

Arrowsmith Program

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Arrowsmith Program Research Summary 2019

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Introduction

Research is an organized and systematic method of exploring questions. It is defined in a number of different ways with a general agreement that it is a process of investigation that follows certain steps in order to further knowledge in an area.

Research in the field of neuroscience led to the formulation of a series of questions posed by Barbara Arrowsmith Young, which Arrowsmith Program has been investigating since 1977.

These initial questions were based on 2 lines of research.

The first: A. R. Luria's work in Russia investigating the identification of the function of different regions of the brain and 'functional systems' (Luria's term) which are now called neural networks.

The second: Mark Rosenzweig's work at Berkeley looking at stimulation leading to neurophysiological changes with resultant improvement in learning (the brains of rats exposed to an enriched and stimulating environment changed physiologically and these animals were able to learn mazes more quickly). This is neuroplasticity – stimulation leading to brain change with resultant learning and behaviour changes.

The questions posed by Barbara Arrowsmith Young: If one could understand the nature of a cognitive function, through studying Luria's work, could one create a task that targets and works that function – what Rosenzweig called 'targeted differential stimulation'? Would working on that task repetitively with a graduated increase in complexity, accuracy and speed of performance lead to neuroplastic change in the brain? Would these changes in the brain lead to changes in learning processes?

Arrowsmith Young was highly motivated to investigate these questions as she was seeking a solution to her significant learning difficulties – and so three exercises were born out of her specific need – Symbol Relations, Spatial Reasoning and Kinesthetic Perception. She was the first Arrowsmith student.

The summary of the research journey that follows answers these questions posed over 40 years ago. The research is categorized as follows:

- A. Academic Outcomes
- B. Cognitive Outcomes
- C. Social, Emotional and Behavioural Outcomes
- D. Brain Imaging Outcomes

A. Academic Outcomes

Rate of Learning

Toronto Catholic District School Board (Canada)

This study conducted in 2007, investigated the rate of acquisition of a series of academic skills for 60 learning disabled students in grade 3 to 9 in seven schools in the Toronto Catholic District School Board. The skills measured were word recognition (the ability to read words accurately); reading speed; reading comprehension; and arithmetic.

Prior to the start of the study, all of these students were receiving a full day of academic classes with special education academic remedial support. Standardized measures, on average, showed that these students were acquiring academic skills at a rate of .5 to .6 of a grade per year. These students then enrolled in the Arrowsmith Program and over the course of the year of the study, engaged in cognitive exercises designed to strengthen their weak learning capacities for 50% of their school day and academic curriculum for the other 50% of the day. At the end of this one year, on standardized measures, these students' rate of learning doubled and, in some cases, tripled.

Data was also collected on 50 of the original student subjects after two years in the Arrowsmith Program, and these gains in rate of learning continued.

The average increase in the rate of acquisition of specific academic skills for students from prior to participation in the Arrowsmith Program compared to the results after one to two years in the program was as follows:

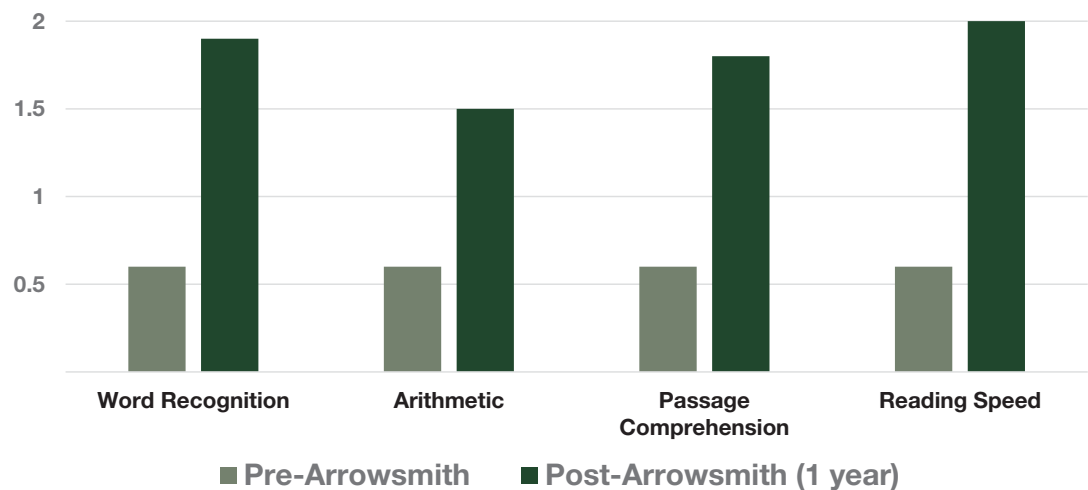
- Word Recognition - 3 times faster
- Arithmetic - 1.5 to 2 times faster
- Reading Comprehension - 2 to 3 times faster
- Reading Speed - 2 to 3 times faster

These gains were supported by student, teacher and parent observations of improvement in these academic areas which appear in the extended report.

Conclusion: Arrowsmith cognitive programs designed to strengthen underlying learning capacities for students with learning disabilities lead to an increased rate of acquisition of academic skills over the course of one and two academic years despite exposure to 50% less academic curriculum.

Cognitive Enhancement: Impact on Rate of Learning

Average grade gain per year prior to Arrowsmith and at the end of one year in the Arrowsmith Program at the Toronto Catholic District School Board (TCDSB)



Rate of learning accelerates after one year of Arrowsmith Program exercises; 60 students in grades 3 to 9 (majority of students in grades 4 to 8) Report on the Arrowsmith Program in the Toronto Catholic District School Board, 2007

Academic Achievement

University of Calgary (Canada)

This study in 2014 examined the effects of Arrowsmith on academic performance over one school year for students identified as having learning disabilities enrolled at Arrowsmith School in Toronto. Dr. Brad Hale’s research team in the Brain Gain Lab at the University of Calgary conducted the study. Each day the students received one period of English and one period of mathematics and six periods of cognitive programs to strengthen the weak cognitive capacities underlying their learning disabilities.

The results of outcomes on academic measures on the Woodcock Johnson Tests of Achievement were presented in a peer-reviewed poster session at the 2014 Canadian Psychological Association Conference in Vancouver.

For students engaged in the Arrowsmith cognitive exercise program statistically significant gains were found in the following measures of academic achievement: word recognition; reading fluency; reading comprehension, word attack (blending sounds into words); math calculation; math fluency; quantitative concepts; spelling; writing fluency; writing samples; understanding directions.

Conclusion: The researchers’ conclusion was: “Strengthening cognitive/neuropsychological functions presumed to underlie academic achievement deficits improves reading, mathematics, and writing by targeting the cause (cognitive deficit) rather than the symptoms (achievement deficit).”

Effects of the Arrowsmith Program on Academic Performance

Pre-Post Mean Differences on WJ-III Achievement Tests

Cluster	Subtest		Mean (SS)	t	P
Reading	Letter Word Identification	Pre	87.80	5.57	< .001
		Post	98.33		
	Reading Fluency	Pre	81.50	8.48	< .001
		Post	90.14		
	Passage Comprehension	Pre	85.53	8.85	< .001
		Post	96.20		
Mathematics	Word Attack	Pre	88.53	5.21	< .001
		Post	101.93		
	Calculation	Pre	82.47	11.69	< .001
		Post	94.13		
	Math Fluency	Pre	72.47	6.61	< .001
		Post	84.07		
Writing	Quantitative Concepts	Pre	87.60	6.20	< .001
		Post	101.27		
	Spelling	Pre	81.93	5.40	< .001
		Post	91.00		
	Writing Fluency	Pre	74.85	8.15	< .001
		Post	94.69		
Receptive Language	Writing Samples	Pre	84.73	7.48	< .001
		Post	100.80		
	Understanding Directions	Pre	93.07	4.62	< .001
		Post	98.02		

Academic Achievement

University of British Columbia (Canada)

This study in 2016 investigated the academic outcomes for students in their first year of the Arrowsmith Program at three schools, one in the United States and two in Canada. Each day, these students were receiving two academic periods (one of English and one of mathematics) and six periods of cognitive programs designed to address their learning disabilities.

The research was conducted by Dr. Lara Boyd and Dr. Rachel Weber at the University of British Columbia. Student performance in September was compared to performance in May (one academic year) on the Woodcock Johnson Tests of Achievement.

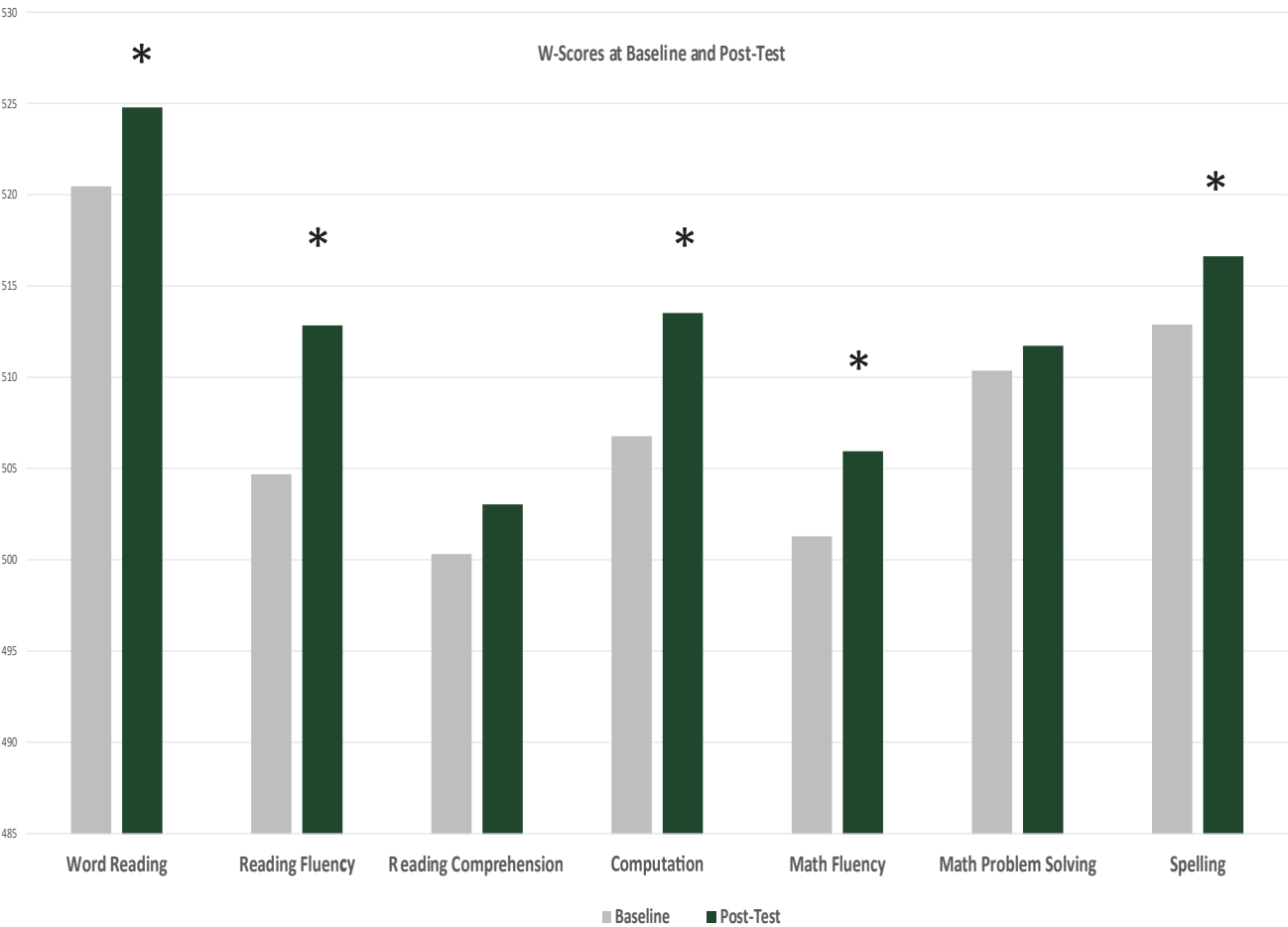
This research was presented in a peer-reviewed poster session at the 2019 International Neuropsychological Society conference in New York City and was published October 2019 in the peer-reviewed journal [Learning: Research and Practice](#).

Significant positive academic achievement gains were found on the following measures of academic achievement:

- Word Reading
- Reading Fluency
- Computation
- Math Fluency
- Spelling

Conclusion: Students with learning disabilities participating in the Arrowsmith cognitive programs over an academic year demonstrated significant gains in academic performance on standardized measures.

RESULTS –ACADEMIC ACHIEVEMENT IMPROVEMENT



Academic Achievement

University of Southern Illinois (United States)

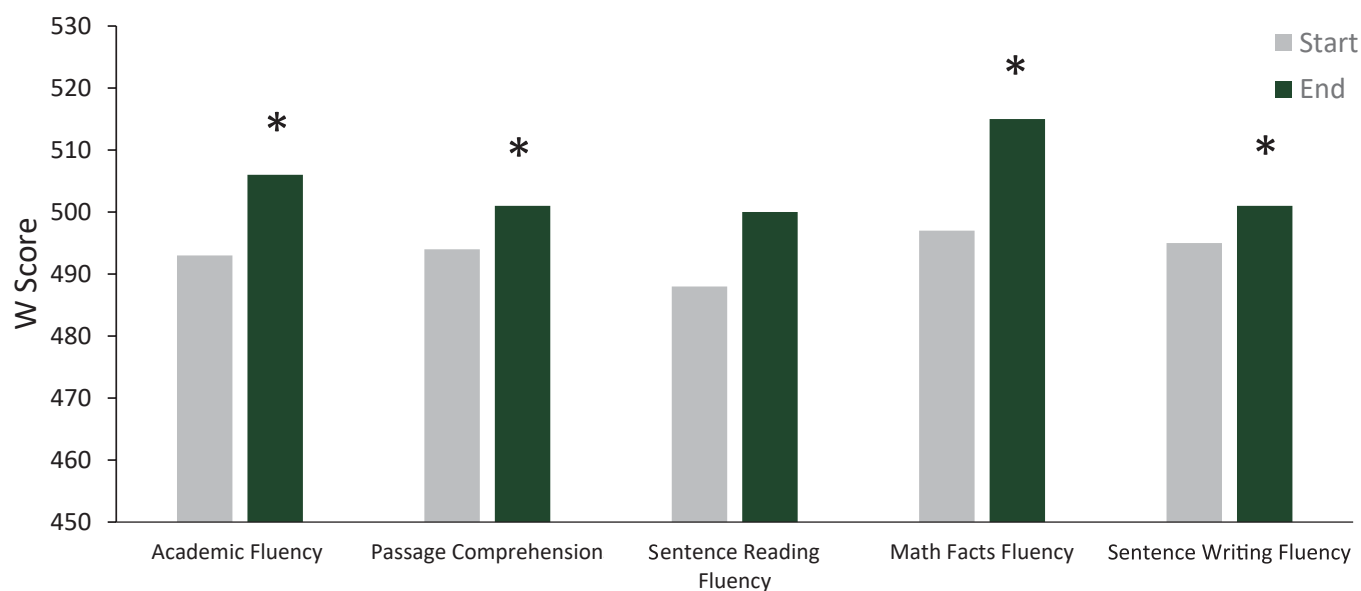
This study investigated the academic outcomes over the 2017-2018 school year for students identified as having learning disabilities. These students were in their first year of the Arrowsmith Program at two schools in Canada. Each day these students received one period of English and one period of mathematics and six periods of cognitive programs designed to strengthen the weak cognitive capacities underlying their learning disabilities. The study was conducted by Dr. Gregory Rose and Dr. Audreyana Jagger-Rickels of the University of Southern Illinois. Student performance in September was compared to performance in May on the Woodcock Johnson Tests of Achievement. Changes on all tests noted with an asterisk on the graph below were at statistical significance.

Significant positive academic achievement gains were found on the following measures of academic achievement:

- Passage Comprehension
- Academic Fluency
- Math Facts Fluency
- Sentence Writing Fluency

Conclusion: Students with learning disabilities participating in the Arrowsmith cognitive programs over an academic year demonstrated significant gains in academic performance on standardized measures.

Cognitive Program Improves Academic Achievement Test Performance (Woodcock Johnson IV)



Overall $p < 0.0001$; * $p < 0.05$ for individual tests

Academic and Learning Behaviours

Toronto Catholic District School Board (Canada)

A study in 2007 was conducted on students in the Arrowsmith Program in the Toronto Catholic District School Board (TCDSB). These students were in grades 3 to 9 in seven schools and all were identified by the school board as having learning disabilities. As part of the study, students, parents and teachers rated change on a range of student behaviours over the course of a year in the program. The results on behaviours related to academic skills and general learning abilities appear in the following chart. The number of individuals rating each item appear beside each rater for that item.

Parents, students and teachers all reported noticeable change on:

- academic behaviours (reading comprehension, legibility of written work, reads for pleasure, understanding ideas, remembering factual information, willingness to attempt/complete homework, understanding & following instructions, telling time)

- general behaviours required for learning (ability to focus, listening skills, organizational skills)

Conclusion: Students in the Arrowsmith Program showed noticeable change on academic and general behaviours required for learning over the course of a school year.

IMPROVEMENT RATING

OF THOSE FOR WHOM THIS WAS A CONCERN

% Never A Concern

% No Change

% Noticeable Change

% Extremely Noticeable Change

Ability to Focus

Student Rating	n=42	12%	7%	65%	16%
Parent Rating	n=62	5%	11%	60%	24%
Teacher Rating	n=55	13%	7%	53%	27%

Understanding / Following Instructions

Student Rating	n=41	5%	10%	53%	32%
Parent Rating	n=54	4%	9%	67%	20%
Teacher Rating	n=55	7%	0%	62%	31%

Listening Skills

Student Rating	n=42	14%	10%	55%	21%
Parent Rating	n=47	4%	17%	60%	19%
Teacher Rating	n=54	18%	2%	54%	26%

Organizational Skills

Student Rating	n=42	14%	14%	51%	21%
Parent Rating	n=45	2%	22%	56%	20%
Teacher Rating	n=55	11%	4%	56%	29%

Willingness to Attempt/ Complete Homework

Student Rating	n=42	10%	7%	50%	33%
Parent Rating	n=58	1%	9%	43%	47%
Teacher Rating	n=55	13%	7%	42%	38%

Remembering Factual Information

Student Rating	n=42	10%	10%	47%	33%
Parent Rating	n=55	4%	12%	57%	27%
Teacher Rating	n=55	4%	5%	60%	31%

Understanding Ideas

Student Rating	n=42	12%	7%	60%	21%
Parent Rating	n=58	5%	10%	57%	28%
Teacher Rating	n=55	7%	2%	56%	35%

Legibility of Written Work

Student Rating	n=42	5%	12%	50%	33%
Parent Rating	n=53	2%	15%	49%	34%
Teacher Rating	n=54	13%	4%	55%	28%

Reading Comprehension

Student Rating	n=42	12%	7%	44%	37%
Parent Rating	n=57	14%	7%	58%	21%
Teacher Rating	n=54	2%	7%	41%	50%

Reads for Pleasure

Student Rating	n=39	13%	28%	41%	18%
Parent Rating	n=54	7%	39%	34%	20%
Teacher Rating	n=54	7%	20%	43%	30%

Telling Time

Student Rating	n=41	17%	7%	17%	59%
Parent Rating	n=51	14%	18%	31%	37%
Teacher Rating	n=54	4%	7%	37%	52%

Average Academic Growth

Holy Trinity Parish Schools (Australia)

This study in 2015 investigated the average academic growth over a school year on academic measures for students in an Arrowsmith Program compared to those in mainstream academic curriculum.

Students at Holy Trinity Parish Schools in Australia undergo standardized testing on measures of Mathematics and Reading Comprehension. These measures, designed by the Australian Council for Education Research, are administered at the beginning and end of the school year for each grade. The average growth in academic skills is calculated for the students in each grade based on their performance over the course of one school year on these measures. The ‘average academic growth’ is the average gain these students make in each grade on these academic measures. The results over the course of the academic year for students in grade 3, grade 4 and grade 5 for students identified as having learning

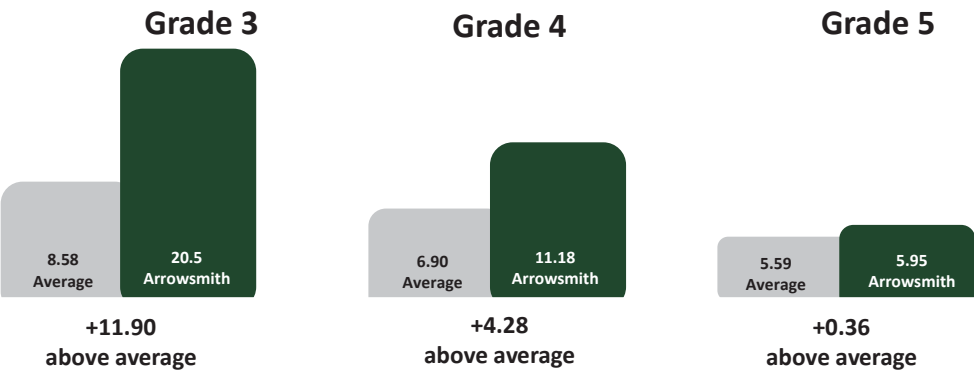
disabilities and enrolled in the Arrowsmith Program who received 50% less academic curriculum were compared to those of all students in the regular academic classes receiving full day academic curriculum. In each grade the students receiving the Arrowsmith cognitive programs showed greater average academic growth on the standardized measures of Mathematics and Reading Comprehension.

Conclusion: Students with learning disabilities participating in the Arrowsmith cognitive programs designed to strengthen underlying learning capacities had greater average growth on standardized measures of Mathematics and Reading Comprehension than students in regular academic classrooms over the course of one academic year. The Arrowsmith group made these gains while involved in 50% less academic curriculum.

Average Student Growth

ACER* – MATHS PLUS TEST

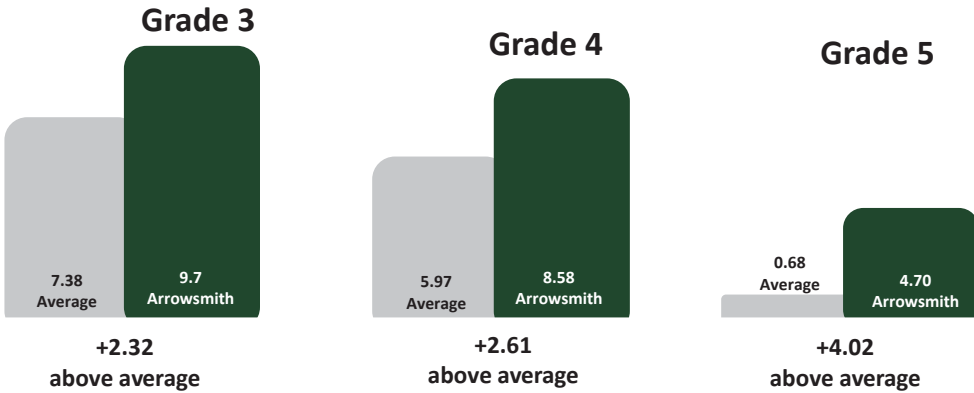
(*Australian Council for Education Research)



Average Student Growth

ACER* – PAT R TEST (Reading Comprehension)

(*Australian Council for Education Research)



Written Proficiency

Motor Symbol Sequencing Whole Cohort Study (Australia)

This study in 2016 investigated the outcomes of implementing the Arrowsmith cognitive program to improve motor planning (Motor Symbol Sequencing) over the course of one academic year with students in grade one in a public school in Australia.

There were four grade 1 classes. The WOLD Sentence Copying Test, a standardized measure that looks at writing proficiency, was administered at the beginning and end of the grade 1 academic year. One class completed 30 minutes per day five days per week over the academic year of the Arrowsmith Program Motor Symbol Sequencing program (MSS) designed to improve motor planning related to reading and writing. The other three grade 1 classes received traditional writing programs.

The study compared the number of students at or above grade level in terms of written proficiency based on test scores at the

beginning of the year and at the end of the year. The students receiving 30 minutes per day of the Motor Symbol Sequencing program showed the greatest improvement in written proficiency over the course of the year.

Five students, identified in kindergarten as being ‘at risk’ for reading problems and requiring reading intervention, were enrolled in the class receiving the MSS program. After 10 weeks in the program their reading improved significantly, and they were no longer considered ‘at risk’ for reading problems.

Conclusion: 30 minutes of cognitive intervention designed to improve motor planning related to writing and reading leads to significant improvement in writing proficiency for students in grade one.

Whole Cohort Cognitive Enhancement – Grade 1

Student Results	Arrowsmith Class		Gifted Class		Academic Class 1		Academic Class 2	
	Pre Test	Post Test	Pre Test	Post Test	Pre Test	Post Test	Pre Test	Post Test
Number of students at or above grade level								
%:	10%	95%	30%	70%	35%	45%	5%	45%
% Change:		85%		40%		10%		40%

- Comparison of results across four Grade One classes
- 3 classes: traditional handwriting program
 - 1 class: 30 minutes/day doing the Arrowsmith exercise for learning motor plans necessary for writing

B. Cognitive Outcomes

University of Calgary (Canada)

This study in 2014 examined the effects of Arrowsmith on cognitive outcomes over one school year for students identified as having learning disabilities enrolled at Arrowsmith School in Toronto. Dr. Brad Hale’s research team in the Brain Gain Lab at the University of Calgary conducted the study. Each day, the students received one period of English and one period of mathematics and six periods of cognitive programs to strengthen the weak cognitive capacities underlying their learning disabilities.

The results of outcomes on cognitive measures on the Woodcock Johnson Tests of Cognitive Ability were presented in a peer-reviewed poster session at the 2014 American Psychological Association Conference in Washington, D.C.

For students engaged in the Arrowsmith cognitive exercise program statistically significant gains were found in the following cognitive measures: auditory processing (sound blending); fluid reasoning (concept formation); processing speed (visual matching and decision speed); short-term memory (numbers reversed and memory for words); phonemic awareness (incomplete words); and working memory (auditory working memory).

Conclusion: The researchers’ conclusion was: “Targeted and individualized interventions designed to remediate cognitive deficits lead to improved academic performance across a broad range of domains [and that] brain plasticity allows for restructuring of cognitive processes, thereby enabling improved cognition and academic performance.”

Effects of the Arrowsmith Program on Cognition

Pre-Post Mean Differences on WJ-III Cognitive Abilities

CHC Factor	Subtests	Mean (SS)		t	P	
Auditory Processing	Sound Blending	Pre	102.00	2.01	< .001	Significant Improvements in • Auditory Processing • Fluid Reasoning • Processing Speed • Short-Term Memory • Phonemic Awareness • Working Memory Children showed significant improvement across cognitive domains
		Post	115.87			
Fluid Reasoning	Concept Formation	Pre	103.73	5.61	< .001	
		Post	114.27			
Processing Speed	Visual Matching	Pre	69.47	12.92	< .001	
		Post	89.00			
	Decision Speed	Pre	79.87	5.85	< .001	
		Post	95.47			
Short-Term Memory	Numbers Reversed	Pre	87.33	5.14	< .001	
		Post	96.87			
	Memory for Words	Pre	94.20	7.27	< .001	
		Post	111.67			
Phonemic Awareness	Incomplete Words	Pre	84.73	6.06	< .001	
		Post	102.80			
Working Memory	Auditory Working Memory	Pre	96.20	4.40	< .001	
		Post	101.80			

University of British Columbia (Canada)

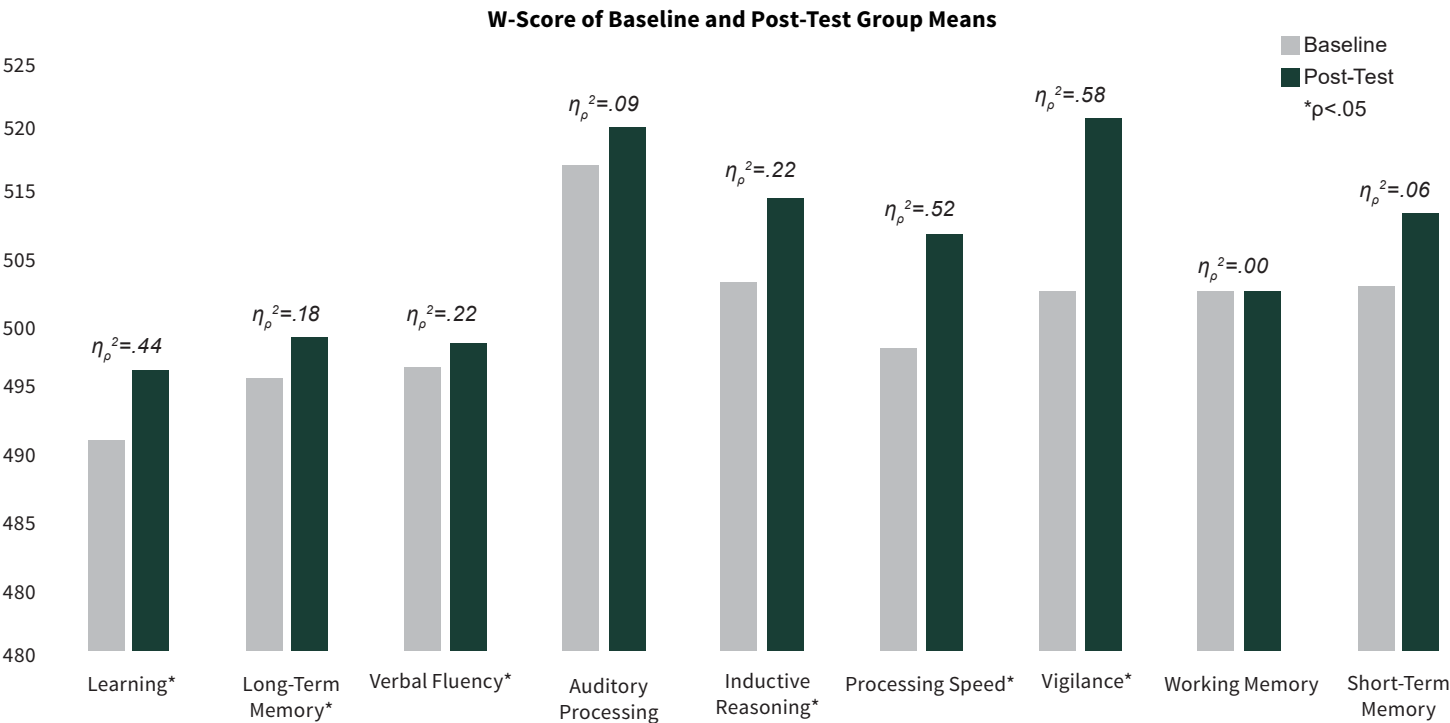
This study in 2016 was conducted by Dr. Lara Boyd and Dr. Rachel Weber at the University of British Columbia on students in their first year of the Arrowsmith Program at three schools, one in the United States and two in Canada. Each day these students were receiving two academic periods (one of English and one of mathematics) and six periods of cognitive programs designed to address their learning disabilities.

Student performance in September was compared to performance in May (one academic year) on the Woodcock Johnson Tests of Cognitive Ability. Changes on all tests noted with an asterisk were at statistical significance. This research was presented in a peer-reviewed poster session at the 2019 International Neuropsychological Society conference in New York City and was published October 2019 in the peer-reviewed journal [Learning: Research and Practice](#).

Significant positive cognitive ability gains were found on the following cognitive measures:

- Learning (Verbal-Auditory Learning)
- Long-term Memory (Verbal-Auditory Learning Delayed)
- Verbal Fluency (Retrieval Fluency)
- Inductive Reasoning (Concept Formation)
- Processing Speed (Decision Speed)
- Vigilance (Pair Cancellation)

Conclusion: Students with learning disabilities participating in the Arrowsmith cognitive programs over an academic year demonstrated significant gains in cognitive abilities on standardized measures.



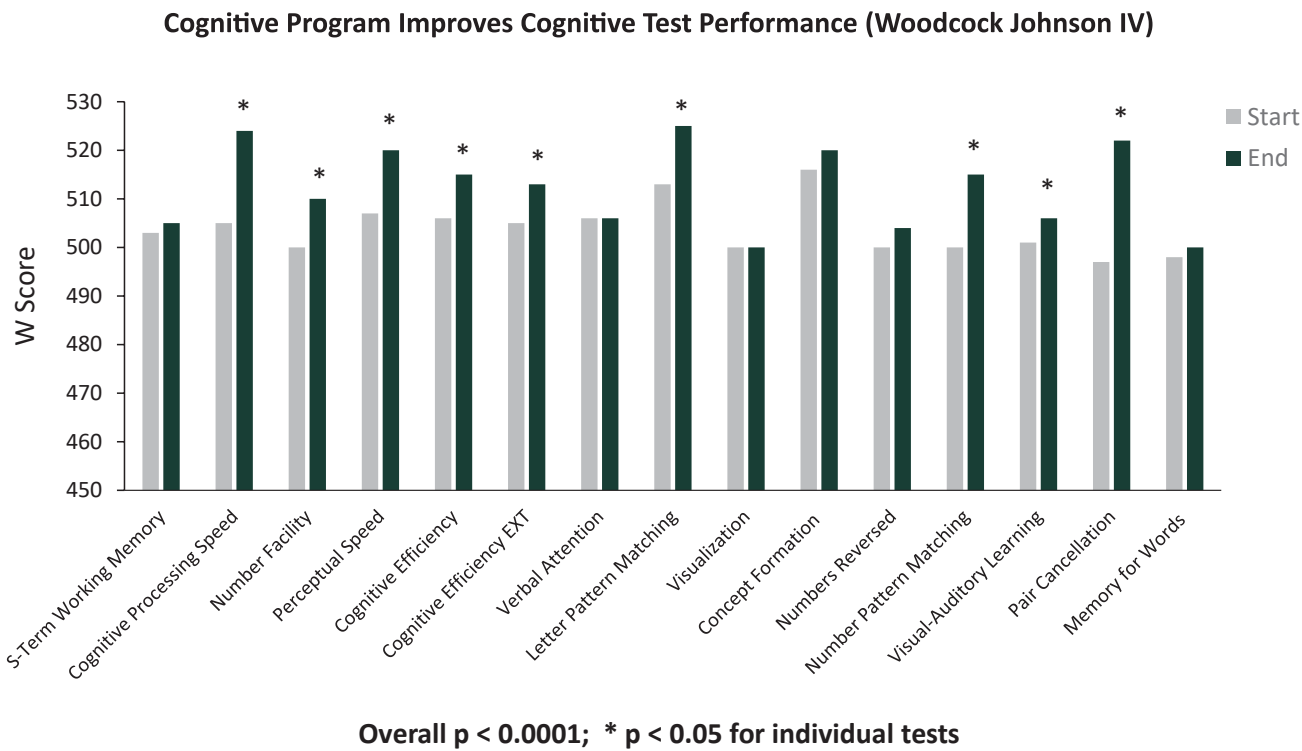
University of Southern Illinois (United States)

This study investigated the cognitive outcomes over the 2017-2018 school year for students identified as having learning disabilities. These students were in their first year of the Arrowsmith Program at two schools in Canada. Each day these students received one period of English and one period of mathematics and six periods of cognitive programs designed to strengthen the weak cognitive capacities underlying their learning disabilities. The study was conducted by Dr. Gregory Rose and Dr. Audreyana Jagger-Rickels of the University of Southern Illinois. Student performance in September was compared to performance in May on the Woodcock Johnson Tests of Cognitive Ability. Changes on all tests noted with an asterisk on the graph below were at statistical significance.

Significant positive cognitive ability gains were found on the following cognitive measures:

- Cognitive Processing Speed
- Cognitive Efficiency
- Perceptual Speed
- Visual Auditory Learning
- Pair Cancellation
- Number Facility
- Number Pattern Matching
- Letter Pattern Matching

Conclusion: Students with learning disabilities participating in the Arrowsmith cognitive programs over an academic year demonstrated significant gains in cognitive abilities on standardized measures.



University of Southern Illinois (United States)

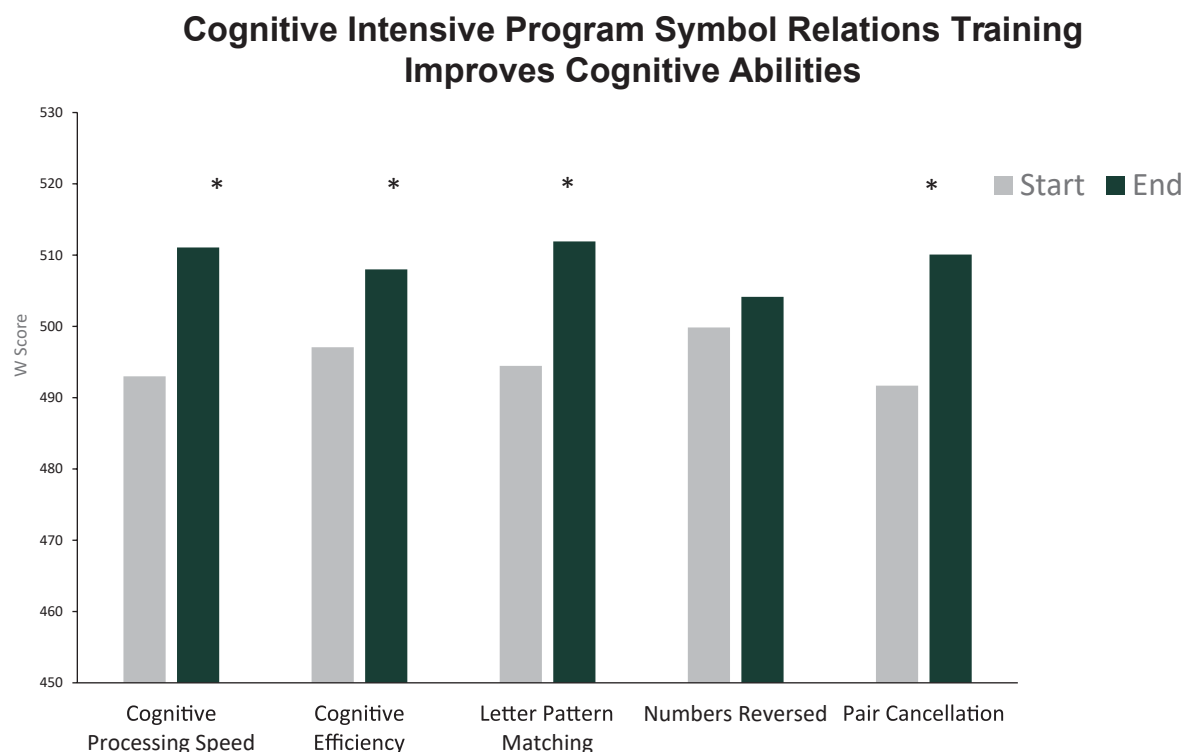
This study in 2018 was conducted to investigate the cognitive outcomes for students identified as having learning disabilities participating in the Arrowsmith 6-week Cognitive Intensive Program. In this program students work on strengthening only one cognitive function – Symbol Relations – designed to strengthen the ability to reason and process information and concepts. The study was conducted at two schools in Canada by Dr. Gregory Rose and Dr. Audreyana Jagger-Rickels of the University of Southern Illinois. The Woodcock Johnson Tests of Cognitive Ability was used and changes on all tests noted with an asterisk were at statistical significance.

Significant positive cognitive ability gains were found on the following cognitive measures:

- Cognitive processing speed
- Cognitive efficiency
- Letter pattern matching
- Pair cancellation

Parents noted these alterations in their children’s behavior: quicker comprehension; improved ability to make connections and ask relevant questions; enhanced emotional intelligence; greater understanding of events and why things happen (cause and effect); better problem solving; increased attentiveness; more flexibility of thought and taking the perspective of others; increased willingness to tackle more challenging work; and greater self-confidence.

Conclusion: Students participating in the Arrowsmith Cognitive Intensive Program over a 6-week period demonstrated significant gains in cognitive abilities on standardized measures.



Overall $p < 0.005$; * $p < 0.05$ for individual tests

University of Southern Illinois (United States)

This study in 2019 was conducted to investigate the cognitive outcomes for students identified as having learning disabilities participating in the Arrowsmith 6-week Cognitive Intensive Program. In this program students work on strengthening only one cognitive function – Symbol Relations – designed to strengthen the ability to reason and process information and concepts. The study was conducted at two schools in Canada by Dr. Gregory Rose and Dr. Audreyana Jagger-Rickels of the University of Southern Illinois. The Woodcock Johnson Tests of Cognitive Ability was used and changes on all tests noted with an asterisk were at statistical significance. This research was presented in a peer-reviewed poster session at the 2019 Society for Neuroscience conference in Chicago.

Significant positive cognitive ability gains were found on the following cognitive measures:

- Brief Intellectual Ability
- Fluid Reasoning
- Short-Term Working Memory
- Cognitive Processing Speed
- Cognitive Efficiency
- Oral Vocabulary
- Numbers Reversed
- Visual Auditory Learning

- Pair Cancellation

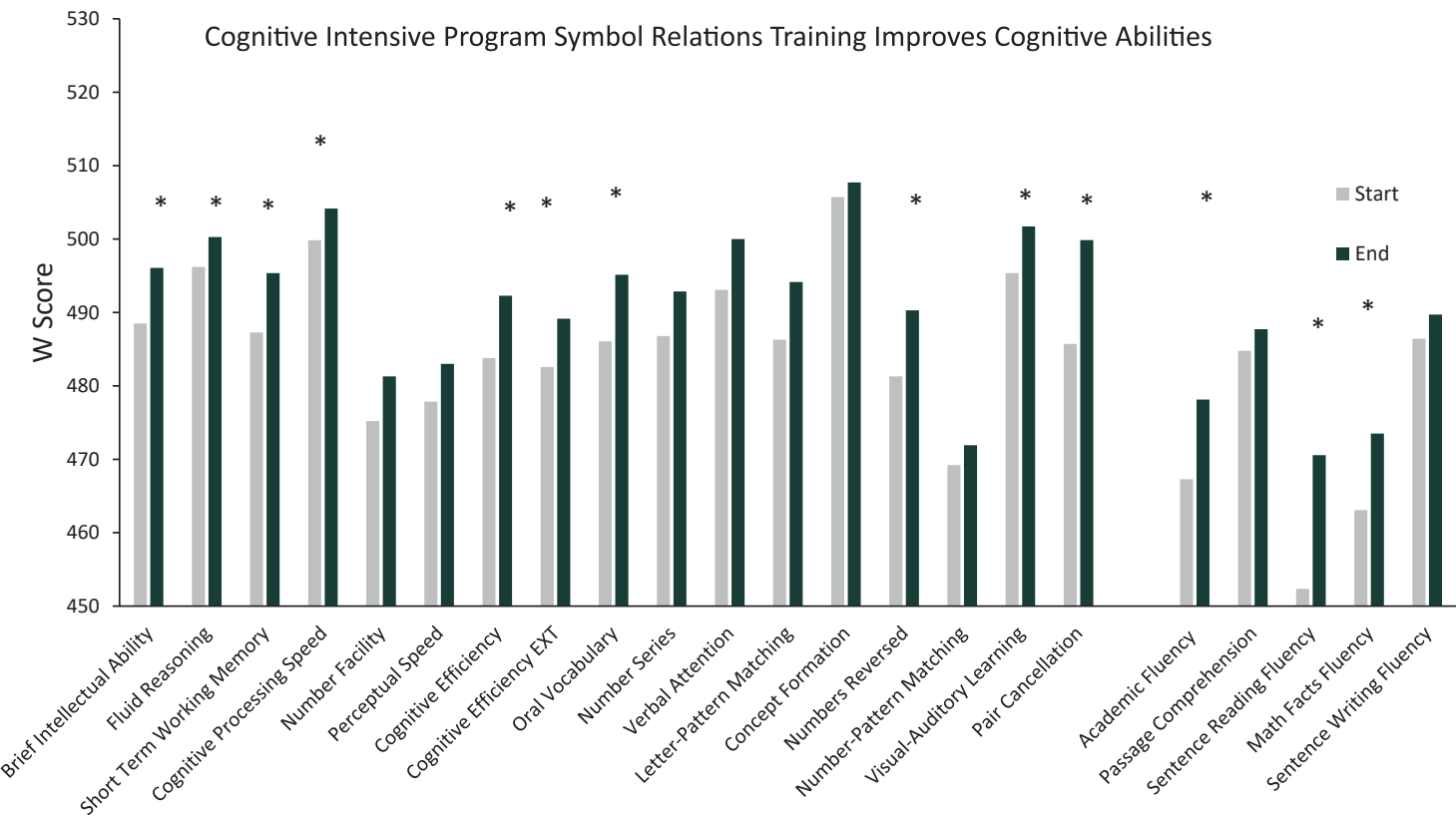
In addition for this group, three significant changes were found on these academic measures:

- Academic Fluency
- Sentence Reading Fluency
- Math Facts Fluency

Parents reported noticeable improvement in their children’s:

- Ability to comprehend more quickly
- Ability to follow conversations and make connections
- Ability to understand the rules in games and sports
- Ability to ask more relevant questions related to discussions
- Ability to see the big picture
- Ability to understand and express emotions
- Emotional intelligence

Conclusion: Students participating in the Arrowsmith Cognitive Intensive Program over a 6-week period demonstrated significant gains in cognitive abilities on standardized measures.



Overall p <0.0001; * p <0.05 for individual tests

University of Southern Illinois (United States)

As part of the study reported on page 15, parents of students in the 2019 Symbol Relations 6-week Cognitive Intensive Program were asked to complete a 50-item questionnaire to determine whether Symbol Relations training affected their child’s functioning in everyday life. This questionnaire was completed approximately three weeks after the beginning of the school year.

Responses were grouped into broad categories. Functional decline was not seen in any area. Scores for “Not a Concern” or “Can’t Tell” were not included, so percentages do not add up to 100%. “Can’t Tell” comprised approximately 50% of School Performance responses, as might be expected early in the academic year.

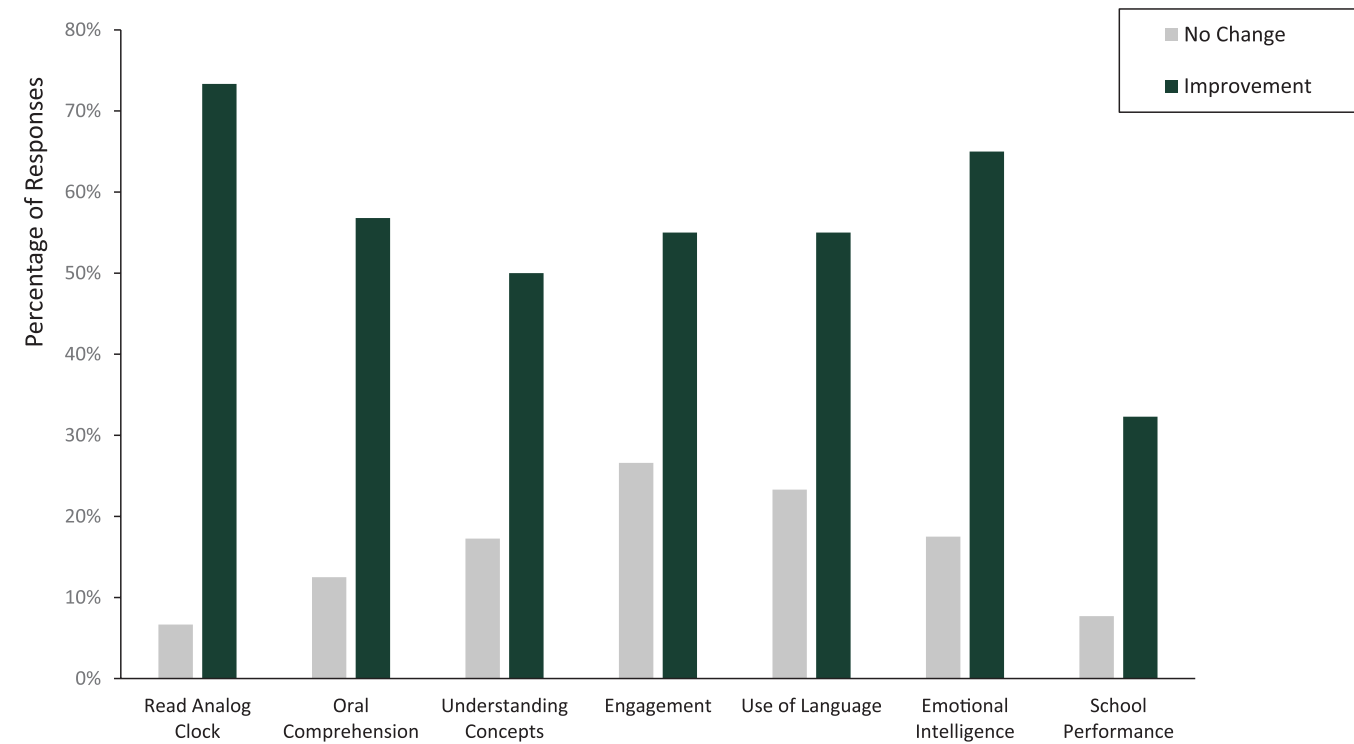
As expected, the ability to read an analog clock face showed greatest improvement. Substantial improvements were also seen across the categories evaluated:

- Oral Comprehension
- Understanding Concepts

- Engagement
- Use of Language
- Emotional Intelligence
- School Performance.

Conclusion: Parents of students participating in the Arrowsmith Cognitive Intensive Program over a 6-week period reported significant observable changes in behaviours related to cognition, learning, emotional intelligence and school performance.

Parent Observations – Symbol Relations
Cognitive Intensive Program July/August 2019



Universidad Camilo José Cela (Spain)

This study in 2016 investigated the outcomes of implementing the Symbol Relations Arrowsmith cognitive program designed to improve reasoning and processing of conceptual information with students not identified as having learning disabilities enrolled in grade 3 in a private school in Spain. These students were engaged in the Symbol Relations cognitive program 40 minutes per day five days per week for three months. They did not speak English as this program does not require students to speak English.

The research was conducted by Dr. Laura Herrero Perez and Dr. Miguel Ángel Pérez Nieto of the Universidad Camilo José Cela.

The following significant cognitive improvements were found for these students on standardized measures:

- Visual Spatial Ability
- Attention
- Planning

Conclusion: Cognitive programming for students in regular academic classes improves fundamental cognitive capacities.

C. Social, Emotional and Behavioural Outcomes

University of British Columbia (Canada)

This study in 2016 investigating social, emotional and behavioural outcomes was conducted by Dr. Rachel Weber at the University of British Columbia on students in their first year of the Arrowsmith Program at three schools, one in the United States and two in Canada. Parent ratings on The Behavior Assessment System for Children (BASC-2) were collected at the beginning and end of the school year.

This research was presented in a peer-reviewed poster session at the 2019 International Neuropsychological Society conference in New York City.

Changes were found on the following measures:

- Competence in Activities of Daily Living (ADL) - Personal Hygiene, Getting Dressed, Acts in Safe Manner, Organizes Chores, Following Routines - improved over the course of the

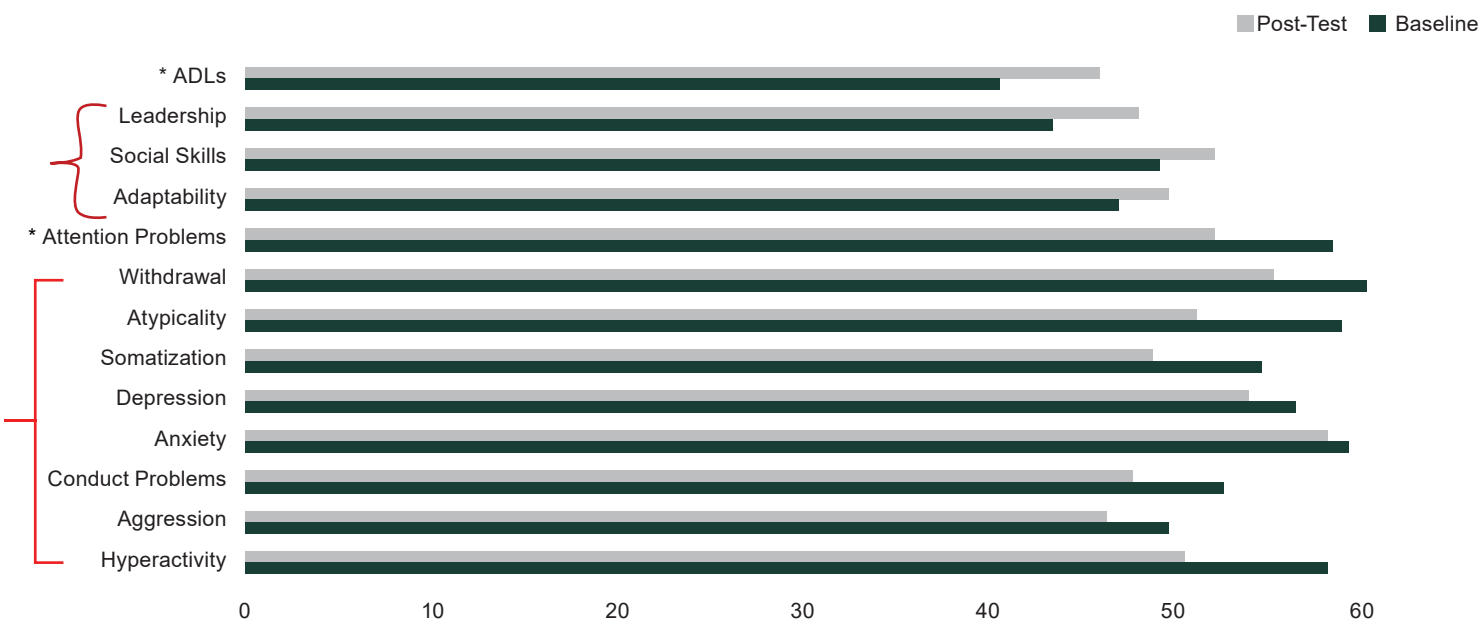
year

- Adaptive scales - Leadership, Social Skills, Adaptability - improved over the course of the year (higher scores are better)
- Maladaptive scales - Withdrawal, Depression, Anxiety, Aggression, Hyperactivity, Conduct Problems - reduced over the year (lower scores are better)
- Attention, listening well, staying focused.

All of these ratings improved over the course of the year and the ones noted with an asterisk were at a statistically significant level.

Conclusion: Parents observed significant positive social, emotional and behavioural changes in their children over the course of a year in the Arrowsmith Program

SOCIAL, EMOTIONAL AND BEHAVIOURAL OUTCOMES



University of British Columbia (Canada)

This study was conducted in 2017 by Dr. Kimberly Schonert-Reichl at the University of British Columbia on students in the Arrowsmith Program at three schools, one in the United States and two in Canada from November to May of one school year. This study examined the impact of Arrowsmith cognitive exercise on students' social and emotional health.

Significant increases were found on:

- self-report measures of happiness and well-being.

Typically, data for students without learning disabilities shows a decrease in these measures as students become more stressed over the academic year whereas Arrowsmith students are reporting they are happier and have a better sense of well-being over this time period.

- self-report measures of efficacy and incremental theory of belief (see self as agency of change and locus of control) [Click here to read about the incremental theory of the mind.](#)

A decrease was found in cortisol levels. Cortisol is a stress hormone.

These results correlate with the development of an incremental theory of intelligence, a concept developed by Carol Dweck, where the student has an open vs. fixed mindset and sees his/her effort as leading to positive results; students see themselves as an agent of change with locus of control. It is hypothesized that the Arrowsmith students are reaping the academic benefits of their improved cognitive capacities; learning is becoming easier and therefore they are feeling better about themselves, in contrast to the students not experiencing these changes and who are facing increasing academic demands as the school year progresses.

Conclusion: Between November and May students in the Arrowsmith Program reported significant increases on measures of happiness and well-being as well as in sense of efficacy. They also had decreased levels of stress as measured by a reduction in cortisol levels.

Toronto Catholic District School Board (Canada)

A study in 2007 was conducted on students in the Arrowsmith Program in the Toronto Catholic District School Board (TCDSB). These students were in grades 3 to 9 in seven schools and all were identified by the school board as having learning disabilities. As part of the study, students, parents and teachers rated change on a range of student behaviours over the course of a year in the program. The results on behaviours related to social emotional well-being appear in the following chart. The number of individuals rating each item appear beside each rater for that item.

Parents, students and teachers all reported noticeable change on:

- social emotional behaviours (growth of self-esteem, growth of confidence and willingness to try new things, frustration level, anxiety level, ability to self-advocate, attitude towards school)

Conclusion: Parents, students and teachers all reported noticeable change on social emotional behaviours over the course of a school year for students in the Arrowsmith Program.

IMPROVEMENT RATING		OF THOSE FOR WHOM THIS WAS A CONCERN			
		% Never A Concern	% No Change	% Noticeable Change	% Extremely Noticeable Change
Growth of Self Esteem					
Student Rating	n=40	17%	10%	33%	40%
Parent Rating	n=55	4%	9%	45%	42%
Teacher Rating	n=54	4%	2%	33%	61%
Growth of Confidence (trying new things)					
Student Rating	n=42	14%	7%	36%	43%
Parent Rating	n=55	2%	13%	45%	40%
Teacher Rating	n=55	5%	2%	35%	58%
Attitude toward School					
Student Rating	n=42	24%	21%	31%	24%
Parent Rating	n=53	17%	11%	38%	34%
Teacher Rating	n=55	36%	5%	26%	33%
Frustration Level					
Student Rating	n=42	20%	7%	41%	32%
Parent Rating	n=54	7%	13%	65%	15%
Teacher Rating	n=54	15%	0%	48%	37%
Anxiety Level					
Student Rating	n=42	14%	19%	38%	29%
Parent Rating	n=54	7%	13%	65%	15%
Teacher Rating	n=54	17%	4%	46%	33%
Ability to Self Advocate					
Student Rating	n=42	16%	14%	39%	31%
Parent Rating	n=54	6%	26%	52%	16%
Teacher Rating	n=44	6%	17%	46%	31%

D. Brain Imaging Outcomes

Efficiency of Processing

University of British Columbia (Canada)

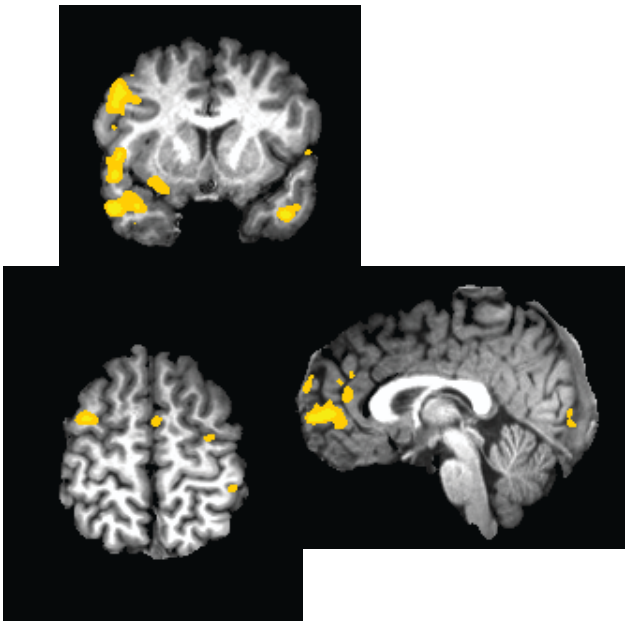
This study was conducted in 2016 by Dr. Lara Boyd at the University of British Columbia on students in their first year of the Arrowsmith Program at three schools, one in the United States and two in Canada. fMRI images were taken prior to intervention, 3 months into the Arrowsmith Program and at the end of 1 year of the program. Students were asked to do a modified Symbol Relations (reasoning) task in the scanner. This research was presented at the 2016 Columbia University Cognitive Remediation in Psychiatry conference in New York City.

Students at 3 months of the Arrowsmith Program required less regions to be activated when performing the reasoning task in the scanner. This change was also seen after 1 year.

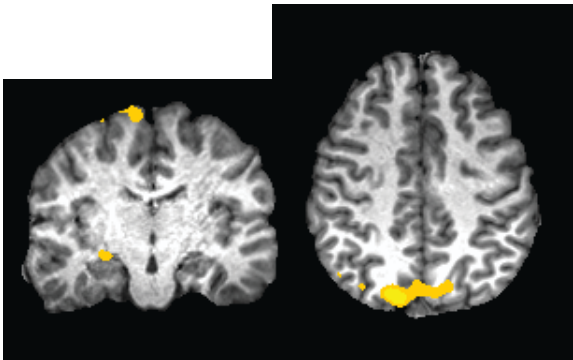
Conclusion: Students with learning disabilities involved in the Arrowsmith Program cognitive exercises demonstrated more efficient processing when completing the reasoning task at both 3 months and 1 year of the program. Less brain real estate required to perform the task reflects more efficient processing.

fMRI during the Symbol Relations/Reasoning Exercise

Time point 0



3 Months



More efficient processing

Activation of the Prefrontal Cortex

University of British Columbia (Canada)

This study was conducted in 2016 by Dr. Lara Boyd at the University of British Columbia on students in their first year of the Arrowsmith Program at three schools, one in the United States and two in Canada. fMRI images were taken while students were in a ‘resting state’, prior to intervention, 3 months into the Arrowsmith Program and at the end of 1 year of the program. This research was presented at the 2016 Columbia University Cognitive Remediation in Psychiatry conference in New York City.

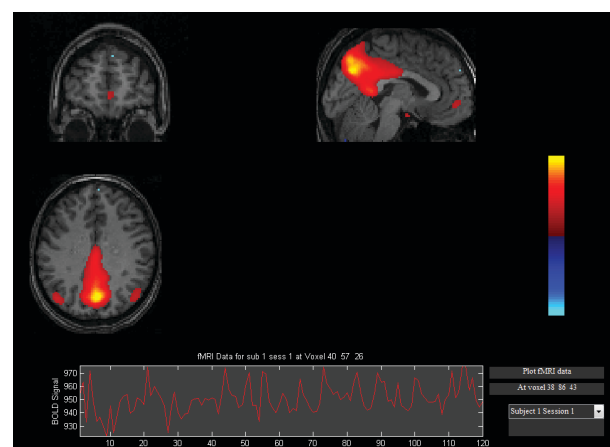
Students at 3 months of the Arrowsmith Program showed an increase in activation in the prefrontal cortex. This change was also seen after 1 year.

The prefrontal cortex is critical for problem solving, strategy generation, working memory and mental initiative in all aspects of learning so increased activation indicates improvements in these cognitive functions.

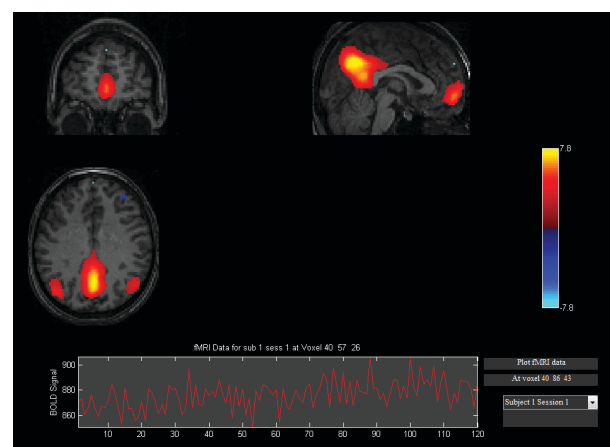
Conclusion: Students with learning disabilities involved in the Arrowsmith Program cognitive exercises demonstrated increased activation in the prefrontal cortex both at three months and at one year of the program.

Resting State Brain Activity

Time point 0



3 Months



Increased Activation in the Prefrontal Cortex

Connectivity Within and Between Brain Networks

Southern Illinois University (United States)

This study in 2016 investigated connectivity within brain networks and between brain networks in adolescents (ages 13 to 19) who did not have learning disabilities and those who did have learning disabilities. Dr. Gregory Rose and Dr. Audreyana Jagger-Rickels of the University of Southern Illinois conducted the research which was presented in a peer-reviewed poster session at the 2019 Cognitive Neuroscience Society Annual Conference in San Francisco.

When the brain networks of students identified as having learning disabilities and attending Arrowsmith were compared to students not identified as having learning disabilities the following pattern was found for the students with learning disabilities:

- A number of areas with less strong connections or under-connectivity
- A number of areas with much stronger connections or hyper-connectivity

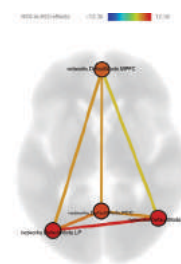
This suggests that the brain networks of the students with learning disabilities are working harder and less efficiently than those of students without learning challenges. It is hypothesized that the hyper-connectivity is in response to the brain working harder to compensate for the areas that are under-connected and that this hyper-connectivity is a compensatory strategy to account for a loss of structural connectivity and that it comes at a cost of slowed processing speed and cognitive fatigue.

Conclusion: The brain networks of students identified as having learning disabilities and attending Arrowsmith, show a pattern of both under-connectivity (areas with less strong connections) and hyper-connectivity (areas with much stronger connections) than those of individuals not identified as having learning disabilities.

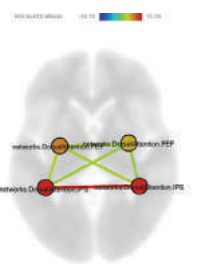
Connectivity in Students without Learning Disabilities

Within Network

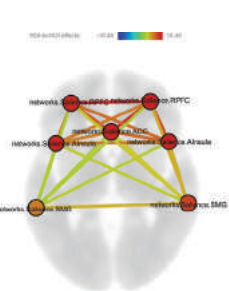
Default Mode



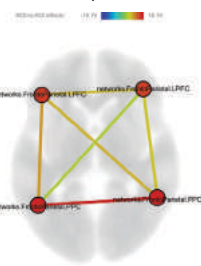
Dorsal Attention



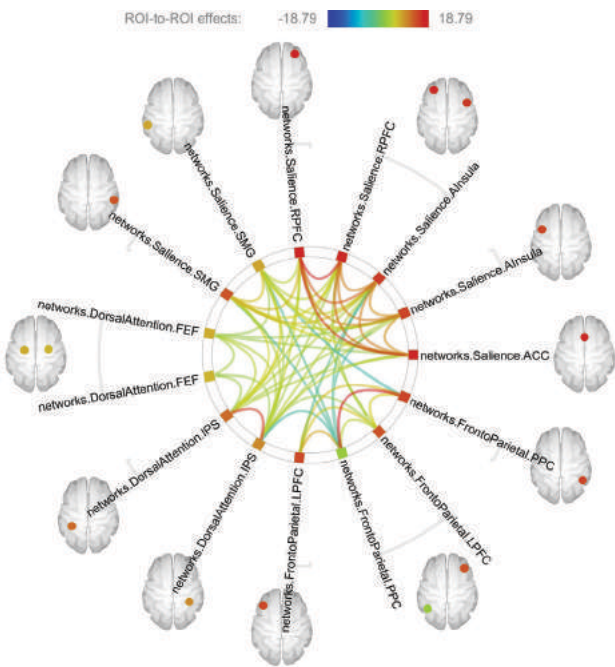
Saliency



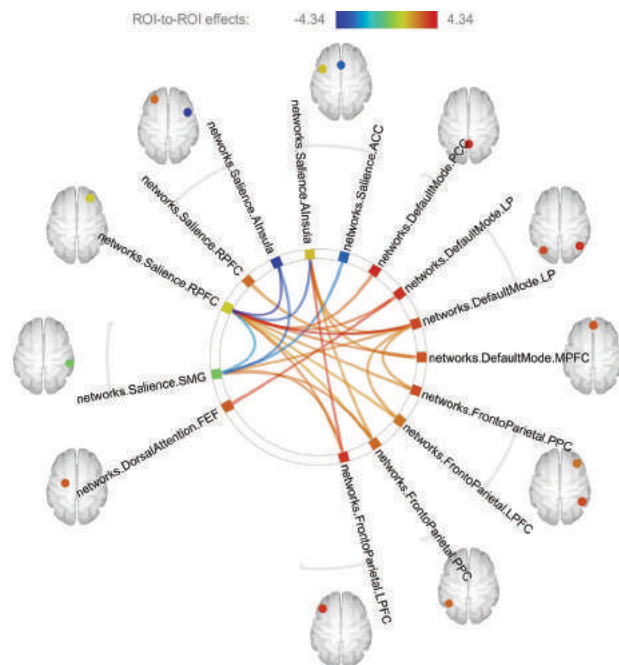
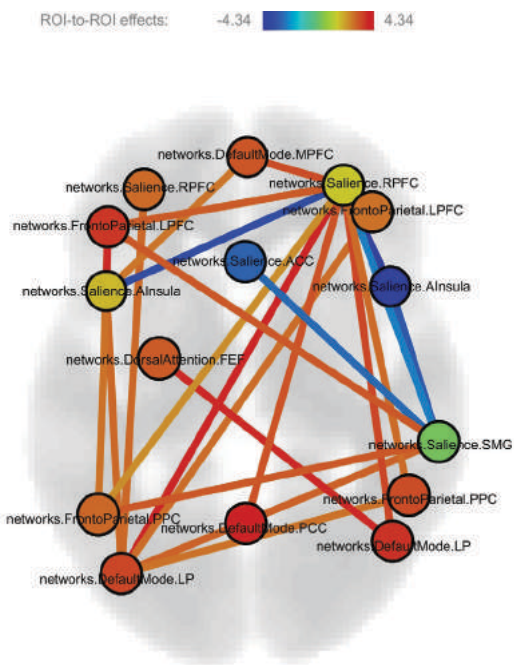
Fronto-Parietal (Executive) Control



Between Networks



Network Connectivity is Altered in Arrowsmith Students with Learning Disabilities



Red lines indicate connections that are stronger, and blue lines weaker, in Arrowsmith students

Connectivity Changes

Southern Illinois University (United States)

This study was conducted in 2016 by Dr. Gregory Rose and Dr. Audreyana Jagger-Rickels of the University of Southern Illinois investigating changes in brain connectivity for students participating in the 6-week Cognitive Intensive Program (CIP) at two schools in Canada. This program focuses on the Symbol Relations function designed to strengthen reasoning and processing of conceptual information. Changes in the resting state networks (RSNs) described below were measured. This research was presented in a peer-reviewed poster session at the 2018 Resting State Sixth Biennial Conference on Brain Connectivity in Montreal.

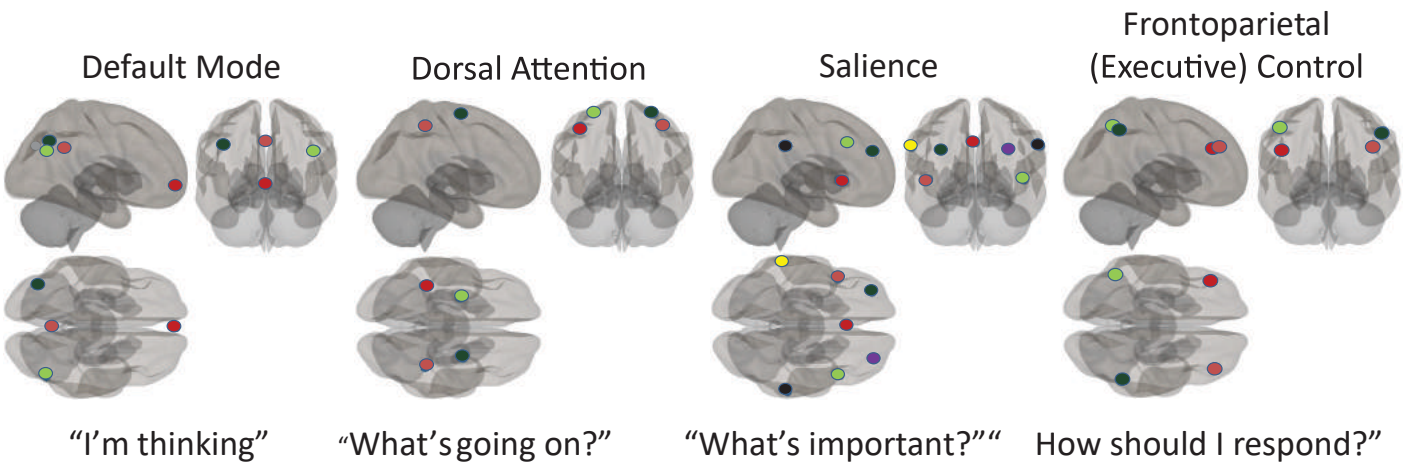
For context, it is useful to understand that Dr. Gregory Rose of the University of Southern Illinois, in his ongoing research into the outcomes of the Arrowsmith Program, is focusing on the following four brain networks in the image below. These four networks are all part of what are called resting state networks (RSNs), of which there are at least a dozen identified so far by neuroscientists. RSNs are networks comprised of groups of brain regions that coordinate their activity to perform specific functions, and this can be observed even when the brain is not actively engaged in a task but is in a ready state. This makes it relatively easy to study and the data acquisition method is easily standardized. The general function of each of these networks is identified by the statement or question noted under each image below.

More than a dozen network connections were observed to be strengthened following the Cognitive Intensive Program (CIP) training. A few of the changes were within individual networks, notably the default mode and salience networks, but the majority

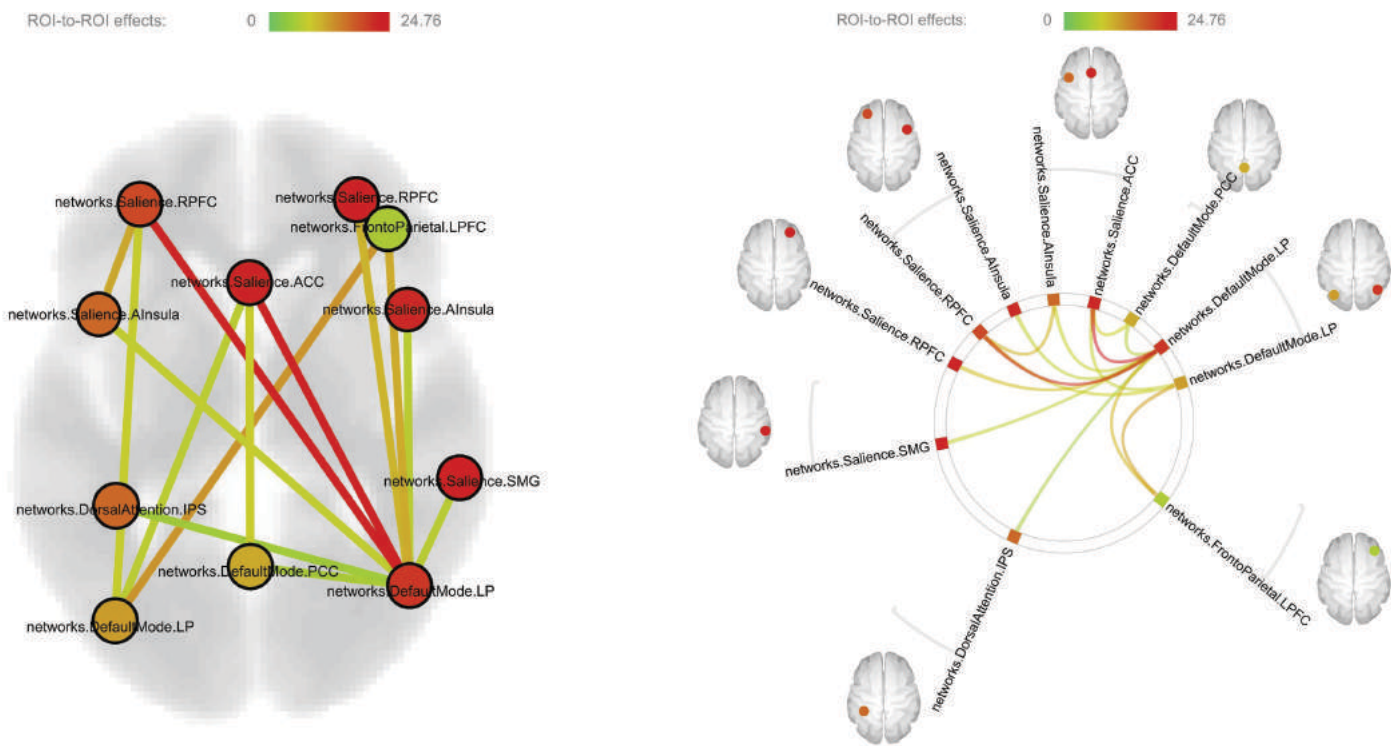
were between default mode network connections (I am thinking) to the dorsal attention (What's going on?), salience (What's important?) and frontoparietal control (How should I respond?) networks. The degree of change in network connectivity correlated to a high degree with the amount of improvement the student made during the six-week program. As the student improved on this cognitive function, so did network connectivity.

These changes allow the students to perform significantly better as they relate to the changes reported on standardized cognitive measures noted on [page 14](#). On cognitive measures significant gains were noted in cognitive processing speed; cognitive efficiency; letter pattern matching; and pair cancellation (a form of sustained attention).

Conclusion: Symbol Relations training over the course of the 6-week Cognitive Intensive Program strengthens network connectivity, both within and between networks.



The dots in each brain image represent regions of the brain that are active within that network



Warmer colors indicate relatively stronger increases in connectivity between network components. Changes are proportional to Symbol Relations improvement. Most of the sites are within or between the Salience and Default Mode networks.

Connectivity Changes

Southern Illinois University (United States)

This study in 2018 investigating the connectivity changes in the brain of students with learning disabilities participating in their first year of the Arrowsmith Program at two schools in Canada was conducted by Dr. Gregory Rose and Dr. Audreyana Jagger-Rickels of the University of Southern Illinois. These students engaged in 6 periods of cognitive programs and one period each of English and mathematics each day over the course of the school year.

After a 10 month academic year in the full time Arrowsmith Program, the hyper-connected areas have toned down and the under-connected areas have strengthened in connectivity and the brains of the students with learning disabilities are approximating what is being seen in the brains of students without learning disabilities.

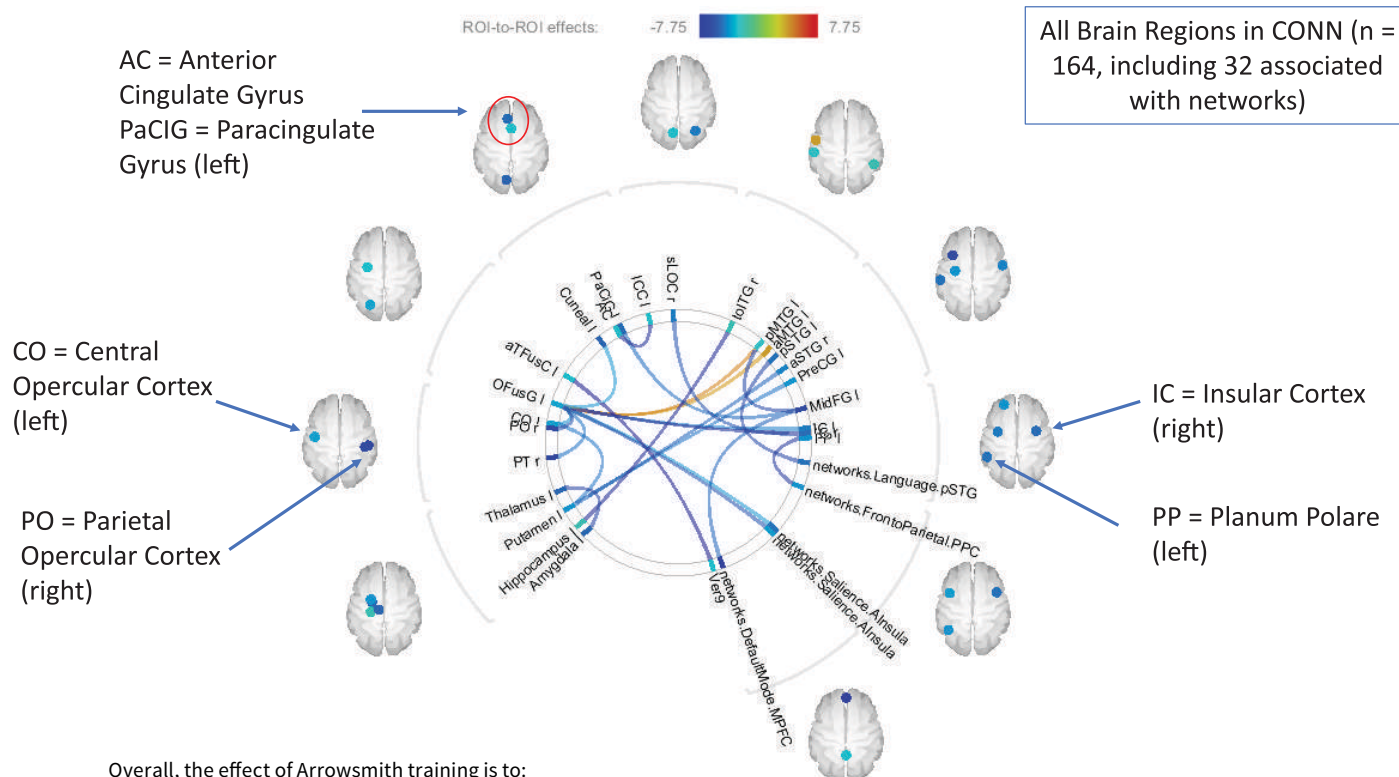
On cognitive measures for these same students (reported earlier in this document on [page 13](#)) significant gains were noted in: Cognitive

Processing Speed; Cognitive Efficiency; Perceptual Speed; Visual Auditory Learning; Number Facility; Number Pattern Matching; Letter Pattern Matching; and Pair Cancellation (a form of sustained attention).

On academic measures for these same students (reported earlier in this document on [page 6](#)) significant gains were noted in: Passage Comprehension; Academic Fluency; Math Facts Fluency; and Sentence Writing Fluency.

Conclusion: One year of participation in the full time Arrowsmith Program leads to changes in brain connectivity both within networks and between networks such that the brains of the learning-disabled individuals are now appearing more like the brains of students without learning disabilities.

Connectivity Changes After One Academic Year of Arrowsmith



- reduce the hyper-connectivity between brain regions seen before training
- increase strength of connections in areas of under-connectivity seen before training

Outcome Research:

Individuals with Acquired Brain Injury

University of British Columbia (Canada)

This study was conducted at the University of British Columbia under the direction of Dr. Naznin Virji-Babul on individuals with Traumatic Brain Injury. These individuals were engaged in the Arrowsmith Program cognitive exercises daily for four of the higher order cognitive functions (Symbol Relations/ Reasoning; Predicative Speech/Sequential Logic; Symbolic Thinking/Executive Functioning; Non-Verbal Thinking) under the Brainex name at the Watson Centre Society for Brain Health in the Vancouver area.

Results were published in the peer-reviewed journal, *Helyion* (July 2017): "Changes in brain-behavior relationships following a 3-month pilot cognitive intervention program for adults with traumatic brain injury". In March 2019 further results were presented in a peer-reviewed poster session at the 13th World Congress on Brain Injury, Toronto, Canada.

The problem of hyper-connectivity and under-connectivity was seen in those suffering from acquired brain injury. In the 2017 publication, the researchers found prior to intervention, "Our data shows that increased connectivity in the frontal regions is in fact correlated with lower cognitive scores suggesting that greater resources are being used that may lead to lower information processing efficiency."

The following significant improvements were found following the three-month program:

- an increase in cognitive performance, most notably fluid cognition, verbal learning, and memory
- changes in functional network connectivity in frontal regions
- a decrease in anxiety and depression.

Fluid cognition is the ability to analyze and solve problems as they arise, to identify patterns and relationships underlying problems, and to reason.

Conclusion: The researchers concluded: [After intervention] "Our results provide preliminary evidence that participating in an intensive cognitive intervention program was associated with neuroplastic changes in adults with chronic TBI that occurred in parallel with improvements in cognition. Overall, we observed a shift from a baseline pattern of network organization that may be characterized by neural inefficiency and decreased cognition to a reorganization that reflected improved efficiency with possible improvements in fluid cognition. Importantly this data suggests that brain network organization is capable of reorganization even in chronic patients with intense intervention. Further work with a larger sample is clearly needed to understand the nuances of how brain organization impacts on cognitive ability and performance."

Summary of the Research Findings to Date

In 1977, Barbara Arrowsmith Young posed these questions: If one can understand the nature of a cognitive function, through studying Luria's work, could one create a task that targets and works that function – what Rosenzweig called 'targeted differential stimulation'? Would working on that task repetitively with a graduated increase in complexity, accuracy and speed of performance lead to neuroplastic change in the brain? Would this brain change lead to change in learning processes?

The research results are demonstrating that for individuals with learning disabilities, Arrowsmith's cognitive programs lead to changes in:

- brain activation and connectivity
- cognitive functioning
- academic achievement
- rate of learning in the acquisition of academic skills
- social emotional well-being
- activities of daily living
- growth mindset (seeing one as an agent of change in one's life)
- stress levels (as measured by reduction in cortisol)

For individuals with Traumatic Brain Injury, Arrowsmith's cognitive programs lead to changes in:

- brain activation and connectivity
- cognitive functioning
- social emotional well-being
- successful return to work

For elementary aged students without learning disabilities, Arrowsmith's cognitive programs lead to changes in:

- cognitive functioning
- academic achievement

As one of the researchers said at a research presentation in New York City in February 2019, "the capacity to learn new things appears to be changing in the Arrowsmith students."

The research has been conducted by different researchers, using different research designs and different measures - academic, cognitive, social emotional and imaging - and studying students in different schools implementing the Arrowsmith Program. For updates on the research being conducted on the Arrowsmith Program, please visit the [Research page on the website](#).

Global Research Initiative

In February 2019, a research collaborative was formed comprised of researchers from the University of British Columbia, Southern Illinois University, Universidad Camilo José Cela, and Tallinn University. The researchers are meeting on a regular basis to collaborate on further research investigations into the outcomes of students in the Arrowsmith Program. Arrowsmith's vision is to create a research institute to further these investigations in the fields of learning disabilities, cognitive enhancement, education and acquired brain injury.



ARROWSMITH PROGRAM RESEARCH SUMMARY 2019

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