Research Report: Arrowsmith Symbol Relations Cognitive Program Outcomes

ARROWSMITH

Arrowsmith Symbol Relations Cognitive Program

The Arrowsmith Symbol Relations task is a computer-based cognitive exercise consisting of a sustained visual-spatial processing task of progressively increasing difficulty. It requires students to use relational reasoning to conceptually and automatically process relationships that increase in complexity. This cognitive exercise is not language dependent so is accessible to participants with different language backgrounds.

Symbol Relations Cognitive Function

The Symbol Relations cognitive function is involved in:

- cause and effect reasoning
- understanding the 'why' of things
- grasping concepts across all academic disciplines
- comprehension of what is read or heard
- making rational and considered decisions
- understanding the world, oneself, and others
- fluid reasoning and flexibility of thought
- logical grasp of mathematical concepts
- processing speed
- insight which is critical to understanding self and others
- semantic grasp of language necessary for comprehension and vocabulary development
- perspective taking which involves the ability to consider other points of view necessary for empathy

If there is a difficulty in this cognitive function all of these processes are impacted.

Benefits to Enhancing the Symbol Relations Cognitive Function

Given the role of this cognitive function as an association area in the brain, enhancement of this function has a broad overarching impact on cognition. In particular, by providing individuals an opportunity to enhance this higher order cognitive function responsible for connecting ideas and concepts, they will be able to:

- understand and analyze complex abstract relationships
- think critically
- comprehend at a conceptual level
- be flexible in thought
- accept and consider other points of view

These are critical abilities required for all aspects of learning across the lifespan. The gains resulting from strengthening this function are generalizable to all aspects of learning that require comprehension and conceptual understanding or reasoning.

Every individual, whether they have a strength or a deficit, can benefit from enhancing this cognitive function. The cognitive program offers a broad range of functional levels, from a starting point of average to superior level of functioning or a severe, moderate, or mild problem.

Research Outcomes of the Symbol Relations Cognitive Program

Over the years, many research projects have been conducted on this cognitive program, with various cohorts of individuals. This report summarizes this research.

Research on the Symbol Relations program outcomes has demonstrated significant improvements in:

- neural networks in the brain
- cognitive functioning
- acquisition of academic skills
- emotional intelligence and well-being

The Symbol Relations cognitive program is offered to different groups of individuals in different delivery models, namely the Symbol Relations Cognitive Intensive Program, the Symbol Relations Whole Cohort Program, and the Symbol Relations Cognitive Enhancement Program. The research on each will be covered separately and a summary provided at the end of the report.

For more information on the research measures used, See Appendix A.

Symbol Relations Cognitive Intensive Program

The Symbol Relations Cognitive Intensive Program is a 6-to-10-week program, either online or in-person, in which participants engage in 4 or 5 hours of this cognitive program every day, five days per week. Research has been conducted since 2017 on the outcomes of this program.

Study 1: Cognitive Intensive Program 2017 - Toronto & Peterborough, Canada

Group

There were 22 participants with learning disabilities or learning difficulties with an average age of 14.6 years. All participants were enrolled in a 6-week in-person Cognitive Intensive Program.

Measures

Resting-state fMRI Imaging

Resting-state fMRI images were collected at the beginning and end of the 6-week program using a Siemens 3T scanner at the Toronto Hospital for Sick Children. The scans were analyzed using the CONN toolbox.

Results

Resting-state fMRI Imaging

Improvements in performance on the Symbol Relations cognitive program were correlated with changes in resting-state brain connectivity. The most notable change was increased connectivity between the Default Mode network, the Salience network and the Frontoparietal (Executive Control) network. As participants improved in the Symbol Relations cognitive function, this network connectivity strengthened.

Presentation (Peer Reviewed)

Audreyana C. Jagger-Rickels and Gregory Rose (2018, September 27). *Exploring the relationship between improvement in an intensive learning intervention and changes in resting-state functional connectivity* [Presentation]. Sixth Biennial Conference on Brain Connectivity, Montreal, Canada.

SIU Cognitive Intensive Program Study Resting State 2018

Study 2: Cognitive Intensive Program 2018 and 2019 Combined Data – Toronto, Canada

Group

There were 27 participants with learning disabilities or learning difficulties enrolled in a 6-week in-person Cognitive Intensive Program. The group was comprised of 19 males and 8 females, with an average age of 13.4 and ranging in age from 9.4 to 18.4 years old.

Measures

Resting-state fMRI Imaging

Woodcock-Johnson IV Tests of Cognitive Abilities and Achievement

The Woodcock-Johnson IV Tests of Cognitive Abilities and Achievement were added to the research battery starting in 2018.

The Woodcock-Johnson IV Tests of Cognitive Abilities is an individually administered, norm-referenced instrument that measures specific cognitive abilities in persons aged 2 to 90.

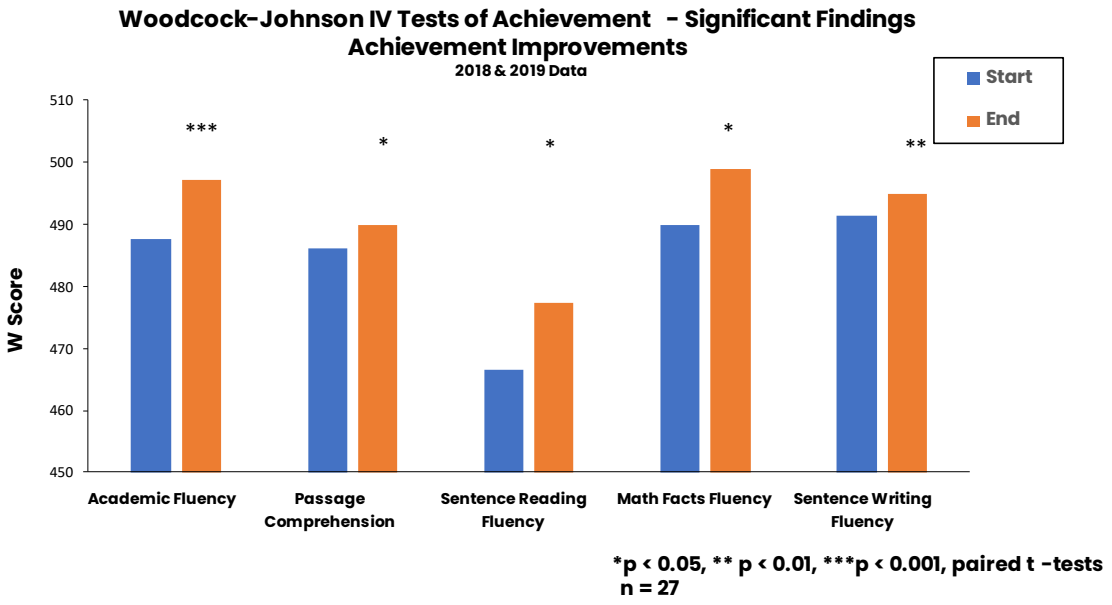
The Woodcock-Johnson IV Tests of Achievement is an individually administered, norm-referenced instrument that measures specific academic achievement areas in persons aged 4 to 90.

Results

Resting-state fMRI Imaging

These results are reported below in the 2017, 2018 and 2019 combined data in Study 4.

Woodcock-Johnson IV Tests of Achievement



Arrowsmith Program Symbol Relations Cognitive Intensive Program

The academic achievement areas showing significant Improvement:

Academic Fluency - measures the ability to perform math and reading tasks quickly and accurately

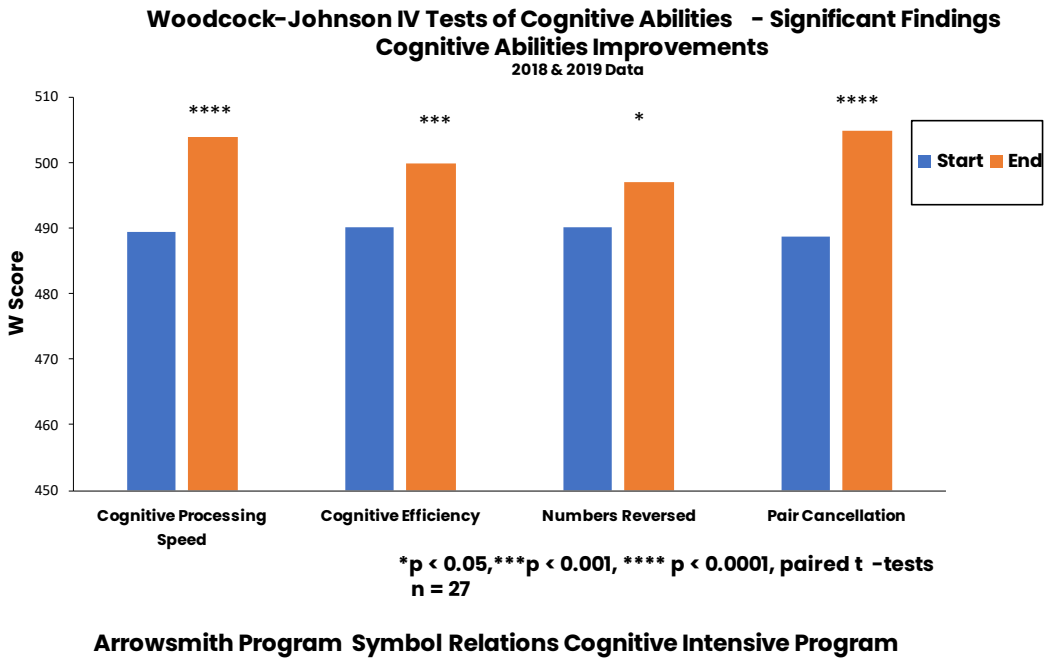
Passage Comprehension - measures the ability to comprehend what is read

Sentence Reading Fluency - measures the ability to read sentences quickly and accurately

Math Facts Fluency – measures the ability to solve math fact computations (addition, subtraction, multiplication) quickly and accurately

Sentence Writing Fluency - measures the ability to write sentences quickly and accurately

Woodcock-Johnson IV Tests of Cognitive Abilities



The cognitive abilities showing significant Improvement:

Cognitive Processing Speed – measures the ability to quickly perform both simple and complex cognitive tasks, particularly when under pressure to sustain controlled attention and concentration.

Cognitive Efficiency – measures the ability to cognitively process information automatically which frees up working memory.

Numbers Reversed – measures short-term auditory working memory.

Pair Cancellation - measures interference and inhibition control (executive processing) and sustained attention (attention/ concentration).

Study 3: Cognitive Intensive Program 2019 - Vancouver, Canada

Group

13 students in Vancouver, Canada, average age 12.9, ranging from 9 to 16 years old, also participated in the in-person Cognitive Intensive Program during the summer of 2019.

Measures

Woodcock-Johnson IV Tests of Cognitive Abilities

Results

Woodcock-Johnson IV Tests of Cognitive Abilities

The cognitive abilities showing significant Improvement for this group were:

Cognitive Processing Speed – measures the ability to quickly perform both simple and complex cognitive tasks, particularly when under pressure to sustain controlled attention and concentration.

Cognitive Efficiency – measures the ability to cognitively process information automatically which frees up working memory.

Fluid Reasoning – measures broad ability to reason, form concepts, and solve problems using unfamiliar information or novel procedures.

Perceptual Speed – measures the ability to rapidly identify matching items.

Oral Vocabulary – measures vocabulary knowledge through assessing synonyms and antonyms.

Visual Auditory Learning – measures long-term storage and retrieval.

Publication (Peer Reviewed)

This publication used data from Cognitive Intensive Program Studies 1, 2 and 3

Negin Motamed Yeganeh, Rachel King, Lara A. Boyd, Gregory M. Rose & Rachel C. Weber (2021) Symbol relations training improves cognitive functioning in students with neurodevelopmental disorders, Applied Neuropsychology: Child, 11:4, 789-796, DOI: 10.1080/21622965.2021.1967154

Symbol Relations Training Improves Cognitive Functioning Neuropsychology Child 2021

Presentations (Peer Reviewed)

These presentations used data from Cognitive Intensive Program Studies 1, 2 and 3

Negin Motamed Yeganeh. (2020, July 2). *Preliminary effects of the Arrowsmith intensive program on student cognitive functioning* [Presentation]. International Neuropsychological Society Conference, Vienna, Austria.

Effects of Arrowsmith Cognitive Intensive Program on Cognitive Functioning 2020

Greg Rose. (2021, May 29). *Brief intensive cognitive training alters resting state connectivity in adolescents* [Presentation]. 33rd American Psychological Society Conference, Virtual.

Brief Intensive Cognitive Training Alters Resting State Connectivity 2021

Negin Motamed Yeganeh. (2021, May 29). *Effects of the Arrowsmith intensive symbol relations training on cognitive functioning* [Presentation]. 33rd American Psychological Society Conference, Virtual.

Effects of Arrowsmith Intensive Symbol Relations Training on Cognitive Functioning 2021

Study 4: Cognitive Intensive Program 2017, 2018 and 2019 Combined Data – Toronto & Peterborough, Canada

Group

There were 49 participants with learning disabilities or learning difficulties with an average age of 13.4 and ranging in age from 9.4 to 18.5 years old. These participants were enrolled in the 6-week in-person Cognitive Intensive Program.

Measures

Resting-state fMRI Imaging

Woodcock-Johnson IV Tests of Cognitive Abilities and Achievement

Symbol Relations Survey Questionnaire

A questionnaire is completed by parents using a five-point rating scale to report on behaviours related to the Symbol Relation cognitive function. These behaviours are grouped into the following categories: oral comprehension; understanding concepts; engagement; emotional intelligence; and school performance.

Results

Resting-state fMRI Imaging

Changes in resting-state network connectivity increased proportionally to the amount of improvement measured in this cognitive function. Most of the regions or network components that improved were within or between the Salience and Default Mode networks, with improvements also seen in the Dorsal Attention and Frontoparietal (Executive Control) networks. The greater the improvement in the Symbol Relations cognitive function, the greater the increase in connectivity within and between these brain networks.

Woodcock-Johnson IV Tests of Cognitive Abilities

Significant improvements were measured in 2018 and 2019 on these cognitive abilities: Processing Speed: Cognitive Efficiency; Numbers Reversed; and Pair Cancellation. See graph of results in Study 2: Cognitive Intensive Program 2018 and 2019 Combined Data above.

Woodcock-Johnson IV Tests of Achievement

Significant improvements were measured in 2018 and 2019 on these areas of academic achievement: passage comprehension; academic fluency; sentence writing fluency; sentence reading fluency; and math facts fluency. See graph of results in Study 2: Cognitive Intensive Program 2018 and 2019 Combined Data above.

Symbol Relations Survey Questionnaire

Parents, on a survey 3 months after completion of the program, reported significant improvements in oral comprehension; understanding concepts; engagement; oral language; emotional intelligence; and school performance.

Presentation (Peer Reviewed)

Greg Rose. (2019, October). *A brief intensive learning intervention affects resting state connectivity and neuropsychological test performance* [Presentation]. Society for Neuroscience Conference, Chicago, IL, United States.
Intensive Learning Intervention Affects Resting-state Connectivity and Cognitive Functioning 2019

2020

Research was not done in 2020 due to the COVID pandemic.

Study 5: Cognitive Intensive Program 2021 Data – Toronto, Canada

Group

There were 32 participants with learning disabilities or learning difficulties, comprised of 21 males and 11 females, with an average age of 13.6 and ranging in age from 9.1 to 18.4 years old. These participants were enrolled in either the 6-week in-person or 8-week online Cognitive Intensive Program.

Measures

Woodcock-Johnson IV Tests of Cognitive Abilities

Additional subtests of the Woodcock-Johnson IV Test of Cognitive Abilities were administered.

Immediate Mood Scaler

This is a questionnaire of 12 items of assessing a range of moods on a 7-point scale from 1 (for negative moods) to 7 (for positive moods).

Creyos (Cambridge Brain Sciences) Cognitive Tasks

This is a computerized set of neurocognitive tasks that measure core elements of cognition.

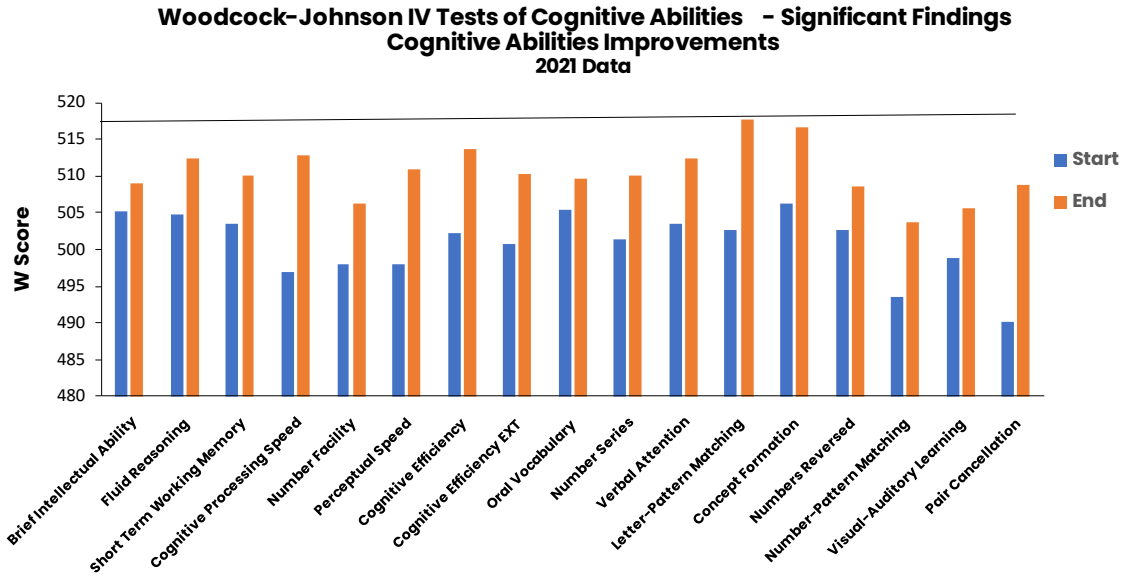
Symbol Relations Cognitive Function Assessment

A test using a 12-point scale is used to assess the level of proficiency in functioning on the Symbol Relations cognitive function from a very severe level of difficulty to above average functioning.

Symbol Relations Survey Questionnaire

Results

Woodcock-Johnson IV Tests of Cognitive Abilities



Arrowsmith Program Symbol Relations Cognitive Intensive Program

All comparisons significant at $p < 0.005$ (most $p < 0.0001$) except for Numbers Reversed ($p = 0.012$)
n = 32

The cognitive abilities showing significant Improvement:

Brief Intellectual Ability – this is a composite scale of several of the cognitive subtests used as a quick assessment of overall intellectual ability.

Fluid Reasoning – measures broad ability to reason, form concepts, and solve problems using unfamiliar information or novel procedures.

Short Term Working Memory – measures the ability to manipulate information in short-term memory to solve problems.

Cognitive Processing Speed – measures the ability to quickly perform both simple and complex cognitive tasks, particularly when under pressure to sustain controlled attention and concentration.

Number Facility – measures speed and accuracy working with numbers.

Perceptual Speed – measures the ability to rapidly identify matching items.

Cognitive Efficiency – measures the ability to cognitively process information automatically which frees up working memory.

Oral Vocabulary – measures vocabulary knowledge through assessing synonyms and antonyms.

Number Series - measures quantitative reasoning and inductive reasoning.

Verbal Attention – measures short term auditory working memory.

Number Series - measures quantitative reasoning and inductive reasoning.

Letter-Pattern Matching – measures the speed at which one can make visual symbol discriminations and identify common orthographic (spelling) patterns.

Concept Formation – measures categorical reasoning based on principles of inductive logic.

Numbers Reversed – measures short-term auditory memory.

Number-Pattern Matching – measures the ability to visually discriminate numbers quickly and accurately.

Visual Auditory Learning – measures long-term storage and retrieval.

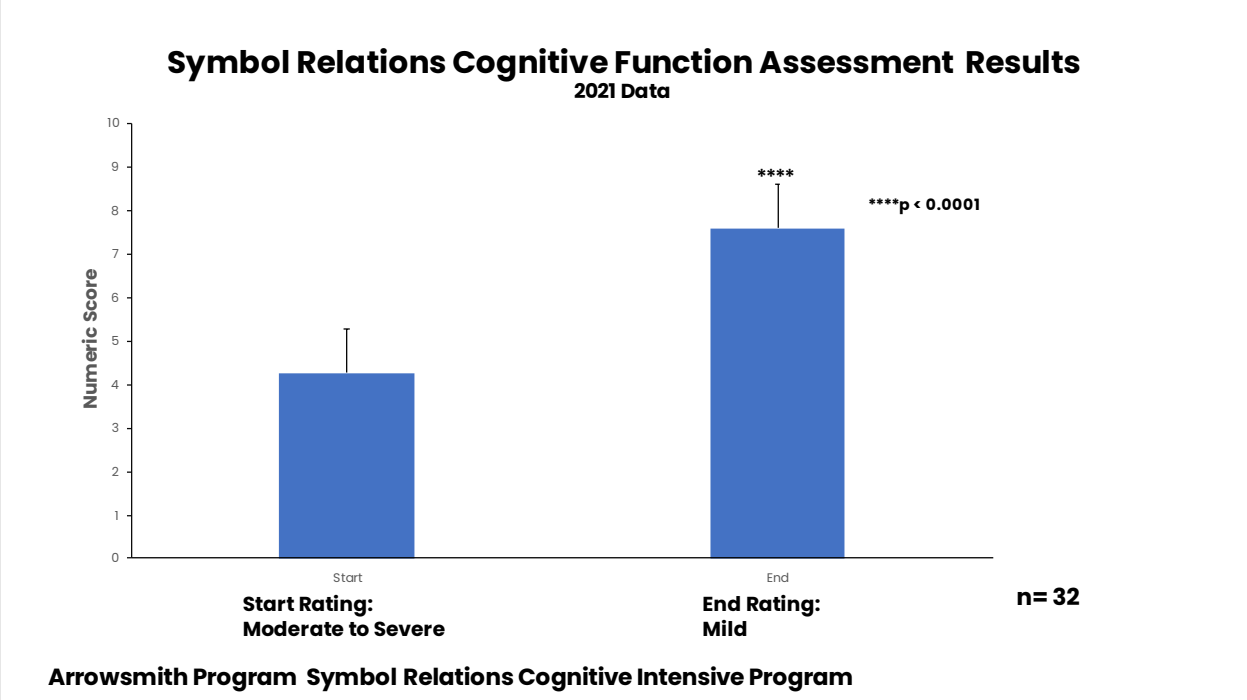
Pair Cancellation - measures interference and inhibition control (executive processing) and sustained attention (attention/ concentration).

Immediate Mood Scaler, Creyos (Cambridge Brain Sciences) Cognitive Tasks and Symbol Relations Survey Questionnaire

Results for these three measures are reported in Study 7: Cognitive Intensive Program 2021 and 2022 Combined Data

Symbol Relations Cognitive Function Assessment

Over 6-weeks of work on the Symbol Relations cognitive function in the Cognitive Intensive Program, participants moved from an initial rating of a Moderate to Severe level of a problem to a Mild rating. This was a statistically significant improvement demonstrating enhancement of this cognitive function.



Study 6: Cognitive Intensive Program 2022 Data – Toronto, Canada

Group

There were 21 participants with learning disabilities or learning difficulties, comprising 13 males and 8 females, with an average age of 13.5 and ranging in age from 10.0 to 18.4 years old. These participants were enrolled in either the 6-week in-person or 8-week online Cognitive Intensive Program.

Measures

Woodcock-Johnson IV Tests of Cognitive Abilities

Immediate Mood Scaler

Creyos (Cambridge Brain Sciences) Cognitive Tasks

Tower of London Task

This is a measure of executive functioning, more specifically planning ability.

Symbol Relations Cognitive Function Assessment

Symbol Relations Survey Questionnaire

Results

The results for Study 6 are reported in Study 7: Cognitive Intensive Program 2021 and 2022 Combined Data.

Study 7: Cognitive Intensive Program 2021 and 2022 Combined Data - Toronto, Canada

Group

There were 53 participants with learning disabilities or learning difficulties, comprising 34 males and 19 females, with an average age of 13.7 and ranging in age from 9.3 to 19.3. These participants were enrolled in either the 6-week in-person or 8-week online Cognitive Intensive. Measures

Woodcock-Johnson IV Tests of Cognitive Abilities

Immediate Mood Scaler

Creyos (Cambridge Brain Sciences) Cognitive Tasks

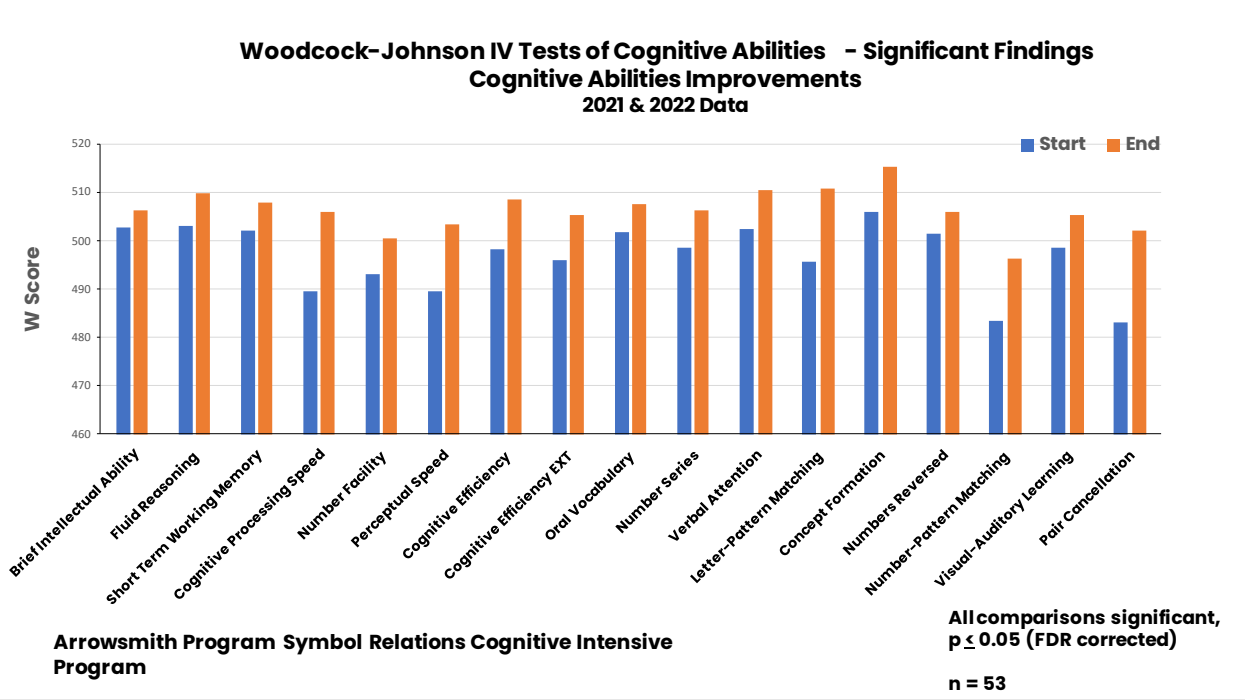
Tower of London Task

Symbol Relations Cognitive Function Assessment

Symbol Relations Survey Questionnaire

Results

Woodcock-Johnson IV Tests of Cognitive Abilities



The cognitive abilities showing significant Improvement:

Brief Intellectual Ability – this is a composite scale of several of the cognitive subtests used as a quick assessment of overall intellectual ability.

Fluid Reasoning – measures broad ability to reason, form concepts, and solve problems using unfamiliar information or novel procedures.

Short Term Working Memory – measures the ability to manipulate information in short-term memory to solve problems.

Cognitive Processing Speed – measures the ability to quickly perform both simple and complex cognitive tasks, particularly when under pressure to sustain controlled attention and concentration.

Number Facility – measures speed and accuracy working with numbers.

Perceptual Speed – measures the ability to rapidly identify matching items.

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Concept Formation – measures categorical reasoning based on principles of inductive logic.

Numbers Reversed – measures short-term auditory memory.

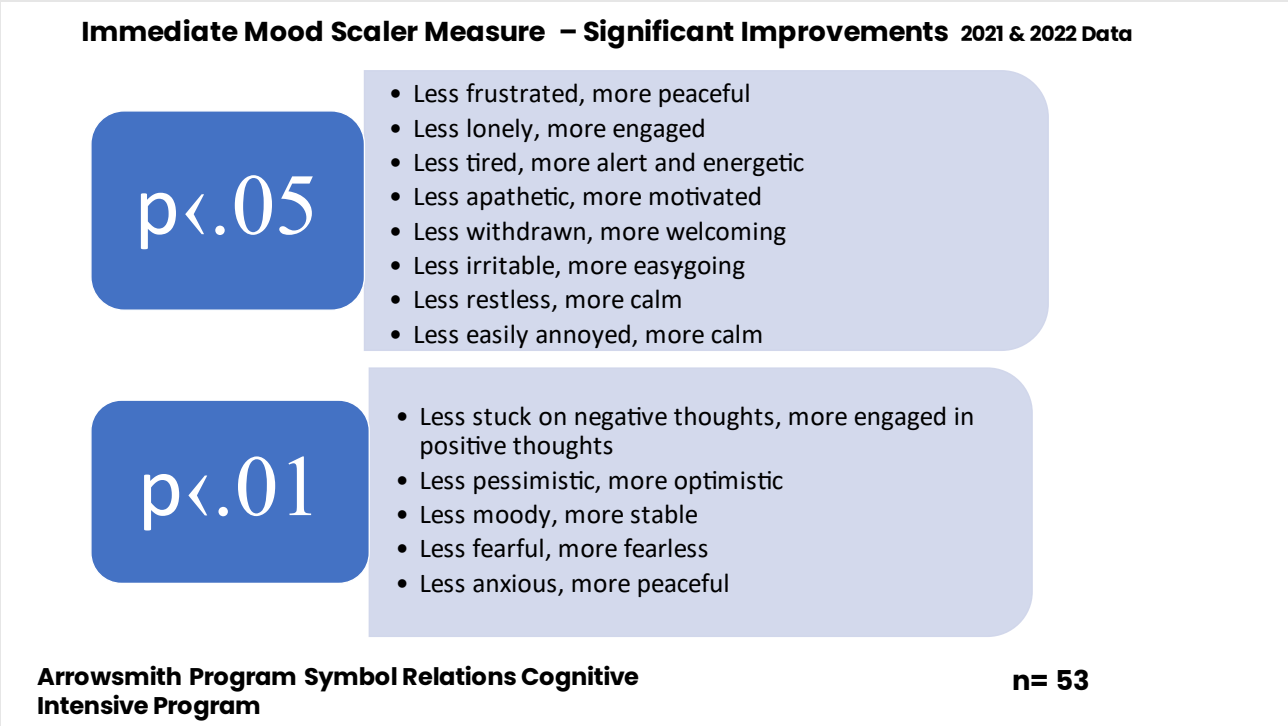
Number-Pattern Matching – measures the ability to visually discriminate numbers quickly and accurately.

Visual Auditory Learning – measures long-term storage and retrieval.

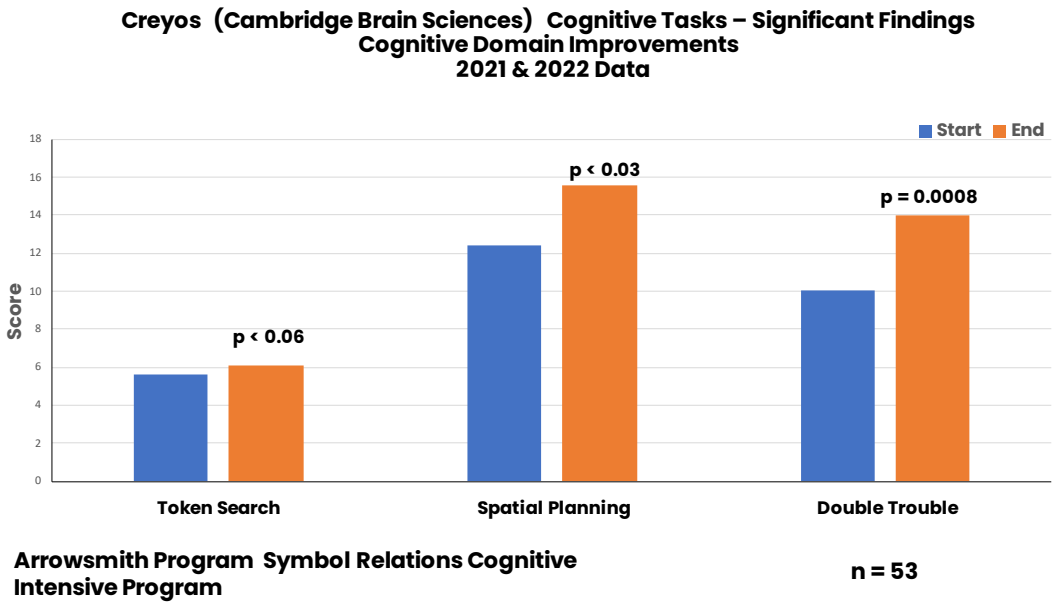
Pair Cancellation - measures interference and inhibition control (executive processing) and sustained attention (attention/ concentration).

Immediate Mood Scaler

Participants reported significant improvements in their mood on the following 13 scales.



Creyos (Cambridge Brain Sciences) Cognitive Tasks



Significant cognitive improvements were on the following measures:

Token Search – this measures working memory, the ability to hold information in memory and manipulate it to solve a problem.

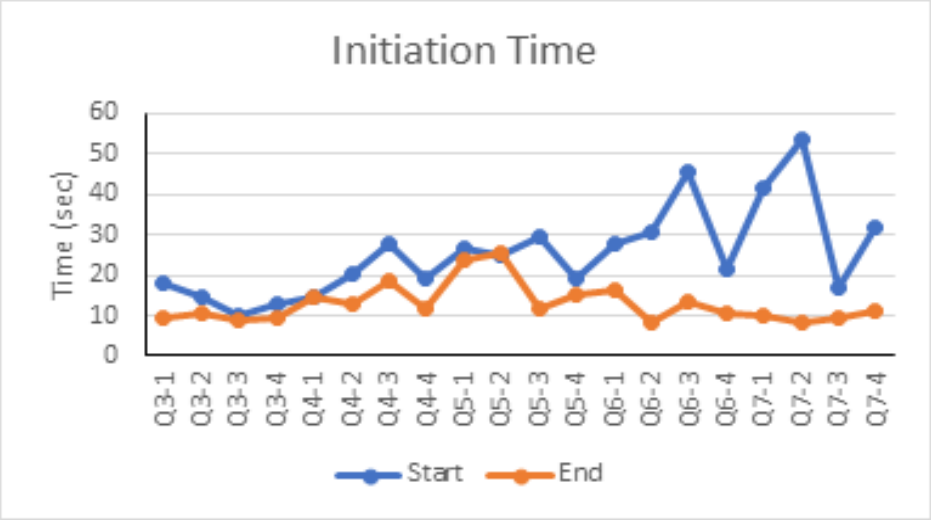
Spatial Planning – this measures the ability to plan and sequence behaviour to reach a goal. (It is based on the Tower of London Task).

Double Trouble - this assesses response inhibition, the ability to focus on relevant information to make a response even when presented with distracting information. (It is based upon the Stroop Task).

Tower of London Task 2022

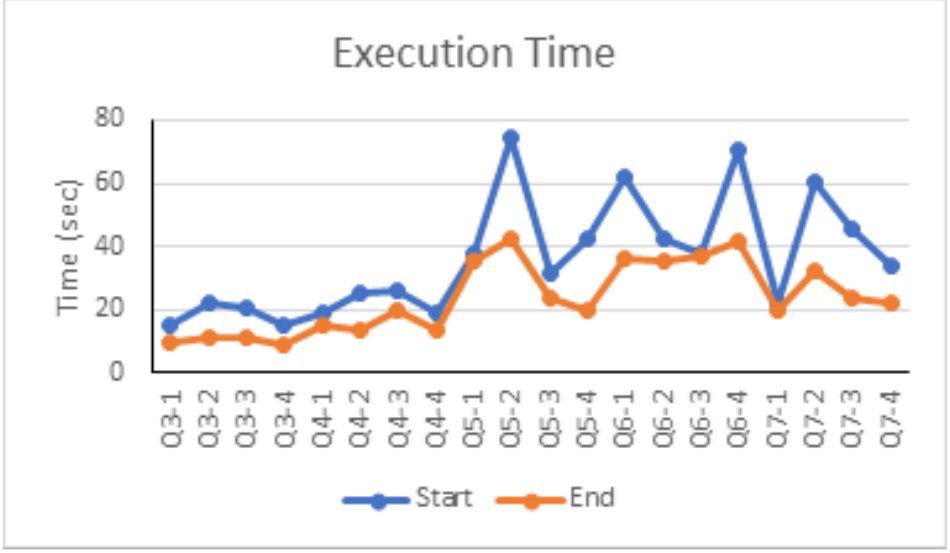
Participants showed significant improvements in their initiation and execution times on this planning task demonstrating that their planning ability was significantly faster and more efficient at the end of the cognitive program than before.

Tower of London Task – Significant Findings 2022 Data



Initiation Time showed significant improvement after CIP training ($p < 0.0001$) n =13

Tower of London Task – Significant Findings 2022 Data



Execution Time showed significant improvement after CIP training ($p < 0.0001$) n =13

Symbol Relations Cognitive Function Assessment

Over 6-weeks of work on the Symbol Relations cognitive function in the Cognitive Intensive Program, participants moved from an initial rating of a Moderate to Severe level of a problem to a Mild rating. This was a statistically significant improvement demonstrating enhancement of this cognitive function.

Symbol Relations Survey Questionnaire

Three to six months after completion of the Symbol Relations cognitive program, parents of the participants completed a questionnaire. Significant improvement was reported in several behaviours which correspond to the results noted above in changes in cognitive abilities. These behaviours were grouped on analysis into the following categories, each of which showed significant improvement.

Oral Comprehension – able to grasp more quickly and accurately what is heard

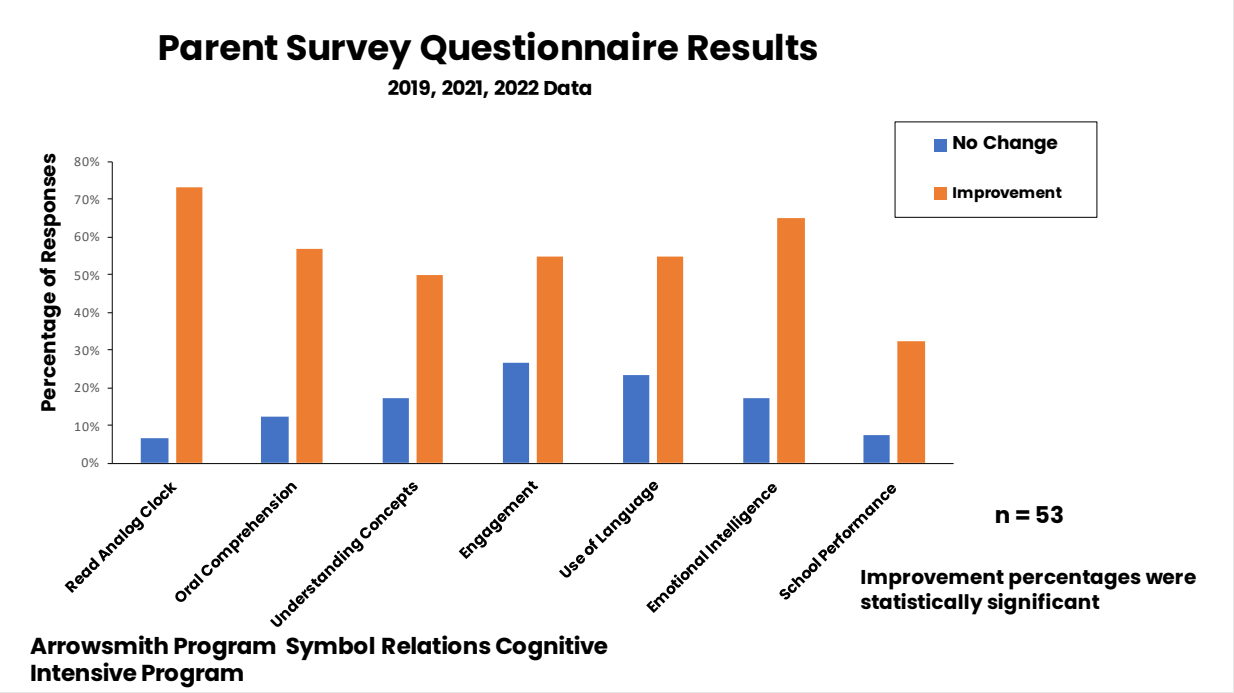
Understanding Concepts – enhanced logical reasoning, understanding rules, seeing the big picture

Engagement – greater focus, attention, and mental initiative

Use of Language – improved vocabulary and communication skills

Emotional Intelligence – more able to interpret and express emotions, to reflect on behavior and problem solve in social situations, to understand interpersonal relationships, and more willing to engage in social situations

School Performance – improved academic achievement



Additional Parent Comments on Survey Questionnaire:

- His comprehension/understanding is happening so much faster.
- She 'gets' math now and can show her understanding and reasoning behind her answers.
- She now enjoys reading as she understands what she reads.
- The questions he asks are more pertinent to the topic and demonstrate better understanding of the situation.
- She now understands concepts in class and can defend her position and rarely backs down now from a discussion.
- He is more able to remember what is taught in class and manage his homework.
- Reading is much easier.
- Her confidence, focus, perseverance and follow through have all improved.
- He can pay attention, remember, and understand more in class.
- He understands what to do the first time it is explained, working quicker, and achieving better than before.
- She is keeping up with her classwork and actually enjoying school for the first time.

- After the program, my child was more aware of his emotions during social situations, was better able to connect his emotions to things happening around him socially, and then could better express his feelings AND communicate how his emotions were connected to social situations.
- We see less anger and frustration and a greater willingness to listen and to work to grasp another perspective.
- We have seen changes in her speech, her reading comprehension, her understanding of new concepts, her social confidence, even her sporting ability.
- Family and friends with whom she has interacted have commented that she is now very aware, and her speech is very fluid, saying exactly what she wants to say and she says things that are on point.
- He reports his speed of thought has improved.
- She is able to make good decisions on the spot and her anxiety when faced with a difficult situation is gone. She is calmer and able to reason things out.
- Transitions are much easier.

Symbol Relations Whole Cohort Program

In this model, all students in a grade, work to enhance one specific cognitive function, in this case, the Symbol Relations cognitive function. Students work 30 to 40 minutes per day five days per week over the academic year.

Study 1 Whole Cohort Program 2018-2019 - Camperdown Academy, U.S.A.

Group

Camperdown Academy provided the Symbol Relations cognitive program to all students in grades 3, 4, 5 and 6 for 40 minutes per day five days per week for a 90-day academic term.

Measure

CNS Vital Signs Neurocognitive Assessment

This is a computerized neurocognitive test that assesses a range of cognitive abilities for individuals ages 8 to 89.

Results

CNS Vital Signs Neurocognitive Assessment

For these students, significant improvements were measured in the following cognitive domains:

- sustained attention
- cognitive flexibility
- processing speed
- executive function
- reasoning
- working memory

Whole Cohort Program – Grades 3, 4, 5, 6

Symbol Relations Cognitive Program

Significant gains in:

Sustained Attention	Processing Speed	Reasoning
Cognitive Flexibility	Executive Function	Working Memory

n = 95 students
48 students (2018) 47 students (2019)

Measured on CNS Vital Signs, a computerized neurocognitive assessment, 90 days after commencement of the Whole Cohort Program

SEK Schools, Madrid, Spain

All research at the SEK Schools in Madrid was conducted by Dr. Laura Herrero and Dr. Miguel Ángel Pérez-Nieto, Universidad Camilo José Cela, Madrid.

Study 2 Whole Cohort Program 2018 Data – St. Isabel, Spain

Group

There were 18 participants in a mainstream grade 3 class at SEK St. Isabel, an elementary school in Madrid, Spain. This group of students engaged in the Symbol Relations cognitive program for 40 minutes per day five days per week over 3 months.

Measures

Raven Progressive Matrices

A test of abstract reasoning and fluid intelligence.

Rey Complex Figure Test

A test of visuospatial abilities, attention, and planning.

Concentration Endurance Test (d2)

A test of selective attention, concentration, processing speed, and endurance.

Trail Making Test

A test of attention, visual search and scanning, sequencing and shifting, motor speed, cognitive flexibility, and processing speed.

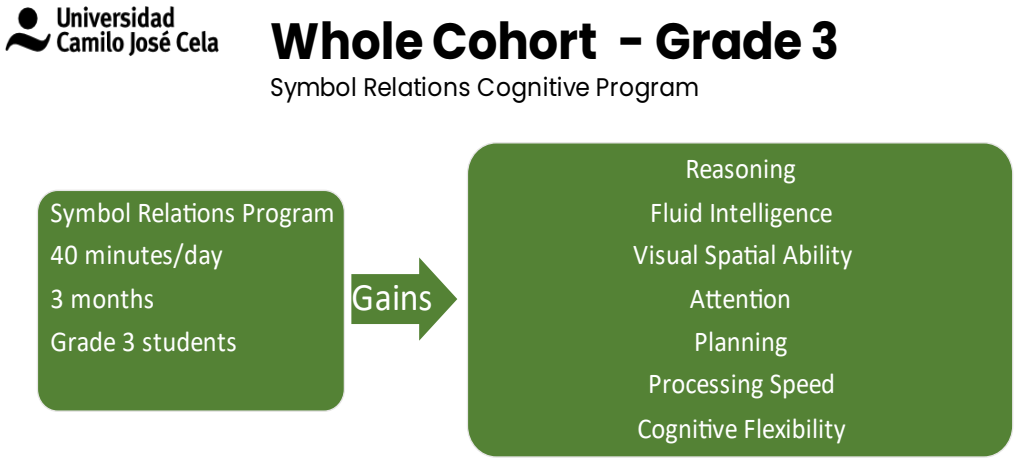
Claves Test

A test of deductive reasoning skills, fluid intelligence, attention and cognitive flexibility

Results

Significant improvements were measured in the following cognitive domains:

- abstract reasoning and fluid intelligence
- visuospatial abilities, attention, and planning
- selective attention, concentration, processing speed, and endurance
- processing speed
- deductive reasoning skills and cognitive flexibility



Research conducted by Dr. Laura Herrero Perez and Dr. Miguel Angel Perez Nieto
32nd International Congress of Psychology, Prague, July 2021

Presentation (Peer-Reviewed)

Laura Herrero, Cecilia Inés Theirs, Francisco David Pascal, and Miguel Ángel Pérez-Nieto. (2021, July). *Visuo-spatial ability improvements in typical development children involved in the Arrowsmith program* [Presentation]. 32nd International Conference of Psychology, Prague, Czech Republic.

Universidad Camilo José Cela Symbol Relations Whole Cohort Study 2021

Study 3 Whole Cohort Program 2022 Data – St. Isabel, Spain

Group

There were 41 participants in the mainstream grade 3 classes at SEK St. Isabel, an elementary school in Madrid, Spain. This group of students engaged in the Symbol Relations cognitive program for 40 minutes per day five days per week over 5 months. In the control group there were 42 grade 3 students in 2 SEK schools in Madrid, matched for SES.

Measures

Wisconsin Card Sorting Test

This is a test of set-shifting, cognitive flexibility, working memory, attention and abstract thinking.

Go No Go Task

This is a test of response inhibition.

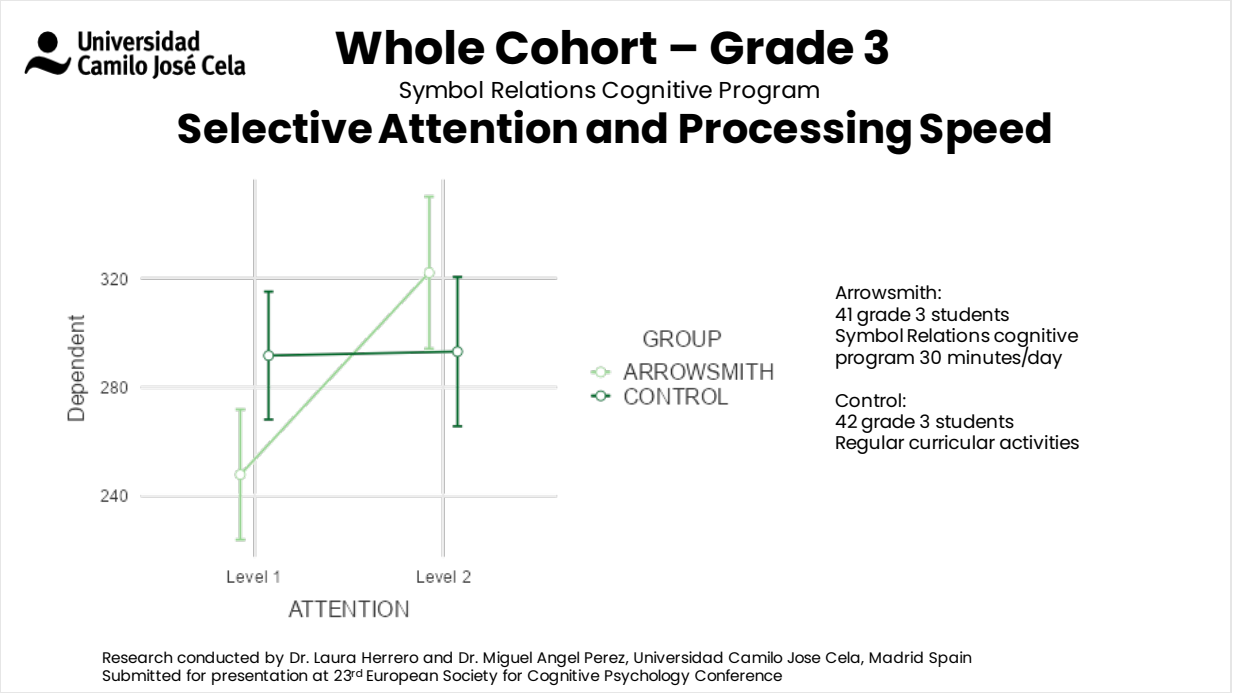
Concentration Endurance Test (d2)

A test of selective attention, concentration, processing speed, and endurance.

Results

For these grade 3 students in the Arrowsmith Whole Cohort Program compared to the control group, significant improvements were measured in the following domains:

- cognitive flexibility and working memory
- response inhibition
- selective attention, concentration, processing speed, and endurance



Presentation (Peer-Reviewed)

This research has been submitted for presentation at the 23rd European Society for Cognitive Psychology Conference, September 2023.

Symbol Relations Cognitive Enhancement Program

The Cognitive Enhancement Program is designed as an opt-in model for students in a school who choose to do a cognitive program as part of their regular academic day. Students are engaged in the cognitive program for 4 hours per week over the course of the academic year.

Study 1 Cognitive Enhancement Program 2018-2019 Academic Year - Gateway Crosspoint Christian School

Group

There were 19 participants in the mainstream grade 6 to 12 classes at Gateway Crosspoint Christian School in Washington State, USA. This group of students engaged in the Symbol Relations cognitive program for 90 minutes every other day over 8 months. Students self-selected this program as an elective in addition to their mainstream academic curriculum.

Measures

California Achievement Test (CAT)

An assessment of academic achievement that provides educators, students and their parents with a measure of achievement and comparison to U.S. national norms in reading, language, and mathematics.

Measure of Academic Progress (MAP)

A measure of academic achievement in reading and math. It measures a student's proficiency in those subjects, as well as their academic growth during the school year.

Questionnaire of Academic Skills and Learning Behaviours

A questionnaire developed by the teachers at Gateway Christian School assessing a range of behaviours and skills identified as necessary for learning.

Results

Cognitive Enhancement

Gateway Schools, WA
Grades 6 to 12

California Achievement Test
Significant changes in
- Vocabulary
- Reading Comprehension
- Math Computation
- Math Concepts and Problem Solving

Measure of Academic Progress
Significant changes in
- Mathematics
- Reading
- Language

English
- 86% Improved reading comprehension
- 81% Able to read faster and make connections between ideas more easily
- 76% Easier to write and take notes

Math
- 95% Able to grasp math concepts more quickly
  Make fewer careless errors & faster at completing math questions
- 81% Easier to figure out steps in math problems
  Able to finish math homework in class

Learning
- 91% More attentive, focused and observant in class
  More self-disciplined
  Better able to follow verbal instructions
- 86% Faster at completing homework
  More able to recall concepts and facts
- 76% More prepared for college

California Achievement Test (CAT) and Measure of Academic Progress (MAP)

Significant improvements were measured in:

- vocabulary
- reading comprehension
- reading
- language
- math computation
- math concepts and problem-solving

Questionnaire of Academic Skills and Learning Behaviours

Students reported the following significant changes in academic skills related to English, mathematics, and general learning:

- improved reading comprehension
- faster reading speed
- able to make connections between ideas more easily
- more able to write and take notes
- increased ability to grasp math concepts – more accuracy and speed
- less erroring in math
- faster at completing math problems
- easier to figure out steps in math problems
- faster at completing math work and able to finish math homework in class
- more attentive, focused, observant in class
- greater self-discipline
- increased ability to follow verbal instructions
- faster at completing homework
- more able to recall concepts and facts
- more prepared for college

Study 2 Cognitive Enhancement Program 2020-2021 -Teen Challenge Queensland Drug and Alcohol Rehabilitation Centres

Group

There were 8 participants enrolled in a treatment program for drug and alcohol addiction and were also enrolled in the Symbol Relations Cognitive Enhancement Program for 4 hours per week over 8 months.

Measures

Woodcock-Johnson IV Tests of Achievement

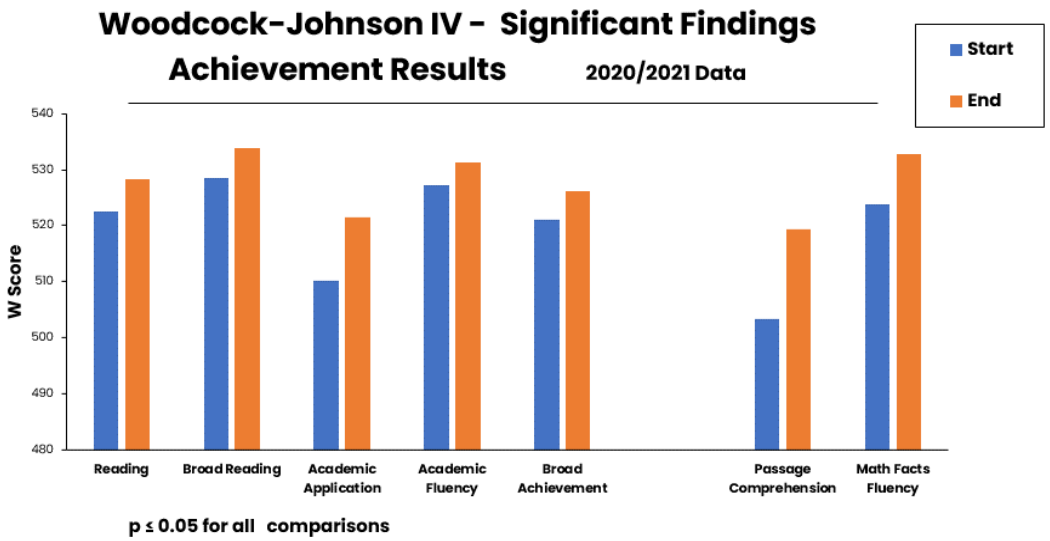
Self-Report Survey Questionnaire

This is a survey questionnaire completed by participants 3 to 6 months after completion of the cognitive program of observed changes across a range of dimensions related to the Symbol Relations cognitive function.

Results

The data analysis for Study 2 was completed by Dr. Greg Rose, Professor Emeritus, Southern Illinois University.

Woodcock-Johnson IV Tests of Achievement



The academic achievement areas showing significant Improvement:

Reading - word identification, reading speed, comprehension

Broad Reading – a composite of letter-word identification, reading fluency and passage comprehension

Academic Applications – a composite of passage comprehension, applied problems and writing samples

Academic Fluency – speed and accuracy in reading, doing simple math calculations and writing sentences

Broad Achievement – word identification, word attack, applied math problems, calculation, comprehension, writing samples, spelling, sentence reading fluency, math facts fluency, sentence writing fluency

Passage Comprehension – reading comprehension

Math Facts Fluency – speed and accuracy in simple math computations

Self-Report Survey Questionnaire

Results reported in combined data for Study 2 and Study 3 below.

Study 3 Cognitive Enhancement Program 2022/2024 - Teen Challenge Queensland Drug and Alcohol Rehabilitation Centres

Group

There were 20 participants enrolled in a treatment program for drug and alcohol addiction who were also enrolled in the Symbol Relations Cognitive Enhancement Program for 4 hours per week over 5 months.

Measures

Woodcock-Johnson IV Tests of Cognitive Abilities

Symbol Relations Cognitive Function Assessment

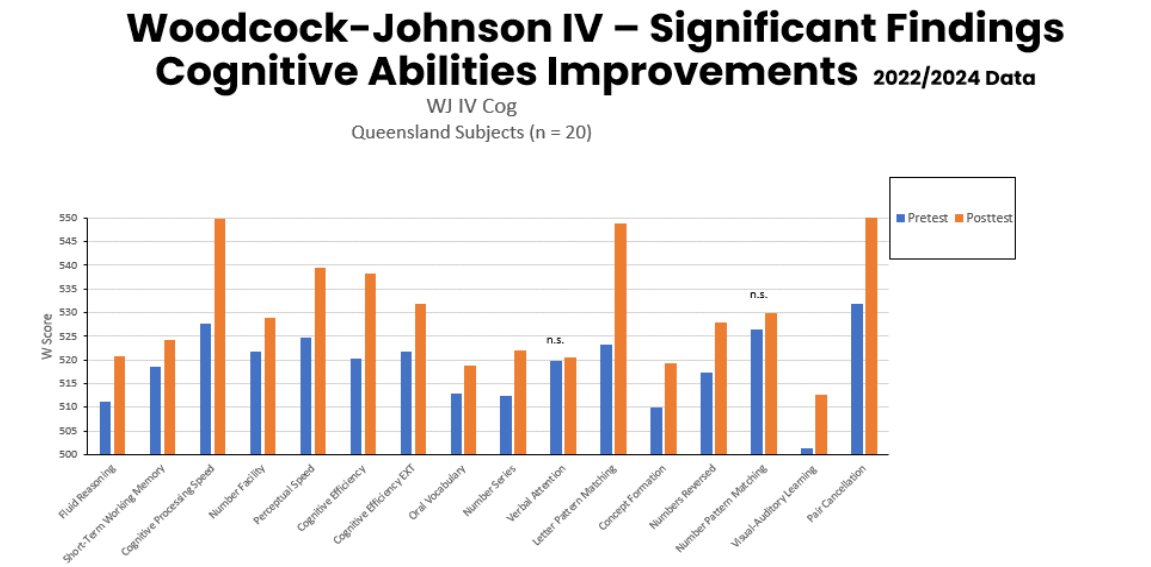
Self-Report Survey Questionnaire

Results

The data analysis was completed by Dr. Greg Rose, Professor Emeritus, Southern Illinois University.

Woodcock-Johnson IV Tests of Cognitive Abilities

The graph below shows after 5 months of the participants engaging in the Arrowsmith Symbol Relations cognitive exercise, statistically significant gains were made in many of the cognitive abilities on this standardised measure.



All Tests Significantly Improved After SR Training except Verbal Attention & Number Pattern Matching
p Values range from 0.039 to < 0.0001

The cognitive abilities showing significant Improvement:

Fluid Reasoning – measures broad ability to reason, form concepts, and solve problems using unfamiliar information or novel procedures.

Short-Term Working Memory – measures the ability to manipulate information in short-term memory to solve problems.

Cognitive Processing Speed – measures the ability to quickly perform both simple and complex cognitive tasks, particularly when under pressure to sustain controlled attention and concentration.

Number Facility – measures speed and accuracy working with numbers.

Perceptual Speed – measures the ability to rapidly identify matching items.

Cognitive Efficiency – measures the ability to cognitively process information automatically which frees up working memory.

Oral Vocabulary – measures vocabulary knowledge through assessing synonyms and antonyms.

Visual Auditory Learning – measures long-term storage and retrieval.

Number Series - measures quantitative reasoning and inductive reasoning.

Letter-Pattern Recognition – measures the speed at which one can make visual symbol discriminations and identify common orthographic (spelling) patterns.

Concept Formation – measures categorical reasoning based on principles of inductive logic.

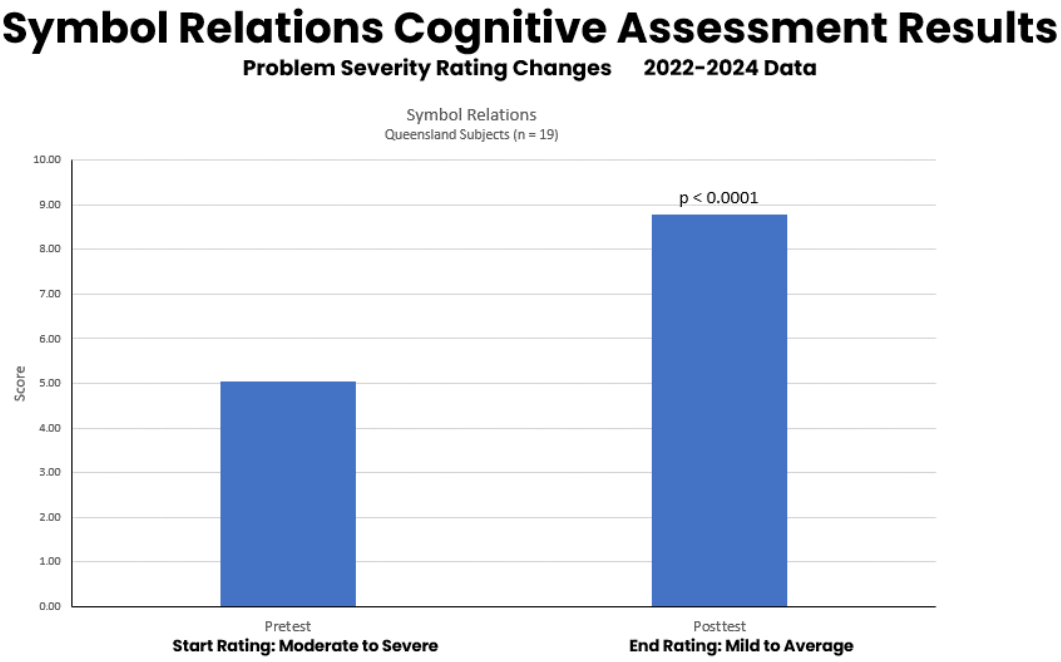
Numbers Reversed – measures short-term auditory working memory.

Visual Auditory Learning – measures long-term storage and retrieval.

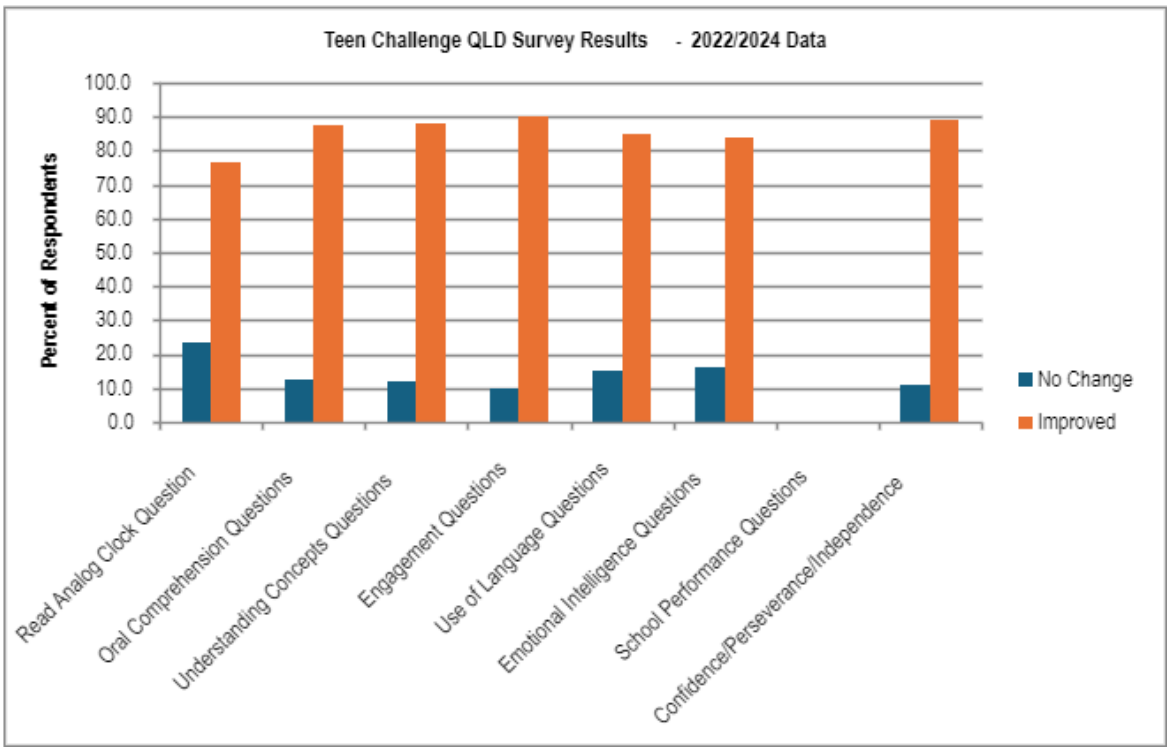
Pair Cancellation - measures interference and inhibition control (executive processing) and sustained attention (attention/ concentration).

Symbol Relations Cognitive Function Assessment

Over 5 months of working on the Symbol Relations cognitive function, participants moved from an initial rating of a Moderate to Severe level of a problem to a Mild to Average rating. This was a statistically significant improvement.



Self-Report Survey Questionnaire Results Data for Study 3 (2022/2024)



Three to six months after completion of the Symbol Relations cognitive program, participants completed a questionnaire. Significant improvement was reported in several behaviours which correspond to the results noted above in changes in cognitive abilities. These behaviours were grouped on analysis into the following categories, each of which showed significant improvement.

Oral Comprehension – able to grasp more quickly and accurately what is heard

Understanding Concepts – enhanced logical reasoning, understanding rules, seeing the big picture

Engagement – greater focus, attention, and mental initiative

Use of Language – improved vocabulary and communication skills

Emotional Intelligence – more able to interpret and express emotions, to reflect on behavior and problem solve in social situations, to understand interpersonal relationships, and more willing to engage in social situations

Confidence/Independence – more self-assured in situations, demonstrating greater perseverance, increased willingness to try new things and engage in challenging situations, more able to work independently, more self-confident.

Additional Participant Comments on Survey Questionnaire:

- greater self-awareness
- ability to think more clearly
- ability to focus for much longer and ignore distractions
- an ability to re-evaluate experiences and make connections as to why things happened
- an ability to perceive past events with more clarity
- a greater capacity to benefit from therapy
- increased empathy and emotional intelligence
- a greater sense of well-being
- increased locus of control through seeing themselves as agents of change in their lives
- improved decision making
- more able to communicate thoughts and feelings
- ability to reason more logically
- increased ability to remember events and details

Participants state:

“The most important way that the program has benefited me is that I know that my mind’s potential has been redeemed and that my mind has been totally restored, perhaps even better than it used to be in past years.”

“The Arrowsmith Program has helped my alertness, overall comprehension and logic of everyday things/activities. Also, improvement in social interactions and conversations/attention.”

“It has helped me to understand things better and to have a new look at my life for the future.”

“I can retain information when I read, my attention span has grown incredibly, and I can communicate better. I can connect my thoughts to my words now which has been a struggle for me for a while.”

"I have felt a dramatic change in my decision making, with my artwork and in my ability to focus.”

“I've noticed I have an improved ability to speak clearly and also an improvement in my anxiety levels. I have really seen an improvement in my ability to think clearly, recall information and match things up for written assessments."

"I have noticed I understand things more logically now when I am doing something. I am also improving a lot in other areas such as emotional and general intelligence."

Conclusion

The Symbol Relations cognitive program has shown to be a very effective adjunct to a treatment program for individuals recovering from addiction. Both the quantitative and qualitative data have shown it improves key cognitive functions which provide benefits in the treatment process.

Addressing cognitive areas that may have been impacted by addiction, helps improve cognitive and academic outcomes as well as assist the individual to gain insight, to regulate and understand emotions of self and others, to attach meaning to their emotional experience, to take the perspective of others necessary for empathy, to learn from past experiences and to apply these learnings to current situations. It helps in better therapy outcomes as well as preparing for re-entering society and the workforce after the participants have completed their program.

Research Report

Arrowsmith Symbol Relations Cognitive Program Outcomes in Teen Challenge QLD Addiction Treatment Program

Study 4 Cognitive Enhancement Program 2022 - Teen Challenge Centre, Tasmania

Group

There were 8 participants, comprised of 3 males and 5 females, with an average age of 13.1 and ranging in age from 8 to 20 years old. They worked on the Symbol Relations Cognitive Enhancement Program for 4 hours per week over 8 months. This population of children have had significant negative impact on their cognition related to trauma, prenatal issues, childhood experiences and substance abuse.

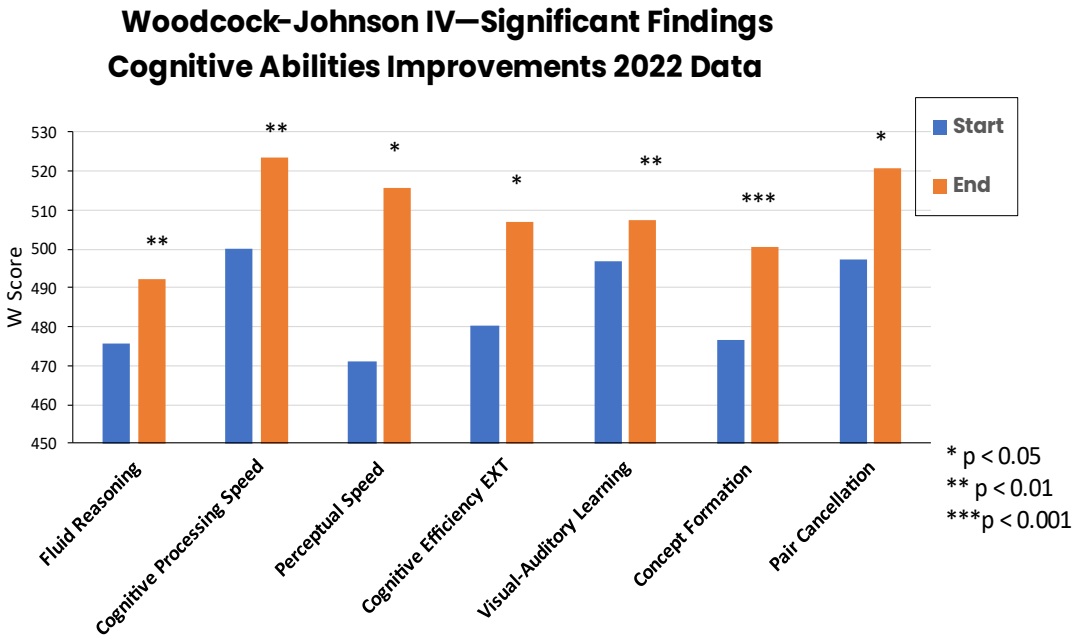
Measures

Woodcock-Johnson IV Tests of Cognitive Abilities and Achievement

Symbol Relations Survey Questionnaire

Results

The data analysis was done by Dr. Greg Rose, Professor Emeritus, Southern Illinois University.



The cognitive areas showing significant Improvement:

Fluid Reasoning – measures broad ability to reason, form concepts, and solve problems using unfamiliar information or novel procedures.

Cognitive Processing Speed – measures the ability to quickly perform both simple and complex cognitive tasks, particularly when under pressure to sustain controlled attention and concentration.

Perceptual Speed – measures the ability to rapidly identify matching items.

Cognitive Efficiency – measures the ability to cognitively process information automatically which frees up working memory.

Visual Auditory Learning – measures long-term storage and retrieval.

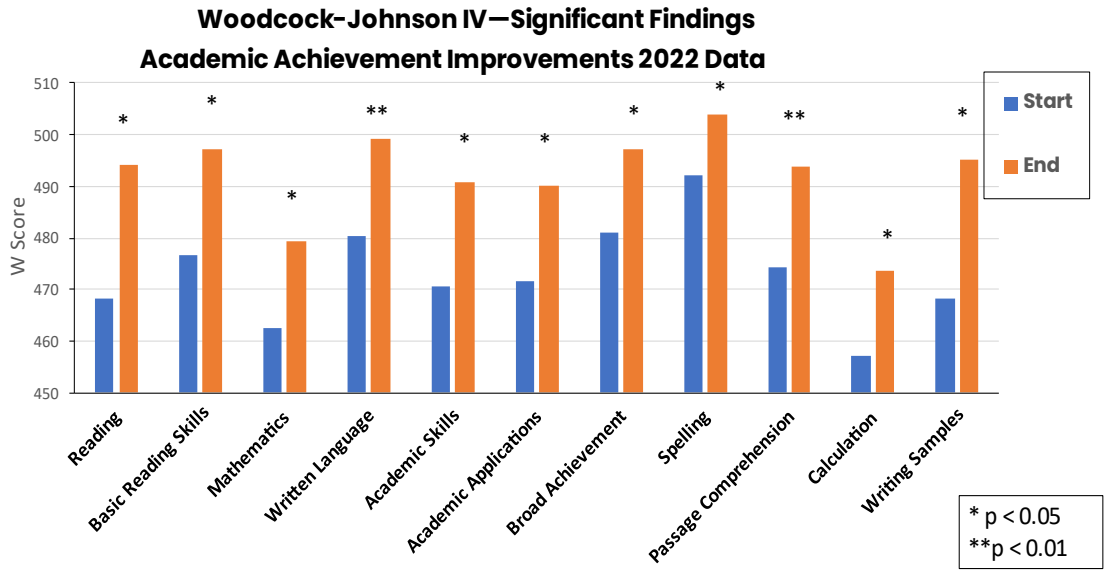
(spelling) patterns.

Concept Formation – measures categorical reasoning based on principles of inductive logic.

Pair Cancellation - measures interference and inhibition control (executive processing) and sustained attention (attention/ concentration).

Woodcock-Johnson IV Tests of Achievement Results

Participants showed statistically significant gains on a standardized measure of academic achievement in several academic skills (Woodcock-Johnson IV Test of Achievement).



The academic achievement areas showing significant Improvement:

Reading - word identification, reading speed, comprehension

Reading Skills- word identification and word attack (phonetics)

Mathematics – applied math problems and calculation

Written Language – spelling and writing samples

Academic Skills – word identification, spelling, calculation

Academic Applications - applied math problems, comprehension, writing Samples

Broad Achievement – word identification, word attack, applied math problems, calculation, comprehension, writing samples, spelling, sentence reading fluency, math facts fluency, sentence writing fluency

Spelling – spelling

Passage Comprehension – reading comprehension

Calculation – math computation

Writing Samples – writing samples based on a verbal or picture cue

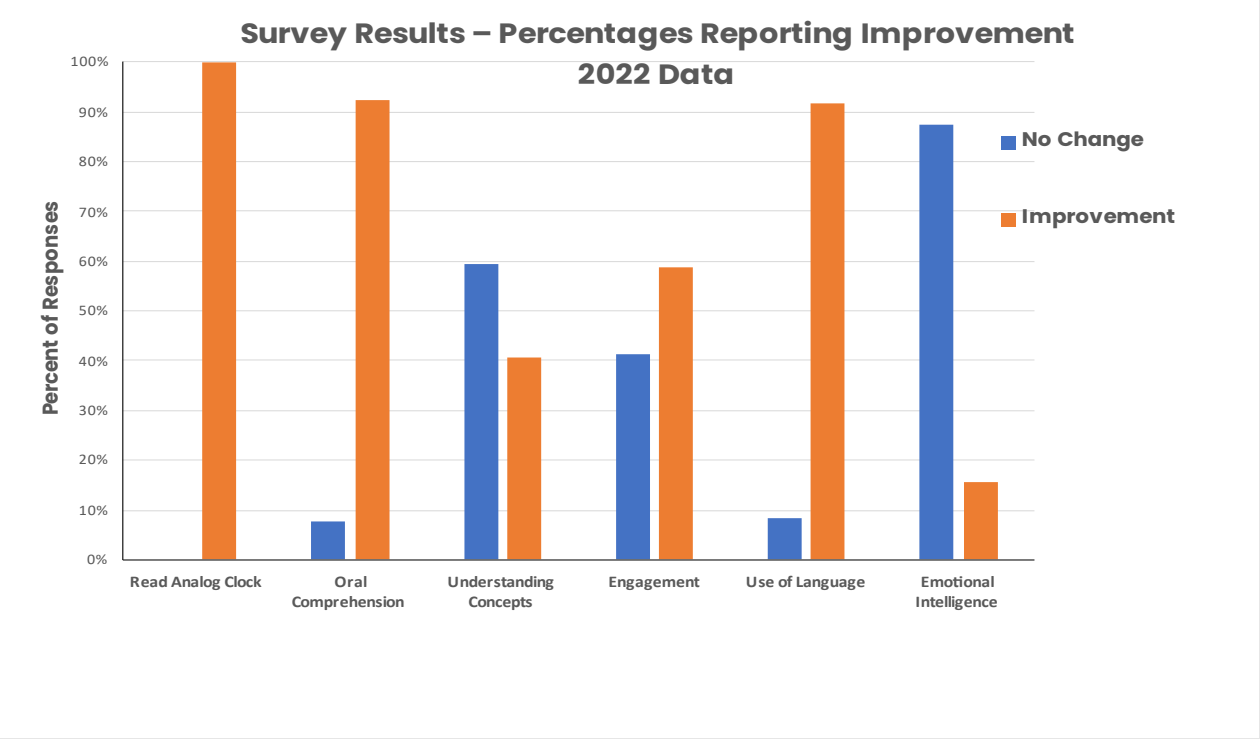
Symbol Relations Survey Questionnaire

Three to six months after completion of the Symbol Relations cognitive program, parents and/or guardians reported significant improvement on several behaviours which correspond to the changes noted above in cognitive abilities. These behaviours were grouped on analysis into the categories, the following of which showed significant improvement.

Oral Comprehension – able to grasp more quickly and accurately what is heard

Engagement – greater focus, attention, and mental initiative

Use of Language – improved vocabulary and communication skills



Parents/Guardians on the Survey reported:

- Now asks in depth questions
- Vocabulary is much better
- More able to understand and comprehend during a conversation
- Better able to argue a point in a clear and thoughtful way
- School is reporting better behaviour
- Better learning outcomes at school and more settled in class
- Teachers report learning is getting better
- Improved understanding of the work in class
- Changes seen in English, Mathematics, Written Expression
- Spelling is better and essays make more sense
- Now enjoying schoolwork and learning new things
- Getting better grades
- Finds schoolwork easier and requires less help
- More eager and motivated to learn
- Getting work done on time and getting good grades
- Becoming confident to go places without me
- Thinking and strategies have improved
- More settled and able to regulate quicker in most situations

Areas of reported concern were behavioural challenges related to previous trauma:

- Still struggles with confidence, but this is trauma based.
- Trauma based behaviour that is extremely challenging.
- Behaviour is trauma based.

Conclusion

The Symbol Relations cognitive program is an effective adjunct to the educational program for this population of students who have had significant negative impact on their cognition correlated to trauma, prenatal issues, childhood experiences and substance abuse. The Arrowsmith Symbol Relations cognitive program fostered significant cognitive and academic gains essential for learning, school success and social-emotional well-being. The cognitive gains translated into significant academic achievement gains.

Research Report

Arrowsmith Symbol Relations Cognitive Program Outcomes in Teen Challenge Tasmania Program

Study 5 Cognitive Enhancement Program 2024 – El Castillo International School, Madrid Spain

Group

There were 12 participants in grades 4 to 6 identified as gifted, with an average age of 10.5 and ranging in age from 9.11 to 11.11 years old. They worked on the Symbol Relations Cognitive Enhancement Program for 2 hours per week over 5 months.

Measures

Raven's Progressive Matrices – pre-test only

Stroop Task

Tower of London

d2 Test of Attention

Claves – WISC-V Symbol Search Spanish subtest

Balanzas – WISC-V subtest

Symbol Relations Survey Questionnaire

Immediate Mood Scaler

Results

The data analysis was done by Dr. Laura Herrero, Professor at Universidad Camilo José Cela and Dr. Greg Rose, Professor Emeritus, Southern Illinois University.

Raven's Progressive Matrices

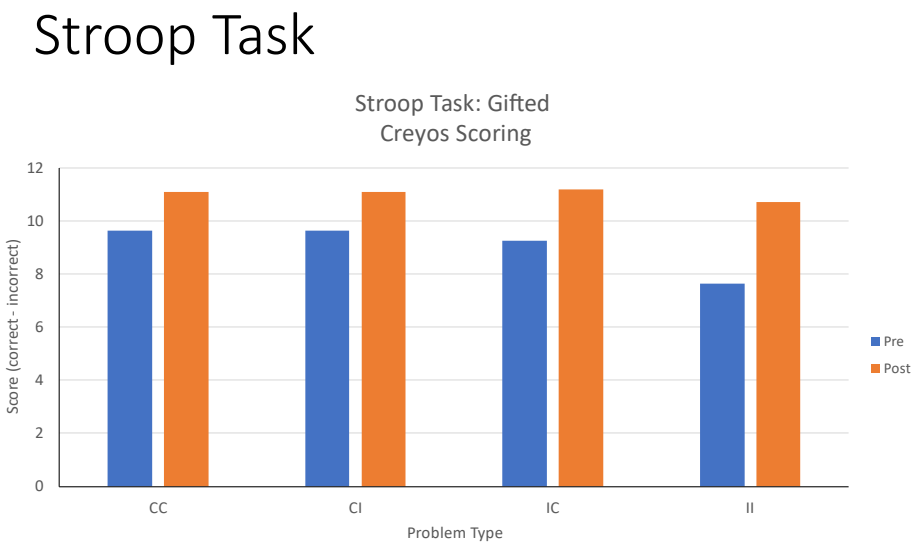
This is a nonverbal test of intelligence. The scores were normally distributed with a mean score of 41.7, a standard deviation of 6.3, and a range of 31 to 55.

Stroop Task

This measure assesses response inhibition - the ability to focus on relevant information in order to make a response when presented with distracting information. It assesses selective attention, processing speed, inhibitory cognitive control, and executive functioning.

For the group of gifted students, the Symbol Relations program resulted in significant improvement (p = .014) on this cognitive measure indicating gains in:

- selective attention
- processing speed
- inhibitory cognitive control
- executive functioning

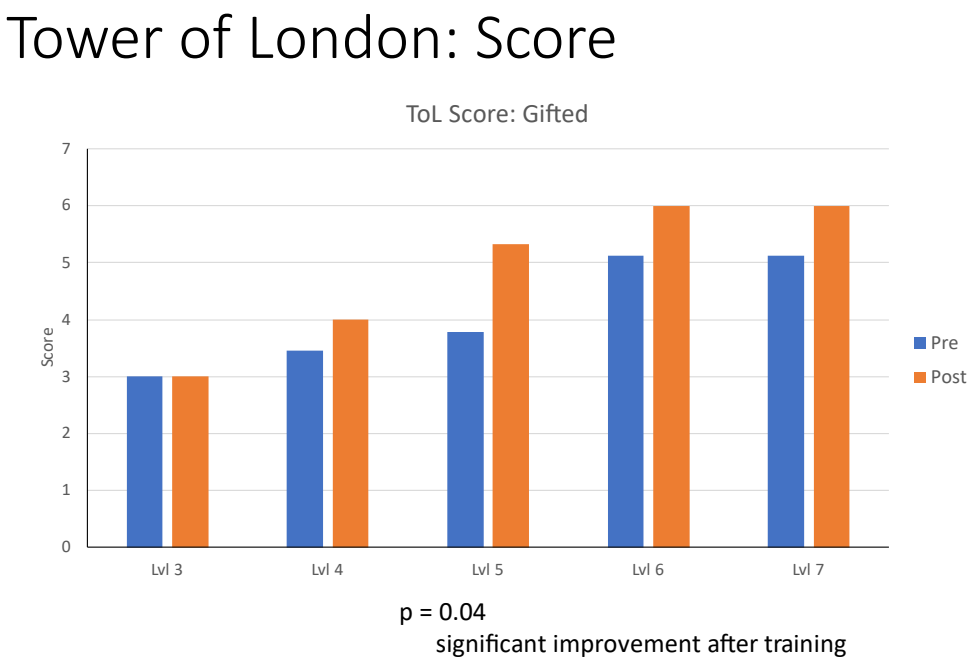


p = 0.014
significant improvement after training

Tower of London

This measure assesses the ability to plan and sequence behaviour to reach a goal.

The gifted group showed significant improvement in their overall score on this measure (p = .04) demonstrating that their planning ability was more accurate at the end of the cognitive program than before.



p = 0.04
significant improvement after training

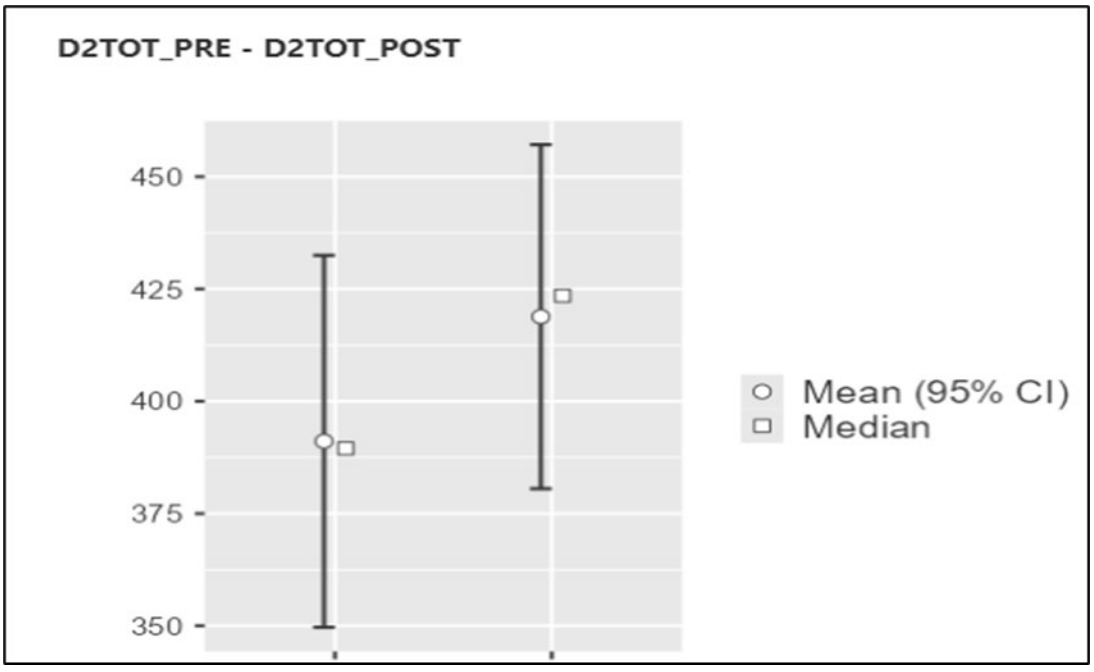
d2 Test of Attention

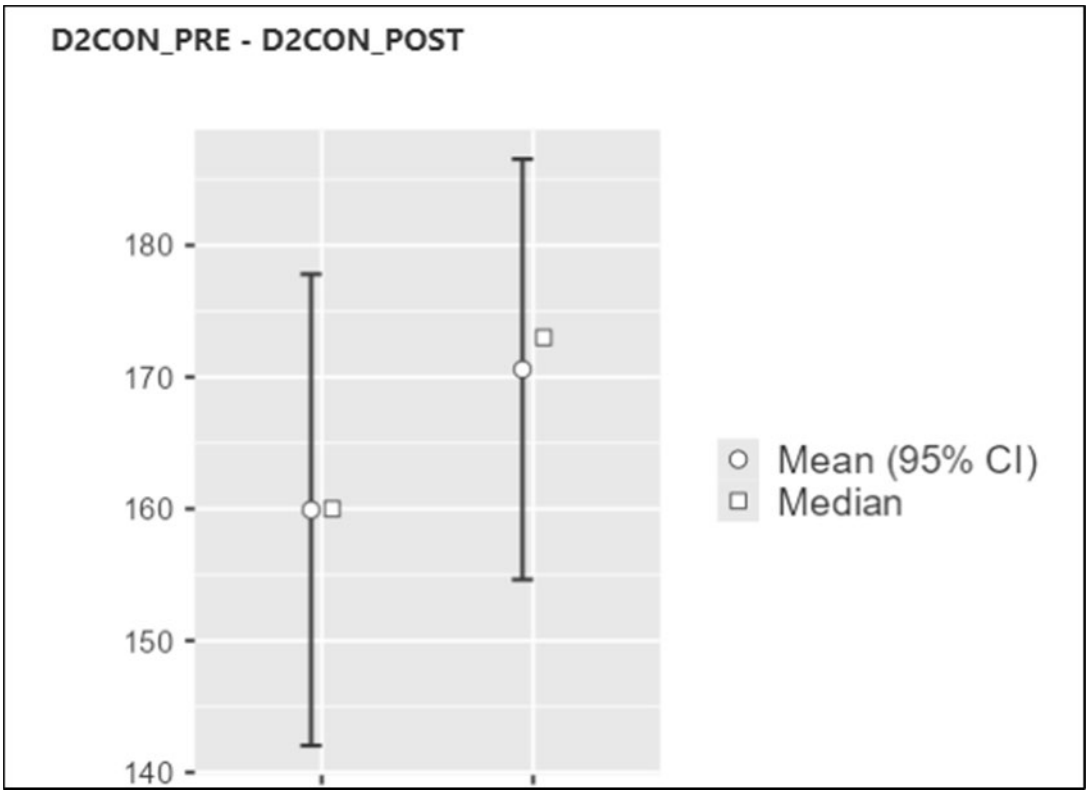
This test assesses selective attention, processing speed, adherence to instructions, and quality of execution in a task involving discrimination of similar visual stimuli. It requires focused attention to a series of relevant stimuli while ignoring irrelevant stimuli.

There are two results reported: D2 TOT which measures general processing speed and selective attention; and D2 CON which is a measure of concentration abilities.

The gifted group showed significant improvement on both aspects of this test (D2 TOT p = .04; D2 CON p = .05) demonstrating improvements in:

- selective attention
- processing speed
- concentration
- executive functioning

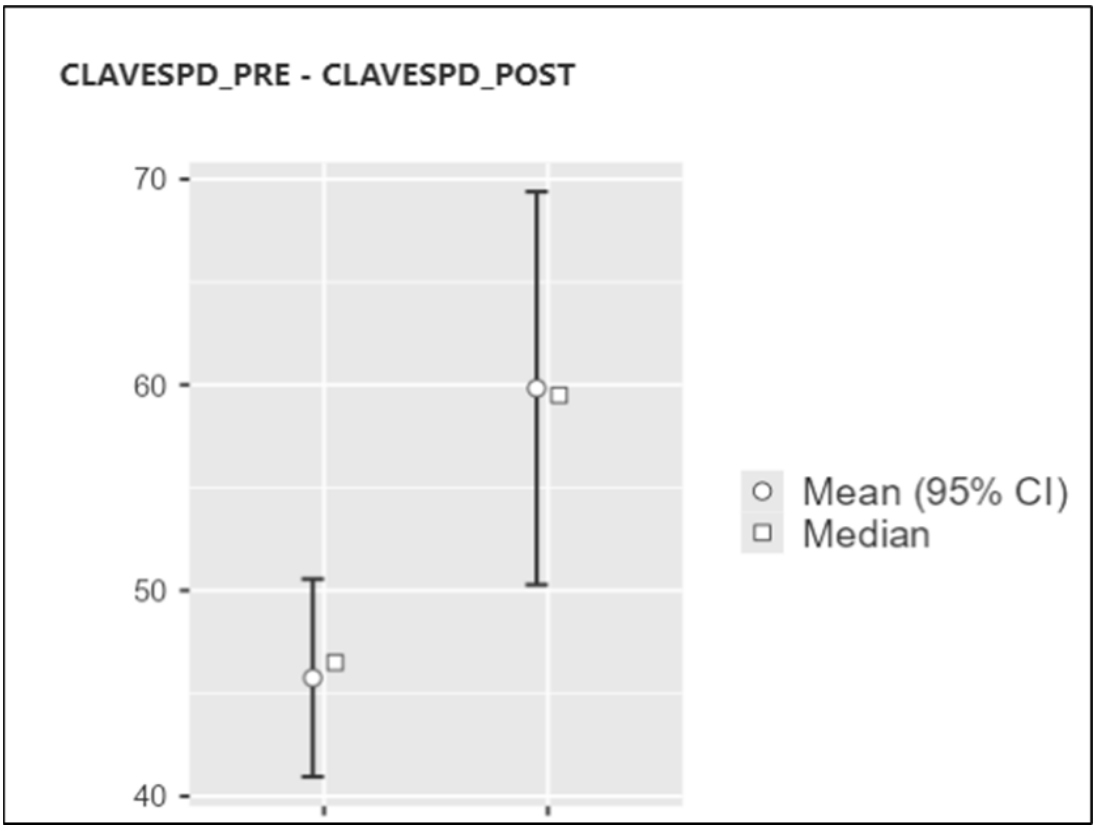



D2CON_PRE - D2CON_POST
180
170
160
150
140
Mean (95% CI)
Median

Claves – WISC-V Symbol Search Spanish subtest

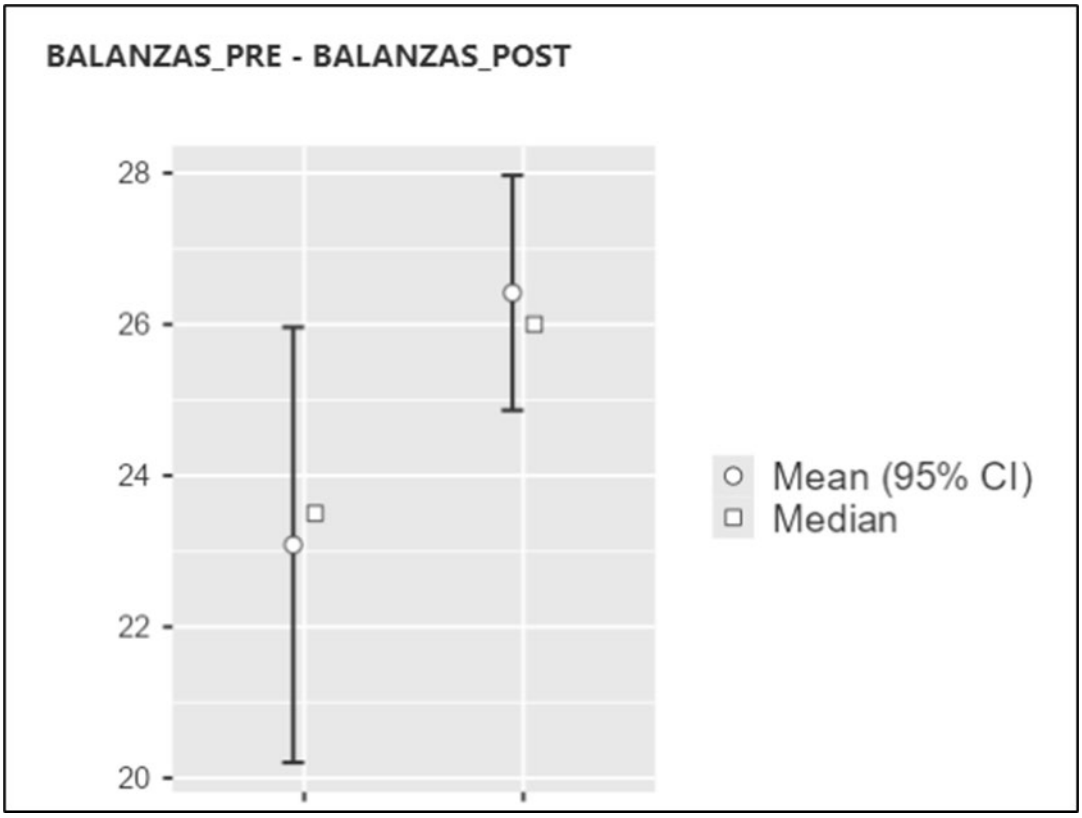
This is the Spanish version of the Symbol Search on the WISC-V. It is a measure of processing speed.

The improvement in processing speed at the end of the cognitive program for students in the gifted group was statistically significant (p = .009).



Balanzas – WISC-V subtest

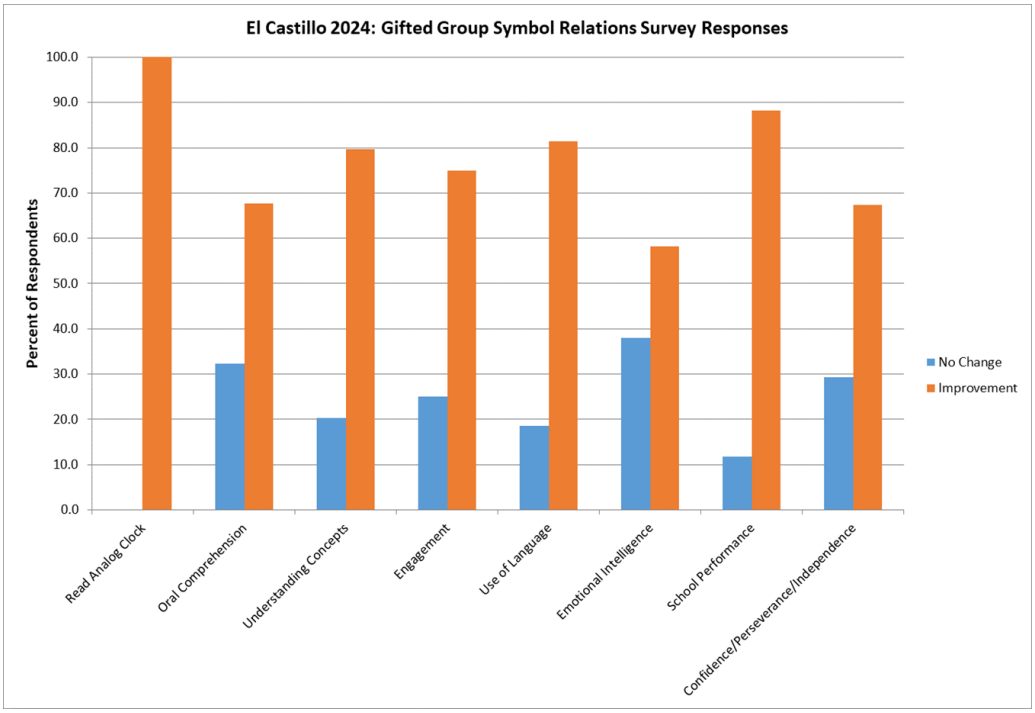
This test measures quantitative and analogical reasoning using physical principles. The change pre and post training approached significance (p = .07).



Symbol Relations Survey Questionnaire

After completion of the Symbol Relations cognitive program, participants and parents completed a questionnaire.

Significant improvement was reported in several behaviours which correspond to the changes measured in these students' cognitive abilities.



On analysis, these behaviours were grouped into the following categories.

Oral Comprehension – able to grasp more quickly and accurately what is heard

Understanding Concepts – enhanced logical reasoning, understanding rules, seeing the big picture

Engagement – greater focus, attention, and mental initiative

Use of Language – improved vocabulary and communication skills

Emotional Intelligence – more able to interpret and express emotions, to reflect on behavior and problem solve in social situations, to understand interpersonal relationships, and more willing to engage in social situations

Confidence/Perseverance/Independence – more self-assured in situations, demonstrating greater perseverance, increased willingness to try new things and engage in challenging situations, more able to work independently, more self-confident.

Immediate Mood Scaler

The researcher noted that the students had difficulty understanding the emotions the test was asking them to rate, so the results were determined as not reliable.

Conclusion

The Symbol Relations cognitive program is an effective adjunct to the educational program for this population of students identified as gifted.

The Arrowsmith Symbol Relations cognitive program fostered significant cognitive gains essential for learning, school success and social-emotional well-being.

Research Report

Arrowsmith Symbol Relations Cognitive Program Outcomes in SEK International Schools

Study 6 Cognitive Enhancement Program 2024 – El Castillo International School, Madrid Spain

Group

There were 12 participants in grades 3 to 6 diagnosed as having dyslexia, with an average age of 9.7 and ranging in age from 8.3 to 11.9 years old. They worked on the Symbol Relations Cognitive Enhancement Program for 2 hours per week over 5 months.

Measures

Raven's Progressive Matrices – pre-test only

Stroop Task

Tower of London

d2 Test of Attention

Claves – WISC-V Symbol Search Spanish subtest

Rey-Osterrieth Complex Figures

Symbol Relations Survey Questionnaire

Immediate Mood Scaler

Results

The data analysis was done by Dr. Laura Herrero, Professor at Universidad Camilo José Cela and Dr. Greg Rose, Professor Emeritus, Southern Illinois University.

Raven's Progressive Matrices

This is a nonverbal test of intelligence. The scores were normally distributed with a mean score of 31.2, a standard deviation of 7.78, and a range of 20 to 45.

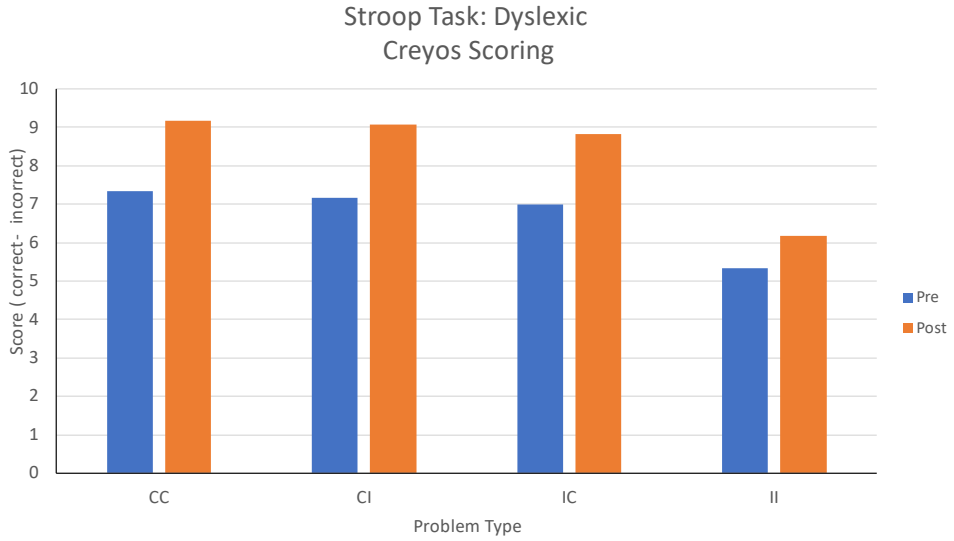
Stroop Task

This measure assesses response inhibition - the ability to focus on relevant information in order to make a response when presented with distracting information. It assesses selective attention, processing speed, inhibitory cognitive control, and executive functioning.

For the students in this study diagnosed with dyslexia, the Symbol Relations program resulted in significant improvement (p = .008) on this cognitive measure indicating gains in:

- selective attention
- processing speed
- inhibitory cognitive control
- executive functioning

Stroop Task



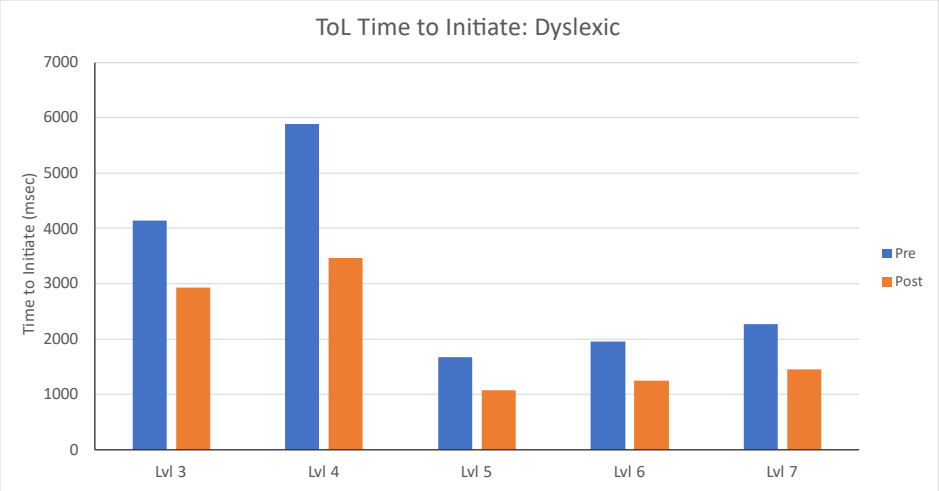
p = 0.008
significant improvement after training

Tower of London

This measures the ability to plan and sequence behaviour to reach a goal.

The dyslexic group showed significant improvement in their time to initiate the task (p = .03) demonstrating that their planning ability was faster at the end of the cognitive program than before.

Tower of London: Time to Initiate



p = 0.03
significant improvement after training

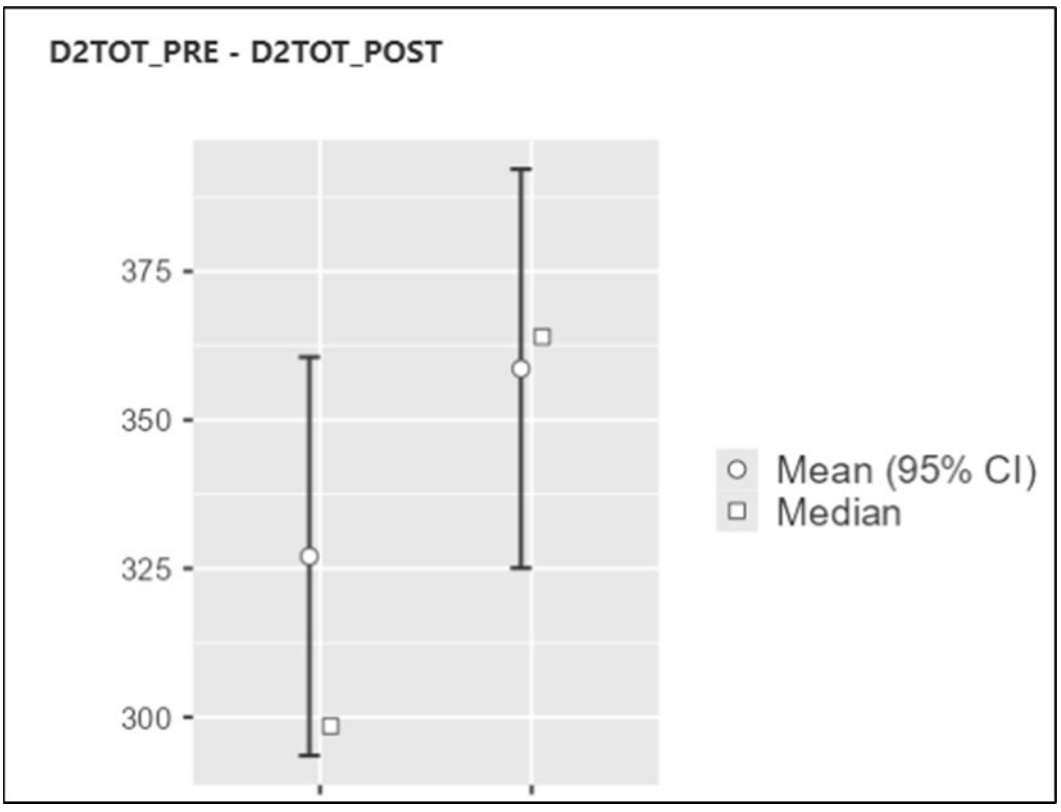
d2 Test of Attention

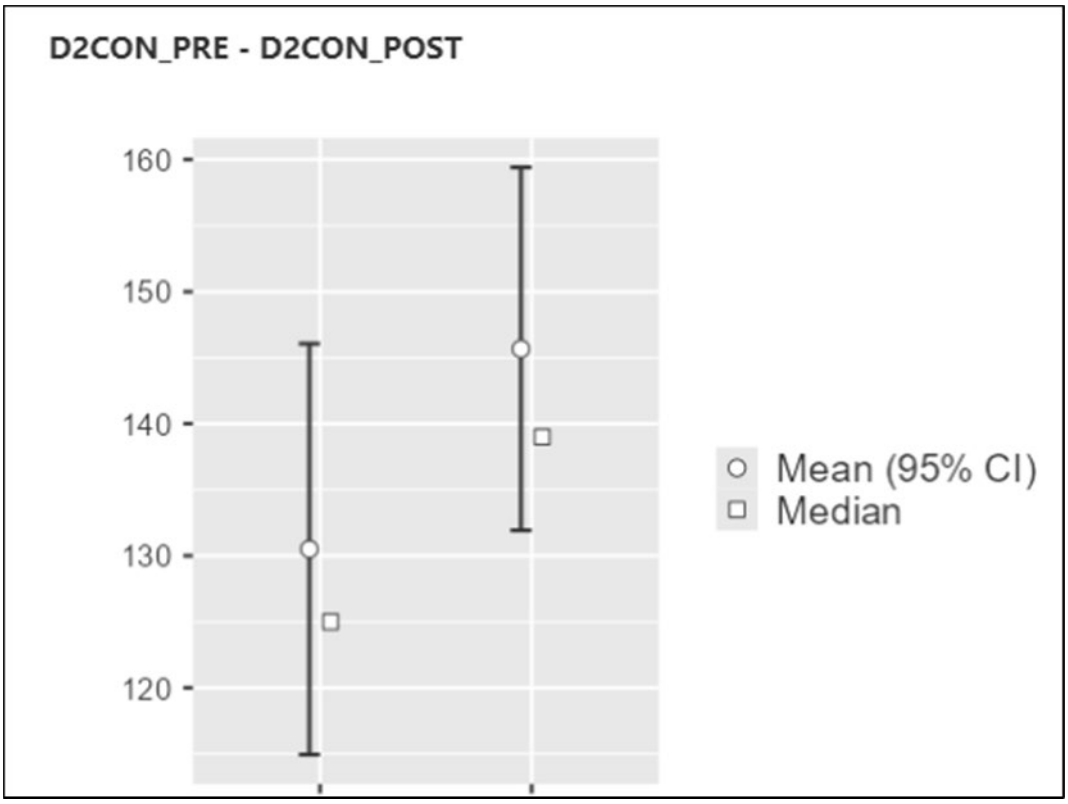
This test assesses selective attention, processing speed, adherence to instructions, and quality of execution in a task involving discrimination of similar visual stimuli. It requires focused attention to a series of relevant stimuli while ignoring irrelevant stimuli.

There are two results reported: D2 TOT which measures general processing speed and selective attention; and D2 CON which is a measure of concentration abilities.

The group of students with dyslexia showed significant improvement on both aspects of this test (D2 TOT p = .02; D2 CON p = .01) demonstrating improvements in:

- selective attention
- processing speed
- concentration
- executive functioning

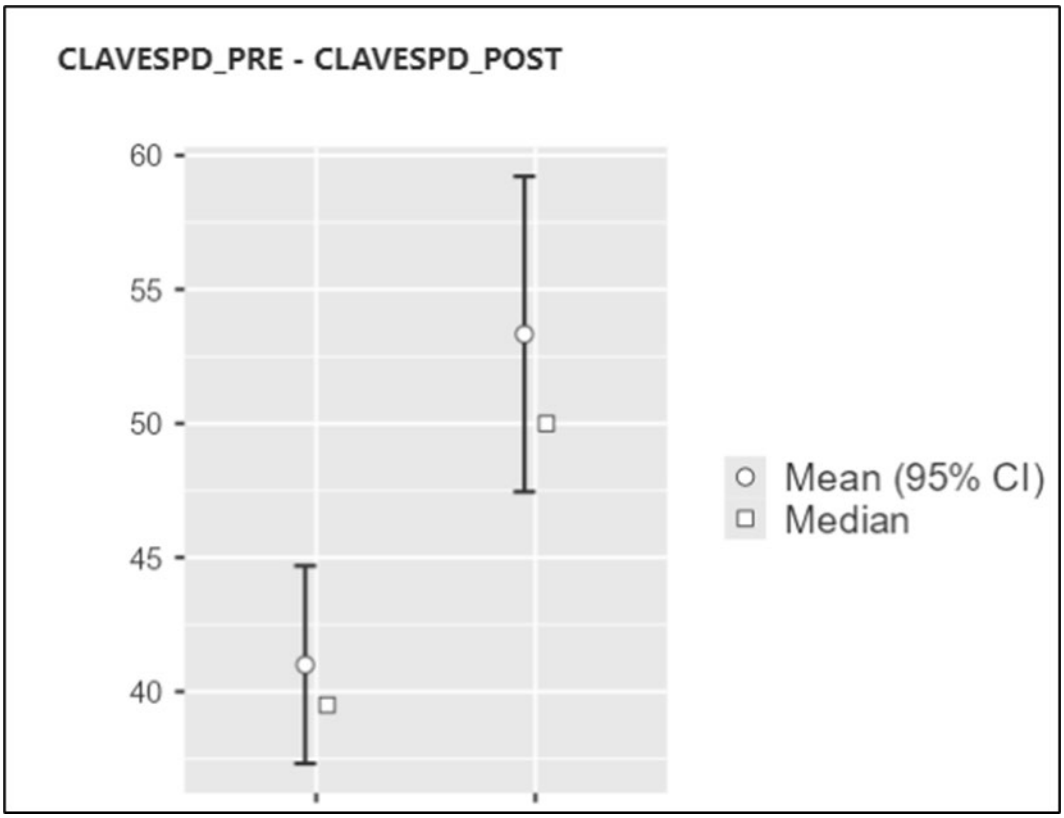



D2CON_PRE - D2CON_POST
160
150
140
130
120
Mean (95% CI)
Median

Claves – WISC-V Symbol Search Spanish subtest

This is the Spanish version of the Symbol Search subtest on the WISC-V. It is a measure of processing speed.

The improvement in processing speed at the end of the cognitive program for students in the dyslexic group was statistically significant (p = .005).



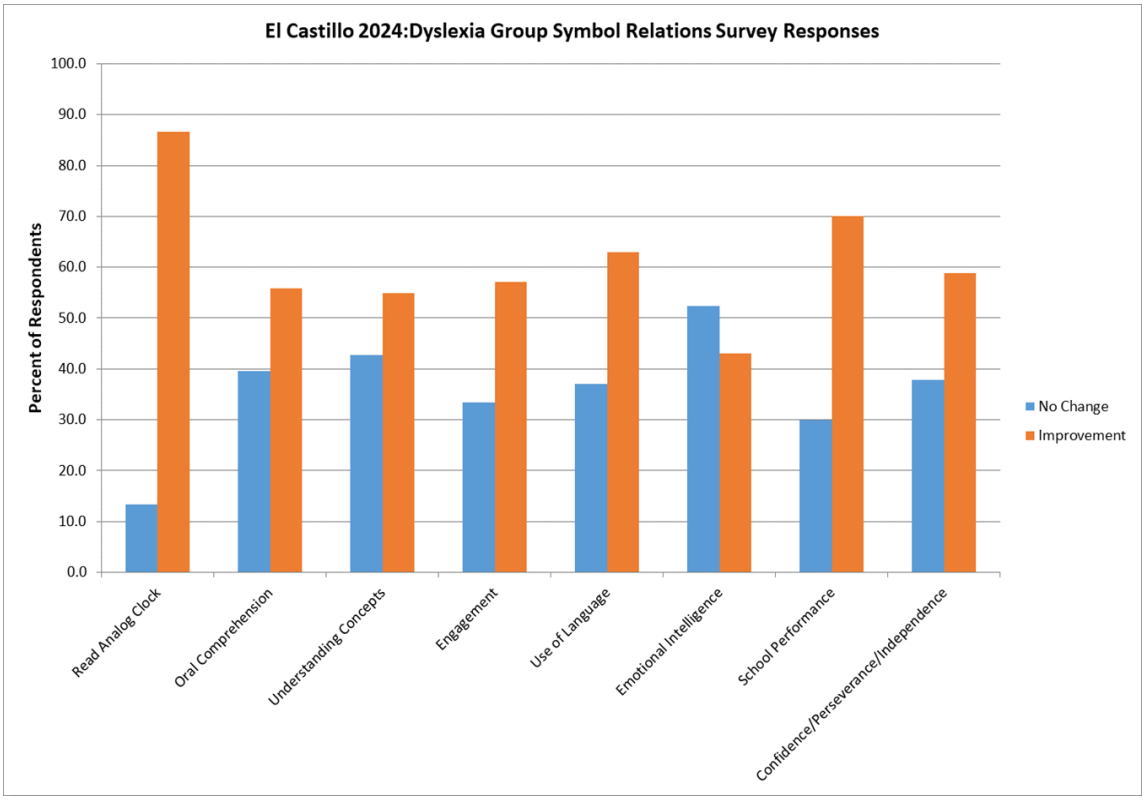
Rey-Osterrieth Complex Figures

This test measures visuospatial planning and memory abilities and involves copying a figure from an image and then from memory. There was improvement on this measure, however the change between pre and post testing was not significant.

Symbol Relations Survey Questionnaire

After completion of the Symbol Relations cognitive program, participants and parents completed a questionnaire.

Significant improvement was reported in several behaviours which correspond to the changes measured in these students' cognitive abilities.



On analysis, these behaviours were grouped into the following categories.

Oral Comprehension – able to grasp more quickly and accurately what is heard

Understanding Concepts – enhanced logical reasoning, understanding rules, seeing the big picture

Engagement – greater focus, attention, and mental initiative

Use of Language – improved vocabulary and communication skills

Emotional Intelligence – more able to interpret and express emotions, to reflect on behavior and problem solve in social situations, to understand interpersonal relationships, and more willing to engage in social situations

Confidence/Perseverance/Independence – more self-assured in situations, demonstrating greater perseverance, increased willingness to try new things and engage in challenging situations, more able to work independently, more self-confident.

Immediate Mood Scaler

The researcher noted that the students had difficulty understanding the emotions the test was asking them to rate, so the results were determined as not reliable.

Conclusion

The Symbol Relations cognitive program is an effective adjunct to the educational program for this population of students who have a diagnosis of dyslexia.

The Arrowsmith Symbol Relations cognitive program fostered significant cognitive gains essential for learning, school success and social-emotional well-being.

Research Report

Arrowsmith Symbol Relations Cognitive Program Outcomes in SEK International Schools

Summary of Research Results for Symbol Relations Cognitive Program

The Symbol Relations cognitive function simultaneously processes multiple stimuli - both external and internal - necessary to understand the world, oneself, and others. It is involved in processing concepts across academic disciplines, understanding and quickly grasping what is read and heard, gaining insight, logical reasoning, seeing connections between ideas, cause and effect reasoning, flexibility of thought, speed of processing, making rational and considered decisions, perspective taking, deep semantic grasp of language and mathematical reasoning.

Research conducted on the Symbol Relations program across different populations and in different delivery models presented in this document has demonstrated significant positive changes in:

- connectivity within and between **neural networks** in the brain (Default Mode Network, Salience Network, Frontoparietal/Executive Control Network, Dorsal Attention Network);
- **cognitive** functioning across a broad range of cognitive domains;
- **academic** achievement; and
- **well-being** and **social-emotional** intelligence

These **neural networks** (Default Mode Network, Salience Network, Frontoparietal/ Executive Control Network, Dorsal Attention Network) are involved in the following processes:

- Reasoning
- Thinking, Planning, Problem-Solving
- Executive Control
- Working Memory
- Attention
- Self-Regulation and Inhibitory Control
- Introspection and Self-Awareness
- Perspective Taking
- Insight
- Goal Setting and Execution
- Cognitive Flexibility
- Cognitive Efficiency
- Evaluating Relevance
- Mental Initiative

As these changes are occurring in the brain, the research is demonstrating significant positive changes in:

Cognitive Abilities

- Fluid Reasoning
- Deductive Reasoning
- Concept Formation/Inductive Logic
- Quantitative Reasoning
- Processing Speed
- Cognitive Efficiency
- Cognitive Flexibility
- Working Memory
- Perceptual Speed
- Oral Vocabulary
- Use of Language
- Oral Comprehension
- Understanding Concepts
- Visuospatial Ability
- Visual-auditory learning
- Sustained Attention
- Selective Attention
- Concentration
- Endurance & Persistence
- Engagement
- Long Term Storage and Retrieval
- Inhibitory Cognitive Control
- Response Inhibition
- Executive Functioning
- Planning Ability

Academic Achievement

- Reading
- Reading Comprehension
- Reading Speed
- Vocabulary
- Writing Speed
- Written Language
- Academic Fluency
- Broad Academic Achievement
- Math Computation
- Math Calculation Speed
- Math Concepts and Problem Solving

Well-Being and Social-Emotional Intelligence

- Reduction in depression and anxiety
- Less frustrated
- More engaged
- More motivated
- More alert and energetic
- Calmer
- Greater Confidence and Self-Assurance
- More optimistic
- More fearless
- More able to understand and express emotions
- More willing to engage in social situations
- Better able to understand interpersonal relationships
- More able to reflect on behaviour and problem solve in social situations
- Improvement in overall mood
- Growth in Emotional Intelligence

Conclusion

The Symbol Relations cognitive program has significant benefit for individuals with learning disabilities and learning difficulties, students diagnosed with dyslexia, students in mainstream classes, gifted students, students whose learning has been impacted by trauma, and adults recovering from addiction. As the brain changes, there are positive cognitive gains which support learning and the acquisition of academic skills as well as social-emotional well-being.

Additional Research

Additional research is available here: Arrowsmith Research

Additional Reading

The nature of the Symbol Relations cognitive function and how a problem in this area manifests itself, is described in Chapter 8, “Lost in Translation” of *The Woman Who Changed Her Brain* by Barbara Arrowsmith-Young.

Appendix A: Research Measures Used

Balanzas (WISC-V)

California Achievement Test

Claves Test (WISC-V Symbol Search)

CNS Vital Signs Neurocognitive Assessment

Concentration Endurance Test (d2)

Creyos (Cambridge Brain Sciences) Cognitive Tasks

- Token Search
- Spatial Planning
- Double Trouble

d2 Test of Attention

Go No Go Task

Immediate Mood Scaler

Measure of Academic Progress

Questionnaire of Academic Skills and Learning Behaviors

Raven Progressive Matrices

Resting-state fMRI Imaging

Rey-Osterrieth Complex Figure Test

Stroop Task

Symbol Relations Cognitive Function Assessment

Symbol Relations Survey Questionnaire

Tower of London Task

Trail Making Test

Wisconsin Card Sorting Test

Woodcock-Johnson IV Tests of Cognitive Abilities and Achievement