Social Rejection, Pain, etc.)		
	C: Social Rejection	Use word "Social Rejection" ➡ Activation Pattern F, from underlying studies		
Part Two	A: Choose Anatomical Term (ROI: e.g., Anterior Cingulate)	Use ROI ➡ Word Cloud	In-class presentation of results; Creation of infographics based on their choice of ROI/Word; Edit Wikipedia	(3) Compare study designs (4) Practice research communication
	B: Choose a Functional Term (e.g., Emotion)	Use Term ➡ Activation Patterns		

Table 3. 200-Level Course Neuroimaging Assignment. Abbreviations: "Activation Pattern F": Anterior cingulate, anterior insula, medial thalamus, somatosensory cortex. ROI: Region of interest. Additional Tools: Brain Atlas - http://www.thehumanbrain.info/; Word Cloud - www.wordclouds.com; MNI Coordinates - https://bioimagesuiteweb.github.io/webapp/.

by assigning the same stressor and physiological variables to more than one group and then comparing their results.

The cleaned data set and corresponding R code for the psychophysiology assignment are available at https://github.com/ShannonStock/JUNE2020.

Neuroimaging Assignment

Neurosynth allows the student to conduct a term-based search that pulls-up related studies, automatically extracts the relevant brain activation coordinates and produces a visualization based on an automated meta-analysis procedure that has been validated against manual meta-analyses. By examining underlying studies, students can practice: (1) Forward inference: where pain stimulation causes a pain-signature pattern of brain activation, and (2) Reverse inference: where the activation of a region of interest (ROI) then primes conclusions about the meaning of some brain activation.

The assignment, which is designed for a 2nd year course, unfolds in 2 parts that share 4 learning objectives (Table 3). In Part One, students are divided into three groups and engage in tasks culminating in a class presentation. In Part Two, students work in two groups and may choose between using their acquired knowledge to edit Wikipedia, give a class presentation, or share an infographic based on their work. These assignments are based on research findings described by Kross et al (2011), Wager et al (2016), Poldrack et al (2012), and Yarkoni et al (2011).

Neuroimaging Assignment Part One

In this first phase of the neuroimaging assignment, students will discover, by various means, that a signature pattern of brain activity is common to both physical and emotional pain. This includes regions we have described as "Activation Pattern F (Table 4). We begin by dividing students into three groups (A-Pain, B-Neuroanatomy and C-Social Rejection). Group A (Pain Group) will use the functional term "Pain" to arrive at Activation Pattern F and write an abstract based on a subset of the underlying studies. For example, in the current version of Neurosynth (August, 2020), this is accomplished by navigating to the Meta-Analyses tab and choosing "Terms" from the drop-down menu. There, one can search for a clinically/psychologically meaningful term or an anatomical term. For example, by

Activation Pattern F (Pain & Social/Romantic Rejection)				
Regions of Interest (ROIs)	MNI Coordinates			
	X	Y	Z	Brodmann Area
L anterior cingulate cortex	-5	39	20	32
R anterior cingulate cortex	6	33	16	32
L anterior insula/ lateral OFC	-40	31	-13	47
R anterior insula/ lateral OFC	38	30	-12	47
Medial thalamus	9	-3	-6	NA
L primary sensory	-40	-27	47	1
R primary sensory	41	-27	47	1
L primary motor	-36	-19	48	4
R primary motor	38	-18	45	4

Table 4. Activation Pattern F. Approximate coordinates provided can be converted between MNI, Talairach. and Brodmann Areas using BioImage Suite

(https://bioimagesuiteweb.github.io/webapp/).

Learning Objectives, Activities & Non-Disposables by Neuroscience Course Level		
Apply knowledge of neuroanatomy, brain -behavior, neuroimaging techniques and the scientific method. Practice research communication.	**100 Level Course**	
	ALO	Explore neural imaging and basic functional neuroanatomy by working between brain activation maps and the underlying literature. E.g., using EduCortex.
	NDA	Create infographics of behavior/neurologically interesting brain regions to share and discuss.
	200 Level Course	
	ALO	Explore the ROI approach and compare forward/reverse inference through the design and testing of hypotheses using metanalyses. E.g., using Neurosynth.
	NDA	Prepare presentations/infographics on the forward/reversely infered brain activation patterns to share and discuss; Edit Wikipedia; Brain discovery blog or podcast.
	300+ Level Course	
	ALO	Compare manual metaanalysis (based on a subset of studies) with automated Neurosynth results; Apply knowledge of behavioral genetics by investigating relationships between brain activation patterns and gene expression; Practice statistical analysis by downloading underlying data sets from original sources for new hypothesis testing. E.g., using Neurosynth & R.
	NDA	Prepare presentations, infographics and/or manuscripts to share and discuss; Identify and help resolve bugs in public datasets; Edit Wikipedia; Brain blog or podcast.
	Abreviations: ALO: Activity & Learning Objective, NDA: Non-Disposable Assignment, ROI: Region of Interest	

Table 5. Suggestions for Adaptation of Neuroimaging Assignment.

entering the word "Pain" one pulls up a "Map" based on 516 current "Studies" comprising that subset of data.

Under "Maps" in this version of Neurosynth, the student can view an interactive visualization derived from the MRI signal data in those 516 studies. The resulting images represent different brain cross-sections including the Y (coronal), X (sagittal), and Z (horizontal) orientations or planes. One can 1) select a highlighted/activated region to obtain its MNI coordinates; or 2) move in rostral-caudal, dorsal-ventral, and medial-lateral directions across sections. Finally, one can examine the z-score and extract the precise X/Y/Z coordinates for regions with positive activation.

Group A students should choose a subset of 25 studies on which to prepare an abstract/summary literature review for class presentation. In contrast, Group B (Neuroanatomy Group) will sequentially enter the anatomical terms comprising Activation Pattern F (i.e., anterior cingulate cortex, anterior insula, primary sensory cortex, primary motor cortex) to generate a series of associated studies, from which a word-cloud based on their titles or abstracts can be produced for class presentation (e.g., Social Rejection, Pain, etc.).

Finally, Group C (Social Rejection Group) will enter the functional term "Social Rejection" to arrive at Activation Pattern F, through careful examination of a few underlying studies. By accessing each of the "Studies" associated with "Social Rejection", through a special hyperlink, the student can see a list of the individual activation coordinates that were reported in the original publication. Also, by clicking directly on highly activated brain regions, they can extract X/Y/Z coordinates for identification, using an atlas. For instance, by examining these studies, a student should find that a brain area at (X=+8, Y=+26, Z=+22) is activated. Upon entering these coordinates into an online atlas, they will note that the region of interest is Brodmann's area 32 in the right hemisphere, which is also known as the right, anterior cingulate cortex—a region known to be involved in the processing of physical pain and part of what we have described as Activation Pattern F. Following their identification of 4-5 regions from each of the handful of publications associated with "Social Rejection", Group C will generate an infographic for sharing in class.

Through the ensuing group presentations of their separate findings and a class discussion, the students should generate the finding that social and emotional pain manifests in a manner analogous to physical pain. By collectively examining the relevant literature, they can gain a better understanding of the range of experimental designs yielding a pattern of activation while also learning to distinguish between forward and reverse inference.

Neuroimaging Assignment Part Two

A second phase of the neuroimaging assignment emphasizes quantitative reasoning, discovery learning, and open-ended inquiry. In this phase, students can formulate their own questions for exploration using Neurosynth and the associated tools. We begin by dividing students into two groups (A - Anatomy Group, B - Function Group). Group A will be instructed to choose an "anatomical term," (e.g., anterior cingulate) and Group B a "functional term," (e.g., emotion). Group A will generate a word cloud based on the titles or abstracts of up to 20 studies associated with their chosen brain region of interest. In addition, Group B will create an infographic based on the dominant activations from 10 studies associated with their chosen functional term. After presenting their findings to the class, students can then carry their research into the public service application of editing Wikipedia for accuracy, depending on the suitability of their chosen topic and their level of comprehension.

A handout with student instructions for Part One and Two of the neuroimaging assignment are available at https://github.com/ShannonStock/JUNE2020.

The 200-level course assignment just described can be easily downgraded for a 100-level course or upgraded for a course targeting students at the 300-level or above. Regardless of the course level, students will get to apply their knowledge of neuroanatomy, brain-behavior interactions, neuroimaging techniques and the scientific method (Table 3). They will also gain practice with research communication. What differs is the complexity of their assignment and its associated non-disposable outcomes.

In the case of the lower-level course, we recommend using EduCortex as a substitute interface for accessing the meta-analytic power of Neurosynth. This web-based tool generates dynamic 3-dimensional brain images (e.g., they can be inflated, rotated, flattened or shrunken) with color code-linked activation and search terms. As such, it represents a visually compelling entry point for interacting with fMRI data. Since it incorporates the same meta-analytic data contained in Neurosynth, students can still access the underlying research publications associated with brain coordinates, functional or anatomical search terms. As a deliverable, beginning students can create presentations based on self-guided or assigned-topical exploration of the brain, using EduCortex.

Advanced undergraduates may still begin with EduCortex. Depending on their familiarity with statistical analysis, they could compare the manual meta-analysis from a subset of findings with the automated meta-analysis of Neurosynth. Alternatively, they could use Neurosynth to explore brain-genetic interactions using fMRI data. Finally, they could download the data associated with individual fMRI experiments for new hypothesis testing. Ultimately, their non-disposable course work could lead to several deliverables not limited to the publication of manuscripts and helping to resolve bugs in public datasets and simulation tools. While beyond the scope of this article, readers are encouraged to investigate an emerging literature supporting Course-based Undergraduate Research Experiences (CUREs) (e.g., Cooper et al., 2017; Shortlidge et al., 2017). In addition to publishing with students in typical journals, instructors may consider the array of peer-reviewed undergraduate research journals, including the *Psi Chi Journal of Psychological Research*, the *Journal of Student Research* and the *Journal of Undergraduate Research and Scholarly Excellence*.

DISCUSSION

NDAs represent a renewable and sustainable source of learning objects for teaching. In this paper, we provide two sample assignments that advance typical neuroscience learning objectives (e.g., familiarity with brain and autonomic nervous system functioning, statistical computing, and scientific communication) while giving students hands-on experience with analyzing psychophysiology data and simulated fMRI meta-analysis. Our approach to the data centered-classroom can be adapted to suit specific course topics in both in-person and remote settings. These assignments have not been formally assessed, but they represent a timely example for teaching neuroscience in a remote or hybrid context.

While students can memorize features of the autonomic nervous system, it is not always easy to grasp how it may be activated by everyday experiences like driving. The psychophysiology experiment not only illustrates sympathetic nervous system functions, but importantly relates to the everyday dilemma and public health concern of distracted driving. In neuroimaging, the difference between forward and reverse inference is often lost, leading to erroneous conclusions about brain activation phenomena, which can emerge from multiple underlying causes. Therefore, the opportunity to grasp this distinction while learning functional neuroanatomy in an undergraduate setting is valuable for future researchers and civically engaged members of the lay public who, for example, may be asked to evaluate brain data in a jury trial.

In conclusion, as part of the data-centered classroom, an instructor can easily employ publicly available data to engage students in hands-on collaborative learning experiences through non-disposable assignments that also teach important lessons about the cognitive impact of stress and the physical manifestations of social rejection with real-world applications for social justice.

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