I am fond of the saying that research is "me-search", meaning that some researchers tend to focus their work on issues that are personal or that they are curious about understanding in some way about themselves. I am one of these researchers. My broad interest in how adolescents learn and apply learned information stems from my own learning experiences as well as my professional and research experiences working with different developmental populations. Here I will highlight aspects of my educational experience that have contributed to my interest specifically in learning mechanisms, and in the period of adolescence.

Interest in Adolescence: As an undergraduate student, I wanted to gain direct experience to explore my interest in clinical psychology. To this end, I volunteered at St. Luke's-Roosevelt Hospital in New York City, working with an ethnically and socioeconomically diverse group of patients in the Alternative Adolescent Day Program (AADP) and the Comprehensive Addictions Program for Adolescents (CAPA). This particular set of outpatient programs appealed to me because in addition to therapy and treatment, the patients took classes towards their General Equivalency Diploma or High School Diploma in a curriculum taught by New York Board of Education teachers. I tutored the patients in their class work, helped them complete their homework, as well as facilitated social milieu therapy projects, such as a school newspaper. The patients reminded me of the Montessori philosophy; Adolescence is a period characterized by changes and challenges, and these patients additionally struggled with psychopathology and addiction, and despite all these obstacles were committed to their schooling.

Interest in Learning: My own passion for learning developed in the Montessori school I attended from 3 to 13 years of age. Two major principles of the Montessori philosophy are that when children are motivated to learn they will engage in self-directed study and that every child has different optimal strategies for learning. Peer-to-peer-learning is also pivotal, and the Montessori classroom is built around encouraging it, with 3 grade-level groups in a single classroom (e.g. 4^{th}, 5^{th} and 6^{th} graders). This structure allows students to tap multiple resources, from books and other materials to more senior students in the classroom, before turning to the teachers (of which there are usually 2-3 per classroom). This unique early experience of seeking academic help from my classmates, and in turn sharing my knowledge with my peers, instilled in me the desire to learn so that I could in turn teach another.

Because of my strong research skills and academic record, I have had the rare opportunity to work under an extraordinary group of mentors. Specifically, Drs. Dima Amso, BJ Casey, and Daphna Shohamy have deeply impressed me as rigorous, female scientists, whose research directly impacts the lives of children and adults, in healthy and other populations. I aspire to be a strong female role model in science, a researcher whose work can improve educational practices across the country, and an educator directly bringing my love of learning to students, and towards these ends I have begun my PhD work at Columbia University. I believe my proposed research holds the potential to expand into a career dedicated to understanding the brain-and-behavior interactions necessary for successful navigation through adolescence.

Broader impact in the community: I am beginning to share the knowledge I have gained from my mentors with a rising generation of hopeful scientists. In early December, I will be presenting and discussing my research at a 'Careers in Science' fair for middle and high school students, organized by the Women in Science at Columbia (WISC) and the Center for Environmental Research and Conservation (CERC). This event will be attended by a socioeconomically diverse group of students from all over New York City, with a focus on encouraging young women in particular to consider careers in the sciences. This emphasis is of particular importance to me, because I am woman working in the sciences, and my greatest role models and influences to follow this course have been women.

A key goal of mine, expressed in my personal statement from my previous submission, was to begin sharing my work directly with adolescents in the community. To this end, I will be making presentations at local high schools, starting with The Calhoun School in Manhattan, speaking in classrooms about what cognitive neuroscience has taught us about changes in behavior and the developing brain during adolescence.

I have been mentoring a high school student, Michael, and supervising him through a research project in the lab that will culminate in his applications to the Intel National Science Talent Search, the New York Science and Engineering Fair, and other award programs. To this end I have been teaching Michael the foundations of research methods, including how to survey the existing literature, statistical tools, and the ethical principles researchers must abide by. Michael is interested in how socioeconomic differences in adolescent populations might relate to the learning and generalization mechanisms outlined in my research proposal and the possible role generalization plays in racial stereotyping. Mentoring Michael has been rewarding, and I was excited at the opportunity to interact one-on-one with a student at his level on such a long-term project, given how uncommon it is to have students before the undergraduate level work hands-on on research projects.

Graduate Training: My first year of graduate study has been punctuated with acknowledgements of my accomplishments. I was the recipient of the Leo Rubinstein Endowed Fellowship. I applied and was awarded a travel grant from the Kavli Institute for Brain Sciences to present results at the recently past Annual Meeting of the Society for Neuroscience [1]. This study, conducted in my first year of graduate work, tested 74 healthy adults behaviorally, and tested a subset of 53 of these adults in a functional Magnetic Resonance Imaging scan. This sample of adults will be used as a comparison group in the cross-sectional, developmental study that I propose in this application. And perhaps most notably, I was recognized with an Honorable Mention on my first submission of my NSF GRFP application. I was pleased and excited to see the enthusiastic responses from the raters of my essays, and found their feedback to be extremely helpful. The points raised by my raters indentified clear areas where my proposal could be improved, and by directly addressing these issues, I believe my current, revised proposal is stronger.

This past semester, I have been taking a course in Methods of Teaching towards improving my skills as a Teaching Assistant (TA) for Undergraduate courses at Columbia University. I will have the opportunity to directly apply my new skills this spring, when I TA for the introductory Developmental Psychology course, a class I am eager to work on, given my strong background in developmental research and methods.

With the support of Dr. Shohamy and her expertise in neural networks for learning, I have an ideal mentor for exploring the development of learning processes over the course of adolescence. With cutting edge behavioral and brain imaging facilities at Columbia, I have access to the testing resources my research requires. Situated in Upper Manhattan, I am surrounded by people with diverse ethnic and socioeconomic backgrounds, providing me access to a representative population of potential research participants that will allow me to generalize my results for the benefit of many children. These elements combined with my research background give me confidence that I will be an outstanding student and researcher whose contributions will impact a number of fields within psychology and beyond.

Reference: 1. **Davidow, J.**, Kahn, I., & Shohamy, D. (November, 2010). *The ability to learn and generalize knowledge is related to intrinsic interactions between multiple memory systems during rest.* SfN Annual Meeting, California, USA.

Learning in adolescence: Neural mechanisms and implications for education.

Keywords: Learning, education, development, adolescence, striatum, hippocampus, fMRI.

Introduction. There have been significant advances in understanding cognitive and neural mechanisms for learning in adults, with important implications for everyday learning situations [e.g. 1, 2, 3]. However, far less is known about the cognitive and brain mechanisms underlying learning during the critical developmental stage of adolescence. This research program aims to bridge this gap. The proposed research will use behavioral studies combined with functional Magnetic Resonance Imaging (fMRI) in healthy adolescents to delineate the cognitive and neural development of specialized learning systems over the course of adolescence (10-18 years of age). **The results will provide a novel understanding of learning mechanisms during adolescence and will inform educational approaches towards learning in the classroom.**

Background & Rationale. Converging evidence from research in animals, patients and healthy adults demonstrates that there are different kinds of learning that depend on distinct neural systems [2, 3]. Gradual, feedback-based learning of stimulus-response associations – often referred to as "habit" or "incremental" learning - depends on the striatum [4, 5]. This system is sensitive to feedback and results in knowledge that is relatively inflexible and specific to the context in which the learning took place [6]. A distinct and independent "declarative" or "episodic" system supports rapid learning of events and depends on the hippocampus [1, 6]. In contrast to the striatum, the hippocampus is thought to form knowledge that is flexible and easily generalized to novel situations and contexts [1, 6]. It has been shown that individuals who show more hippocampal activation during learning are more likely to integrate and generalize what they learned [5]. Together, these findings indicate that in the healthy adult brain, there is a balance between activity in the striatum and the hippocampus during learning, with consequences for how learned knowledge is used. **A key open question is how developmental changes in learning mechanisms relate to changes in the striatum and the hippocampus during adolescence.**

Some insight into this question comes from longitudinal research of structural brain changes, which revealed differential developmental trajectories in the striatum and the hippocampus [7]. The volume of the striatum peaks around pubertal onset and then diminishes, with reductions continuing into early adulthood [7, 8]. Far less is known about the developmental trajectory of the hippocampus [7, 9]. However, existing results support relatively early maturation of the hippocampus, consistent with adult-level episodic learning performance in children [10]. Together, these findings suggest that **the striatum and the hippocampus may develop at different rates during adolescence, with important implications for learning**. Given the structural differences in the brain's learning systems over the course of adolescence, what is the trajectory of different forms of learning ('incremental' vs. 'episodic')? To address questions about interactions between behavior and brain mechanisms, I will characterize the relationship between learning processes and brain development in human adolescents using a paradigm demonstrated in adults to be a sensitive index of both striatal-dependent incremental learning and hippocampal-dependent episodic learning. These studies will investigate the neural mechanisms in adolescent learning so that educational programs can be informed directly by cognitive neuroscience data from adolescents, instead of making inferences from studies of adults.

Experimental methods. I propose three studies that make use of an incremental learning and generalization paradigm ('acquired equivalence')[e.g. 5], shown to selectively probe different forms of learning and their neural substrates in adults. Although ideally these studies would be conducted longitudinally, the constraints of my time as a graduate student make cross-sectional and between-subject studies most feasible. The acquired equivalence (AE) task consists of two phases. First, subjects engage in feedback-based learning where they learn to associate a series of

faces with different objects. This feedback-based learning phase has been shown to depend on the striatum. In the second phase, subjects are tested on their memory for the previously learned associations. Critically, they are also asked to *generalize* what they learned to novel stimulus combinations. This ability to generalize depends on the hippocampus [e.g. 5].

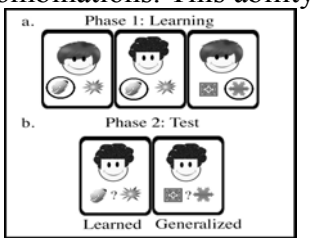

Figure. 'Acquired Equivalence' task structure.
a. In Phase 1, subjects learn a set of independent but overlapping associations. Learning is incremental and based on feedback.
b. In Phase 2, subjects are tested for their (1) memory on learned pairings (Learned) and for (2) inferential transfer to novel combinations they have not previously seen (Generalized).

This paradigm is particularly well suited for studying special populations, including younger subjects. Specifically, it allows as many learning trials as is necessary before the second test phase. This unique feature will permit us to independently explore adolescent learning trajectories for both incremental learning and for episodic generalization. Using fMRI, I will record brain activity at learning and test phases of the task while measuring subjects' behavioral responses. By using converging methods, I can simultaneously characterize incremental learning from feedback and flexible generalization of learned information in adolescents while exploring individual differences in reliance on neural networks implicated in adult performance. **Study 1** will use the AE task with feedback during the learning phase to ask how adolescents learn to associate items and generalize to novel pairings, and delineate the underlying neural networks. **Study 2** will use an AE task that compares active learning-with-feedback to passive learning-by-observation, with no feedback. This manipulation has been shown to modulate both hippocampal and striatal contributions [4] and will allow me to compare memory and generalization from active versus passive learning, qualify what kinds of learning are most effective for different kinds of outcomes, and probe the role of active engagement for successful learning. **Study 3** will use the AE task and will manipulate whether the feedback involves monetary rewards or not, to explore the impact of heightened reward sensitivity during adolescence [8] on learning behaviors. Together, these studies will build a foundation for understanding (I) learning and generalization behaviors, (II) differential maturation of brain function, and (III) behavior-and-brain interactions over the course of adolescent development. This foundation will be critical in bridging the research fields of neuroscience, development, and education, and also holds potential to impact society with implications for special education, early learning intervention, and psychopathology.

Future studies will probe the role of individual differences on learning behaviors, including influences from social environment and genetic phenotypes. Due to the dearth of learning research in healthy adolescents, my proposal promises to put forward novel information about behavior and behavior-and-brain interactions to bear on several fields. Understanding typical adolescent development of learning mechanisms and how knowledge is applied in novel circumstances is imperative to adolescents' success in the classroom and when faced with challenging decisions.

References

1. Eichenbaum, H.E. & Cohen, N.J. From "Conditioning to Conscious Recollection", 2001.
2. Gabrieli, J.D. Annual Review of Psychology, 1998. 49: 87-115.
3. Knowlton, B.J., Mangels, J.A., & Squire, L.R. Science,1996. 273: p. 1399-1402.
4. Shohamy, D., et al. Brain, 2004. 127: p. 851-859.
5. Shohamy, D., & Wagner, A.D. Neuron, 2008. 60: p. 378-389.
6. Shohamy, D., et al. Journal of Cognitive Neuroscience, 2008. 21(9): p. 1820-1832.
7. Giedd, J.N. Journal of Adolescent Health, 2008. 42: p. 335-343.
8. Somerville, L.H., Jones, R.M., & Casey, B.J. Brain and Cognition, 2010. 72(1): p. 124-133.
9. Gogtay, N., et al. Hippocampus, 2006. 16: p. 664-672.
10. Ofen, N., et al. Nature Neuroscience, 2007. 10(9): p. 1198-1205.

Score for Davidow, Juliet

Intellectual Merit Criterion

Overall Assessment of Intellectual Merit

Excellent

Explanation to Applicant

The candidate has an excellent record of research experience. This is evidenced by her two co-authored papers and multiple presentations. Also, her references speak to her independent contributions to the research programs. She has presented a very well crafted research proposal. The justification for her hypotheses is compelling and the methods are sound. It will be an interesting and potentially important study.

Broader Impacts Criterion

Overall Assessment of Broader Impacts

Excellent

Explanation to Applicant

I appreciate the candidate's recognition of the important role that scientists have in improving science education in their communities. She shows ample evidence of giving back to her community through her mentorship of young people and participation in community projects. She will be an engaged scientist who will continue to help others in her broad community.

Score for Davidow, Juliet

Intellectual Merit Criterion

Overall Assessment of Intellectual Merit

Excellent

Explanation to Applicant

The applicant demonstrates are strong record of research training through their undergraduate and post-baccalaureate employment including an excellent record of publication/presentation. She has demonstrated both independence and insight. Her broad training is noted.

Broader Impacts Criterion

Overall Assessment of Broader Impacts

Excellent

Explanation to Applicant

The applicant demonstrates a sustained commitment to the ideals of this criterion through her volunteer, mentoring, and service activities. These include participation in WISC events, speaking at local high schools about cognitive neuroscience, and mentoring high school students. Her application would be even stronger with concrete plans that address this criterion in the near and far terms.

Score for Davidow, Juliet

Intellectual Merit Criterion

Overall Assessment of Intellectual Merit

Very Good

Explanation to Applicant

The applicant has considerable experience working in various laboratories and has mastered a large set of research skills that have prepared her to function as a research scientist. She has two journal articles, one article submitted for publication, and several national conference presentations. Thus she understands the process of scientific research from beginning to end.
Her proposed line of research is based on a broad appreciation of the literature and is thoughtfully and carefully planned. There were a few details lacking in the research plan that were important in understanding the practicality of the proposed effort.

Broader Impacts Criterion

Overall Assessment of Broader Impacts

Excellent

Explanation to Applicant

Evidence for the applicant's enthusiasm for education and diversity issues can be found in her past volunteer work, her efforts to mentor students in research, and in her choice of research topics.
The proposed research, if successful, has some broad applications that were clearly indicated by the applicant.

Logo-asee-print

NSF GRFP RESULTS

Juliet Davidow | logout </ratingsheets/logout>

Rating Sheets

* *2010 Rating Sheet 1*
* 2010 Rating Sheet 2 </ratingsheets/ratingsheets/84303>
* 2010 Rating Sheet 3 </ratingsheets/ratingsheets/84304>

Overall Assessment of Intellectual Merit: Very Good
Explanation to the applicant:

Excellent academic preparation with impressive GRE scores. Sought out undergraduate and postgraduate research experiences and has continued to produce at the graduate level, with one published paper and nine conference papers (one first-authored). her letters of recommendation were very strong and attested to her fine research ability. Her proposed research plan was well-articulated and based on past published research.

Overall Assessment of Broader Impacts: Very Good
Explanation to the applicant:

The broader impacts of her research and her role as a scientist were not articulated directly. She has an excellent record of community service and has demonstrated an understanding of the scientist's roe in communicating findings to the larger community. Articulated an interest in montoring and teaching,

OTHER YEARS

* *2010*

OUTSIDE LINKS

* Fastlane <https://www.fastlane.nsf.gov/grfp/>

* NSF GRFP Program Announcement <http://www.nsf.gov/grfp>

National Science Foundation Graduate Research Fellowship Program
Operations Center Administered by: American Society for Engineering Education (ASEE)
1818 N Street NW, Suite 600 Washington, DC 20036 | 866-NSF-GRFP, 866-673-4737
(toll-free from the US and Canada) or 202-331-3542 (international) | info@nsfgrfp.org <mailto:info@nsfgrfp.org>

Logo-asee-print

NSF GRFP RESULTS

Juliet Davidow | logout </ratingsheets/logout>

Rating Sheets

* 2010 Rating Sheet 1 </ratingsheets/ratingsheets/84302>
* *2010 Rating Sheet 2*
* 2010 Rating Sheet 3 </ratingsheets/ratingsheets/84304>

Overall Assessment of Intellectual Merit: Excellent
Explanation to the applicant:

The applicant has extensive research experience and a strong academic background. Her proposed research plan is well laid out. She has good communication skills, works well with others and independently.

Overall Assessment of Broader Impacts: Very Good
Explanation to the applicant:

The applicant expresses a desire to be a role model and participate in outreach programs to deliver science to those who might not otherwise be exposed to it. Her research will enhance scientific and technical understanding. Improved understanding of how adolescents learn will do doubt benefit society. The applicant could more explicitly address the broader impact criteria, especially regarding encouraging diversity.

OTHER YEARS

* *2010*

OUTSIDE LINKS

* Fastlane <https://www.fastlane.nsf.gov/grfp/>
* NSF GRFP Program Announcement <http://www.nsf.gov/grfp>

National Science Foundation Graduate Research Fellowship Program
Operations Center Administered by: American Society for Engineering Education (ASEE)
1818 N Street NW, Suite 600 Washington, DC 20036 | 866-NSF-GRFP, 866-673-4737
(toll-free from the US and Canada) or 202-331-3542 (international) | info@nsfgrfp.org <mailto:info@nsfgrfp.org>

Logo-asee-print

NSF GRFP RESULTS

Juliet Davidow | logout </ratingsheets/logout>

Rating Sheets

* 2010 Rating Sheet 1 </ratingsheets/ratingsheets/84302>
* 2010 Rating Sheet 2 </ratingsheets/ratingsheets/84303>
* *2010 Rating Sheet 3*

Overall Assessment of Intellectual Merit: Very Good
Explanation to the applicant:

Strengths: The applicant has participated in undergraduate research and as a lab manager, followed by work as an RA, and is now enrolled in graduate study. From these experiences, the applicant learned basic psychological research tools, including behavioral study design and analysis, measuring eye movements, ERPs and fMRI. All of these skills will be highly valued in the applicant's ongoing training. The applicant's research efforts have resulted in an honors thesis, one local invited talk, one first authored international conference presentation, authorship on numerous additional conference abstracts, and authorship on two manuscripts in various stages of publication.
Weaknesses: The research plan lacks some important information. For example, is there any behavioral evidence that the incremental and episodic learning systems have different developmental trajectories? This is important to establish prior to moving the experiment into the scanner, which isn't going to tell us much about mechanisms, just more about "where". I'm assuming that this is a between-subjects design, and not a longitudinal study, because a graduate student career is likely too short to measure longitudinally. However, this is not specified. The applicant does not have any first-authored peer-reviewed manuscipts at this time.

Overall Assessment of Broader Impacts: Very Good
Explanation to the applicant:

The applicant has served both as a peer counselor and as a volunteer

tutor working with teenagers with drug addiction difficulties. These experiences motivated the applicant to pursue studies on the typical adolescent development. The applicant intends to promote neuroscience in K-12 classrooms with the help of SFN's online materials.

OTHER YEARS

* *2010*

OUTSIDE LINKS

* Fastlane <https://www.fastlane.nsf.gov/grfp/>
* NSF GRFP Program Announcement <http://www.nsf.gov/grfp>

National Science Foundation Graduate Research Fellowship Program Operations Center Administered by: American Society for Engineering Education (ASEE)
1818 N Street NW, Suite 600 Washington, DC 20036 | 866-NSF-GRFP, 866-673-4737
(toll-free from the US and Canada) or 202-331-3542 (international) | info@nsfgrfp.org <mailto:info@nsfgrfp.org>