Arrowsmith Research Initiatives Report

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Introduction

This Arrowsmith Program *Research Initiatives Report* provides an update on all ongoing studies on the Arrowsmith Program. Reports and other updates to the ongoing research will be released as they become available.

The Arrowsmith Program is founded on the principles of neuroplasticity and over 35 years of experience demonstrating that through targeted cognitive exercises, it is possible for individuals to strengthen the weak cognitive capacities underlying their specific learning difficulties.

In 2014, Arrowsmith Program's Research Team, headed by Arrowsmith Program Director, Barbara Arrowsmith Young, and Research Director, Howard Eaton, began engaging with researchers to investigate how participation in the Arrowsmith Program may alter brain function. These studies will investigate changes in the brain as well as academic, cognitive, emotional and social outcomes that occur for students engaged in the Arrowsmith Program. There is also a large body of existing research on the outcomes of individuals engaged in the Arrowsmith Program as well as some of the theoretical constructs underlying the Arrowsmith Program that date back as early as 1997. Information on all studies both existing and ongoing can be found at:

http://www.arrowsmithschool.org/arrowsmithprogram-background/research.html

The Arrowsmith Program Research Summary Document also provides an overview of both completed and ongoing research.

Arrowsmith Program Brain Imaging Study - in process

University of British Columbia - Brain Behaviour Laboratory

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http://brain.rehab.med.ubc.ca/people/investigators/ | www.brain.rehab.med.ubc.ca

Main Aim: This study represents an essential first step in expanding our understanding of how neuroplastic change may be operationalized in individuals with learning disabilities and what types of change are stimulated by the Arrowsmith Program.

The aims of the pilot study are:
1) To provide information regarding the feasibility of brain imaging in this population.

2) To generate preliminary data to power and motivate future studies of the Arrowsmith Program with larger scope.

The first aim has already been accomplished; brain imaging is feasible in this population. The second aim will be accomplished once the larger control groups are recruited and tested.

Population: In this pilot study there are currently 32 students from the Arrowsmith Program, 14 students with learning disabilities who are not in the Arrowsmith Program, and 10 students who are typically developing and do not have a learning disability. All participants in this pilot are between 9 and 17 years of age; both genders are involved.

The researchers aim to increase each control group to 30 participants.

Experimental Overview: To begin to assess how the Arrowsmith Program may alter the brain, a multiple time point design has been used to capture neuroplastic change associated with cognitive training in individuals with a learning disability.

To date, 56 participants have been enrolled in the study. Given the variability in how students learn and develop, the ability to enroll a larger sample has significantly increased the power to detect

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study are placed into three groups according to their participation and length of time in different educational programs for learning disabilities.

Group 1) students with learning disabilities enrolled in the Arrowsmith Program

Group 2) students with learning disabilities enrolled in other educational programs (e.g., Public School system, or another private school in Vancouver)

Group 3) typically developing students matched for age and sex

Each student enrolled in Groups 1 and 2 has a diagnosis of learning disability. Educational psychologists confirm the diagnosis and administer a battery of educational and cognitive tests. Multiple forms of imaging take place, including structural (T1 anatomy, myelin water imaging) and functional (resting and task-based functional MRI).

For each group, three brain imaging time points have or will take place. To date, the research team has performed interim analyses on the first 40 study participants (28 from Arrowsmith Program, 15 learning disabled controls, and 7 typically developing controls).

For students in Group One, time point one imaging took place in early 2014; time point two imaging occured in June 2014, after 3-4 months of participation in the Arrowsmith Program; time point three imaging took place in early 2015, after one academic year of participation in the Arrowsmith Program. The first round of cognitive testing was also completed in early 2014. The second round of cognitive testing was completed in early 2015, as a 1-year delay is required between many of the tests being employed.

Imaging Protocol: The pre-post brain imaging approach enables consideration of the influence of the Arrowsmith Program on: 1) brain structure, specifically white matter (myelin water imaging); and 2) brain function resting state functional connectivity and event related fMRI during the Arrowsmith Program's reasoning task.

Education/Cognitive Testing: Under the direction of the educational psychologist Dr. Lapointe, study participants have completed or will complete a battery of education and cognitive tests in early 2014 (time point 1) and again in early 2015 (time point 3). This data cannot be collected at time point 2 as the tests require a 1-year interval before they may be repeated. Participants are given the option of completing testing in 1 full day with a lunch break, or over two half day sessions. Testing takes place at UBC in the quiet room within the Brain Behaviour Lab and consists of the following four assessments:

Woodcock-Johnson Test of Cognitive Abilities is a set of tests designed to provide information on cognitive abilities.

Otis-Lennon School Ability Test (OLSAT) assesses skills such as detecting likenesses and differences, recalling words and numbers, defining words, following directions, classifying, establishing sequence, solving arithmetic problems, and completing analogies.

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Canadian Achievement Test (CAT) assesses the essential learning outcomes of the following basic skill areas: reading, language, spelling, and mathematics.

Wechsler Intelligence Scale for Children (WISC) or Wechsler Adults Intelligence Scale (WAIS) generates a Full Scale IQ (FSIQ) which represents overall cognitive ability.

Data from each test will be referenced to known norms. Change in test scores between time point 1 and 3 will be calculated. These change scores will be entered into statistical tests (below) to determine if there are relationships between change in brain and behavioural function.

Statistical Plan and Power Calculations:

The current study is designed as a pilot investigation with its main purpose being to generate preliminary data that can be used for power calculations in future studies.

A secondary exploratory analysis will be run to determine whether change in cognitive or educational function correlates with altered brain function. Though recognized that this study will be underpowered to consider all possible relationships, consideration will be given to whether any changes that may be noted between brain function are paralleled by similar changes in cognitive ability. It is the intent that by assessing these preliminary data, refinement of the data collection procedures and analyses in future work will be possible.

Future Directions:

The research team hopes to continue recruiting participants to the study until the total goal of 90 participants across all three groups is achieved, as well as to continue following the students in Group One through their second year of the Arrowsmith Program. The additional study participants will be invaluable in generating enough power to detect significant differences among the students, and this data will be crucial in determining the long-term impact of the Arrowsmith Program on individuals who have received this training.

As the team works to complete the pilot study and prepare for the large-scale assessment of the Arrowsmith Program's impact on brain plasticity, interdisciplinary collaboration with the Faculty of Medicine's Human Early Learning Partnership (HELP) will also be explored. Current and future studies will advance knowledge in both education and neuroscience to further enhance the Arrowsmith Program as an educational intervention that stimulates learning in students and support them in reaching their full potential.

Resting State MRI Measures of Brain Function in Children - in process

University of Southern Illinois - Center for Integrated Research in Cognitive & Neural Sciences

Investigators:
Gregory M. Rose, PhD, Professor of Anatomy
David Gilbert, PhD, Professor of Psychology

http://www.siumed.edu/circns/profiles/rose.html | http://www.siumed.edu/circns/profiles/gilbert.html

Purpose: The purpose of this study is to determine how participation in the Arrowsmith Program may alter fMRI-assessed measures of brain function compared to students participating in a traditional education program. Resting state networks and the strength of white matter pathways will be assessed using fMRI and diffusion tensor imaging (DTI), and will be examined both within and across both study groups.

The expectation is that while both programs will result in a strengthening of resting state networks and white matter pathways, subjects enrolled in the Arrowsmith Program will experience greater changes in these measures that will correlate with accelerated academic progress.

The current study is designed as a pilot investigation to gather preliminary data that can be used in further studies. Dr. Rose and Dr. Boyd of UBC are discussing ways to collaborate in order to use some of the same imaging protocols so that data can be compared between the study at USI and UBC.

Subjects: In this study there are currently 31 participants with a mean age of 16; 18 enrolled in the Arrowsmith Program at Brehm Preparatory School located in Carbondale, Illinois, and 13 students with learning disabilities participating in a traditional learning program.

Inclusion criteria will be that the individuals be between 11 and 20 years of age. Potential subjects will receive medical history, neurological history, psychological history, drug history and metal screening questionnaires. The fMRI and DTI sessions will take place at the Memorial Hospital Imaging Center in Carbondale, IL.

Methodology: To begin to understand how the Arrowsmith Program may alter brain function, study participants will undergo three different types of scans. While subjects are in the scanner, they will undergo brain scans while focusing on a fixation crosshair.

1) Structural MRI scan

MRI scans will be acquired using an echo-planar imaging sequence sensitive to Blood Oxygenation Level Dependant (BOLD) signal. Unlike the imaging sequence used in normal MRI (to produce a structural image), EPI-BOLD assesses brain

Resting State MRI Measures of Brain Function in Children - in process

University of Southern Illinois - Center for Integrated Research in Cognitive & Neural Sciences

activation by monitoring the regional changes in blood flow correlated with neuronal activity.

2) fMRI scan to evaluate each individual's resting state network activity

3) Diffusion Tensor Imaging (DTI) scanning protocol to allow visualization of white matter pathways in the brain that connect brain regions

Data collected from this study will be published in journal articles and presented at scientific conferences.

The Impact of a Cognitive Intervention Program in Adults With Traumatic Brain Injury - in process

University of British Columbia - Djavad Mowafaghian Centre for Brain Health, Faculty of Medicine

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http://pal.rehab.med.ubc.ca/

Main Aim: The main aims of this study are to unravel the complex changes in the brain and human behaviour following traumatic brain injury (TBI) and to evaluate the effectiveness of an innovative educational intervention—the Arrowsmith Program—in identifying and stimulating change in cognitive function.

Population: In this preliminary study 12 participants who have sustained a non-penetrating mTBI at least three months previously have volunteered to participate. Four age- and sex-matched healthy controls have also been tested.

Experimental Overview: This unique multi-modal approach, which uses a combination of novel and current neuroimaging tools combined with targeted clinical and neuropsychological assessments, will lead to the development of a brain signature of TBI that can be used diagnostically to predict functional outcomes and evaluate the effectiveness of intervention.

The research team expects that fluid cognition will be impacted to a greater extent than crystallized cognition following brain injury and that this measure will also be more reflective of changes due to learning/intervention.

Scans on six participants with TBI have been completed at baseline and the three-month follow up. The age- and sex-matched healthy controls were also scanned. Five minutes of resting state EEG was collected on all 12 participants at baseline and at the three-month follow up.

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Imaging Protocol: All participants will undergo pre-post brain imaging using the following neuroimaging techniques: high resolution anatomical MRI, diffusion tensor imaging, functional MRI (fMRI), myelin water imaging and resting state electroencephalogram (EEG).

Myelin water imaging is a relatively new technique capable of resolving the fraction of water molecules that are located between the layers of myelin. This technique has shown tremendous promise in investigating both normal and pathological brain myelination. Since myelin plays a key role in speeding up the propagation of nerve signals in the brain, myelin damage results in impaired brain function.

Education/Cognitive Testing: Under the direction of the educational psychologists Ivan Torres and William Panenka, the cognitive function of all participants will be evaluated using the NIH Toolbox Cognitive Battery. The battery assesses fluid cognition (the capacity for new learning and information processing in novel situations, especially influenced by biological processes and less dependent on past exposure) and crystallized cognition (representing an accumulated store of verbal knowledge and skills and is thus more heavily influenced by education and cultural exposure).

Future Directions: Dr. Virji-Babul and her research team hope to expand the sample size of the intervention group to 20 participants and to recruit a control group of adults with TBI who will not be involved in the intervention, allowing for critical comparisons to determine if the changes seen in the intervention group can be linked with the intervention and not to other factors.