Using Neuropsychometric Measurements in the Differential Diagnosis of Specific Learning Disability

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ABSTRACT

Introduction: The aim of this study was to develop a neuropsychometric battery for the differential diagnosis of specific learning disability (SLD), with specific respect to attention deficit hyperactivity disorder (ADHD), and to help resolve the conflicting results in the literature by an integrative utilization of scores on both the Bannatyne categories and neuropsychological tests.

Methods: The sample included 168 primary school boys who were assigned to SLD (n=21), ADHD (n=45), SLD and ADHD (n=57), and control groups (n=45). The exclusion criteria were a neurological or psychiatric comorbidity other than ADHD, a level of anxiety and/or depression above the cutoff score, medication affecting cognitive processes, visual and/or auditory disorders, and an intelligence level outside the IQ range of 85–129. Psychometric scores were obtained from the SLD Battery and Wechsler Intelligence Scale for Children-Revised in the form of Bannatyne category scores. Neuropsychological scores were from the Visual–Aural Digit Span Test-Form B, Serial Digit Learning Test, Judgment of Line Orientation, and Mangina Test. The battery was called the Integrative Battery of SLD.

Results: The correctness of estimation for classifying cases into the diagnostic dyads (SLD/ADHD, SLD/SLD+ADHD, and SLD+ADHD/ADHD) by an integrative utilization of both the Bannatyne category scores (n=4) and scores from the four neuropsychological tests (n=10) was 92.4%, 81.4%, and 71.8%, respectively. These proportions were generally higher than those obtained using the Bannatyne category scores alone (86.4%, 75.5%, and 73.1%, respectively). The same trend was seen in the classification of children into diagnostic and control groups. However, the proportion of the correctness of estimation was higher than that obtained for the diagnostic dyads.

Conclusion: When conducted using appropriately chosen research designs and statistical techniques and if confounding variables are sufficiently controlled, a neuropsychometric battery that includes capacities that relate to intelligence (Bannatyne categories) and those that relate to neurocognitive processes (neuropsychological tests) can be useful in the differential diagnosis of SLD.

Keywords: Specific learning disability, attention deficit hyperactivity disorder, differential diagnosis, Bannatyne categories, neuropsychological tests

INTRODUCTION

Specific learning disability (SLD) is defined as the performance of a child falling below what one would predict given the child's chronological age, measured intelligence (IQ), and education level in individual standard tests for reading, math, and using written language (1). Children with SLD are frequently diagnosed with a secondary behavioral disorder (2): the most common comorbidity is attention deficit hyperactivity disorder (ADHD), with rates varying between 10% and 92% (3,4,5,6,7,8).

The comorbidity of SLD and ADHD has a broad spectrum of resemblances from a clinical perspective as well. In both disorders, there are visuospatial perception deficits, the failure to recognize geometric shapes and copy them (9,10), and temporal and spatial orientation deficits. Deficits in depth perception cause problems in predicting distance, which result in accidents (9,11,12,13,14,15,16). In both groups, the ability to distinguish between input in visual, auditory, and sensory modalities; attention, memory, and fine motor skills (such as buttoning and unbuttoning, using scissors, and handwriting); and gross motor skills (such as skipping with a rope, throwing a ball, and riding a bike) manifest themselves as negative (10,13,17,18,19).

Because the clinical findings of SLD overlap in a wide spectrum with those of ADHD, this creates difficulties in the differential diagnosis of SLD. One of the measuring tools used for differential diagnosis is the Specific Learning Disability Battery (SLDB). In eight of the nine subtests, the scores of a control group were significantly higher than those of an SLD group as well as those of a group with SLD as a comorbidity of ADHD (SLD+ADHD) (20). However, the SLD subtests did not differentiate between the two diagnostic groups (SLD, SLD+ADHD) (20).

Another psychometric tool administered for the purposes of both practice and assessment of the diagnosis of SLD is the Wechsler Intelligence Scale for Children-Revised (WISC-R) (21). SLDB scores are believed to match WISC-R scores with certain patterns (22,23,24).

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However, a literature study has shown that there is no single profile of SLD. Among the profiles, there are various patterns where the Verbal Intelligence Quotient (VIQ) is 15–40 points higher than the Performance Intelligence Quotient (PIQ), the PIQ is 10–30 points higher than the VIQ, or there is no discrepancy between the VIQ and PIQ (yet there is a difference of 7–12 points between the subtests) (25,26,27). Some researchers claim that there is no systematic and clear correlation between the patterns of SLDB and WISC-R and that the abovementioned patterns of WISC-R can be found in many gifted children as well; therefore these patterns should not be used to diagnose SLD (26).

Bannatyne (28) points out that in the assessment of children with SLD, a classification based on the discrepancy between verbal and performance scores in WISC-R is not sufficient. Bannatyne developed an alternative classification in which the subtests are clustered into four categories. These categories are currently among the most widely used scoring units for diagnosing children with SLD (22,29,30,31). However, in another study (26), it was found that the scores obtained from the subtest categories of WISC-R were not conclusive. There are findings that suggest that the categorization scores of the subtests of the Wechsler Intelligence Scale for Children-Third Edition (WISC-III) differentiate SLD (32); additionally, there are findings that suggest that they do not differentiate SLD (31).

WISC-R is one of the leading psychometric scales for assessing diagnosis in ADHD clinics as well as in SLD clinics. However, the validity of WISC-R for SLD is also true for ADHD, and the literature includes all the possibilities of correlational variance between VIQ and PIQ (lower VIQ, lower PIQ, and both lower VIQ and lower PIQ) (21). In Turkey, a study that tested the validity of WISC-R for differentiating ADHD was conducted in various settings (33). WISC-R scores categorized 141 out of a total of 259 healthy subjects into the ADHD category and categorized 63 out of a total of 415 ADHD subjects into the healthy category. These findings show that WISC-R does not provide satisfactory categorization, even in "pure" ADHD without any comorbidity.

The above findings and the interpretation of these findings indicate that WISC-R is not a sufficient tool in itself for the differential diagnosis of SLD and ADHD cases where the two disorders show overlapping clinical findings, and therefore, point out that supplementary and/or alternative techniques should be used to assess cognitive traits in the abovementioned disorders (21,34). Cognitive deficits are primary in SLD. There are also cognitive disorders in ADHD as well as biological factors (35). Neuropsychological tests have a special place in assessing ADHD because it involves both biological and psychological factors (36). Neuropsychological tests have been studied extensively both with healthy subjects and in clinical research and have been used to measure and assess brain-based cognitive processes (37,38). These tests can also be used to define the cognitive features of SLD and ADHD.

The purpose of our study was to design a neuropsychological battery to be used in the diagnostic differentiation of SLD in connection with ADHD. Therefore, scores obtained from neuropsychological tests standardized for Turkey were used jointly with WISC-R-based Bannatyne categorization scores. We hypothesized that such a unifying approach to the differential diagnosis of SLD would provide a more accurate prediction than that derived solely from Bannatyne categorization scores. Should the hypothesis be confirmed, it was predicted that the contradictory findings derived from WISC-R scores in the cognitive diagnosis of SLD and ADHD would be replaced by consistent patterns.

METHODS

Sampling

The sample in the study consisted of 168 male elementary school students, 21 of whom had SLD, 45 ADHD, 57 SLD and ADHD, and 45 were in the control group. The clinical cases were among those who sought help in a child psychiatric clinic with symptoms such as literacy problems, academic failure, attention deficit, hyperactivity, and impulsivity. In this group, we categorized those who were already diagnosed as SLD only, ADHD only, and ADHD and SLD comorbidity (ADHD+SLD) by the child and adolescent mental health specialist based on the DSM-IV Disruptive Behavior Disorders Screening and Rating Scale. In diagnosis, the scores obtained from WISC-R, SLDB, and the Learning Disability Symptom Screening Checklist, and, for disruptive conduct disorder, the DSM-IV-based Disruptive Behavior Disorders Screening and Rating Scale were taken into consideration as well.

The clinical cases were selected from the population who had been to the clinic for the first time with symptoms and had been diagnosed with SLD, SLD+ADHD, or ADHD according to the DSM-IV scale with no prior history of any diagnosis of the related symptoms and who had started medication and yet had stopped taking the prescribed medication at least 48 h prior to the study. As part of the exclusion criteria, patients with any psychiatric or neurological comorbidity other than SLD and ADHD, clinical-level anxiety and/or depression, any kind of medication that would affect cognitive processes, and visual and/or aural disorders were excluded.

The control group consisted of 45 male children who had no psychiatric or neurological disorder age-matched with the ADHD group. In both groups, the total intelligence quotient (TIQ) was required to be between 85 and 129 and the age typical for the grade level at school.

Instruments

Diagnostic tests and scales
Wechsler Intelligence Scale for Children-Revised (WISC-R): All 12 subtests in the Turkish version of the WISC-R were implemented thoroughly. The WISC-R scores were categorized according to Bannatyne clusters. The points for Acquired Knowledge and General Information were derived from Arithmetic and Vocabulary points; Verbal Conceptualizing Ability and Similarities from Vocabulary and Comprehension points; Sequencing Memory Ability and Digit Span from Arithmetic and Coding points; and Spatial Ability from Picture Completion, Block Design, and Object Assembly points.

Specific Learning Disability Battery (SLDB): This subject instrument was first used by Korkmazlar (30). In later studies, the battery has been expanded with the addition of new tests (20,40,41). Thus, the battery comprises subtests that assess literacy and basic arithmetic skills and tests that assess disorders or problems in visual perception, ranking and sequencing skills, the hand–eye–ear test of Head, lateralization, and fine motor skills.

During follow-up periods, revisions were made in the number of questions, the materials used, and the methodology and scoring. The revised SLDB includes subtests for literacy, which assess reading speed and errors (40) in alphabetizing the letters, tasks that assess primacy and latency through the days of the week and the months of the year, hand–eye–ear tests (to distinguish right and left in the subject's own body) (42), the 145

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Harris Lateralization Test (42), and the Clock Drawing Test (20,43). In the battery, the subtest for writing has a normative value (40,41,44).

Learning Disability Symptom Screening Checklist: This instrument was designed by Korkmazlar with 36 items (30). Erman (9) later added new subdomains to the screening checklist and increased the number of items that were already in the subdomains. The checklist used in the SLDB is by Erman (9). The Learning Disability Diagnosis Checklist includes a rating of the symptoms of the subjects by their teachers and parents (3,9). The checklist has a total of 88 items, including 17 subdomains: each item is rated as 0 (never), 1 (sometimes), 2 (often), or 3 (always). In our study, this scale was used during the diagnostic process and in the evaluation of SLD.

DSM-IV-based Disruptive Behavior Disorders Screening and Rating Scale: This scale, which was designed by Turgay (45) based on DSM-IV diagnostic measures, includes nine items regarding attention deficit, six items regarding hyperactivity, three items regarding impulsivity, eight items regarding defiance, and 15 items regarding conduct disorder.

Each item is rated as 0 (not at all), 1 (just a little), 2 (fairly much), and 3 (very much). The number of criteria met and the total score for each section are calculated separately for each section and for the total test (46). In our study, the scale was used to assess ADHD and to exclude other disruptive behavior disorders.

Children's Depression Inventory (CDI): This scale, which was developed by Kovacs (47,48), is used for people between 6 and 27 years of age. The scale has 27 items. The individual is required to select one of the three phrases given for each item, taking his/her past 2 weeks into consideration. The phrases define depression levels as 0, 1, or 2. The highest possible score in the scale is 54. In the Turkish adaptation (49), the cutoff point has been determined to be 19. In our study, this scale was used to exclude those with clinical-level depression.

Neuropsychological Tests
Visual Aural Digit Span Test Form B (VADS-B): VADS-B, which was developed by Karakas and Yalın (50,51), is modeled on the Visual Aural Digit Span Test (VADS), which is designed to assess short-term memory capacity (52). In VADS-B, the theoretical and methodological errors in the original test have been corrected. The standardization of VADS-B was based on numerous studies performed with participants at developmental stages between 6 and 95 years of age (37,38,50,53,54,55).

VADS-B consists of four subtests, which require the presentation of digit spans of different lengths as either aural (A) or visual (V) inputs to subjects, and the recording of the responses is either oral (O) or written (W). Four basic scores are calculated in each of the subtests of VADS-B (AO, VO, AW, and VW). The scores measure the cognitive span under different sensation–response combinations. In four of the six combined scores, the cognitive span, types of input (Aural Input: AO+AW; Visual Input: VO+VW), and types of response (Oral Expression: AO+VO; Written Expression: AW+VW) are measured separately. The other two combined scores represent sensation-response integration. Integration is calculated separately as the Intrasensory Integration (INTRA) Score (AO+VW) and Intersensory Integration (INTER) Score (VO+AW) (55).

The studies were conducted with multivariate statistical analysis and analysis in which structural equation modeling was used. VADS-B was found to measure limited cognitive span (attention/short-term memory span) under various stimulus–response modalities (56,57).

In our study, VADS-B was used to assess SLD affected by (9,58,59,60,61,62) sensation/perception (specifically visual and aural), response organization (specifically written and oral/phonological), and cognitive span in various stimulus–response combinations (aural–oral, visual–oral, aural–written, and visual–written).

Serial Digit Learning Test, Turkish Version (SDLT): In SDLT, it is measured how long it takes for the subject to remember a given specific serial digit correctly after how many learning repetitions (63). The SDLT implementer who is assessing the learning skill reads an 8-digit series aloud and asks the child to repeat the same digits aloud in return. The test implementation continues until the child repeats the serial digits correctly twice in a row or completes all 12 rounds, and the test is assessed on a single score (64,65). The test has been standardized for Turkish adults (37,38). SDLT has normative values for the 6–11-year-old age group (37,38). In our study, SDLT was used to measure learning ability, which is the major area of disorder in SLD.

Judgment of Line Orientation Test (JLOT): JLOT consists of five drills and 30 test items that measure the orientation component of visuospatial perception orientation (66). In the test booklet, there are lines numbered from 1 to 11 that all emerge from the same center at the top of the page, and at the bottom of the page there are 1/3rd sections of any two of the 11 lines above (64,65). The subject is required to find to which two of the 11 lines those two pieces correspond. The test has been standardized for Turkish adults (64,65,67). JLOT also has normative values for the 6–11-year-old age group (37,38). In our study, JLOT was used to measure visuospatial orientation, which is one of the domains affected in SLD (10,14,17).

Mangina Test (MT): In SLD, visuospatial spans are affected not only in perception and orientation (the features measured by JLOT) but also in visualization and cognition (15,68). MT, which was developed to measure visual perception and perceptive learning (69), includes 44 pairs of geometric shapes of increasing difficulty as input. Each item contains a geometric shape and a complex pattern hidden in the shape. To find the hidden pattern, the individual is expected to make directional/spatial orientation (D/SO) and size/dimension (S/D) assessments and also a mixed (M) assessment of both D/SO and S/D. There are five scores, which are obtained from S/D, D/SO, M, preparatory input (PI), and the total calculated in the test. The standardization of MT for Turkish culture is still ongoing (37,38).

In MT, the items that require D/SO are associated with reading and comprehension; the items that require S/D are associated with math skills (70,71,72). Accordingly, MT was initially used for diagnosing SLD (70,71,72). Currently, due to the prevalence of SLD/ADHD comorbidity, MT is used to measure visual-spatial cognition in the diagnosis of both groups, and in SLD cases it is specifically used to measure learning and retention ability (73).

Procedure
For the clinical sampling in this study, the child mental health and behavioral disorders specialist recorded the story of boys who had been brought to the clinic with symptoms of academic failure, difficulty in reading and writing, attention deficit, and hyperactivity. The specialist diagnosed the cases using DSM-IV diagnostic criteria. The parents and teachers were given the Learning Disability Symptoms Checklist to specify SLD and its rating, and for the diagnosis and rating of ADHD and for the exclusion of all other disruptive behavioral disorders, the Screening and Assessment Scale based on DSM-IV was used. The control group consisted of elementary

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school children who were at the clinic for routine check-up purposes, and some participants were included via families with children with ADHD or via a snowball effect. The children who participated in the study went through a physical check-up, and those with no signs of neurological or psychiatric disorders were included in the control group.

All participants completed WISC-R, and those who were within the normal range for TIQ (85–129) were included in the sample group for the study. All participants were also administered SLDB. The processing time for WISC-R and SLDB is approximately 90 min. To control fatigue and habituation factors, the tests were applied in two separate sessions, balancing the order of application. In the neuropsychological tests (VADS-B, SDLT, WISC-R, and MT) that were given at a later stage, the effect of sequencing was controlled via a balancing method.

Permission for the research was granted by the Ethics Committee of the Dr. Sami Ulus Gynecology and Pediatric Health Training and Research Hospital and the Ethics Committees of Gazi University and Hacettepe University. The parents, and to a certain degree the children as well, were informed of the steps and applications involved in the research. The children of the parents who were informed and who agreed with the terms of the research were included in the research with ''volunteer'' status.

Statistical Analyses

The data were analyzed by IBM Statistical Package for the Social Sciences for Windows, version 21.0; (IBM Corp., Armonk, NY, USA). The accuracy of clustering (SLD, ADHD, SLD+ADHD, and control groups) was achieved by adding the neuropsychological test scores to the points derived from the four Bannatyne categories in WISC-R, and they were examined via logistic regression analysis (LRA).

RESULT

Table 1 includes descriptive statistical information for the research groups: the number of participants and their ages. The impact of age in the groups (SLD, ADHD, SLD+ADHD, and control groups) was analyzed via one-way analysis of variance (ANOVA). The Kolmogorov–Smirnov test was used for testing normality of data distribution, and Levene's test was used to test the homogeneity of variances. The analysis of the scores yielded a normal distribution (p>0.05), and the variance distribution was homogeneous (p>0.05). The ANOVA results show that age had no meaningful impact on the groups (p=0.397). This finding confirms that there was no meaningful age difference between and among the groups.

In our study, the clustering of our participants into groups (SLD, ADHD, SLD+ADHD, and control groups) by neuropsychometric scores was analyzed by LRA, where a retroactive elimination technique was applied. Criteria for a differential diagnostic status of the scores were analyzed via LRA processes using diagnostic group pairs (Table 2). Criteria to differentiate clinical and control group status of the scores were analyzed via LRA processes using each diagnostic group and the control group (Table 3). Four of the total of 14 points used in predictions were obtained from Bannatyne categories (Acquired Knowledge, Verbal Conceptualization, Sequencing, and Spatial categories), and the other 10 predictors were obtained from neuropsychological test scores (VADS-B: AO, VO, AW, and VW; SDLT; JLOT; and MT: PI, S/D, D/SO, and M).

In LRA, regarding the differential diagnosis (7th step) of SLD from ADHD, the Acquired Knowledge and Spatial category points were found to be meaningful with respect to the SDLT, VADS-B (VO, VW), and MT (S/D) scores (Wald=7.92, SD=1, p=0.005; Wald=6.17, SD=1, p=0.013; Wald=5.08, SD=1, p=0.024; Wald=4.27, SD=1, p=0.039; Wald=4.29,

Table 1. Age distribution in study groups and related descriptive statistics

| Group | n | Age (month) | |
		Mean	Standart error
SLD	21	101.24	3.44
ADHD	45	103.47	2.60
SLD+ADHD	57	98.53	1.94
Control	45	103.20	2.67
Total	168		

SLD: specific learning disability; ADHD: attention deficit hyperactivity disorder; SLD+ADHD: specific learning disability+attention deficit hyperactivity disorder

Table 2. Summary table for logistic regression analysis of differential diagnosis. Predictors: Bannatyne category and neuropsychological test scores. Predictors in parentheses: Bannatyne category points only

| A | Predicted group | | |
Observed group	SLD	ADHD	Correctness of estimation
SLD (n=21)	19	2	90.5 (71.4)
ADHD (n=45)	3	42	93.3 (93.3)
Total			92.4 (86.4)

| B | Predicted group | | |
Observed group	SLD	SLD+ADHD	Correctness of estimation
SLD (n=21)	4	17	19.0 (0.0)
SLD+ADHD (n=57)	5	52	91.2 (100)
Total			71.8 (73.1)

| C | Predicted group | | |
Observed group	SLD+ADHD	ADHD	Correctness of estimation
SLD+ADHD (n=57)	49	8	86.0 (78.9)
ADHD (n=45)	11	34	75.6 (71.1)
Total			81.4 (75.5)

SLD: specific learning disability; ADHD: attention deficit hyperactivity disorder; SLD+ADHD: specific learning disability+attention deficit hyperactivity disorder

SD=1, p=0.038; Wald=3.95, SD=1, p=0.047). In the model where the total clustering accuracy rate was 92.4% (chi-squared=56.980, p=0.0000000018, respectively), the clustering accuracy rates for the diagnosis of SLD and ADHD were found to be high and similar (90.5% and 93.3%, respectively) (Table 2) (Wald=4.52, SD=1, p=0.034). In the model where the total clustering accuracy was 71.8% (chi-squared=7.92, p=0.048), for the SLD+ADHD diagnosis group, the clustering accuracy rate was found to be high (91.2%), but the accuracy rate for diagnostic clustering for SLD was very low (19.0%) (Table 2).

There was no meaningful score in the LRA model to distinguish the SLD group from the control group (Table 3).

In LRA (11th step), regarding the differential diagnosis of the SLD+ADHD group from the control group, the Acquired Knowledge category score was   147

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Table 3. Summary table for logistic regression analysis of differentiation of clinical from healthy subjects. Predictors: Bannatyne category and neuropsychological test scores. Predictors in parentheses: Bannatyne category points only

A	Predicted group		
Observed group	SLD	Control	Correctness of estimation
SLD (n=21)	21	0	100 (81.0)
Control (n=45)	0	45	100 (97.8)
Total			100 (92.4)
B	**Predicted group**		
Observed group	SLD+ADHD	Control	Correctness of estimation
SLD+ADHD (n=57)	55	2	96.5 (89.5)
Control (n=45)	2	43	95.6 (82.2)
Total			96.1 (86.3)
C	**Predicted group**		
Observed group	ADHD	Control	Correctness of estimation
ADHD (n=45)	36	9	80.0 (71.1)
Control (n=45)	6	39	86.7 (73.3)
Total			83.3 (72.2)

SLD: specific learning disability; SLD+ADHD: specific learning disability+Attention deficit hyperactivity disorder; ADHD: attention deficit hyperactivity disorder

found to be meaningful with respect to the SDLT and MT scores (D/SO) (Wald=7.28, SD=1, p=0.007; Wald=4.02, SD=1, p=0.045; Wald=8.82, SD=1, p=0.003, respectively). In the model where the total clustering accuracy rate was 96.1% (chi-squared=115.978, p=0.00000000000010), the accuracy rates of clustering in diagnosing children with comorbidity and the control group were found to be high and analogous (96.5% and 95.6%, respectively) (Table 3).

In LRA, for differentiating the ADHD diagnosis cluster from the control group (6th step), the Sequencing Ability score and SDLT and MT scores (D/SO) were found to be meaningful (Wald=5.10, SD=1, p=0.024; Wald=7.89, SD=1, p=0.005; Wald=5.67, SD=1, p=0.017, respectively). In the model where the total clustering accuracy rate was 83.3% (chi-squared=49.749, p=0.00000012), for clustering children into ADHD and control groups, similar accuracy rates were found to occur (80.0% and 86.7%, respectively) (Table 3).

DISCUSSION
The comorbidity between SLD and ADHD is high and they overlap clinically as well. This situation creates problems for the differential diagnosis of SLD from ADHD. The SLDB, which was developed to support the diagnosis, differentiates the clinical group from the control group; however, this battery does not contribute to the differential diagnosis. In this regard, there is no meaningful discrepancy between the battery scores of the SLD+ADHD group and those of the control group; therefore, it is not possible to produce a generalizable profile of SLD by means of the scores obtained (20). Another psychometric scale commonly used to diagnose SLD is Bannatyne category points calculated with WISC-R. Despite its common use, there are conflicting findings regarding its usefulness in the differential diagnosis of SLD (26,29,31,32).

The conflicting findings from WISC-R also apply to ADHD that has SLD as a comorbidity (21).

The discrepancies found in the literature may be due to the quality of the research groups involved in the studies, the techniques used in statistical analyses, and other complex issues. All these factors were taken into consideration in our study, in which we aimed at developing a neuropsychometric battery for the differential diagnosis of SLD from ADHD to create a profile of SLD. Accordingly, the groups formed for the research to differentiate SLD from ADHD were purely clustered as SLD only, ADHD only, comorbidity of SLD+ADHD, and healthy control groups.

The approach of clinical practices and studies that aim to find results on an individual basis by working with each case individually is idiographic. The specific purpose of such studies is to diagnose each case accurately, in other words, to be able to diagnostically categorize cases in accordance with their disorders. We analyzed the accuracy rates of clustering of the cases in our study, which aimed to develop a measuring tool for differential diagnosis. Accordingly, the data from our research were analyzed by LRA in line with idiographic research rather than the variance analysis techniques that are used in nomothetic research.

In our study, the challenging factors that could emerge from measuring tools were eliminated and controlled by using only those psychometric tools that had been standardized in and for Turkey (37,38). The tools were selected from among those that would measure learning ability, visual-spatial perception and cognition, performance in different stimulus–response modalities, and executive functions, in accordance with the disorders related to SLD and ADHD (64,65). The contradictory features that might emerge from the characteristics of the participants were controlled by including subjects who were of the typical age group for the grade level in school, had a normal TIQ of 85–129, and were of the same gender (male).

To control the clinical features that could cause problems in the findings, the cases were required to be in the first referral stage without having started any medication or having quit medication at least 48 h prior to the data collection. To qualify as a subject, the participants were required to be taking no medication that would affect cognitive processes and also not to have any comorbidity other than SLD and ADHD or any clinical-level anxiety and/or depression.

The Role of an Integrated Battery in the Differential Diagnosis of SLD
Our study aimed at developing a battery that would be used in the differential diagnosis of SLD from ADHD. The study included the integrated application of Bannatyne categories (4 points), four neuropsychological tests (10 points), and a newly created measuring scale called Specific Learning Disorder Integrated Battery (SLD-IB). The total clustering accuracy obtained from SLD-IB was in general higher than that obtained from Bannatyne categories alone. The total accuracy rates in the diagnostic groups (SLD/ADHD, SLD/SLD+ADHD, and SLD+ADHD/ADHD) for the diagnostic pairs were 86.4%, 73.1%, and 75.5%, respectively, when only the category points were taken into consideration in the diagnosis, whereas the rates were found to be 92.4%, 71.8%, and 81.4%, respectively, when the neuropsychological test scores were added. In the model in which SLD and SLD+ADHD groups were analyzed, the clustering rate (73.1%) obtained with categorization only was higher than the clustering rate with the neuropsychological test scores added. However, this figure is misleading because all the subjects were clustered under the comorbidity in the aforementioned model, where the sensitivity was found to be 0 (Table 2).

The same situation existed in separating the clinical groups from the control groups (SLD/Control, SLD+ADHD/Control, and ADHD/Control). The accuracy rates for clustering with the categorization points only were 92.4%, 86.3%, and 72.2%, respectively, whereas the accuracy rates became 100.0%, 96.1%, and 83.3%, respectively, when the neuropsychological test scores were added for the groups. The integrated battery has succeeded in clustering the SLD and control groups with perfect accuracy.

SLD is primarily a learning disorder with variations such as reading deficit (dyslexia), disability in math (dyscalculia), disability in written expression, and other unidentified learning disorders (1). In our study, the three groups of findings point to the central significance of learning in SLD. 1) The findings from SLD-IB and those obtained from SDLT, which measures learning ability via numeric material expressed orally, gave results as predicted. In this regard, in the LRA model that differentiates SLD from ADHD, SDLT was calculated along with five other points; in the model that differentiates SLD from comorbidity (SLD+ADHD) as one point; and in the model that differentiates SLD+ADHD comorbidity from the control group as one of three points. These results reveal the fact that SDLT has crucial significance in the measurement and assessment of SLD. 2) Another finding in line with the features of SLD was obtained from the Bannatyne category of Acquired Knowledge. In the LRA model that differentiates SLD from ADHD, comorbidity with ADHD, and the control group, Acquired Knowledge was assessed along with other scores. (For details, see the Findings section.) Acquired Knowledge is assessed by the General Information, Arithmetic, and Vocabulary subtests in WISC-R. The correlation of the abovementioned subtests with academic achievement proves the obvious role that learning and memory play in academic achievement. (28,29,74). 3) Another predicted finding that learning and related processes exhibit essential deficits in SLD was obtained from MT. In this test, the S/D and D/SO scores were used in the model that differentiated each clinical group from the control group. The first score in the model is for reading and reading comprehension (dyslexia in SLD) and the second is for math skills (dyscalculia in SLD) (70–73).

Explanations regarding deficits in visual and/or aural sensation/perception in SLD are taken into consideration in theories on the subject (58,75). Difficulties in the self-expression of subjects are documented by studies that analyze deficits in phonological processes (60,76). In our study, these processes were measured by VADS-B scores multidirectionally, and it was found that the subtest scores with visual content (VO and VW) are significant in the differential diagnosis of SLD from ADHD in the LRA model. These results show that VADS-B can be beneficial in revealing in which modality (aural or visual) the subjects process the stimuli better. The findings obtained from VADS-B may reveal the strengths and weaknesses of subjects, and it is believed that this information can be useful for rehabilitation programs specially designed for the individual.

The differential nature of the visual content scores in VADS-B suggests that there is a visuospatial cognition deficit in SLD as well. In this regard, the JLOT scores of the SLD group with reading deficit are meaningfully lower than those of the control group (14). In a study in which the Rey–Osterrieth Complex Figure Test was used to assess visuospatial cognition (16), the ADHD+SLD group had scores that were meaningfully lower than those of the ADHD group and the scores of both groups were found to be lower than those of the control group. The findings of our study are compatible with the findings that in SLD there exists not only visual perception deficit but also visuospatial perception and cognition deficits (9,10,16). In our study, in the model that differentiated SLD from ADHD and differentiated the comorbidity group from the ADHD group, we used Bannatyne's Spatial Ability category scores (calculated from the Picture Completion, Block Design, and Object Assembly scores in WISC-R) and the JLOT score measuring visuospatial orientation.

In ADHD, where the basic clinical features are attention deficit and hyperactivity, there are quite a few cognitive deficits as well. However, there are findings (33,77,78,79,80,81) and theories based on those findings that claim that those deficits are generally dysexecutive syndromes (35).

In the study, the Bannatyne Verbal Conceptualization Ability category score, which was used in differentiating ADHD from comorbidity in the LRA model (calculated from the Similarities, Vocabulary, and Comprehension subtests in WISC-R), and the score for Sequencing (memory) Ability (calculated from the Digit Span, Arithmetic, and Coding subtests in WISC-R), which was used in differentiating the ADHD group from the control group, were found to be meaningful (82,83). In these WISC-R subtests, specific executive functions are measured: in the Similarities subtest, forming analogies; in the Comprehension subtest, abstraction and conceptualization; in the Digit Span total score, chronological and spatial sequencing; and in the Digit Span subtest, by repeating the digit span backwards, functional memory is measured (78,84–86). These findings obtained from our study regarding executive functions are compatible with dysexecutive syndrome.

One of the limits of the study is the low number of subjects in the "pure" SLD diagnosis group. It is suggested that the findings of this study should be repeated with a wider range of subjects. Because both SLD and ADHD are more widespread among male children, our study focused initially on that gender (87–90). For further studies, it is recommended to include female children among the subjects to find out if there are gender differences in cognitive processes in SLD.

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