REYNOLD LEARNING

A Study of the Effectiveness of Sensory Integration Therapy on Neuro-Physiological Development

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- Abstract

Background:
Sensory integration theory proposes that because there is plasticity within the central nervous system (the brain is moldable) and because the brain consists of systems that are hierarchically organised, it is possible to stimulate and improve neuro-physiological processing and integration and thereby increase learning capacity.

Objective:
Accordingly, the objective of this study was to assess the effectiveness of sensory integration therapy on improving the neuro-physiological capacity of children identified as having learning difficulties.

Method:
The Beery VMI and the TVPS-3 were used as appropriate neurological development tests to measurement the improvement in neuro-physiology of the children. The study of 62 children diagnosed as having learning difficulties was conducted over the 2007-08 and 2008-09 school years.

Results:
In both visual perceptual and visual motor integration assessments, the median standardized scores for the study cohorts over the two academic years showed extremely statistically significant and very statistical significant results with a correlated increase in neuro-physiological performance across the two assessment schemes.

Conclusion:
The results suggest an unusual advancement in the children’s development. They indicate that the sensory integration therapy program was distinctly effective in improving the neuro-physiological development of children with learning difficulties.

As the brain processes and integrates information through its sensors, it is able to plan and organise behaviour in order to make adaptive responses in the ongoing process of learning. This neuro-processing of sensory information is called sensory integration (Ayres, 1979). However, where the brain is not properly receiving sensory input, and/or not integrating the sensory information properly, learning is belated. Learning is implicitly a neurological function and the capacity to learn is dependent upon neurological efficiency (neuro-efficiency).[1]If the sensory system is not functioning as it should, or where sensory information is not appropriately integrated, there is said to be a learning disorder/difficulty.[2]

Accordingly, the objective of this study is to test the effectiveness of a sensory integration program in improving the neuro-physiological development of children with learning difficulties. In accepting that perception and integration of information are fundamental aspects for efficient neurological function (see Literature Review), it is proposed to use tests of visual perception and visual-motor integration to measure the degree of improvement of children in the study.

Theoretical Background

Sensory Integration Theory

Sensory integration (SI) theory postulates that the brain is in interaction with its environment through its sensory systems establishing a process of reaction-interaction-and-learning. The process is understood to be both cyclical and accumulative as the interaction process builds on, or accumulates information for further interaction and learning. The elements of the cycle are: sensory intake, sensory integration, planning and organising, adaptive behaviour and learning, and feedback (Bundy et al., 2002).

This integrating process of sensory input Kayser (2007) argues is fundamental to the thinking process. As new information is perceived it is first processed by the mid-brain and brain stem regions of the central nervous system in the pathways for sensory integration. The integration process continues and occurs in higher-level regions of the brain and very early in the 'thinking' process. The point being that improving the sensory process and integration of the brain is fundamental to increasing neuro-efficiency and correcting a learning difficulty.

Learning Difficulties

Sensory integration theory seeks to address problems in learning and behaviour that cannot be attributed to central nervous system damage or abnormalities. Learning difficulties stem from dysfunctions in central processing and integration of sensory inputs (Bundy et al., 2002) and encompasses a range of neuro-physiological impairments to detecting, modulating, interpreting, or responding to sensory stimuli (Miller, Coll, & Schoen, 2007). It is estimated that up to 15% of children in the USA have sensory integration dysfunctions causing them to be slow learners and have behavioural problems (Ayes, 1979; Lyon 2003; McElgunn 1996).

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[1] Neuro-efficiency refers to the degree of neuro-physiological ability to learn. Thus, a good learner is understood to have "neuro-efficiency" and a poor learner, to have "neuro-inefficiency". Providing the brain stimulus to respond appropriately to sensory input is here referred to as the process of effecting neuro-efficiency.

[2] Note: The implication is that a learning disability is not the result of poor academic teaching and will not be alleviated by increased or intensive academic tuition (see Abikoff, Ganeles, Reiter, Blum, Foley, & Klein, 1987).

Literature Review

Jean Ayres began her research of child neurodevelopment in the 1950s. By the 1980s, a debate had developed over the efficacy of sensory integration treatment (Bundy et al., 2002; Cermak & Henderson, 1989; Densem, Nuthall, Bushnell, & Horn, 1989; Hoehn & Baumeister, 1994; Humphries, Wright, McDougall, & Vertes, 1990; Miller & Kinnealey, 1993; Ottenbacker, 1982; Schaffer, 1984). The main criticism of sensory integration research concerned the validity and reliability of the instrumentation used for assessment with the claim that there is often inconsistence between the theoretical models that guide the practice and the treatment methods used for assessment (Mauer, 1999; Miller & Kinnealey 1993; Rodger et al., 2005). Accordingly, the particular concern of this literature review is to briefly discuss this issue of the effectiveness of sensory integration treatment methods in improving neurological development in children.

A review of the sensory integration studies suggests that the most common research method used has been the comparison of a randomly selected test group to one or two other active or non-active cohorts. The range of research to measure sensory integration efficacy has been wide and included fine motor skills, visual-motor skills, gross motor and upper limb coordination, postural skills, vestibular functioning, language development, handwriting evaluation, and reading evaluation (Hoehn & Baumeister, 1994; Miller & Kinnealey, 1993; Pressley, 1976; Solan 1987; Taylor, 2007; Taylor, 1999). Yet, despite this impressive list of evaluations, sensory integration therapy has had its critics who have been unconvinced that any of this research was effective (Hoehn & Baumeister, 1994; Leong & Carter, 2008; Polatajko, Kaplan & Wilson, 1992). The primary problem being that one randomly selected controlled experiment can differ widely from the next and not produce the needed consistency for a body of research demonstrating therapy efficacy. There also appears to have been a broad approach to defining and measuring 'efficacy,' with little positive result.

In the array of research, there is a noticeable lack of focus on the specific effectiveness of sensory integration therapy to improve neurological function within neurological assessment parameters. Indeed, as an intervention treatment for neurological dysfunction, the study of the effectiveness of sensory integration in neurological studies appears to be deficient.

In pursuing this line of enquiry, however, there is a field of study that addresses the issue of learning capacity from the medical perspective of neurological function. Fenger (1998) and Davies and Gavin (2007), for example, have shown a correlation between neurological activity and neurological ability/disability. Fenger, with reference to a number of studies in this field,[3] argues that children with learning disabilities demonstrate slower brain wave patterns and that there is a correlation between visual motor integration levels and brain wave scores. Davies and Gavin (2007) used EEG technology to identify sensory processing disorders and demonstrate that such children show less sensory gating and display unique brain processing mechanisms against typically developing children (Davies & Gavin, 2007). Similarly, earlier studies by Lubar, Bianchini, Calhoun, Lambert, Brody, and Shabsin (1985), Lubar (1991), and Linden (1991) assessing children with learning difficulties found that they exhibited slower brain wave patterns than their control group and that it was possible to predict learning difficulty or normal development.

[3] Studies of this issue date back over 40 years: Linden, 1991; Satterfield & Braley, 1977; Tucker, 1976; Winkler, Dixon & Parker, 1970).

Fundamentally, the challenge in demonstrating the efficacy of sensory integration therapy appears to be one of designing, or finding, an assessment paradigm that has consistency between what sensory integration therapy purports to do and the instrumentation used to test the efficacy of the program. Given that sensory integration theory is grounded in a 'medical-model' for improving neurological function and organisation, the instrumentation used to assess the efficacy of sensory integration should, accordingly, measure neurological function and organisation. Assessing the efficacy of sensory integration therapy, thus, becomes an exercise in assessing its ability to improve neurological activity. Accordingly, and for the purpose of this study, the Beery-Buktenica Developmental Test of Visual Motor Integration: Fifth Edition (VMI; Berry & Beery, 2006) and the Test of Visual Perception Skills: Third Edition (TVPS-3; Martin, 2006) have been chosen as appropriate instruments to measure change in the neuro-physiological development of children over a period of sensory integration therapy.

Using the VMI and TVPS-3 to monitor neuro-efficiency is not without precedent and has been the subject of research for some forty years (Brown & Gaboury, 2006; Haring & Bateman, 1977; Piaget & Inhelder, 1969; Tucker, 1976). Piaget and Inhelder (1969) assert that visual motor functions are fundamental to learning development suggesting that the sensory-motor scheme may constitute the basis for the later operations of thought. Study of the relationship between visual motor development and higher learning has shown the fundamental importance of visual-motor development to thinking (Bruner, 1964), to psycholinguistic variables (Bannatyne, 1969), handwriting and reading (Maeland, 1992; Oliver, 1990; Weil & Amundson, 1994), and to general academic success (Abikoff, Ganeles, Reiter, Blum, Foley, & Klein, 1987; Duffy, Pitier, & Fedner, 1976). Further, Fenger's (1998) study shows the importance of visual-motor activities in the development of intellectual skills.

The relationship between visual perceptual abilities to academic achievement has also been a subject of investigation (Barker, 1974; Beery & Beery, 2006; Carroll, 1972; Kulp, Edwards, & Mitchell, 2002). As seventy percent of sensory input for humans is visual, it follows that vision and perception are fundamental neurological functions to the process of learning (de Montfort, 2005; Hannaford, 1995) and improving visual perceptual ability will influence neuro-efficiency.

Methodology

Ethical Considerations

First at meetings in the initial phase of the program, parents of the children selected for the study were required to give their informed consent and support. Second, instruction was given to the eight therapists involved in the program. A senior therapist, with sensory integration certification, was assigned to supervise the assessments and liaise with parents (Scores were given to the research managers for interpretation and tabulation, information not seen by the therapists during the program).

Selection Criteria

Children were selected for the study program through a process of identifying children with learning difficulties (dysfunctions in central processing and integration of sensory inputs) from a regime of assessments (see below) to identify children with neurological dysfunction. Children on medication, with physical disability, born with a mental impairment, a syndrome, poor eye sight or children whose academic and intelligence scaled scores were below 65 were eliminated from the study. All children selected for the study were identified as mentally capable of learning but struggling to do so. (Children were required to have vision and hearing tests prior to entering into the school and therapy program).

Because the precise nature of a learning disorder is not easily identified, a regime of assessments is required to gain a neuro-physiological profile of a child. Accordingly, to first provide a neuro-efficiency quotient of the children the Beery Visual Motor Integration (VMI; Beery & Beery, 2006) assessment and the Test of Visual Perception Skills-TVPS-3 (Martin, 2006) assessment were used. Added to these were the Sensory Profile (Dunn, 1999), the Clinical Observations of Motor and Postural Skills (COMPS; Wilson, Kaplan, Pollock & Law, 2000) assessments, the Clinical Evaluation of Language Fundamentals (CELF-4; Semel, Wiig & Secord, 2006) and the Wechsler Individual Achievement Test (WIAT-II; Wechsler, 2001). This comprehensive regime of assessments identified children with learning disorders and in meeting the other criteria, their parents were asked if the children could be included in the study.

Demographics

Sixty two school children participated in a sensory integration program over the 2007-08 and 2008-09 school years. The children were aged from 6 to 14 years (Table 1) and came from eight regions across the world.[4] There were 12 females and 50 males participating in the study.

Of the 36 children selected for the program in 2007-08, 11 moved to other schools or countries before post-program assessments were conducted. Thus, there were 25 children who completed the assessment-year in 2007-08 (Cohort A). For the second year, 2008-09, there were 68 new children identified with learning difficulties, and of these, 49 completed the program, classified as Cohort B. A subset of Cohort A and Cohort B was created, Cohort C, to identify 12 children who continued in the program over the 2 years (Table 1).

Demographics

Cohort	Year	No. Beginning	No. Completing	Male	Female	Int. Av. Age	VMI Score Range	VMI Median	TVPS-3 Score Range	TVPS-3 Mean
Cohort A	2007-08	36	25	21	4	8.1	66 to 111	82.7	3 to 14	93
Cohort B	2008-09	68	49	39	12	9.5	68 to 108	87.4	56 to 120	98
Cohort C	2007-09	12	12	9	3	8.1	73 to 101	84	74 to 118	95

Table 1

Research Procedure

In the first four weeks of the program children's response to therapy was monitored and evaluated in order to design an Individual Development Program (IDP) for each child. In the third and sixth month of the program, therapists met with parents to review the children’s

[4] Children described as coming from eight regions refers to and includes the different countries within their ethnic origin (English, Celts, African, European, Gulf Arabs, North African Arabs, South East Asian and Asian). Use of the term ‘ethnicity’ is not considered appropriate here as Anglo-Celt children, for example, came from several countries with different cultural and education systems. It is important to mention the national background of the participants as both the VMI and TVPS-3 are designed as unbiased assessments of child development.

progress. In the tenth month, the VMI and TVPS-3 assessments were conducted and a final report given to the parents.

At the conclusion of the two year study, an independent analyst was consulted for statistical analysis. Statistics were generated from the Statistical Package for Social Sciences (SPSS) Base 8.0 for Windows. Two-tailed t-tests were used to calculate statistical significance between visual-perceptual quotients (VPQ) scores on the TVPS-3 for all cohorts between initial testing and post program testing. The same procedure was followed for the standardized scores on the VMI.

Treatment Model

Sensory integration therapy is driven by four main principles: The Just Right Challenge; Adaptive Response; Active Engagement; and Child Directed Therapy (Bundy et al., 2002). Accordingly, the treatment model was designed to fulfil these principles:

1. Over four days per school week, children received one 30 minute session per day of SI therapy. The children were taken out of class at a prescribed time according to a weekly schedule.
2. The child and the therapist interact in a choice of rooms set up for sensory integration development with SI equipment for various vestibular, proprioceptive, tactile, gross-motor, fine motor, perceptual and auditory activities.
3. The SI program activities were conducted by SI trained therapists (see footnote 7) and modified on an ongoing basis according to the treatment plans and the progress shown in weekly progress notes.

Fidelity and Study Control

In accordance with Sensory Integration Therapy Assumptions and Principles (Ayres, 1979; Bundy et al., 2002) a standardized sensory integration treatment approach was used for the children derived from the organization's sensory integration therapy manual.[5] Eight occupational therapists were assigned between 5 and 8 children each. All occupational therapists had been trained in sensory integration therapy[6] as well as treatment procedures, assessments and progress documentation. All children and therapists had access to five therapy rooms designed for sensory integration therapy in the school/clinic. Each therapist remained with her designated children throughout the year (unless for unusual reasons a relationship was changed). The same therapist administered both the initial and final VMI and TVPS-3 assessments of their designated children. The therapists were 'blind' to the results of children's tests and to the tabulation, calculation, and graphing processes of the study. [7]

[5] The organisation's Sensory Integration Therapy Manual covers a number of theoretical and practical topics. Subjects includes: neuro-physiology, the sensory system, sensorimotor preferences, autonomic nervous system, developing the gifted brain, emotions and learning, attention and arousal, and working with sensory processing disorders.
[6] Sensory Integration Training from Sensory Integration International (USA), South Africa Institute for Sensory Integration (SAISI) who have an MOU with USC/WPS, or Sensory Integration Network of UK & Ireland.
[7] Note: The inter-scorer reliability for the VMI is .92 (Beery & Beery 2006) and for the TVPS- 3 the reliability coefficients range from .83 to .91. Having the same therapist conduct the assessment for pre-program and post-program is not considered by the VMI and TVPS-3 authors as having a debilitating effect upon the test results.

Instrumentation

As discussed in the Literature Review, the Beery-Buktenica Developmental Test of Visual Motor Integration: Fifth Edition: VMI (Beery & Beery, 2006) and the Test of Visual-Perception Skills: Third Edition: TVPS-3 (Martin, 2006) are considered valid tests of neurological function and indicators of a child's intellectual ability. They are standardized assessments with generalized scoring systems which allow this current study to make cross-study comparisons of research results, as Beery and Beery point out (Beery & Beery, 2006, p. 94). Thus, the VMI and TVPS-3 developmental schemes provide universal control groups and baselines against which the results of this study are compared for analysis.

The Beery and Buktenica Developmental Test of Visual Motor Integration: Fifth Edition (VMI)

The VMI assessment of child neurological development maps the predictable development path for children and teenagers. Raw score test results are scaled against chronological age and then standardized against a development range where predicted standardized score change is zero as raw score achievement increases. Standardized scores between 83 and 117 are classified as within a range of typical ability and development. Children with scores below 83 are considered low and very low neurological performers and depicted as children with learning difficulties (Beery & Beery, 2006). The VMI tests are not biased with regard to gender, ethnicity, socioeconomic status, and residence.

In designing the VMI scheme, Beery and Buktenica graphed a medians developmental curve for normal development (Beery & Beery, 2006) and their scheme has been adopted for this present study and accordingly, their standard error of measurement (SEM) is incorporated as a 5% margin.

Test of Visual-Perception Skills: Third Edition (TVPS-3)

The TVPS-3 test is also a developmental assessment and measures a child's abilities as a progression against a standardized scale of development. While raw achievement scores increase against chronological age, the scores are standardized to depict typical development and a range of neuro-physiological function. Thus, like the VMI, the TVPS-3 raw score scheme can be graphed to reveal a development path continuum of predicted raw score outcomes through the course of a child's development.

The TVPS-3 measures 7 visual-perceptual skills: visual discrimination, visual memory, visual spatial-relationship, visual form-constancy, visual sequential-memory, visual figure-ground, and visual closure. The TVPS-3 is also a test that shows progressive typical development for 4 to 12 year old children.

The TVPS-3 is an indicator of how a child is visually perceiving and interpreting the world around them, including their academic tasks. Visual-perception has a direct impact on essential academic areas of reading, writing, comprehension, and reasoning. The TVPS-3 is a non-language test and is not biased according to ethnicity, culture, education or gender (Martin, 1996).

Research Results

Cohort A Results

As expected for a developmental scheme, the raw score results for all the children increased in at least one of the three VMI test and sub-test categories with 80% of the study sample showing positive gains in all three tests (allowance for a SEM of 5% and child test readiness). The pre-program average age of the cohort was 8 years and 1 month and the post-program average age was 8 years, 11 months. The expected baseline improvement for one year of chronological development is 2 points but Cohort A improved by 3.6 median raw score points.

VMI Median Raw Scores Comparisons

Title	Research Year	No. of Children	Initial Raw Score	Final Raw Score	Predicted Change	Actual Change	Grade Change
Group A	2007-08	25	14.4	18	2	3.6	2
Group B	2008-09	37	16.3	19.6	1.2	3.3	2
Group C	2007-09	12	14.6	20.8	2.5	6.2	4

Table 2

VMI Median Standard Scores Comparisons

Title	Research Year	No. of Children	Initial St'd Score	Final St'd Score	Predicted Change	Actual Change	% Change	P Value
Group A	2007-08	25	82.7	93	0	10.3	12.4%	< 0.0001
Group B	2008-09	37	87.5	94.7	0	7.2	8.4%	< 0.0001
Group C	2007-09	12	84	97.5	0	13.5	16%	< 0.0012

Table 3

TVPS-3 Median Raw Scores Comparisons

Title	Research Year	No. of Children	Initial Raw Score	Final Raw Score	Predicted Change	Actual Change	Grade Change
Cohort A	2007-08	25	10	13	1	3	4
Cohort B	2008-09	37	9.9	12.4	0.8	2.5	3
Cohort C	2007-09	12	10.5	13.7	2	3.2	4

Table 4

The Cohort A pre-program median raw score was 14.4 points; the age-achievement score for a 5 year, 8 month old child. This was 2 years, 5 months below the expected average score. At the conclusion of the program, the Cohort A median raw score had risen to 18 points. The improved scores brought the Cohort to an average achievement age of 7 years 9 months: An increase of 2 age-achievement years, where less than 1 year of achievement-development was to be expected (Figure 1). From a standardized score perspective, Cohort A improved by 10.3 standardized points: A capability improvement of 12.4% in 1 year, rising from the median score of 82.7 to 93 points (Table 3). With a P Value of < 0.0001 the improvement is extremely statistically significant.

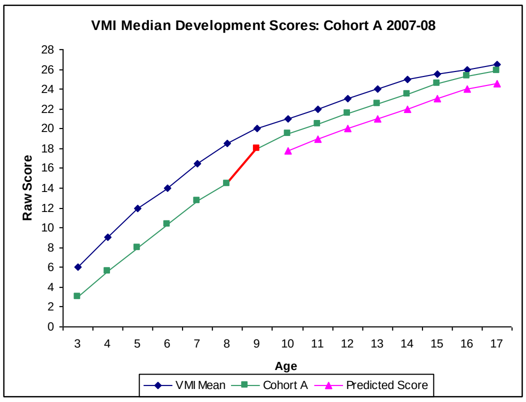

Fig. 1. VMI Median Development Scores for Cohort A 2007-08

At the beginning of the study, the Cohort A TVPS-3 median raw score was 10 points; the age-achievement score equivalent for a 7 year old child: 1 year below expected average score. At the conclusion of the program, the Cohort A median raw score had risen to 13 points. The improved scores brought the cohort to an average achievement age of an 11 year old child: An increase of 4 age-achievement years, where 1 year of achievement-development was to be expected at best (Figure 5). The initial standardized median score for Cohort A was 93 points, and where this score was expected to remain constant, the Cohort improved by 10 points to 103. This was an improvement in capacity of 10.7% in 1 year (Table 5). With a P Value of < 0.0001 the improvement is extremely statistically significant.

TVPS-3 Median Standard Scores Comparisons

Title	Research Year	No. of Children	Initial St'd Score	Final St'd Score	Predicted Change	Actual Change	% Change	P Value
Cohort A	2007-08	25	93	103	0	10	10.7%	< 0.0001
Cohort B	2008-09	37	88	99	0	11	12.5%	< 0.0001
Cohort C	2007-09	12	95	106	0	11	11.5%	< 0.0090

Table 5

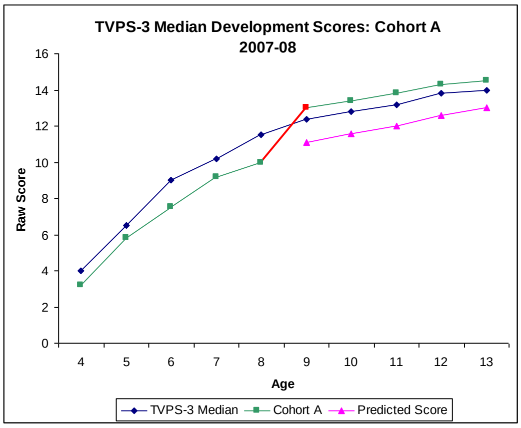

Fig. 2 TVPS-3 Median Development Scores for Cohort A 2007-08

Cohort B Results

The pre-program median raw score of 16.3 points and the post-program tests showed the median raw score had risen to 19.6 points: An improvement of 3.3 median raw score points where 1.2 points was to be expected for the VMI median cohort (Figure 2). From the perspective of the standardized scores, without intervention, the VMI median standard score would remain at 87.5, whereas Cohort B standard score improved to 94.7 points – an increase of 8.4% in neurological ability in the 1 year (Table 3). With a P Value of < 0.0001 the improvement is extremely statistically significant.

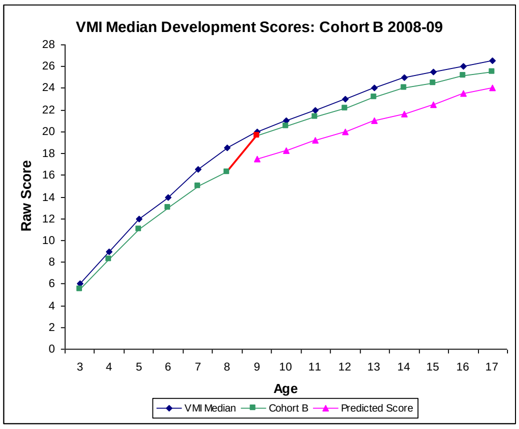

Fig. 3. VMI Median Development Scores for Cohort B 2008-09

The initial TVPS-3 median raw score of 9.9 points (the equivalent to a 6 year, 10 month old child) improved to 12.4 points: An improvement of 3 age-grade levels rising to a TVPS-3 median level for 'average' child development (Figure 6). From the perspective of the standardized scores, Cohort B improved from an initial median assessment of 88 points to 99 points, where no improvement was to be expected. This actual change of 11 points was a 12.5% improvement over the children's initial pre-program assessments (Table 5) and with a P Value of < 0.0001 the improvement is extremely statistically significant.

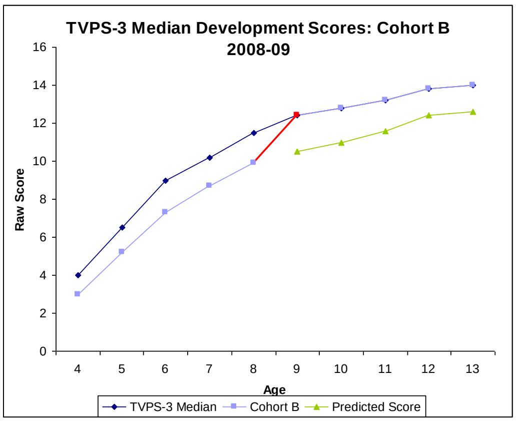

Fig. 4 TVPS-3 Median Development Scores for Cohort B 2008-09

Cohort C Results

As a sub-set of the Cohort A and B groups, the Cohort C group of children participated in 2 school years of the sensory integration program, with a 3 month break over the summer holidays and a 4 month break between assessments. Their VMI scores show some minor differences: Cohort C 2007 initial median standard score of 84 points was slightly higher than the larger group's score of 82.7 points (Figure 3). For the median raw scores, Cohort C improved from an initial score in 2007 of 14.6 points, and a grade level of a 6 year, 4 month old child, to the level of a 9 year, 10 month old child with a score of 20.8 points in 2009. Over the 2 years of the program, Cohort C improved from 84 to a median standard score of 97.5 points: An improvement of 16% in capacity and an improvement of four age-grade levels (Figure 4). With several children in this small cohort not responding to therapy as well as the others, their scores had a debilitating effect on the overall cohort score. Nevertheless, over the two years, the P Value for the improvement was < 0.0012 and is still very statistically significant.

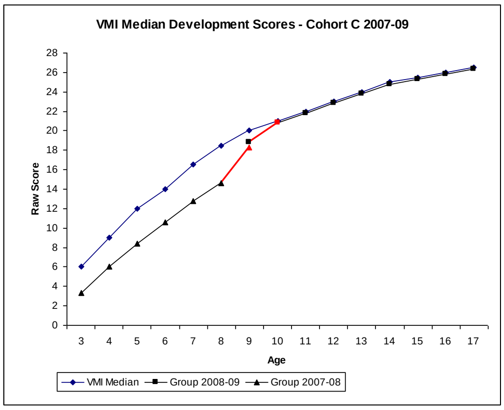

Fig. 5 VMI Median Development Scores for Cohort C 2007-09

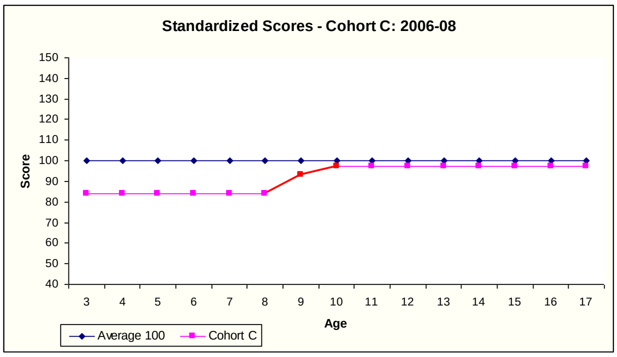

Fig. 6 VMI Median Standard Scores for Cohort C 2007-09

For the TVPS-3, over the two years, Cohort C's median raw score improved from 10.5 points to 13.7 points: An actual change of 3.2 points where 2 points was expected. This translates into a movement from an initial average age-grade level of a 7 year old to an age-grade level of an 11 year old, or a jump of four age-grade levels (Figure 7). In parallel, the Cohort C median standardized score, with no expected change, rose from 95 to 106 points. While both scores are within the 'average' range, the actual change of 11 points, or 11.5%, is significant because it shows consistent, and sustained, improvement over the two years (Table 5). With a P Value of < 0.0090 the improvement is very statistically significant.

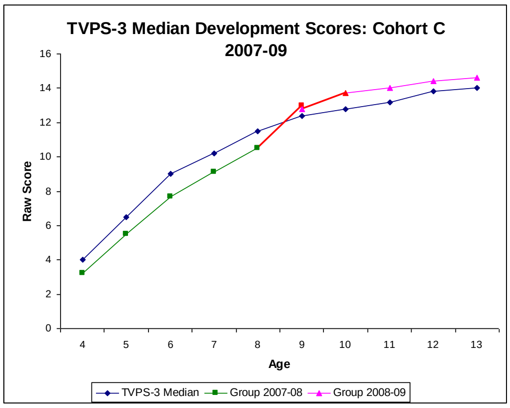

Figure 7. TVPS-3 Median Development Scores
for Cohort C 2007-09

Discussion of Results

The objective of this study was to assess the effectiveness of sensory integration therapy for improving the neurological development, and thus the neuro-efficiency, of children identified as having sensory integration based learning difficulties. With reference to the Literature Review, the first consideration is whether the VMI and the TVPS-3 were suitable instruments to provide specific and comparable statistical information to test the effectiveness of the intervention program.[8]

The VMI as a visual motor integration test, is considered a 'higher level' assessment of neurological functioning as it indicates the degree of 'integration' of neurological ability (Beery & Beery, 2006). Further, the VMI and TVPS-3 are understood as related assessments in as much as the VMI scores can be stifled by poor visual perception or, conversely, an improvement in visual perception will have an impact on visual-motor integration. The correlated test results of both assessments across the study testify to their compatibility.

In progression, the second issue arising out of the literature review is the fundamental question of whether the VMI and TVPS-3, as neurological assessments, demonstrate that sensory integration therapy can be used as an intervention program to improve neuro-physiological ability.

For all three research samples, the results show extremely and very significant statistical improvement of the children for the VMI and TVPS-3 tests. The improvement in the TVPS-3 raw scores across the three Cohorts show an increase in age-grade ability by 4 grades, 3 grades and 3 grades respectively, where 1 grade level, or less, was predicted for

[8] The Sensory Integration Praxis Test (SIPT; Ayres, 2004) could be considered as a reliable test of neuro-physiology but it was designed as a diagnostic tool for children up to the age of 8 years and 11 months. and not as an outcome measure for neuro-physiological improvement. A full SIPT takes 8 hours of interviews, assessment and report writing.

Cohorts A and B and 2 grade levels for Cohort C. Similarly, the VMI raw scores show improvement of 2 grades, 2 grades and 4 grades respectively, where 1 grade level was predicted for Cohorts A and B and 2 grade levels for Cohort C.

Of particular interest are the results of Cohort C, where the standard scores for the VMI tests improved in the range of 8.4% to 16% and the TVPS-3 standard scores improved in the range of 10.7% to 11.5%. It is noted that the TVPS-3 median standard score increased for Cohort C did not improve in the second year as much as the score for the first year. The P Value for Cohort C 2007-08 was < 0.0001 and extremely statistically significant and in 2008-09 the P Value was < 0.0002 and also extremely statistically significant but when seen over the two years and gauged against expected norms, the P Value dropped to < 0.0090. This can be explained by the fact that the Cohort had already increased from 95 points to 103 points in the first year, to a high average score, and then increased further above the average to 106 points in 2008-09. (It can also be explained by several children not responding to therapy as well as others which affected the overall cohort score.) The results also indicate that while SI therapy can improve children’s neuro-efficiency, children will respond at different rates and in accordance with their biological and environmental conditions.

Median Standard Scores Comparison

		Lower Scores Group		Change	Percent	P Value		Higher Scores Group		Change	Percent	P Value
VMI	2007-08	76.6	89.3	12.7	16.5%	< 0.0034		90.8	100.6	9.8	11%	< 0.0048
	2008-09	85.1	93.7	8.6	10.1%	< 0.0010		98	105.1	7.1	7.2%	< 0.0069
TVPS-3	2007-08	87	100	13	15%	< 0.0001		100	109	9	9%	< 0.0064
	2008-09	80	92	12	15%	< 0.0072		111	120	9	8%	< 0.0009

Table 6

Still, there is also the possible indication that sensory integration therapy is more impressive for children with lower capacity than for children of higher capacity. As a post program statistical analysis exercise, the pre-program and post-program assessment scores for Cohort A and Cohort B were divided into a lower score sub-group and a high score sub-group of 10 participants in each in order see if there was a significant difference. Across both VMI and TVPS-3 tests, there is noticeable consistent improvement with the lower capacity sub-groups improving more than the higher capacity sub-groups. The implication is that sensory integration therapy may well have a more significant impact on those children with more severe learning difficulties whereby addressing specific issues allows other capabilities to develop as well producing a more rapid increase in development (Table 6).

By way of specifically addressing the issue of the efficacy of sensory integration therapy, as raised in the literature review, there are two further and intrinsic issues that require discussion: The issues of predictability and sustainability.

Both the TVPS-3 and the VMI are considered reliable indicators of predictable academic performance. As stated earlier, there is a evidence of a correlation between visual-motor development to reading ability (Maeland, 1992; Oliver, 1990; Weil & Amundson, 1994) and to general academic achievement (Abikoff, Ganeles, Reiter, Blum, Foley, & Klein, 1987; Duffy, Pitier, & Fedner, 1976; Sortor & Kulp, 2003) but the VMI has also been consistently used to predict the reading ability of a child at a future age (Beery & Beery, 2006). However, where it is possible to improve neuro-efficiency through an intervention program, academic capability, and subsequently performance, can also improve and a ‘new’ developmental path be predicted. The forecast qualities of these assessments mean that it is possible to identify specific learning difficulties affecting academic performance and to address such issues. This present study provides evidence that intervention by way of the sensory integration therapy program can improve neuro-physiological function and, by implication, redirects their predictive development pathway. Again, based on the premise that it is possible to stimulate and improve neurological processing and integration, learning disorders can be corrected and learning capability increase.

On the second issue of sustained neurological development, it has been proposed here that a sensory integration intervention program can increase neuro-efficiency. But the question is whether an induced improvement in neuro-efficiency can be sustained once the therapy stops. While increased practice of a task or perception cannot increase neurological capability, as is possible with academics (Abikoff, Ganeles, Reiter, Blum, Foley, & Klein, 1987), where neurological development occurs as a result of increased sensory integration ability, it can reasonably be expected to be sustained development.[9] The results of Cohort C for both the VMI and the TVPS-3 address this issue. Over the two years where there was a four month hiatus between both schooling and therapy, there was marginal variation in the test results from the post-program assessment of 2007-08 and the pre-program assessments of 2008-09.[10] While these two samples do not allow conclusive proof of sustainability, the results do provide evidence of sustainability and the effectiveness of this sensory integration program (Figure 3 and Figure 7).

Conclusion

To state that the brain is constantly learning or that it is possible to teach the brain new processes is not an issue for argument. But, to suggest that it is possible to increase neurological capabilities and thereby influence the ability to learn is an important assertion.

The results of this two year study show that positive stimulation of the neuro-sensory system can increase neurological function, or, neuro-efficiency. The consistency of extremely statistically significant results and the correlation of results between the TVPS-3 and VMI range of scores of the three cohorts over two years of sensory integration therapy program provide considerable evidence to indicate the effectiveness of sensory integration therapy. While the use of sensory integration therapy can increase neuro-efficiency and in consequence, reading ability and academic results, an improvement of visual perceptual and visual-motor integration abilities can affect intelligence as well (Beery and Beery 2006; Breen, Carlson &Lehman, 1985; Davies & Gavin, 2007; Fenger 1998).[11]

[9] Increasing neurological function, or efficiency, is not to be understood as the same as increasing academic ability or performance. To increase a child's ability to do maths, for example, is to address short and long term memory abilities, for both skill retention and information retention. Learning maths is not be understood as the same as increasing the brain's neuro-efficiency.

[10] For the VMI, the 2008 post-program median raw score was 18.3, which increased slightly to the 2009 pre-program median raw score of 18.8. For the TVPS-3 the 2008 post-program median raw score was 13, which decreased slightly to the pre-program assessment score of 12.8.

[11] Beery and Beery (2006) explain that the VMI tests examine nonverbal aspects of intelligence and, thus, VMI test results correlate well with nonverbal intelligence test results of the Wechsler assessments (Wechsler, 2003) and the Slossan IQ (Slossan, 2006) . In discussing the correlation between the VMI and the WISC-R, they say: "Although the Beery VMI correlates with intelligence, ... it appears to be a more sensitive index than intelligence for at least some physiological/ neuropsychological problems in child development." (Beery and Beery 2006, 111) In support of this logic, a study by Breen, Carlson and Lehman (1985) found significant correlations between the VMI and the WISC-R Performance IQ.

While study of the correlation between the VMI and intelligence quotient assessments, particularly the WISC, is somewhat limited and dated, there is a body of research that demonstrates the correlation between neuro-efficiency (also as neural efficiency and neuro development) and intelligence (Duncan et al., 2009; Neubauer & Fink, 2009; Parker, 1973; Rypma & Prabhakaran, 2009). The implication being that as a child's neuro-efficiency is increased through stimulating sensory perception and integration so the child's intelligence (as assessed through neurological, academic or Intelligence Quotient assessments) will also improve: A topic worthy of further research.

The conclusion of this study, then, becomes an axiom: As the brain is more able to process and integrate information through its sensory system so, in consequence, there is an improvement in neuro-efficiency and learning ability.

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