Construction of an Arabic computerized cognitive skill battery for the diagnosis of children with specific learning disabilities

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Objective

Most of the previously designed Arabic tests for the assessment of specific learning disabilities (SLDs) are noncomputerized and do not pay attention to many of the cognitive skills that are believed to have an important role in the early stages of literacy development and its relations with learning disabilities. Computer usage supports and enhances children's creativity, self-esteem, and cooperative learning. Therefore, we aimed to design an Arabic computerized cognitive skill battery for the detailed assessment of children with SLD, through the assessment of their auditory as well as visual processing skills, to identify their points of weakness that might contribute to their learning disability.

Participants and methods

This study was carried out in Assiut city, Egypt. All fourth grade students from six chosen public primary schools ($n = 858$ students) were interviewed except those who were absent during their school visits ($n = 142$ students), or those who did not complete the test battery ($n = 56$ students). The rest of the sample (660 students) completed the test battery. The study included four stages. The first stage included identification of students with SLD with previous standardized tests [the Arabic reading test, the writing test (it is the sum of the script part of visuomotor test, which was specifically designed for this study, plus spelling part of Arabic reading test), the Math test, and the Wechsler Intelligence Scale for Children-Revised to assess their IQ level]. The second stage included battery construction by seven expert staff members (this took 1 year from 1 October 2012 to 30 September 2013). The third stage included application of the newly constructed battery in a pilot study to 10 normal students (9–10-year-old) to ascertain clarity of the tests of the battery. The fourth stage included test standardization.

Results

The reliability of the battery was proven using Cronbach's α correlation coefficient ($\alpha \geq 0.7$), interitem correlations (all values are positive and highly significant), and corrected item-total correlation coefficient (all values >0.3). Validity was proven with judgment validity, construct validity (factorial analysis) (all loadings ≥ 0.5), contrasted group validity, and predictive validity (sensitivity and specificity).

Conclusion

The constructed battery was thus proven to be highly reliable and valid for the assessment of SLDs among Arabic reading children, and thus remediation programs can be directed properly and early.

Keywords:
Arabic, children, learning disabilities, test battery

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Introduction

Learning disability (LD) is defined by the Individuals with Disabilities of Education Improvement Act as a group of disorders in one or more basic psychological processes involved in understanding or in using language, spoken or written, that may manifest itself as an imperfect ability to listen, think, speak, read, write, spell, or to perform mathematical calculations [1].

The American with Disabilities Act *http://www.ada.gov* added that the term LD does not include learning problems that are primarily the result of visual, hearing, motor disabilities, mental retardation, emotional disturbance, and environmental, cultural, or economic disadvantage. A child who still has LD, not attributed to one of these factors, was termed as having specific learning disability (SLD) [2].

LD is one of the most prevalent forms of developmental disabilities.

The National Institutes of Health [3] estimates that 15–20% of the general population has some form of a LD.

Dyslexia was found to be a multifactorial outcome of deficits in phonological [4], neurological [5], visual [6], verbal short-term memory [7], and auditory perception [8], which are suggested to have genetic factor [9], together with other aggravating factors such as psychological, educational, or environmental factors [10]. Dysgraphia is defined as a pattern of learning difficulties characterized by problems with spelling, grammar and punctuation accuracy, clarity, or organization of written expression, whereas dyscalculia is defined as a pattern of difficulties characterized by problems in processing numerical information, learning arithmetic facts, and performing accurate or fluent calculations [11].

The commonly used tests for the diagnosis of LDs among Arabic-speaking children are either translated Arabic versions of foreign tests such as the Illinois Test of Psycholinguistic Abilities, which is considered as a diagnostic psychoeducational test that assesses specific abilities and achievement of a child [12] or the constructed Arabic tests that assess achievement abilities in children as a test for the measurement of reading ability in dyslexic children [13], or test for the diagnosis of LDs in pupils at primary grade [14]. Other Arabic constructed tests assess reading in the light of one or more of the cognitive processes, such as the standardized Arabic language test [15], which is used to assess syntax at both receptive and expressive levels, and the Arabic reading test (ART) [16], which assesses reading ability with special reliance on phonological awareness and to some extent on auditory discrimination skills.

These tests are noncomputerized and do not pay attention to many cognitive skill problems, which might be a major contributing factor for SLDs. Recent decades have witnessed a great revolution in technology, and it was found that skills related to technology usage are better to be retained [17], besides the easier and greater inclusion of computer usage in learning of children with special needs [18].

Thus, the present work aimed at the construction and standardization of an Arabic computerized battery for detailed study of auditory and visual cognitive skills that contribute mostly to the process of learning.

Patients and methods

Patients

Study group

This cross-sectional study was conducted on school children between 9 and 10 years of age from six geographically distributed governmental fourth grade primary school students in Assiut city.

They fulfilled the following criteria:

(1) Normal IQ (≥90) on the Wechsler Intelligence Scale for Children-Revised (WISC-R) test [19].

(2) Poor scholastic achievement:

Obtaining less than mean ± SD score on one or more of the following standardized achievement tests:

- (a) ART [16]
- (b) Writing test (it is the sum of visuomotor test, which was specifically designed for this study, plus spelling part of ART)
- (c) Math test [20].

(3) Normal neurological, basic audiological, and ophthalmological examination.

Control group

The control group was selected from fourth grade students of the same public schools who fulfilled the following criteria:

(1) Normal IQ (≥90) on the WISC-R test

(2) Good scholastic achievement:

- (a) Obtaining more than mean ± SD score according to the standardized ART, writing, and Math tests
- (b) On the basis of the end of the year exam school marks, students with normal IQ (>90) were arranged in a descending manner according to their school marks, and students with marks in the highest quarter (the control group) were compared with those in the lowest quarter (probably SLD)

(3) Normal neurological, basic audiological, and ophthalmological examination.

Methods

The current study included four stages:

First stage: identification of students with SLD.

Second stage: construction of an Arabic computerized diagnostic battery based on the suggested auditory and visual cognitive skills that contribute mostly in the process of learning and that might be deficient among students with SLD.

Third stage: pilot study.

Fourth stage: standardization of the constructed diagnostic battery.

First stage: identification of students with specific learning disability

All students in fourth grade from the chosen six public primary schools in Assiut city (*n* = 858 students) were interviewed, except those who were absent during their school visits (*n* = 142 students), or those who did not complete the test battery (*n* = 56 students). The rest of the sample (660 students) completed the test battery personally under the supervision of four neuropsychiatrists, two expert psychometrists, and 12 social workers.

All students were subjected to the following:
(1) Evaluation of intelligence level using the WISC-R [19]
(2) Evaluation of achievement level:
The ART for reading [16]; the Math test [20] for mathematic; and the writing test for writing.

After these two steps (IQ and achievements), three groups from students with IQ 90 or more (*n* = 323 students) were selected.

(1) Group I: this included those with poor achievement (scores < mean ± SD) and were considered students with SLD (our target in this study) (*n* = 106 students)
(2) Group II: this included those with average achievement (scores = mean ± SD) and were considered students with average scores (*n* = 85 students) (were excluded from the study)
(3) Group III included those with good achievement (>mean ± SD) and were considered as a control group (*n* = 132 students).

Thereafter, the students with SLD were subjected to the following:
(1) Complete neurological examination with special emphasis on soft neurological signs [21]
(2) Psychological assessments:
  (a) Assessment of depression using the Arabic translation of Children Depression Inventory [22]
  (b) Assessment of anxiety using the Arabic translation of State–Trait Anxiety Inventory for Children [23]
  (c) Assessment of Attention Deficit Hyperkinetic Disorder (ADHD) using the Arabic translation of Conner's test [24].

(3) Audiological assessments: basic tests (audiometry and tympanometry) to exclude peripheral hearing loss
(4) Ophthalmological examination: visual acuity was simply assessed by counting fingers at 6 m to exclude gross visual deficits.

Second stage: construction of an Arabic computerized diagnostic battery

This stage took about 1 year, from 1 October 2012 to 30 September 2013. It was carried out by seven expert staff members in the fields of neurology and education.

The constructed battery was designed in a game-like manner to test a wide range of cognitive skills that are supposed to have importance in the early stages of literacy development. It includes the following:
(1) Visual cognitive skills (visual closure, visual discrimination, visual memory and visual sequential memory, visual comprehension, visuospatial ability, whole–part relationship, and visuomotor integration)
(2) Auditory cognitive skills (phonological awareness, auditory discrimination, auditory memory, auditory sequential memory, auditory comprehension, and auditory attention).

Third stage: pilot study

A pilot study was conducted, in which the constructed battery was applied to 10 normal students between 9 and 10 years of age with no LD and IQ of 90 or more using the WISC-R, to assess the clarity of the items and time required for completion of the battery. Accordingly, some subtests were modified to fulfill clarity, others were shortened (memory and visual closure), and presentation of the subitems was modified from easier to more difficult subitems.

Fourth stage: standardization of the constructed battery:

(1) Reliability:
For measurement of reliability of our study, we used internal consistency reliability, which in turn depends on the measurement of values of Cronbach's α correlation coefficient [25], values of interitem correlation matrix, corrected item-total correlation coefficient [3], and by factorial analysis depending on values of communalities, which were considered an indicator of reliability [26].

(2) Validity:
For the measurement of the validity of our study, we depend on measuring the following:

  (a) Judgment validity: the test was judged by well-experienced referees (seven experts) to show the relevance and appropriateness of individual test items to the study purpose

(b) Construct validity: we used factor analysis to determine construct validity
(c) Contrasted group validity: we used *t*-test for comparison of scores of SLD (group I) and the control group (group III)
(d) Diagnostic validity: sensitivity, specificity, positive predictive value, and negative predictive value were used to determine diagnostic validity.

Results

Standardization of the newly constructed diagnostic battery.

Reliability

Internal consistency reliability showed following (Table 1):

(1) All visual and auditory subitems were significantly positively correlated to their main subtests and to the total visual and auditory cognitive scores, respectively
(2) All values of the corrected item-total correlation of the visual and auditory cognitive skill tests were more than 0.2. This means that all items belong to the same construct and all tests of visual and auditory cognitive skills are reliable
(3) Cronbach's α coefficient values of all items were more than 0.70
(4) The values of communalities using factor analysis of all items were more than 0.40, indicating high reliability except auditory attention item (0.263).

Validity

Construct validity

Factor analysis validity (Table 2): all loadings of visual and auditory cognitive skill tests are significantly high (all loadings ≥0.3 according to Guilford criterion).

Contrasted group validity

According to the used standardized achievement tests (Tables 3 and 4), the results show that the control group (good readers, those with good writing abilities, or good mathematical abilities) has significantly higher mean scores compared with students with dyslexia, dysgraphia, or dyscalculia, respectively, in most visual and auditory cognitive skill tests.

According to end-of-the-year school marks in Arabic and Math, on comparing cognitive skills of the control group (those with the highest quarter school marks) with those with the lowest quarter school marks (probably with dyslexia, dysgraphia, and/or dyscalculia), it was found that the control group (good achievers in Arabic school marks or good achievers in mathematics school marks) had significantly higher mean scores compared with poor achievers in Arabic school marks (probably with dyslexia and/or dysgraphia) or poor achievers in mathematics school marks (probably with dyscalculia respectively) in the total visual and auditory cognitive skill tests and all their subitems.

Diagnostic validity

Table 5 illustrates the results of the sensitivity and specificity of the visual, auditory, and total cognitive

Table 1 Reliability statistics of visual and auditory cognitive skill tests

Items	Interitem correlation coefficient with total visual and auditory scores	Corrected item-total correlation coefficient	Cronbach's α coefficient values	Communalities of visual and auditory cognitive skill tests
Total phonological awareness	0.740***	0.727	0.750	0.617
Total auditory discrimination	0.650***	0.637	0.721	0.459
Total auditory memory	0.777***	0.723	0.791	0.605
Total auditory sequential memory	0.797***	0.706	–	0.645
Total auditory comprehension	0.792***	0.779	0.767	0.669
Total auditory attention	0.523	0.486	0.780	0.263
Total auditory	–	–	0.837	0.997
Total visual closure	0.614***	0.655	0.762	0.528
Total spatial relations	0.643***	0.684	0.759	0.571
Total visual memory	0.697***	0.697	0.757	0.547
Total whole–part relationships	0.641***	0.673	0.821	0.645
Total visual discrimination	0.770***	0.780	0.746	0.685
Visual comprehension	0.456	0.471	–	0.441
Visuomotor	0.755***	0.629	0.748	0.924
Total visual	–	–	0.746	0.994
Total whole battery	–	–	0.877	–

***P <0.001.

skill battery in different types of SLDs (dyslexia, dyscalculia, and dysgraphia).

Discussion

The newly constructed battery has proved to be reliable, and this was evident in many ways. In the study of interitem correlation matrix of both visual and auditory cognitive skill tests, it was found that there were significantly positive correlations between all subtests and total scores in both visual and auditory cognitive skill tests. In this respect, National Institutes of Health 2007 and Pallant [3] reported that, for the examined test to be reliable, all subitems included in the construct should be positively correlated to this construct.

Table 2 Loadings of visual and auditory cognitive skill tests

Items	Loadings
Total visual cognitive skills	0.918
Whole–part relationships	0.776
Visual discrimination	0.767
Spatial relations	0.748
Total visual+visuomotor	0.743
Visual memory	0.671
Visual closure	0.653
Visual comprehension	0.637
Total auditory cognitive skills	0.955
Auditory sequential memory	0.796
Auditory memory	0.776
Auditory comprehension	0.722
Phonological awareness	0.655
Auditory discrimination	0.593
Auditory attention	0.489

Furthermore, National Institutes of Health 2007 and Pallant [3] also reported that, for the tests to be reliable, its Cronbach's α value should be 0.70 or more. Accordingly, a newly constructed battery is proved to be highly reliable, with Cronbach's α value for the whole battery 0.877 (good).

According to Field [27], small corrected item-total correlation (>0.2) indicates that the corresponding item does not correlate very well with the total scale, and thus it may be dropped. Consequently, as all values of the corrected item-total correlation of the newly constructed battery in both visual and auditory cognitive skill tests are 0.2 or more, they are highly reliable and all items included measure the same construct.

Moreover, factorial reliability is another way that confirmed the high reliability of the newly constructed

Table 3 Visual and auditory cognitive skill profile of students with specific learning disability (dyslexia, dyscalculia, and dysgraphia) in comparison with good achievers (according to standardized achievement tests)

Items	Dyslexia			Dyscalculia			Dysgraphia		
	Mean±SD		*P*	Mean±SD		*P*	Mean±SD		*P*
	Dyslexics (*n*=35)	Control (*n*=70)		Student's with dyscalculia (*n*=75)	Control (*n*=79)		Student's with dysgraphia (*n*=38)	Control (*n*=58)	
Visual closure	21.5±4.2	24.1±1.8	0.001	22.8±2.9	24±1.2	0.002	22.6±3.8	24.2±0.9	0.002
Visuospatial relation	20.2±5.1	22.7±6.5	0.053	22.3±4.8	22.9±4.6	0.406	20.7±5.7	23.1±5.3	0.043
Visual memory	61.5±11.2	70.5±6.1	0.001	63.8±12.1	68.9±6.6	0.001	63.3±11.6	70.4±6.7	0.001
Whole-part relationships	12.8±5.3	15.7±4.7	0.005	14.4±4.3	15.9±3.6	0.021	13.2±5.3	16.3±4.2	0.002
Visual discrimination	106.4±16.7	115.8±5.4	0.001	112.3±10.5	115.5±4.5	0.015	107.4±14.5	116.1±4.4	0.001
Visual comprehension	3.5±1.6	3.9±1.3	0.143	3.7±1.3	3.8±1.2	0.710	3.4±1.5	3.8±1.4	0.181
Visuomotor	45±19.2	61.4±15.1	0.001	57.5±17.2	57.2±17.1	0.920	27.3±14.3	71.8±4.7	0.001
Total visual	226.06±38.5	252.7±19.04	0.001	239.5±28.06	251.04±15.7	0.001	230.63±35.8	253.81±17.03	0.001
Total visual+visuomotor	270.9±47	314±25.8	0.001	296.9±35.1	308.3±22.4	0.018	257.95±39.2	325.66±17.7	0.001
Phonological awareness	20.6±6	26.4±3.6	0.001	23.2±4.7	25.6±4.4	0.002	22.2±6.1	26±3.4	0.001
Auditory discrimination	22±6.1	29.6±5.5	0.001	24.7±5.9	29.4±5.2	0.001	25.5±6.1	29.9±5	0.001
Auditory memory	35.3±11.9	41.8±10.1	0.005	37.8±10.2	42±9.5	0.008	36.7±11.7	40.8±10.6	0.077
Auditory sequential memory	14.9±8.2	23.9±10.5	0.001	17.9±8.8	22.8±9.6	0.001	16.9±10.4	22.2±9.7	0.012
auditory comprehension	18.9±8.4	27.7±4.6	0.001	21.9±6.9	27.3±4.8	0.001	21.4±7.8	27.4±5	0.001
Auditory attention	13±7.3	17.1±6.5	0.005	14.2±7.4	14.3±6.9	0.001	14.8±6.9	17.2±5.7	0.065
Total auditory	124.7±34.5	166.5±27.8	0.001	139.8±31.6	165.1±26.2	0.001	137.5±37.5	163.5±26.2	0.001

Table 4 Visual and auditory cognitive skill profile of poor achievers (probably with dyslexia and/or dysgraphia and dyscalculia) in comparison with good achievers (according to Arabic and mathematics school marks)

Items	Arabic school marks			Mathematics school marks		
	Mean±SD		*P*	Mean±SD		*P*
	Dyslexics and/or dysgraphics (lowest quarter) (*n*=80)	Control (highest quarter) (*n*=80)		Dyscalculics (lowest quarter) (*n*=80)	Control (highest quarter) (*n*=80)	
Visual closure	22.1±3.6	24.00±1.543	0.001	22.36±3.465	24.05±1.457	0.001
Visuospatial relations	20.74±4.722	23.70±5.220	0.001	21.00±4.765	24.06±4.465	0.001
Visual memory	62.35±10.230	70.43±5.281	0.001	62.16±10.344	70.89±5.668	0.001
Whole–part relationships	12.76±4.562	16.08±4.471	0.001	13.43±4.477	16.33±4.469	0.001
Visual discrimination	107.86±13.254	116.79±4.692	0.001	108.61±13.261	116.84±4.769	0.001
Visual comprehension	3.35±1.342	3.96±1.257	0.001	3.40±1.327	4.11±1.091	0.002
Visuomotor	54.66±18.350	59.83±15.416	0.031	56.55±18.680	57.48±16.935	0.031
Total visual	226.06+38.56	252.7+19.04	0.001	239.48+28.06	251.04+15.69	0.001
Total visual+visuomotor	283.85±41.245	314.78±21.761	0.001	287.51±41.9.06	313.75±22.197	0.001
Phonological awareness	3.70±1.436	4.40+.773	0.001	3.76±1.362	4.43+.759	0.001
Auditory discrimination	22.79±6.396	30.20±4.362	0.002	22.66±6.197	29.71±4.675	0.001
Auditory memory	34.69±12.336	41.58±10.450	0.001	35.43±12.069	40.71±11.793	0.006
Auditory sequential memory	2.74±2.713	5.06±2.901	0.001	14.54±10.087	22.20±9.482	0.001
auditory comprehension	19.26±7.240	27.29±4.492	0.001	20.00±7.107	27.36±4.811	0.001
Auditory attention	14.04±7.166	18.00±6.724	0.001	12.75±7.447	17.69±6.411	0.001
Total auditory	125.56±34.088	167.23±25.217	0.001	125.64±34.015	164.45±27.869	0.001

Table 5 Sensitivity, specificity, positive predictive value, and negative predictive values of auditory, visual, and whole cognitive skill battery in different types of specific learning disability

Items	Total battery			
	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Dyscalculia				
Total auditory	62.7	81	75.8	69.6
Total visual	54.7	63.3	58.6	59.5
Total battery	58.6	75.9	69.8	65.9
Dyslexia				
Total auditory	77.1	85.7	72.9	88.2
Total visual	80	82.8	70	89.2
Total battery	52.8	90	53.3	70
Dysgraphia				
Total auditory	60.5	79.3	65.7	75.4
Total visual	97.4	94.8	92.5	98.2
Total battery	100	77.9	75.5	100

battery. On reviewing the values of the communalities of both visual and auditory cognitive skill tests, it was found that all subitems of the battery are reliable (communalities are >0.4) [26], except auditory attention, which necessitates modification.

As regards construct validity, Hunter and Schmidt [28] reported that factor analysis could be used in the determination of construct validity.

In our battery, it was found that the loadings of all main and total tests in both visual and auditory cognitive skill battery were positive and statistically significant (≥0.3 using Guilford criterion), with the highest loading for auditory cognitive skills (0.955), followed by loading of total visual cognitive skills (0.918). Therefore, the newly constructed battery has high validity in the detection of SLD.

As regards contrasted group validity, the newly constructed battery has proved to be highly valid in the diagnosis of different types of SLD.

Dyslexia

Differences between students with dyslexia and good readers (depending on the standardized achievement tests) in all main visual cognitive skill tests and auditory cognitive skill tests were highly significant, except on visual comprehension, in which the difference was not significant. Although difficulties in reading comprehension is an essential symptom and core sign in the diagnosis of dyslexia, which is considered a specifier in the diagnosis of reading impairment in DSM-V, the lack of significant differences between dyslexic and nondyslexic students on visual comprehension might reflect deficiency in newly constructed test battery; it was too concised with restricted marks (five marks) and thus it should be modified.

The present study showed that the dyslexic group performed worse compared with the control group on phonological awareness, and the difference between the two groups was statistically significant. These findings are consistent with the study by Scarborough [29], who found that children with poor letter–sound knowledge and who later become poor readers were also deficient in phonological awareness. Thus, he considered weakness in rhyme detection and phonological awareness as a precursor to later reading disabilities.

The significantly poor performance of the dyslexic group compared with the control group in the auditory memory and sequential auditory memory tasks of the battery may indicate the importance of auditory memory deficits in the etiology of dyslexia and justifies its importance in the newly constructed diagnostic battery. These results are consistent with the study by Slaghuis and Ryan [30], who found that dyslexic children have auditory memory deficit. This poor auditory memory makes dyslexic students to forget parts of words, phrases, or sentences before they have been completely understood, resulting in poor comprehension and spelling errors [31].

The significantly poor performance of the dyslexic group compared with the control group on the auditory comprehension task of the battery may indicate the importance of auditory comprehension deficits in the etiology of dyslexia, especially in responding to teacher's instructions. This is consistent with earlier studies by Vellutino [32], which found that failure to use good comprehension strategies can contribute to poor reading and reduced scores in spelling.

Dyscalculia

Differences between students with dyscalculia and those without dyscalculia in all main visual cognitive skill tests and auditory cognitive skill tests were highly significant except in visual comprehension, visuomotor, and total visuospatial relations, in which the difference was not significant. These findings were surprising; taking in consideration the close relation of visuospatial skills (in the parietal lobe) to processing of numerical concepts such as magnitude, numerosity, and quantity (in the intraparietal sulcus [33]). Unexpectedly, students with dyscalculia had nonsignificantly lower scores of visuospatial skills compared with students with good mathematical abilities. Visuospatial skills have the importance in the estimation of place value and magnitude comparison of different combinations or pattern of digits. However, this lack of significant differences between students with dyscalculia and those without dyscalculia might be an important indicator for modification of this item in the newly constructed battery. Besides, it might reflect the heterogeneous nature of dyscalculia (not all students with dyscalculia exhibit the same cognitive skill deficits). This is in agreement with Geary's [34] opinion, who suggested the presence of a specific (third) subtype of mathematical learning disability (MLD) and referred to it as visuospatial MLD. This type of MLD is characterized by difficulties in representing numerical relationships spatially and interpreting and understanding spatially presented information.

The dyscalculic group performed worse compared with the control group on visual and auditory memory, and the difference between the two groups was statistically significant. This might be consistent with the first type of MLD proposed by Geary [34], who estimated that between 5 and 8% of children have MLD in which the child has procedural deficits in visual and auditory memory. Furthermore, a meta-analysis by Johnson *et al.* (2010) found that, these students, despite having average intelligence, were significantly different from typically achieving students in several cognitive categories. Specifically, they scored significantly lower on tests of auditory and visual working memory, executive function, processing speed, and short-term memory.

As regards dysgraphia, students in group I had significantly poor performance on visuospatial subtests compared with the control group. This might indicate that this subtest is a good differentiator between dysgraphics and normal writers.

The significantly poor performance of students with dysgraphia compared with the control group in the visuomotor task of the battery may indicate the important role of visuomotor deficits as an underlying pathophysiology of dysgraphia. This is consistent with the findings of Abbott and Berninger [35], who reported that spelling and visuomotor skills are needed for writing development. Furthermore, Feder and Majnemer [36] reported that visuomotor, spelling, and handwriting instructions could be used efficiently in treatment interventions in students with dysgraphia.

Using school marks as a dominator for achievement level (Table 4), we found significant differences between those with the lowest quarter of school marks (in Arabic and/or mathematics) (poor achievers probably dyslexics, dysgraphics, and/or dyscalculics) and those with the highest quarter of school marks (good achievers) in all visual and auditory cognitive skill tests. This might reflect the importance of the role of the visual and auditory cognitive skills, involved in the newly constructed battery, as essential contributors for the process of good achievement in reading, writing, and mathematics.

Hence, our battery was a valid measure of specific learning abilities because the test results could differentiate between individuals who have a known diagnosis of LD from those who were good achievers.

Sensitivity and specificity of the newly constructed battery as a diagnostic validity

Reiman *et al.* [37] linked acceptability values of the sensitivity and specificity to the purpose of testing as follows:

(1) Some tests are sensitive but lack specificity and hence are only useful as 'screening' tests
(2) Other tests are specific but lack sensitivity, and hence are useful for 'diagnosis'

(3) Some tests lack both and hence are ineffective for ‘screening or diagnostics’
(4) Cicchetti *et al*. [38] and Dollaghan [39] presented criteria for judging the sensitivity and specificity of a test. Accordingly, values less than 0.70 are considered poor, values between 0.70 and 0.79 are considered fair, values between 0.80 and 0.89 are considered good, and values greater than 0.90 are considered excellent (for both sensitivity and specificity values).

On revising the results of the sensitivity and specificity of the visual and auditory cognitive skill battery tests in different types of SLD (dyslexia, dyscalculia, and dysgraphia), it was found that the total battery has an excellent specificity in the diagnosis of dyslexia (0.90), and fair specificity in the diagnosis of dyscalculia (0.75) and dysgraphia (0.77), and has perfect sensitivity in the screening of cases of dysgraphia (Table 5).

Conclusion

From previous results we can conclude the following:
(1) The newly constructed battery was proved to be reliable and valid for the identification of domains of weakness in cognitive profile that underlie LD
(2) The newly constructed diagnostic battery has excellent specificity in the diagnosis of dyslexia, and fair specificity in the diagnosis of dyscalculia and dysgraphia, and has perfect sensitivity in the screening of cases for dysgraphia.

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