COLUMBIA | SOLER
Science of Learning Research Initiative

2020 Provost SOLER Seed Grants
Proposal Template

Section 1: Project Summary			
Award Year:	2020-2021		
Title of Study:	Imaging the brain activity of students studying brain imaging		
Principal Investigator (PI) Information			
PI #1 Name:	Alfredo Spagna		
PI #1 Title:	Lecturer in Discipline of Psychology, Director of Undergraduate Studies in Neuroscience and Behavior		
PI #1 Department:	Psychology		
PI #1 Email:	as5559@columbia.edu		
Co-Investigator (CI) Information Use an asterisk (*) to denote any CI who will serve as a Co-PI.			
CI #1 Name:	Xiaofu He*	**CI #2 Name:**	
CI #1 Title:	Assistant Professor of Clinical Neurobiology	**CI #2 Title:**	
CI #1 Department:	Psychiatry	**CI #2 Department:**	
CI #1 Email:	xh2170@cumc.columbia.edu	**CI #2 Email:**	
CI #3 Name:		**CI #4 Name:**	
CI #3 Title:		**CI #4 Title:**	
CI #3 Department:		**CI #4 Department:**	
CI #3 Email:		**CI #4 Email:**	

Abstract: Describe the project in lay terms; articulate the project objective; specify what makes the project innovative; describe your assessment or evaluation plan to ascertain student impact. (Limit 250 words.)

Instruction and research are typically treated as separate entities in academia. The dissociation is presumably justified by the distinct needs of the two arenas: a fluid environment promoting creativity and critical thinking for instruction versus a controlled laboratory setting ensuring reliable measurement for research. Recently, however, approaches that integrate instruction and research have emerged. For instance, the field of neuroscience of education aims to develop instructional approaches that are informed by neurobiology and cognitive science. Adopting the neuroscience of education framework, we propose to bring the neuroscience laboratory inside the classroom to study the brains of students studying the brain. Using portable electroencephalography (EEG) headsets, we will record brain activity of students enrolled in a hands-on neuroimaging course. Subjective measures, questionnaires, and physiological recordings will collectively examine the relationships between student engagement, attentional focus, academic performance, and EEG indices. We will temporally align classroom recordings with students' EEG signals and extract brain wave frequencies associated with on-task

versus mind-wandering attentional states. For each student, correctly and incorrectly answered questions on the exams will be compared with respect to the attentional states identified during the relevant class segment. We predict that correctly answered questions will be associated with on-task attentional states. Additionally, we will compare students' learning and attitude outcomes to those of students in a control course – taught by one of the instructors during the same term – that has similar objectives but no hands-on activities. We predict that students in the experimental course will exhibit enhanced learning and attitude outcomes relative to the control course. Our results will illuminate the benefits of practical research experiences in neuroscience education and contribute to the growing body of neuroscience of education literature.

Section 2: Project Description
Please complete each subsection taking into consideration the accompanying guidelines.

Section 2a: Project Scope. (Limit 500 words.)

- *Framing: Specify your overarching objectives; identify and describe sub-goals or specific aims and how these align with the overarching objectives; identify how the proposed innovation will meet those goals.*
- *Participants: Identify your target participants (e.g., students); specify how participants will be identified and contacted; approximate how many participants will be impacted during the grant period; briefly describe how the innovation will continue to benefit later student cohorts beyond the PSSG duration.*

Framing

Objective 1. Examine students' subjective ratings of knowledge acquisition, instructor enthusiasm and organization, quality of group interaction, instructor-student bond, and the range of topics covered. Students will complete a questionnaire (see Section 2c) at the end of each class (with respect to that day's activity) and at the end of the course (with respect to the overall course).

- Hypothesis 1. Consistent with evidence that inquiry-based learning enhances class engagement and student interaction, questionnaire responses should be more favorable in the experimental course relative to the control course.

Objective 2. Examine group-level neural markers of in-class performance. Portable EEG headsets will be used to record neural activity from students during seminars in the experimental course (in-person). Brain activity in the gamma (>30 Hz) band, a known correlate of attentional focus, will be extracted from EEG data.

- Hypothesis 2.1. Gamma power should be lower at the end of the class relative to the beginning of class – a marker for students' fatigue.
- Hypothesis 2.2. Gamma power should be greater when students are engaged in practical activities compared to when they are passively listening to the instructor.

Objective 3. Examine the relationship between objective and subjective measures of class performance and class engagement. Correlations between questionnaire scores and gamma activity from each class will reveal which components of instruction are most related to sustained attention and engagement.

- Hypothesis 3. Gamma power and the questionnaire dimension of *enthusiasm* should be positively correlated.

Objective 4. Examine the relationship between neural markers of in-class attentive behavior and academic performance. For each student, correctly and incorrectly answered questions on the exams will be compared with respect to the attentional states (as inferred from EEG data; see Objective 2) during the relevant lecture/discussions in class.

- Hypothesis 4. Correctly answered questions should be associated with on-task attentional states whereas incorrectly answered questions should be associated with mind-wandering states. Teaching style is predicted to be a mediating variable: for exam questions relating to class segments that were conducted in active learning style, EEG should be more predictive of performance relative to exam questions relating to class segments that were conducted passively.

All of the above objectives constitute unique innovations of this project.

Participants
Twelve students enrolled in the course Fundamentals of Human Brain Imaging (GU4930) will serve as the experimental group; twelve students enrolled in the course Consciousness and Attention (GU4225) will serve as the control group. In both courses the participants will be a mix of undergraduates and graduate students. Subjective and objective measures of student engagement will be collected throughout the semester for the experimental group, whereas only subjective measures will be collected for the control group. Instructional activities will be comparable to regular academic activities. By participating in this study, students enrolled in GU4930 will learn how to collect, analyze, and write about scientific data; such skills provide an essential foundation for advanced study in the sciences and other fields. The innovations explored in this study will shape later iterations of these courses in ways that will enhance the learning experiences of future students.

Section 2b: Rationale and Literature Review. Highlight key findings of relevant educational research. Include citations as appropriate. Describe any prior work your team has done in this space. (Limit 500 words).

In the recent publication "Are we ready for real-world neuroscience?" Matusz and colleagues (2019) pose a central question in neuroscience about the extent to which the results from studies conducted in a controlled, laboratory setting apply to everyday life situations. Without rejecting the value of conducting research studies in well-controlled paradigms, the authors highlight many discrepancies between laboratory-generated data and models of natural cognition. Other authors have proposed more radical approaches to the investigation of ecological cognition (e.g., Hamilton and Huth's provocatively titled 2020 article "The revolution will not be controlled: natural stimuli in speech neuroscience"). The optimal approach may in fact lie in real-world settings that offer a certain degree of controllability. For example, Dikker and colleagues (2017) investigated the patterns of brain-to-brain synchrony in a class of high-school students. Using portable EEG headsets, a series of subjective measures of social interactions, and a clever experimental design, they devised a sophisticated method of investigating the neuroscience of group interactions in a natural setting. The reproducibility of their methodology and the reliability of their results contributed to our idea of studying the brains of students studying the brain.

Using portable EEG headsets in a classroom at Columbia University will allow us to study the neural markers associated with three key contributors in students' educational experience and predictors of course outcome: (1) attentional focus, (2) class engagement, and (3) their reciprocal modulation. Our approach derives from the ARCS motivation theory (Attention, Relevance, Confidence, and Satisfaction; Keller, 2008), which posits that attention is the most proximal factor to learning acquisition (Michie et al., 2011). Furthermore, inquiry-based learning – in our case, a course centered around designing original experiments and collecting and analyzing data – enhances student outcomes relative to direct (passive) instruction (Furtak et al., 2012).

Merging the research and educational expertise of the two co-PIs of the project – Dr. Spagna (Faculty of the Psychology Department), with over ten years of experience in studying attention in multisensory settings; and Dr. He (Faculty of the Psychiatry Department and of the Data Science Institute), with extensive experience in computer science, machine learning, and brain imaging – strongly positions us for successful completion of the project.

References:

- Dikker, S., Wan, L., Davidesco, I., Kaggen, L., Oostrik, M., McClintock, J., ... & Poeppel, D. (2017). Brain-to-brain synchrony tracks real-world dynamic group interactions in the classroom. *Current Biology, 27*(9), 1375-1380.
- Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching: A meta-analysis. *Review of Educational Research, 82*(3), 300-329.
- Hamilton, L. S., & Huth, A. G. (2020). The revolution will not be controlled: natural stimuli in speech neuroscience. *Language, Cognition and Neuroscience, 35*(5), 573-582.
- Keller, J. M. (2008). First principles of motivation to learn and e-learning. *Distance Education, 29*(2), 175-185.
- Matusz, P. J., Dikker, S., Huth, A. G., & Perrodin, C. (2019). Are We Ready for Real-world Neuroscience? *Journal of Cognitive Neuroscience, 31*(3), 327–338.
- Michie, S., van Stralen, M.M., & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science, 6*, 42.
- Raca, M., & Dillenbourg, P. (2013, April). System for assessing classroom attention. In *Proceedings of the Third International Conference on Learning Analytics and Knowledge* (pp. 265-269).

Section 2c: Assessment and Evaluation Plan. Address how sub-goals or specific aims will be measured: Describe novel or to-be-adapted measurement tools (e.g., surveys). Outline key comparisons and briefly describe data analysis procedures. Indicate how you will monitor the effectiveness of the project as it evolves. Identify curricular changes you envision your project leading to at Columbia and describe how such changes will be achieved.
(Limit 250 words).

Objective 1: Examine students' subjective ratings of knowledge acquisition, instructor enthusiasm and organization, quality of group interaction, instructor-student bond, and the range of topics covered. We will administer the Student Evaluation of Educational Quality (SEEQ) (Marsh et al., 1982; Knipfer et al., 2019), a widely used student feedback questionnaire with a robust factor structure, excellent reliability and reasonable validity.

- Key comparison: Questionnaire responses are predicted to be more favorable in the experimental course relative to the control course.
    - Analysis method: Mann-Whitney test to compare mean (Likert-scale) ratings that are not normally distributed.

Objective 2: Examine group-level neural markers of in-class performance.

- Key comparisons:
    - Lower average group-level gamma power is predicted at the end of the class, compared to the beginning of class – a marker for students' fatigue.
    - Gamma power is predicted to be greater when students are engaged in practical activities compared to when they are passively listening to the instructor.
        - Analysis method: Spectral analysis to compare gamma band power between samples. This comparison can involve t-tests or other tests depending on characteristics of the samples. Bootstrapping methods may be necessary due to the small sample size.

Objective 3: Examine the relationship between objective and subjective measures of class performance and class engagement.

- Key comparison: Gamma power and the SEEQ questionnaire dimension *enthusiasm* are predicted to be positively correlated.
    - Analysis method: Spearman correlation for calculating the relationship between an ordinal (questionnaire ratings) and ratio (gamma power) variable.

Objective 4: Examine the relationship between neural markers of in-class attentive behavior and academic performance.

- Key comparison: Correctly answered questions are predicted to be associated with on-task attentional states whereas incorrectly answered questions should be associated with mind-wandering states.
    - Analysis method: Spectral analysis to compare gamma band power between samples (see Objective 2).

Monitoring procedures are described in Section 3 below.

This project may lead to curricular changes such as enhanced incorporation of hands-on activities and data collection experiences in neuroscience courses. This can be achieved by demonstrating the benefits of such experiences for student learning and attitude outcomes.

References:

- Knipfer, C., Wagner, F., Knipfer, K., Millesi, G., Acero, J., Hueto, J. A., & Nkenke, E. (2019). Learners' acceptance of a webinar for continuing medical education. *International Journal Of Oral And Maxillofacial Surgery, 48*(6), 841-846.
- Marsh, H. W. (1982). SEEQ: A reliable, valid, and useful instrument for collecting students' evaluations of university teaching. *British Journal of Educational Psychology, 52(*1), 77-95.

Section 2d: Role of Key Personnel. Specify the expectations and obligations of all project personnel. Include a brief description of requested assistance from SOLER facilitators.
(Limit 150 words.)

Drs. Spagna and He will alternate the lecture portion of the project and will manage the adherence of planned research activities to the project timeline. Funds of the present project will be used to hire two part-time students as Research Assistants – one each from the Psychology and Psychiatry departments – who will conduct data collection, real time data quality checks during recordings, and data analysis. The RAs will benefit from this multidisciplinary environment by sharing complementary expertise in data acquisition, analysis, and coding while growing their technological and theoretical knowledge. The critical contribution of SOLER facilitators is required to ensure that activities of the project are in line with the timeline (see below) and that the successful completion of the current project will serve as the basis for an extension of the work to be proposed for the Fall 2022 funding cycle at the National Science Foundation.

Section 3: Project Timeline
Use a timeline to depict the schedule for your project. The timeline should include start and finish dates for your project as well as the dates or periods during which various project tasks will occur. All elements of the project should be completed within 12 months of receiving funds.

(See also attached graphical timeline.)

Due to the hands-on nature of the project, activities originally planned for Spring 2021 will be postponed until Fall 2021, i.e., when in-class instruction is expected to resume. A pilot study involving the instructors and other personnel (including, perhaps, some graduate students) will be conducted in Spring 2021. Prior to the start of Fall 2021 semester, a kick-off meeting including all the members of the Research Team – the two PIs and the two students – will be held to discuss in detail the overall timetable, analytic pipelines, and potential contingency plans. The last data acquisition will occur near the end of semester. Data quality checks will be conducted after each acquisition, and two interim analyses will be conducted to ensure that the analytic pipeline works as expected (during Week 3) and that the pattern of results approximate our prediction (during Week 10). The final month of the semester will be used to refine the data analysis pipeline. The following semester, Spring 2022, will be used for preparing a manuscript that summarizes the results of the project and that will be submitted to a peer-reviewed journal where related work cited in this project has been published (e.g., Current Biology). We expect to submit the manuscript by June 2022. As indicated above, successful completion of the project will serve as the basis for an extension of the work to be proposed for the Fall 2022 funding cycle at the National Science Foundation.

Section 4: Budget Overview and Justification.
Provide a detailed budget and justification for funds. Funding can be used for course preparation, external course content, technology and media development costs, administrative costs, and teaching assistants/research assistants. Please mention all other sources of funding, if any. The total requested budget should not exceed the maximum award amount of $5,000.

Funds of the present project will be used to hire two part-time students as Research Assistants – one each from the Psychology and Psychiatry departments – who will conduct data collection, real time data quality checks during recordings, and data analysis. Hourly rate will be set between $15-20 / hour, for a total of at least 250 hours. Each student will be hired for 125 hours, totaling about 8 hours / week over the 15-weeks of a semester.

Total amount requested: $5,000

Research activities are partially co-funded by additional support from the Data Science Institute (Columbia Data Science Institute (DSI) Collaboratory project - Project UR010951 - Interdisciplinary Human Brain Imaging) to Alfredo Spagna and Xiaofu He (Co-PIs). Funds from the DSI grant are allocated to purchase the instrumentation required to complete the project (i.e., 14 portable EEG headsets; 14 laptops; hard drive to store the data; publication fees).

Project Timeline

Fall 2020

Project
1. Project Submission
2. Notification of Award
3. IRB Protocol Submission

Pilot Study Phase, initially planned for Fall '20, was postponed to Spring '21 due to the restriction to data collection.

Spring 2021

Pilot Study
1. IRB Protocol Approval
2. EEG montage testing
3. Pilot Data Collection
4. Create Analytic Pipeline
5. Test pipeline on 2nd pilot data collection

Experimental Phase, initially planned for Spring '21, was postponed to Fall '21 due to the restriction to data collection.

Fall 2021

Experimental Phase
1. Kick-off Meeting
2. Data Collection (part 1/3)
3. Preliminary Data Analysis
4. Contingency Plan Meeting
5. Data Collection (part 2/3)
6. Preliminary Data Analysis
7. Final Data Collection and Analysis

Spring 2022

Dissemination Phase
1. Manuscript Redaction and Submission
2. Redaction of End of Project Report
3. Meeting with SOLER for follow-up project

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK
PSYCHOLOGY DEPARTMENT

September 22, 2020

Dear Colleagues,

I write to express my enthusiastic support for Dr. Alfredo Spagna's proposal to deliver a new innovative course, *Fundamentals of Human Brain Imaging*, that bridges the gap between the instruction and research in academia, by bringing the laboratory setting into the classroom. This course will fill an important gap in our undergraduate curriculum, complementing existing courses that focus on functional neuroimaging results already present in the literature, by delivering an in-depth and hands-on neuroimaging course that merges theory and practice. This will no doubt be a very popular seminar course among our undergraduate and post-baccalaureate Psychology and Neuroscience & Behavior students, many of whom are particularly interested in acquiring practical neuroimaging expertise and hoping to pursue careers in neuroscience. Given the strength of the topic and Alfredo's immense talents as an educator, I foresee this course becoming one of the core seminars for students interested in a deeper understanding of neuroimaging.

Alfredo has an extraordinary command of the material. His engaging and charismatic teaching style and his clear dedication to his students' learning makes him a wonderful instructor and a true asset to our department. Alfredo already teaches some of the most important courses in our department, particularly for students pursuing the Neuroscience & Behavior major: *Behavioral Neuroscience*, an upper-level lecture course examining brain and behavior from a more molecular basis, primarily using animal models; *Cognitive Neuroscience*, an upper-level course examining brain and behavior in human models, drawing primarily on functional neuroimaging techniques; *Fundamentals of Human Neuropsychology*, an upper-level course that explores the brain-behavior relationship from the lesion standpoint, and two advanced seminars, exploring the primary empirical literature in the fields of attention, perception, and consciousness. Alfredo's course evaluations are nothing short of first-rate, with students extolling his "magnificent" teaching style, his "passion" for neuroscience, his "empathy" for his students, his extraordinary ability to explain even the most complicated of subjects and leave students walking out of office hours feeling like they "truly understood each concept." As one student commented, Alfredo "puts some life into neuroscience" so that the course material is "accessible to everyone."

Alfredo is deeply committed to his students' learning, and I am confident that he will design an excellent new course for our department, enabling students to develop a deep knowledge of content regarding the relationship between the brain and behavior, but, perhaps even more importantly, enabling them to hone their creativity and critical thinking skills and their ability to collaborate effectively. Leveraging the most current research into active learning and best practices in pedagogy, Alfredo will design this new course using engaging activities, such as in-class experiments and the creation of podcasts/conceptual maps to ensure deep learning and long-lasting retention and to give students agency in creating their own materials to support their learning.

In supporting group work, giving students the space to be creative, and promoting active learning strategies, Alfredo demonstrates his commitment to fostering inclusive classrooms, in which all students have the opportunity to learn and thrive. Alfredo's work will serve as an important model for other faculty, demonstrating how a hybrid design can enhance student learning and promote inclusivity in our classrooms.

Sincerely,

Kevin Ochsner
Professor and Chair