THE RELATIONSHIP BETWEEN DEVELOPMENTAL DYSPRAXIA AND SENSORY RESPONSIVITY IN CHILDREN AGED FOUR YEARS THROUGH EIGHT YEARS

PART I

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PART I

ABSTRACT

Developmental Dyspraxia and Sensory Modulation Dysfunction (SMD) are disorders of Sensory Integration (SI) and widely known to occupational therapists who use a SI framework to guide clinical practice. These disorders have been widely researched and documented as separate disorders of deficient sensory processing. The co-occurrence of these disorders has also been reported as concomitant and described as such. SMD is viewed as the tendency to over or under respond to sensory information and Developmental Dyspraxia has a confirmed relationship with inefficient sensory discrimination. The aim of this article is to determine if a relationship exists between Developmental Dyspraxia and sensory responsivity. This was accomplished by correlating data from the Sensory Profile and Sensory Profile School Companion with data from the Sensory Integration and Praxis Tests. The results of the study did not confirm a relationship, but yielded interesting correlations that add value to the interpretation of children's sensory responsivity tendencies in the presence of Developmental Dyspraxia.

Key words: Developmental Dyspraxia, sensory responsivity, relationship, Sensory Profile, Sensory Profile School Companion, Sensory Integration and Praxis Tests

INTRODUCTION

Many occupational therapists who practice in the paediatric field make use of a Sensory Integration (SI) frame of reference to guide clinical reasoning during assessment and treatment of children. Developmental Dyspraxia and Sensory Modulation Dysfunction (SMD) are two disorders of deficient Sensory Integration and are well documented in occupational therapy literature.[1,2,3] Developmental Dyspraxia was first described by Jean Ayres who pioneered the theory of SI. Ayres stated that children with Developmental Dyspraxia often have trouble coping with life situations including childhood occupations like play, academic learning and social behaviour.[1] This disorder therefore has a profound impact on children and their daily life occupations.

Developmental Dyspraxia was first identified with a measurement instrument developed by Ayres in 1972, the Southern California Sensory Integration Test (SCSIT) and later the Sensory Integration and Praxis Tests (SIPT) in 1989. [2] Through development of the SCSIT and the SIPT, Ayres [2] and later Mulligan [4] was able to link poor discrimination of tactile, vestibular and proprioceptive input with dyspraxia. [4,5] This confirmed association between Developmental Dyspraxia and sensory discrimination contributed to the development of treatment protocols for Developmental Dyspraxia.

SMD is a pattern of Sensory Integration Dysfunction (SID) in which a person under-or over-responds to sensory input from the body and environment [5] and is identified through self-report measures like the Sensory Profile (SP) and the Sensory Profile School Companion (SPSC). Dunn [6] is the author of the SP and based her model for evaluating children's sensory responsiveness on neurological thresholds and behaviour of responding to sensory experiences. Sensory Modulation is also referred to as sensory responsiveness.

Continuous research in the field of SI locally and specifically in the United States of America (USA) has resulted in an abundance of information published on the subject of SI. [7-11] However, it also resulted in terminology related to SI being used interchangeably and has led to confusion. Efforts to reach consensus and uniformity when describing SID culminated in a proposed nosology for classifying Sensory Processing Disorders (SPD) which views Developmental Dyspraxia as a sub-pattern of sensory-based motor disorder while SMD is viewed as a pattern of SPD.[12] The literature further states and accentuates the relation between SMD and Developmental Dyspraxia as concomitant.[12]

The relationship between sensory discrimination and Developmental Dyspraxia is supported in literature and has been clinically observed in practice through formal testing with the SIPT. Another relationship of interest that has been observed in clinical practice is the prevalence of SMD in children with Developmental Dyspraxia. This relationship is however only regarded as a concomitant relationship. Review of literature on Developmental Dyspraxia accentuated the role of information processing in praxis. Information processing is a model that allows sensory modulation in the process of praxis through acknowledging stimulus identification as one of the first steps in ideation. It is posited that stimulus detection (sensory registration) must take place before identification and fits with Murray-Slutsky's[13] model of registration, orientation and arousal to sensory stimuli. Thus, considering clinical experience in practice and the information in literature, the question arose as to what the relationship is between Developmental Dyspraxia and sensory responsiveness? This study was directed at determining if a relationship existed and what the nature of such a relationship was.

LITERATURE REVIEW

Merging frameworks that underpin developmental dyspraxia and sensory modulation dysfunction

Ayres pioneered the theory of SI and she defined it as the organisation of sensory input for use.[14] A SI framework guides intervention protocols, specifically pertaining to different SI dysfunctions. Developmental Dyspraxia is a dysfunction of sensory integration and is defined as a developmental difficulty with planning unfamiliar movements resulting from poor body scheme, which is based in turn on poor processing of sensation, especially visual, vestibular, proprioceptive and tactile.[15]

SI is one of the frameworks that underpin Developmental Dyspraxia as a construct. From a SI perspective, it is essential to have knowledge of the three processes of praxis in order to understand Developmental Dyspraxia. These processes namely ideation, motor planning and motor execution are normally implicated when praxis is deficient. Developmental Dyspraxia consists of four types of dyspraxia that was derived from factor and cluster analysis of the SIPT. Ayres and Mulligan [16] identified the following types of dyspraxia: Visiodyspraxia, somatodyspraxia, bilateral integration and sequencing deficits and dyspraxia on verbal command.[17] Dyspraxia on verbal command, though not considered a pure SI dysfunction, has a linguistic and a postural component, and is most discrete and variable in the way it manifests among children.[5] The researcher elected to include dyspraxia on verbal command in the research study based in clinical observations in practice. These forms of Developmental Dyspraxia are the result of inefficient sensory discrimination which is central to this construct and a SI framework.

Another frame of reference that underpins Developmental Dyspraxia is motor learning. Motor learning consists of two models of which the closed-loop model is one. This model uses sensory feedback to acquire and refine acquired skills while the second model, an open-loop model, makes use of a pre-planned action sequence without using feedback to plan and execute motor actions.[18] Skill acquisition is also dependent on phases of learning, types of feedback, practice and types of tasks. These factors determine how a skill is learnt, practiced and refined.[19] Motor learning further builds on the premise that acquisition of skill should be contextual and meaningful and thus has a shared perspective with SI of context dependent intervention that elicits an adaptive response.

In addition, motor learning encompasses information processing that entails cognitive processes and presumes that learning cannot take place without considering perception and cognition. [20] Information processing pertaining to SI and Developmental Dyspraxia is relevant in the interval between the stimulus and the actual motor movement. This interval includes stimulus recognition and identification as well as response selection and fits with the ideation phase described by Ayres. Another dimension of information processing proposed by Bruner [21] is that intention (ideation) is accompanied by an increased arousal state. In order to identify a stimulus enough attention should be generated to detect a stimulus and this concept is very similar to the [21] registration, orientation and arousal process associated with sensory modulation and proposed by Murray-Slutsky.[17]

Praxis is thus from a SI and motor learning perspective, dependent on sensory processing, information processing and adequate amounts of Central Nervous System (CNS) arousal. Inadequate or too much arousal of the CNS could potentially impact on information and sensory processing and affect a pratic process such as ideation. CNS arousal is also central to the construct of sensory modulation.

Sensory modulation is the ability to regulate and manage one’s responses to sensory input in a graded and adaptive manner.[8] Deficient sensory modulation results in SMD which is the tendency to over-or under respond to sensory input disproportional to the input.[22] For the purpose of this study the SMD sub-patterns of sensory under-repsonsiveness (SUR) and sensory over-responsiveness (SOR) are under discussion.

SUR is the tendency to respond less to sensory stimuli in the environment and not to detect incoming sensory information that can lead to apathy, lethargy and impeded socialisation and exploration. [12] SOR on the other hand, is the tendency to respond to sensation faster, with more intensity or for a longer duration. Behaviours in children with SOR range from active, negative, impulsive or aggressive to withdrawal or avoidance of sensation.[12] Although Dunn[6] uses a classification system of high and low thresholds to describe children's sensory modulation tendencies, the researcher elected to use the term SUR to group Dunn's high threshold quadrants (poor registration and sensory seeking) and SOR for low threshold quadrants (sensory sensitive and sensation avoiding).

Apart from the sub-patterns of SMD the process of detecting sensory information is critical. Murray-Slutsky identified three phases of sensory modulation which are registration, orientation and arousal.[13] These phases of modulation link up with the stages of information processing related to ideation and give substance to Bruner's[21] proposal that ideation (intention) is accompanied by increased arousal. Thus, if under- or over responsiveness occur resulting in less tendency to detect sensory input and leading to CNS under-arousal, or, in a more intense and longer response to sensory input leading to an over-aroused CNS, intention (ideation) can be affected which in turn could impact on praxis and result in dyspraxia.

AIM OF THE STUDY

This study aimed at investigating the relationship between Developmental Dyspraxia and sensory responsiveness. This was accomplished by:

- Investigating if a relationship existed between Developmental Dyspraxia and sensory responsivity.
- Determining if a relationship existed between types of Developmental Dyspraxia and sensory under-or over-responsiveness of sensory systems.
- Determining if specific items on the SP and SPSC were related to different types of Developmental Dyspraxia. (This objective was adjusted after research results became known)

METHODOLOGY

The research study was a non-experimental correlational study which examined the relationship among variables. Sampling was purposive and the eventual sample size was 73 children. The sample consisted of children tested in the researcher's occupational therapy practice as well as children tested in Gauteng and the Western Cape by occupational therapists who are SIPT certified and who actively provided data for the research study. No data was received from occupational therapists based in the Free State (Bloemfontein) though a number of therapists were recruited to provide data for the study. Inclusion criteria included stipulations pertaining to age, namely children aged 4 years to eight years, SI dysfunction diagnoses namely children with developmental dyspraxia identified through the SIPT and, language criteria namely English and Afrikaans speaking children due to the availability of SIPT instructions in English and Afrikaans. Exclusion criteria entailed the exclusion of conditions that were not purely developmental in nature such as neurological conditions or acquired neurological damage.

Instruments

The measurement instruments used in the study were the Sensory Integration and Praxis Tests [4], the Sensory Profile [6] and the Sensory Profile School Companion.[23]

The SIPT has been in use in South Africa since 2006 and requires skill and expertise of the tester to administer the test according to prescribed norms. Occupational therapists certified in the use of the SIPT undergo a certification process offered by the South African Institute for Sensory Integration (SAISI). It is a comprehensive, standardized battery of tests used to identify and measure sensory integration deficits in children 4 years old to 8 years 11 months. The SIPT consists of 17 individual tests that have been categorized into four overlapping areas (a) form and space perception tests; (b) somatic and vestibular sensory processing tests; (c) praxis tests; and (d) bilateral integration and sequencing tests.[24] It takes about two hours to administer the SIPT in its entirety. Evidence for construct validity, discriminant validity and test-retest reliability are reported in the SIPT Manual. [25]

The SIPT is scored and interpreted through use of computerized scoring where the subject's raw scores are entered into the SIPT scoring program and raw scores are converted to standard deviation (SD) scores. SIPT test results are expressed in SD scores. Scores between -1.0 SD and +1.0S D are considered in the average range, whereas scores below -1.0 suggest possible problems.[26] The SIPT computer generated report consists of a 15 page report. It briefly describes each test and the obtained standard score, has a summary bar graph that show the major results, lists various scores such as the Standard error of measurement (SEM), SD scores, measurements of lateral function and an audit of test data. The last page contains a summary graph comparing the child's SD scores to the significant cluster group mean scores.

The Sensory Profile consists of 125 items. It is a judgment- based caregiver questionnaire. Each item describes the child's responses to various sensory experiences. The caregiver who has daily contact with the child completes the questionnaire by reporting the frequency with which these behaviours occur (always, frequently, occasionally, seldom or never). The therapist then scores the responses on the questionnaire. Certain patterns of performance on the Sensory Profile are indicative of difficulties with sensory processing and performance. Items on the SP questionnaire unite to form nine meaningful groups or factors and the 125 items of the questionnaire are grouped into three main sections: Sensory processing, modulation, behavioural, and emotional responses.[6]

There are four quadrants that describe the child's neurological threshold and their related behaviours and include Low Registration, Sensation Seeking, Sensory Sensitivity, and Sensation Avoiding. The child's score will either be much less than most people, similar to most people, more than most people or much more than most people in each quadrant.[6]

The Sensory Profile School Companion is a standardised assessment tool for measuring a student's (child's) processing abilities and their effect on the child's functional performance in the classroom and school environment. It is intended to be used as part of a comprehensive performance assessment of children, ages 3 years to 11 years 11 months. The Sensory Profile School Companion results, when combined with findings from the Sensory Profile caregiver questionnaire, provide a comprehensive view of a child's performance in different contexts. The teacher and caregiver each provide unique perspectives of the student's performance. [23]

The questionnaire consists of 62 items. The items are organised into four sensory groups: Auditory, visual, movement, touch and behaviour. The teacher who has routine contact with the child completes the questionnaire by reporting the frequency with which behaviours occur (almost always, frequently, occasionally, seldom, or almost never). Responses are scored and the occupational therapist looks at performance patterns that may indicate sensory processing difficulties. The questionnaire yields four quadrant scores (registration, seeking, sensitivity and avoiding), four school factor scores (school factors 1, 2, 3 and 4) and section scores for four sensory groups and one behaviour group (auditory, visual, movement, touch and behaviour).[23]

Construct validity, internal consistency and test-retest reliability of both the SP and SPSC is reported in the respective manuals of the SP and SPSC.[6,23]

Procedure

Data collection was done by the researcher and occupational therapists recruited to provide data for this study. Occupational therapists certified in the use of the SIPT were approached and asked to contribute data from their private practices. Recruitment of therapists was focused on large cities where there was a higher concentration of SIPT certified occupational therapists. Twenty-two therapists from Johannesburg (and surrounds), Pretoria, Bloemfontein and Cape Town were recruited of whom ten actively contributed to the study. They were informed about the procedures for data collection and provided with the SP and SPSC. Informed consent forms (parental, teacher, principal and occupational therapist), assent forms (children seven years and older) and data collection guidelines were also given once they agreed to partake. SP and SPSC questionnaires were returned to the researcher and scored with a computer software package (SP or SPSC Select Scoring Assistant). SIPT computer reports were used, specifically page 15 where the subject's performance were likened to the SIPT groups identified from cluster analysis. D-squared values from four SIPT groups were recorded and the quadrant, section and item scores of the SP and SPSC were recorded for subsequent data analysis. The four SIPT groups that represent Developmental dyspraxia were: SIPT 1 = Bilateral integration and sequencing deficits (SIPT Group 1 is listed as Low Average Bilateral Integration and Sequencing which does not necessarily reflect dysfunction, but the researcher selected this group to indicate a practic dysfunction when the SIPT scores of a subject were in the deficient range on the following SIPT tests: Graphestesia (GRA), Oral Praxis (OPr), Sequencing Praxis (SPr), Bilateral Motor Coordination (BMC) and Standing Walking Balance (SWB). These scores were in contrast to the rest of the SIPT test scores which were not necessarily in the deficient range); SIPT 2= Generalised sensory integration dysfunction; SIPT 3= Dyspraxia on verbal command; and SIPT 4= Visio- and somato-dyspraxia.

Data Analysis

Statistical analysis of the data set was done by correlating D-squared value scores from the SIPT with section and quadrant scores of the SP and the SPSC. A non-parametric test namely the Spearman's rank-order correlation coefficient was used to calculate the relationship between variables. The significance level was taken at 90%. This was used in the statistical analyses pertaining to the research aim and the first two objectives. Exploratory analysis and frequency distributions were also done to shed light on response tendencies of caregivers and teachers. Internal consistency reliability of items of the SP and SPSC were computed in fulfilment of objective three by means of the Cronbach Alpha Coefficient. Frequency procedure was conducted of the data set to isolate the SMD population from those without SMD and to calculate the representation of the four SIPT groups in the SMD sample. This was used in clinical analysis of data to examine demographics of the sample and to view the data set from a different perspective.

RESULTS

Statistical calculation of correlations between SIPT groups (Developmental Dyspraxia) and sensory responsivity (quadrant and section scores of the SP and SPSC) did not reveal any significant strong positive relations. Some weak inverse correlations and one significant weak positive correlation were observed between SIPT groups and quadrant scores. The weak positive correlation was between SOR and generalised SI dysfunction ($p=0.068$; $r=0.214$) and was later repeated between generalized SI dysfunction and vestibular SOR ($p=0.051$; $r=0.228$). Correlations between SIPT groups one to four and sensory systems that were also represented by SOR and SUR again revealed weak to significantly weak inverse correlations. The amount of possible correlations compared to the actual correlations that were observed was disappointing. The correlations that were observed are given in table I. They are reported in terms of the objectives one and two (objective two is divided into objectives 2a and 2b) to provide for more detailed analysis of data.

Table I. Summary of Correlations between SIPT Groups, SUR, SOR, Quadrants and Sensory Systems of the SP and SPSC

OBJECTIVE 1: Relation between Developmental Dyspraxia and SUR and SOR		
SP : SUR	SIPT 1: BIS deficit	r = -0.208 p = 0.076
SP: SOR	SIPT 1: BIS deficit	R = -0.205 p = 0.08
SP&SPSC: SOR	SIPT 1: BIS deficit	r = -0.023 p = 0.041
OBJECTIVE 2 a: Relation between types of dyspraxia and SUR and SOR of sensory systems		
SP (auditory) SUR	SIPT 4: Visio- and somatodyspraxia	r = -0.246 p = 0.035
SP (touch) SOR	SIPT 1: BIS deficit	r = -0.217 p = 0.064
SPSC (auditory) SOR	SIPT 1: BIS deficit	r = -0.249 p = 0.033
	SIPT 3: Dyspraxia on verbal command	r = -0.231 p = 0.049
	SIPT 4: Visio- and somatodyspraxia	r = -0.228 p = 0.051
SPSC (movement) SOR	SIPT 1: BIS deficit	r = -0.233 p = 0.046
	SIPT 2: Generalised SI dysfunction	r = 0.228 p = 0.051
SPSC (touch) SOR	SIPT 1: BIS deficit	r = -0.206 p = 0.079

OBJECTIVE 2b: Relation between types of dyspraxia and sensory systems		
SP (auditory)	SIPT 1: BIS deficit	r = 0.200 p = 0.089
	SIPT 4: Visio- and somatodyspraxia	r = -0.225 p = 0.054
SPSC (auditory)	SIPT 1: BIS deficit	r = -0.226 p = 0.053

Objective three was amended and examined the internal consistency reliability of the data set obtained from the SP and SPSC. Cronbach Alpha Coefficient of items of the SP and SPSC revealed high internal consistency reliability for the SPSC with Alpha values ranging from 0.7 to 0.8. The SP's Alpha values varied more and ranged from 0.3 to 0.9 which suggests fluctuating internal consistency reliability for the SP. Two factors appeared to have influenced the Alpha values of the SP namely the number of items per section with fewer items lowering the Alpha value and response tendencies of caregivers. The Alpha values of the SP are given in table II to illustrate the variety and range.

Table II Summary of the Cronbach Coefficient Alpha for the Variables of Sections of the SP

SP Variables	Alpha	SP Variables	Alpha
Items 1-8	0.76416	Items 75-84	0.679059
Items 9-17	0.718299	Items 85-91	0.613773
Items 18-28	0.65226	Items 92-95	0.570404
Items 29-46	0.81147	Items 96-99	0.535083
Items 47-53	0.707572	Items100-116	0.88156
Items 54-65	0.922545	Items 117-122	0.708806
Items 66-74	0.861622	Items 123-125	0.385411
Sections of items with low Alpha Value			

DISCUSSION

This study was aimed at determining if a relationship existed between Developmental Dyspraxia and sensory responsivity through correlation of SIPT, SP and SPSC scores. Statistical analysis of the data set mostly produced inverse correlations between certain SIPT groups and sensory systems, SUR and SOR. One significant weak correlation was found between SOR and generalised SI dysfunction. These results did not support a relation, but the inverse correlations and one positive correlation are discussed in terms of the interpretation and implications associated therewith.

The positive correlation between SOR and generalised SI dysfunction (p=0.068; r=0.214) and later repeated with SOR of the vestibular system (p=0.051; r=0.228) is worth discussion. It is inferred that in the case of generalised SI dysfunction there is a probability that SOR will occur and as such either result in avoidance behaviour or withdrawal. If this is the case SOR may very well contribute to the severity of this dysfunction. Should avoidance and withdrawal cause less exposure to sensory experiences it is possible that processes of praxis such as ideation and motor planning is affected. This correlation warrants further investigation into the relation of SOR with generalized SI dysfunction.

Another observation from the results is the number of negative correlations between a bilateral integration and sequencing (BIS) deficit and SUR (one correlation) (p=0.076; r= -0.208) and SOR (four correlations) (p=0.08; r= -0.205); (p=0.041; r= -0.023); (p=0.064; r= -0.217); (p=0.046; r= -0.046) which leads to the researcher questioning the role of sensory responsivity in BIS deficits. The inverse correlations suggested that the closer the fit to a BIS deficit, the smaller the tendency of SUR or SOR. The deduction would then be that if reduced sensory responsivity occurs together with BIS deficits, the relationship would be concomitant and not causal. It is possible that sensory discrimination is the primary basis for BIS deficits and that there is a breakdown of vestibular and proprioceptive processing after stimulus detection. Such a breakdown would be at the feed-forward and feedback level of information processing and consequently impact on the motor planning and motor execution level of praxis.

There were also three weak inverse correlations between visio- and somatodyspraxia and the auditory system and SUR (p=0.035; r= -0.246) or SOR (p=0.051; r= -0.228); (p=0.054; r= -0.225) of the auditory system. The inverse relation suggests that detection of auditory input in this type of Developmental Dyspraxia is not problematic and is in agreement with factor analysis of the SIPT where the 'praxis on verbal command' test score is the highest SIPT score in the group that indicates dysfunction.[5] Although auditory detection may not be a problem with this type of dyspraxia, caution should be used against assuming that language will be good. Poor ideation in visio- and somatodyspraxia is presumably not the result of poor language as language is a cortical function.[21] The inverse relationship between auditory function and visio- and somatodyspraxia is thus supportive of the possibility that poor ideation is caused by factors other than poor auditory detection that could impact on auditory processing and subsequently on language.

The final weak inverse relation under discussion is between dyspraxia on verbal command and SOR of the auditory system (p=0.049; r= -0.231). This relationship infers in the case of dyspraxia on verbal command that insufficient detection of auditory input is not the result of SOR of the auditory system. Poor auditory detection is therefore not due to avoidance of auditory input or 'shutdown' as a result of exposure to auditory input. The author proposes that SUR of the auditory system may be implicated as this phenomenon was observed in clinical practice. This proposal is however purely based on clinical observation and not substantiated by statistical analysis. In the instance of dyspraxia on verbal command the SIPT score of the praxis on verbal command test will be poor, but not as a result of the inverse relation with SOR of the auditory system.

The varying Alpha values of the SP items according to sectional division imply less internal consistency reliability of the data set from the SP. The low Alpha values could be contributed to some sections that contained only a few items and thus lowering the Alpha value. Another observation was that sections with low Alpha values that contained enough items (variables) had very little variation in selected responses. Thus the standard deviation for responses was small and accounted for a number of sequential items. The calculation of the Cronbach Alpha Coefficient is very relevant in discussion of limitations of this study, but will be covered in the sequel to this article.

CONCLUSION

This study produced results that firstly did not offer support for the alternative hypothesis associated with the aim. Secondly it offered results that highlighted the role of SOR in generalised SI dysfunction, thirdly the possibility that auditory detection does not play a role in ideation in visio- and somatodyspraxia and, fourthly, that BIS deficits may only have a concomitant relation with sensory responsivity and are most likely caused by deficient sensory discrimination. Lastly, that dyspraxia on verbal command is not related to auditory SOR, but that poor auditory detection may rather be due to SUR of the auditory system. It is proposed by the researcher that the variation in internal consistency of the SP also supports the use of the SPSC when assessing SMD to give credibility to the reliability of self-report measures. It is the sincere hope of the researcher that the results from this research will assist occupational therapists in their interpretation of sensory responsiveness tendencies in the presence of Developmental Dyspraxia.

The limitations and recommendations for future research will be offered in the sequel to this article that will also offer results from clinical analysis and the amalgamation of statistical and clinical results with subsequent discussion thereof.

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