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Use of computerized tests to evaluate psychomotor performance in children with specific learning disabilities in comparison to normal children

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***Background & objectives*: Children with specific learning disabilities (SpLD) have an unexplained difficulty in acquiring basic academic skills resulting in a significant discrepancy between their academic potential and achievements. This study was undertaken to compare the performance on a battery of six psychomotor tests of children with SpLD and those without any learning disabilities (controls) using computerized tests.**

***Methods*: In this study, 25 children with SpLD and 25 controls (matched for age, socio-economic status and medium of instruction) were given three training sessions over one week. Then children were asked to perform on the six computerized psychomotor tests. Results were compared between the two groups.**

***Results*: Children with SpLD fared significantly worse on finger tapping test, choice reaction test, digit picture substitution test and card sorting test compared to the controls ($P<0.05$).**

***Interpretation & conclusions*: Children with SpLD have impairment of psychomotor skills like attention, sensory-motor coordination and executive functioning. Further research is needed to evaluate if the remedial education plan results in improvement in psychomotor performance of children with SpLD on these selected tests.**

Key words Attention deficit - computerized tests - psychomotor skills - specific learning disabilities - SpLD

Specific learning disabilities (SpLD) is a generic term that refers to a heterogeneous group of neurobehavioural disorders manifested by significant, unexpected, specific and persistent difficulties in the acquisition and use of efficient reading (dyslexia), writing (dysgraphia) or mathematical (dyscalculia) abilities despite conventional instruction, intact senses, normal intelligence, proper motivation and adequate socio-cultural opportunity[1,2]. SpLD are now believed to be a result of functional problems with brain "wiring" rather than an anatomical problem[1]. The term SpLD does not include children who have learning problems which are primarily the result of visual, hearing, or motor handicaps, of subnormal intelligence, of emotional

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disturbance, or of socio-cultural disadvantage[1,2]. Although, still a matter of debate, this definition was adopted by the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV), the International Classification of Diseases (ICD-10), and classification of mental and behavioural disorders[3,4].

Up to 5-17.5 per cent of "seemingly normal" school children have dyslexia, a subtype of SpLD[1,2,5]. SpLD are intrinsic to the individual, presumed to be due to central nervous system dysfunction, and are chronic life-long conditions[1,2]. The same dysfunctions that interfere with normal learning processes also impact on self-image, peer and family relationships, and social interactions[6].

In children who experience learning problems, an appropriate evaluation of abilities and skills can provide the foundation for an accurate diagnosis and useful management recommendations[7]. Children with SpLD can have psychomotor deficits, attention deficits, tactile-perceptual deficits and memory disorders which may be correlates of learning problems[8]. A battery of well standardized and validated psychomotor tests which are conventionally used to evaluate the effects of centrally acting drugs[9,10], assesses a subset of the domains of brain function which are affected in SpLD[7]. We hypothesized that children with SpLD would perform differently on this battery of psychomotor tests compared to children without any learning disabilities (controls) and this study was carried out to test this hypothesis.

Material & Methods

Permission from the Institutional Review Board was taken, and written informed consent and assent were obtained from parents and children above seven years, respectively. This prospective, parallel group, pilot study was carried out in the department of Pediatrics and Clinical Pharmacology, Seth GS Medical College and KEM Hospital, Mumbai, Maharashtra, India, between August 2010 and December 2011.

Diagnosis of children with SpLD: Purposive sampling method was used. Children referred to the Learning Disability clinic in Pediatrics department for assessment of academic underachievement were assessed by multidisciplinary team comprising paediatrician, counselor, clinical psychologist, and special educator[2]. Only children above seven years of age were included in the study[2,5]. Audiometric and ophthalmic examinations were done to rule out non-correctable hearing and visual deficits (of ≥40 percentage disability) as such children do not qualify for a diagnosis of SpLD[2,5]. The paediatrician took a detailed clinical history and did a detailed clinical examination. The counselor ruled out that emotional problem due to stress at home or at school was not primarily responsible for the child's poor school performance. The Wechsler Intelligence Scale for Children-Revised (Indian adaptation)[11] was employed by the clinical psychologist to determine that the child's global intelligence quotient score was an average or above average (≥85).

SpLD was diagnosed based on a curriculum-based assessment, which is a recommended method for its diagnosis[2,5,12-14]. Employing a locally-developed and validated curriculum based test, the special educator conducted the educational assessment in specific areas of learning, namely, basic learning skills, reading comprehension, oral expression, listening comprehension, written expression, mathematical calculation, and mathematical reasoning[15]. Based on this test, an academic underachievement of up to two years below the child's actual school grade placement or chronological age led to a diagnosisof SpLD[2,5,15].

Diagnosis of children in the control group: Children in the control group (n=25) were identified from mainstream schools (Grades I to VII) after consultation with their respective classroom teachers. The controls had normal medical history and physical examination, and had no history of academic underachievement or poor school performance.

Thus, both groups were selected using the purposive sampling. Both groups of children were comparable in terms of age (7 to 14 yr), gender, socio-economic status and medium of instruction (English medium schools). Children with visual or hearing impairment, physical disability, cerebral palsy, tic disorder, attention deficit hyperactivity disorder (ADHD) or any other systemic illness that may affect psychomotor testing were excluded from the study.

Psychomotor testing: The automated psychometric test battery system consists of a series of individual tasks namely, the finger tapping test (FTT), simple reaction test (SRT), choice reaction test (CRT), choice discrimination test (CDT), digit picture substitution test (DPST) and card sorting test (CST). Each test is preceded with instructions and the software allows for recording of demographic data of each subject and reporting test results as separate files. Each test in the battery is individually administrable and results of each test are automatically stored. The number of

clicks (total, correct and wrong attempts) and average reaction time in milliseconds were taken as dependent variables for analysis. Computerized testing runs for about 20-30 min and assesses various psychomotor skills of children. These computerized tests were performed using Mindomatics™ software (M/s Sristek, Hyderabad)[16] which had been previously validated in our department in healthy adults (unpublished observation) as well as by Pilli *et al*[9].

Description of individual tests:[9]

1. Finger tapping test - The duration of the test is 20 seconds, during which the subject has to continuously tap on the "Enter Button" on the response box in quick succession. The test provides information on motor system performance.

2. Simple reaction test - The duration of the test is 60 seconds. In this test, on the click of a start button, test time will begin and a picture of a boy will appear on the center of the screen for 20 times. Subject has to press the "BOY" symbol button on response box as quickly as possible every time the "BOY" picture appears on the monitor. This test assesses attention and sensory-motor performance of brain.

3. Choice reaction test - The duration of the test is 60 seconds and this test assesses the attention and sensory-motor performance of brain and estimates the psychomotor response speed.

4. Choice discrimination test: The duration of the test is 60 seconds. This test assesses the attention, integration and sensory-motor performance of brain and estimates the psychomotor response speed.

5. Digit picture substitution test: In this test, the upper panel of the screen will display 1-9 digits with their corresponding target picture placed over each digit. Subject has to carefully concentrate and remember the corresponding digit for these pictures. The total duration of the test is 90 seconds. This test assesses attention, response speed, central integration, and visuo-motor coordination.

6. Card sorting test - In this test, the subject was asked to sort a set of 52 cards based on the different colours and shapes using a computer mouse. The sorting principle was constant throughout unlike in the Wisconsin card-sorting test[17]. This test assesses sensory, motor, central integrative and executive functions. Results are presented in terms of average time (seconds) taken to complete the sorting and the number of correct and wrong cards.

7. Training session - All children were given three training sessions (20 to 30 min per training session) over a period of one week so that they got familiar with a computer and the software. On the study day, children performed a series of six tests in a sequential manner without any breaks in between the tests. This was carried out in a quiet room.

Statistical analysis: No formal sample size calculation was done for this exploratory pilot study, as there were no data available on the use of a battery of psychomotor tests in children with specific learning disabilities. Quantitative data were tested for normality using Kolmogorov-Smirnov test. The "between groups" comparison was done using unpaired t-test (if normally distributed) or Mann-Whitney 'U' test (if not normally distributed). The qualitative data were compared using Fisher's exact test.

Results & Discussion

Both groups were comparable with respect to baseline characteristics (Table I). There was no significant difference between boys and girls in performance on psychomotor tests within each group. The mean Intelligence quotient (IQ) score of children with SpLD was 98.43 ± 5.46. There were significant differences in finger tapping test, choice reaction time,digit picture substitution test and card sorting test between SpLD and control groups. However, simple reaction time and choice discrimination test did not show significant difference between the two groups (Table II).

It was found that the number of total clicks in finger tapping test and digital picture substitution test were significantly (P<0.001) lower in SpLD children compared to the controls. Average reaction time in choice reaction test, digit picture substitution test and card sorting test was significantly (P<0.001) higher in the SpLD children compared to the controls.

Table I. Demographic details of participants

	SpLD children (n=25)	Controls (n=25)
Age in years (mean ± SD)	10.92 ± 1.12	10.48 ± 1.26
Sex (Male : Female)	3:2	1:2
Monthly family income (₹) median (range)	30,000 (10,000-200,000)	35,000 (12,000-120,000)

SpLD, specific learning disabilities; SD, standard deviation

Table II. Comparison of results of psychomotor tests between children with specific learning disabilities (SpLD) (n=25) and controls (n=25)

	Total no. of clicks		No. of wrong attempts		Average reaction time in milliseconds	
Test	SpLD	Controls	SpLD	Controls	SpLD	Controls
Finger tapping test	30.9 ± 9.84	47.2 ± 10.54	NA	NA	346.3 ± 116.06	221.6 ± 46.38
	$P < 0.001$				$P < 0.001$	
Simple reaction time	19.8 ± 0.41	17.7 ± 4.43	0 (0, 1)	0 (0, 2)	402.9 ± 71.59	379.6 ± 69.03
	$P = 0.06$		$P = 0.98$		$P = 0.25$	
Choice reaction time	10.6 ± 2.98	8.36 ± 3.34	0 (0,11)	0 (0, 4)	556 (471, 715)	497 (371, 3908)
	$P = 0.01$		$P = 0.12$		$P = 0.01$	
Choice discrimination test	10.2 ± 2.73	10.3 ± 8.45	0 (0,11)	0 (0,21)	597.2 ± 146.76	599.6 ± 94.52
	$P = 0.26$		$P = 0.06$		$P = 0.95$	
Digit picture substitution test	40.68 ± 7.08	52.32 ± 8.91	0 (0, 7)	1 (0, 5)	2273.7 ± 378.6	1786.8 ± 314.13
	$P < 0.001$		$P = 0.66$		$P < 0.001$	
Card sorting test	NA	NA	0 (0, 8)	0 (0, 4)	189400 ± 69480	110500 ± 38030
			$P = 0.34$		$P < 0.001$	

NA, not applicable
Data expressed as mean ± standard deviation or median (range) wherever applicable

Children with dyslexia have impairment in attention and short-term memory, poor balance and general clumsiness[18]. Some children with dyslexia show poor performance on cerebellar motor tasks, including eye movement control, postural stability, and implicit motor learning[18]. The significantly lower number of taps by SpLD children in the finger tapping test compared to the controls confirmed the finding of clumsiness and impaired attention in these children.

In the present study, the choice reaction time, but not simple reaction time, was significantly (P<0.01) longer in children with SpLD indicating that these children had difficulty in making choices between different visual stimuli and took longer to respond to multiple stimuli. This showed that they had impairment in sensory-motor coordination, reflecting slower decision-making. Children with SpLD are known to find it difficult to perform complex tasks in daily life[6]. This test could be a useful addition to the battery of tests used for evaluating children with SpLD. In the CDT, which also assesses attention, integration, visual-motor coordination and psychomotor response speed SpLD children performed comparably to the controls, suggesting that task-specific impairment in psychomotor response is a key finding in SpLD children.

The integration of complex neuropsychological processes including visual scanning, mental flexibility, sustained attention, psychomotor speed, and speed of information processing influence simple responses generated in the digit picture substitution test (DPST)[19,20]. In the present study, longer average reaction time and lesser number of total clicks in DPST in SpLD children indicated that these children had significant impairment of these complex psychomotor skills. The DPST, therefore, could be an important measure to assess psychomotor performance in SpLD children.

The Wisconsin card-sorting test (WCST) assesses sensory, motor, and central integrative functions. In addition, it has also been one of the most distinctive tests of prefrontal (executive) function.[17] The test was devised as an index of abstract reasoning, concept formation, and response strategies to changing contextual contingencies[17]. In the present study, children with SpLD were significantly (P<0.001) slower than the controls on the card sorting test (CST). Similar results have been reported in adolescents and young children with dyslexia[21,22] indicating problems in executive functioning in such individuals.

The cornerstone of treatment of SpLD is remedial education[1,2]. Early referral to a special educator for remedial education is crucial[1,2]. Using specific teaching strategies and teaching materials, the special educator formulates an Individual Education Programme (IEP) to reduce, eliminate or preclude the child's deficiencies

in specific learning areas such as reading, writing and mathematics identified during the child's educational assessment. The child has to undergo these remedial sessions twice or thrice weekly for a few years (about two to five years). Although remedial education concentrates almost exclusively on trying to impart academic skills by "teaching around" disabilities, it is known to alleviate underlying cognitive problems and help achieve academic competence[23].

The present study showed impaired performance on selected psychomotor tests by children with SpLD. While devising an education plan for the child, the deficits identified on this battery of psychomotor tests would be useful to individualize the remedial programmes. Improved academic performance is the only measure of assessing the beneficial effect of remedial education. It would be interesting to find out whether there is also a simultaneous improvement in their psychomotor performance on these selected computerized tests. Small sample size was a major limitation of the present study.

In summary, the present study documented that Indian children with SpLD performed poorly on selected psychomotor tests. Additional studies are required in a larger sample size in various geographic locations of the country, in children from wider socio-economic strata, and those who study in medium of instruction other than English.

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