Developmental Changes in Tissue Iron to Examine Dopamine's Role in Adolescent Reinforcement Learning and Memory

Helena Brain, YSP Student, *North Reading High School*
Sheila Kastrati, YSP Student, *Quincy High School*
Brianna Aubrey, Erica Niemiec, Psychology Department, *Northeastern University*
Prof. Juliet Davidow, Psychology Department, *Northeastern University*

Abstract

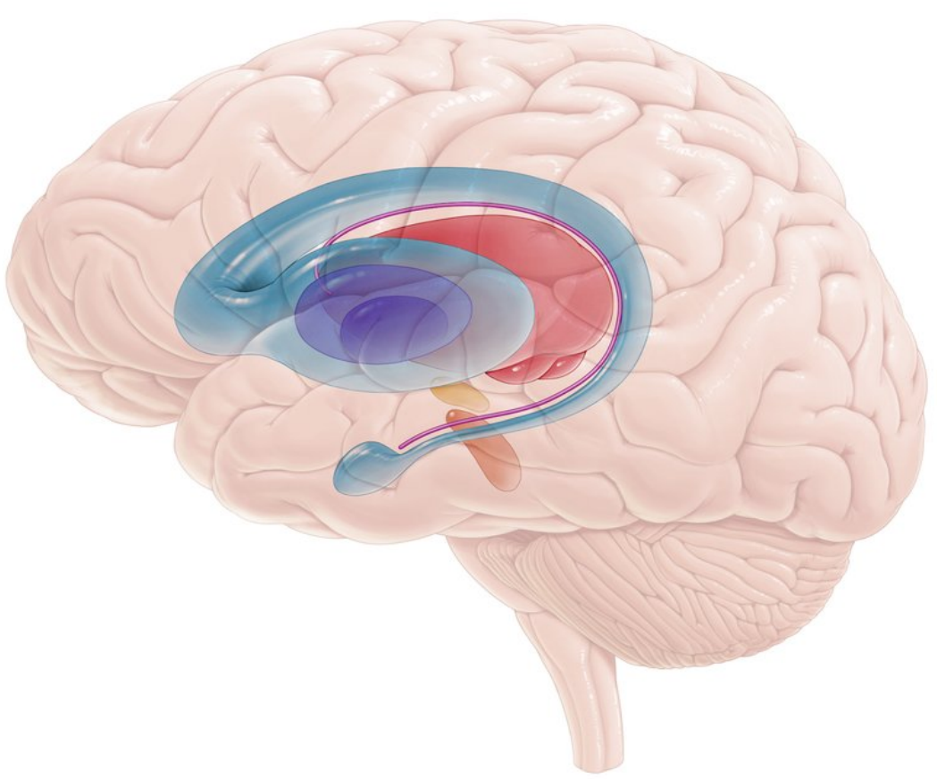
Adolescence is a time of increased independence, leading to changes in decision making, learning, and memory. Cognitive changes in adolescence are supported by brain development in earlier-developing reward-sensitive regions like the striatum which promote risk-taking and later-developing prefrontal cortical regions which support executive control [1]. These differences make adolescents especially sensitive to reward. To understand and study reward processing in the adolescent brain, we used magnetic resonance imaging (MRI) to measure striatal tissue iron in a developmental sample (N = 105, range 7-24 years, Mean Age = 18.71 years, N_{Female} = 57). Tissue iron accumulation acts as a proxy for dopamine synthesis, allowing us to study the relationship between dopamine, reinforcement learning, and memory [2]. MRI quality control (QC) is necessary to ensure that data acquisition and preprocessing steps were performed correctly, improving data reliability and signal to noise ratio. Specifically, we checked for alignment between expected and available data, correct segmentation of gray and white matter, accuracy of mapping from subject to standard space, presence of artifacts, and excessive motion. The goal of our research is to explore developmental changes in tissue iron and dopamine's relationship with reinforcement learning and memory. We hope to gain a better understanding of how adolescents learn and take risks and how dopamine signalling changes across development. This can help inform education methods, improve understanding of peer interaction and identity formation, and mitigate dangerous risky behaviours, such as substance use.

Background

- Adolescents experience significant changes in behaviors such as curiosity, learning and memory, and risk-taking.
- Behavioral changes in adolescence are driven by increased sensitivity to reward, and supported by brain development in regions such as the striatum [3].
- Dopamine is a key neurotransmitter involved with striatal reward signaling for learning, memory, and risk-taking. [4]
- Brain tissue iron accumulation measured via MRI has been used to study dopamine signaling [2].

Long-term study goal: Our project aims to use MRI to examine striatal tissue iron to understand changes in dopamine signaling and its impacts on reinforcement learning and memory across development.

Summer project goal: Perform literature review and quality control checks for preprocessed MRI data.

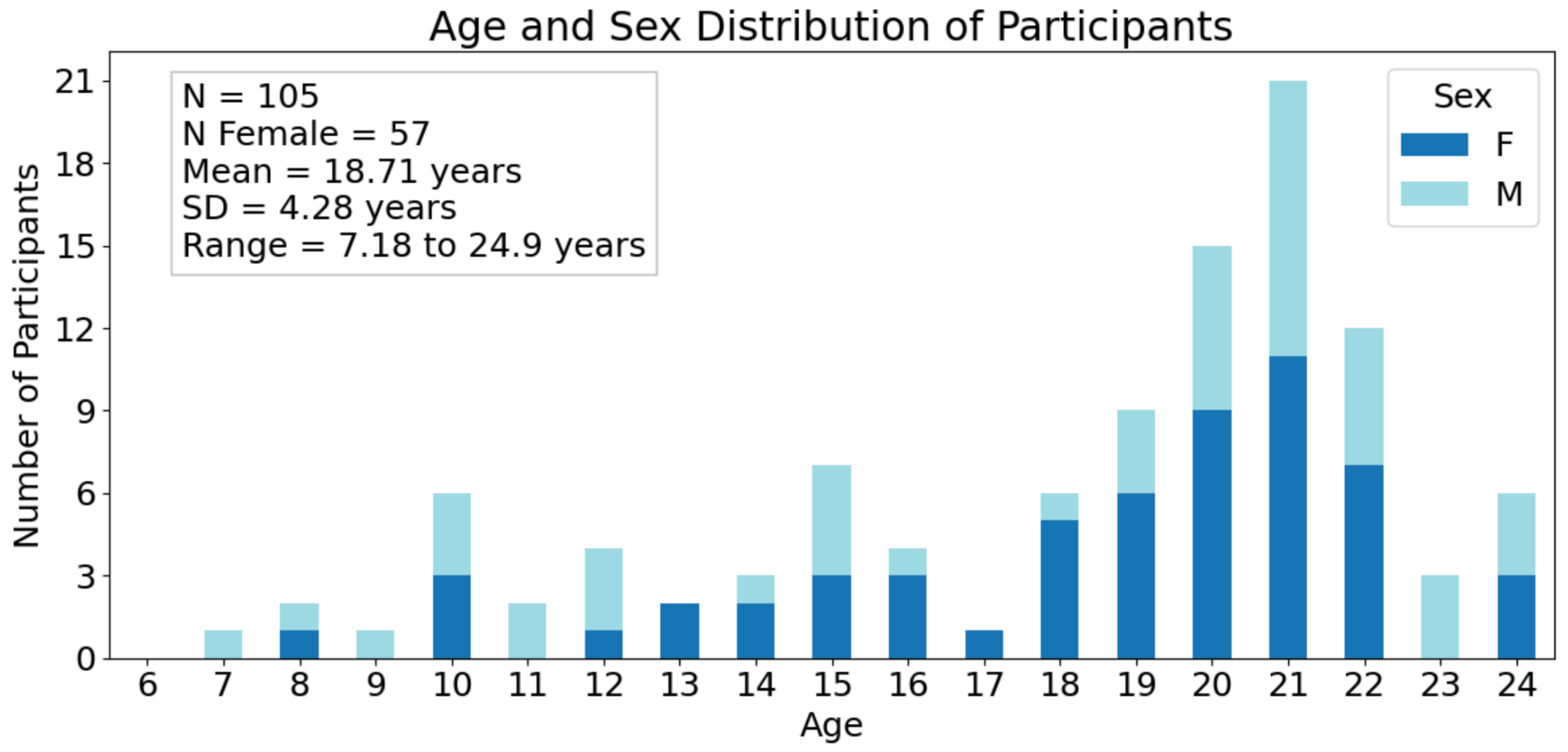


[5] The striatum is located in the basal ganglia.

Experimental Methods

1. Literature review to understand knowledge gaps.
2. MRI scans to collect brain data: structural (brain anatomy) and functional (brain activity)
3. Raw images were preprocessed using the software tool fMRIPrep [6].
4. Visual quality control checks to ensure successful fMRIPrep outputs. Unsuccessful outputs were noted via quantitative rating and qualitative comments for review and possible reprocessing or exclusion.
5. Planned analyses of tissue iron will calculate signal for each region of interest to determine how tissue iron concentrations change with age and relate to learning performance.

🟨 indicates steps taken this summer

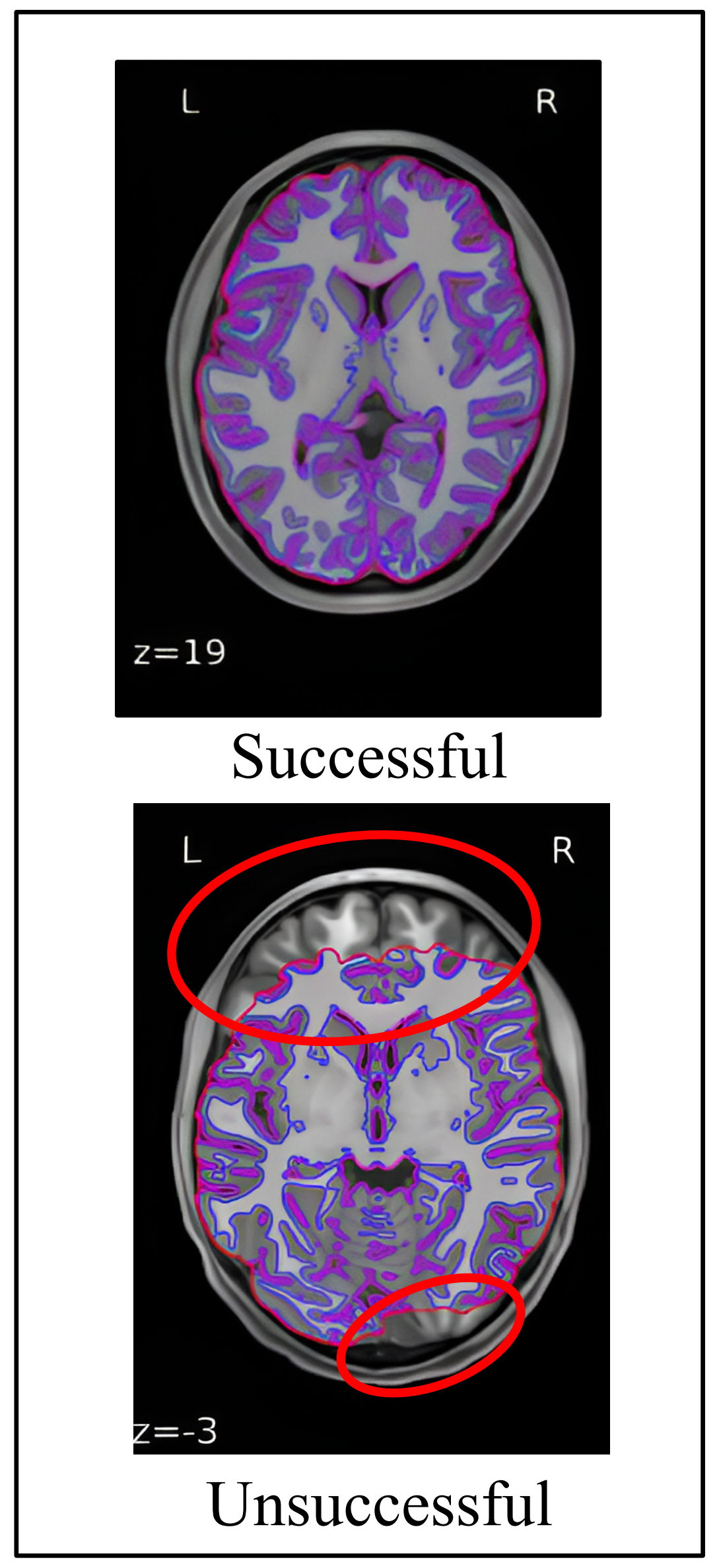


[7] Northeastern's 3T MRI Scanner, located in NUBIC.

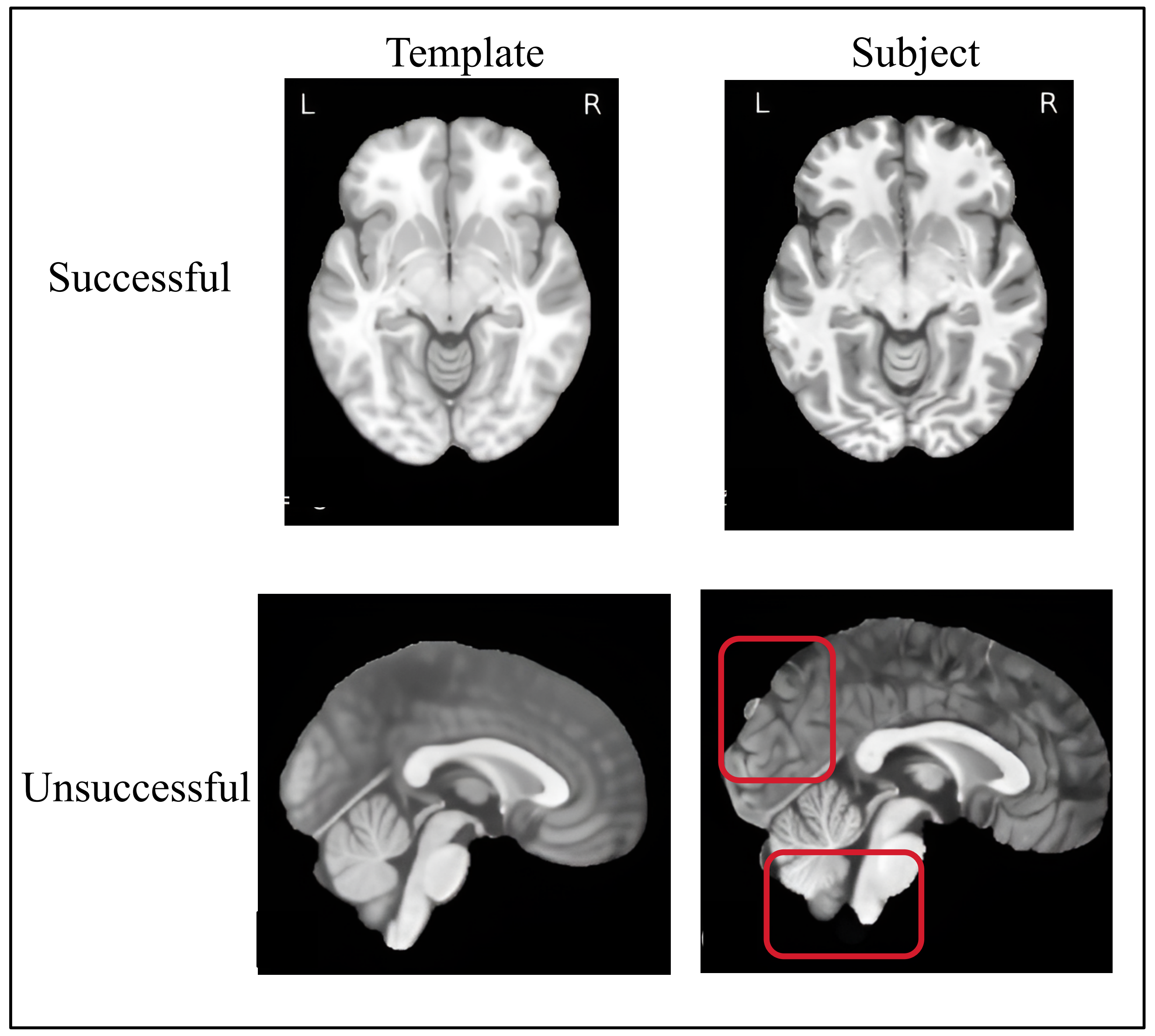
Results

Quality control ensures data reliability by identifying scanner artifacts and unsuccessful preprocessing.

Segmentation



Spatial normalization



Future Steps

- Continuing work on this project will examine how the developmental changes in tissue iron that exist throughout adolescence impact reinforcement learning and memory.
- The intellectual merits of this study are:
  - Better understanding of how adolescents learn and why they may take risks,
  - Increased knowledge about the development of different parts of the brain at different times and implications for learning and memory,
- Broader impacts of the study include: implications for education strategies, mitigating substance use, and identifying and promoting adaptive risk-taking.

References

[1] Davidow, J. Y., Insel, C., & Somerville, L. H. (2018). Adolescent Development of Value-Guided Goal Pursuit. *Trends in Cognitive Sciences*, *22*(8), 725–736. https://doi.org/10.1016/j.tics.2018.05.003
[2] Larsen, B., Olafsson, V., Calabro, F., Laymon, C., Tervo-Clemmens, B., Campbell, E., Minhas, D., Montez, D., Price, J., & Luna, B. (2020). Maturation of the human striatal dopamine system revealed by PET and quantitative MRI. *Nature Communications*, 11(1). https://doi.org/10.1038/s41467-020-14693-3
[3] Davidow, Juliet Y., Foerde, K., Galván, A., & Shohamy, D. (2016). An Upside to Reward Sensitivity: The Hippocampus Supports Enhanced Reinforcement Learning in Adolescence. *Neuron*, 92(1), 93–99. https://doi.org/10.1016/j.neuron.2016.08.031
[4] Klein, M. O., Battagello, D. S., Cardoso, A. R., Hauser, D. N., Bittencourt, J. C., & Correa, R. G. (2019). Dopamine: Functions, Signaling, and Association with Neurological Diseases. *Cellular and Molecular Neurobiology*, 39(1), 31–59. https://doi.org/10.1007/s10571-018-0632-3
[5]Alexandru Andrușca. (2015, May 26). Basal ganglia. Kenhub; Kenhub. https://www.kenhub.com/en/library/anatomy/basal-ganglia
[6] Esteban O, Markiewicz CJ, Blair RW, Moodie CA, Isik AI, Erramuzpe A, Kent JD, Goncalves M, DuPre E, Snyder M, Oya H, Ghosh SS, Wright J, Durnez J, Poldrack RA, Gorgolewski KJ. fMRIPrep: a robust preprocessing pipeline for functional MRI. *Nat Meth*. 2018; doi:10.1038/s41592-018-0235-4
[7] Equipment | Northeastern University Biomedical Imaging Center. (2025). Northeastern University Biomedical Imaging Center. https://nubic.northeastern.edu/about/equipment/

Acknowledgements

The Learning and Brain Development Lab
Juliet Davidow, Assistant Professor
Brianna Aubrey, Erica Niemiec, PhD Students
Center for STEM Education
Claire Duggan, Executive Director
Jennifer Love, Associate Director
Victoria Berry, Ahmed Othman & Dmitra Mukasa YSP Coordinators
Nicolas Fuchs, Program Manager
Mary Howley. Administrative Officer

Young Scholars Program at Northeastern University
Claire Duggan, Program Director

This work was supported by the National Science Foundation