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Research Article

Identifying Acquired Dyslexia and Dysgraphia Patterns in Greek Patients After Traumatic and Non-Traumatic Brain Disorders

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Abstract

Introduction: Acquired reading and writing difficulties, characterized as acquired dyslexia (AD) and dysgraphia (ADg), are potentially unique patterns of communication disabilities observed after traumatic and non-traumatic brain disorders (T-nTBDs).

Objectives: In this study, we investigated whether a very early differential diagnosis between AD/ADg and Aphasia is attainable. We sought to form, analyze, and interpret well-defined AD/ADg, aphasia-differentiated, diagnostic profiles.

Methods: A total of 23 Greek patients with T-nTBDs, with no previous history of language disabilities, were recruited. All patients were administered the Western Aphasia Battery (WAB) and Dyslexia Adults Screening Test (DAST), before and six months after completing a systematic rehabilitation program.

Results: 24% of patients were diagnosed with AD/ADg as the predominant disorder at two testing stages, while surface AD/ADg types were underlined. In both testing stages, the highest 'At-Risk' for Dyslexia Quotient was recorded in the domains of reading, writing, spelling, and rapid naming. Statistically significant correlations were also observed between these domains. After a six months speech and language therapy not tailored to AD/ADg difficulties, identical reading and writing deficits to the baseline examination were observed.

Conclusions: The findings showed that a number of patients with T-nTBDs exhibit unique AD and ADg patterns, aphasia differentiated, and potentially identified at a very early diagnostic stage. They underlined specific skills affected, highlighting a system of complex interactions in the lexical retrieval route of the reading and writing process, reflecting surface dyslexia and dysgraphia. Such findings particularly emphasize the importance of developing effective, AD/ADg oriented treatments.

Keywords: Traumatic and Non-Traumatic Brain Disorders; Aphasia; Acquired Dyslexia; Differential Diagnosis

Introduction

Traumatic and non-traumatic brain disorders (T/nTBDs) can cause diverse language disabilities, described under the wide term Aphasia, also including reading and writing difficulties, characterized as acquired dyslexia (AD) and acquired dysgraphia (ADg), respectively [1-4].

Aphasia is an expressive and/or perceptive language disability -verbal and written- resulting from damage at the prevalent for language brain hemisphere [5]. Moreover, the severity of Aphasia affects both the type and severity of reading and writing deficits [2].

AD and ADg, formerly known as alexia and agraphia, occur in literate people in whom the already developed reading and writing abilities are affected by a traumatic or non-traumatic brain disorder [6,7]. However, it is supported that AD and ADg along with their subcategories may coexist with other communication deficits of Aphasia or may present alone [6].

Generally, dyslexia known as reading disorder, involves various difficulties in reading, spelling, and slowness in processing written symbols, despite adequate teaching, normal intelligence, and unimpaired sensory functions [8]. It is divided into developmental and acquired dyslexia (AD), which concerns the loss or deterioration of reading skills due to brain injury [9]. It is classified as phonological dyslexia [10,11], surface dyslexia [12,13], and deep dyslexia [10].

ADg is defined as the loss of previously intact writing function [14]. The disability to compose written texts may be marked by spelling errors, grammatical or punctuation errors within sentences, or poor paragraph organization [15]. Clinically, ADg can be divided into phonological dysgraphia and lexical dysgraphia [16].

Considering the importance of the early differential diagnosis between aphasia and AD/ADg in in the clinical practice, through this study, we aimed to answer whether unique Acquired Dyslexia and Dysgraphia patterns could be well identified in patients with traumatic and non-traumatic brain disorders, even at an initial diagnostic stage. To this, we examined whether the diagnosis of AD/ADg in 23 Greek patients with traumatic and non-traumatic brain disorders could be differentiated from that of Aphasia; we further attempted to classify and formulate the underscored types of reading and writing deficits investigating whether they form unique AD/ADg patterns; finally, we aimed to interpret the language substrate of these patterns, thereby creating a well-defined, Aphasia-differentiated AD/ADg clinical entity.

Methods

The study was carried out in the Department of Physical Medicine and Rehabilitation of the University Hospital of Ioannina. It was approved by the Scientific Council of the University Hospital of Ioannina, Greece (45**Π**846906**Η**-4**ΧΘ**) and was conducted in accordance with the ethical principles defined by the General Assembly of the World Medical Association [17]. All the participants and their relatives signed an informed consent form to participate in this study.

Participants

A total of 23 patients with acquired communication deficits after T/nTBDs participated in the study. The main criterion for participation was the absence of previous history of developmental learning disorders or developmental dyslexia.

All participants, 17 males and 6 females, were native Greek speakers, with an average age of 49.27 years, while their education level was either secondary or higher. The patients' demographics and diagnoses are presented in Table 1.

Data collection

To determine the AD and ADg's patterns, all the patients were administered the Dyslexia Adults Screening Test (DAST), [18], which was translated and well-adapted to Greek by the research team. All the DAST tests, especially those including language material, were culturally adapted according to the components of the Greek language system, such as phonological characteristics, grammar and syntax, vocabulary, and semantic content. Compared to the (test-retest) reliability of the original test (r =.959), the reliability for the Greek adaptation was determined to be excellent (α =.930), while the tests' reliabilities were rather comparable to those of the prototype, thus strengthening the Greek ones.

DAST includes three 'tests of attainment' (One Minute Reading, Two Minute Spelling, One Minute Writing) and eight 'diagnostic tests' (Rapid Naming, Postural Stability, Phonemic Segmentation,

Diagnosis	n	Type of Aphasia	n	Manual Dominance				Age			Patients		
				R		L		M	F	n	M	F	N
				M	F	M	F						
Ischemic stroke	17	Mild/Moderate Anomic/ Severe Broca's Aphasia	18	11	5	1	0	51,6	50,2	51,2	12	5	17
Non-traumatic intracerebral emorrhage	2	Global Aphasia	2	2	0	0	0	45,5	0	45,5	2	0	2
Traumatic intracerebral hemorrhage	4	Moderate Anomic Aphasia	3	3	1	0	0	42,7	54	45,5	3	1	4
N	23		23	16	6	1	0	49,3	50,8	49,7	17	6	23

Table 1: Demographic characteristics of the participants in the study.

Notes: R: Right; L: Left; M: Male; F: Female

Backwards Digit Span, Nonsense Passage Reading, Nonverbal Reasoning, and Verbal and Semantic Fluency). It should be noted that the test of Postural Stability was not applied due to the orthostatic weaknesses that the patients had, especially in the acute testing phase. The subjects' scores are compared with those expected for their age, deriving an 'at risk' quotation score (ARQ). When ARQ is close to or above one (ARQ ≥ 1), the risk for dyslexia is considered strong.

To assess Aphasia, the Greek edition of the Western Aphasia Battery (WAB) [19,20] was also administered to all participants. Based on the test's reliability analysis, WAB was also found to have excellent reliability (α =,964). It is comprised of 8 subscales: spontaneous speech, auditory verbal comprehension, repetition, naming, word finding, reading, writing, apraxia constructional task, visuospatial task, and calculation task. The severity of Aphasia was defined as follows: Very severe Aphasia = 0-25, Severe Aphasia = 26-50, Moderate Aphasia = 51-75, Mild Aphasia = 76-93.7, and Non-Aphasia = 93.8-100.

Rehabilitation

All patients were initially evaluated at the acute phase of brain disorder (initial testing stage) and six months later (retest stage), during which period they received a systematic rehabilitation therapy, attending the standard therapeutic protocol of the department considering all the patients as aphasic, with no adjustments to the study's goals. The whole treatment protocol was same, while the implementation was depended on the type and severity of Aphasia. It was tailored to the patients' weaknesses, the complications of the disorder and the patient's age, the patient's psychological state, and the response to the treatment. All participants carried out five treatment sessions per week, including speech-language therapy, physiotherapy, and occupational therapy, for six months. The tasks of speech-language therapy are presented in s. table 1.

Statistical analysis

For the statistical analysis, descriptive techniques (frequency) were used to observe the distribution of the variables' values. To assess whether the clinical profile of patients with AD/ADg was differentiated between the initial testing and retest stage, we used the paired sample t-test for parametric variables. All data were analyzed using the SPSS v.26 software, while the results were considered significant at $p \leq 0.05$ and $p \leq 0.01$.

Results

According to their performance in the DAST and WAB tasks, the patients were classified into three categories: (i) patients with Aphasia as dominant disorder (ARQ ≤1 and aphasic score ≤93.8), (ii) patients with AD and Aphasia (ARQ ≥1 and aphasic score ≤93.8), and (iii) patients with AD as dominant disorder (ARQ ≥1 and aphasic score ≥93.8).

The results of WAB and DAST tasks at the initial testing stage are shown in table 2. Interestingly, in this baseline evaluation 5 patients were classified in the third category, with dominant AD/ADg disorder (ARQ ≥1) and Non-Aphasia (aphasic score ≥93.8).

Type of Aphasia	Tasks of speech-language therapy All tasks are used gradually from less to more difficult
Mild Anomic Aphasia	Recognizing, identifying, and naming objects Associative naming Categorizing-grouping objects Finding synonyms and antonyms Rhymes Finding similarities-differences of images Solving crossword puzzles with familiar words Finding words through mnemonic activities Reading texts with hidden or picture words Describing images (making stories) Spontaneous speech (discussion) Reading Oral and written expression Questions of general knowledge Spatio-temporal orientation
Moderate Anomic Aphasia	Recognizing body parts Facial muscle functional exercises, isotonic and isometric Production of sounds through auditory stimuli (animal sounds, environment) Phoneme synthesis to form syllables, words and word Segmentation at the level of syllables and phonemes Recognition, identification, naming of objects Reading texts with hidden or picture words
Global Aphasia	Facial muscle functional exercises, isotonic and isometric Recognition of body parts Production of sounds through auditory stimuli (animal sounds, environment) Assisted joint placement exercises to produce articulation execution of commands with YES/NO
Broca's Aphasia	Intake of auditory, motor and gustatory stimuli muscle functional facial, isotonic and isometric exercises recognition of body parts-body awareness Production of sounds through auditory stimuli (animal sounds, environment) Assisted joint placement exercises to produce articulation execution of commands with YES/NO Phoneme synthesis to form syllables, words and word segmentation at the level of syllables and phonemes recognition, identification, naming of objects

S. Table 1: Speech-language therapy tasks used by type of aphasia

		DAST			*N*
		High	**Low**	**No**	
WAB	Very severe	3	0	0	3
	Severe	1	0	0	1
	Moderate	3	0	0	3
	Mild	8	1	0	9
	No Aphasia	**5**	2	0	7
N		20	3	0	23

Table 2: Combined results of WAB and DAST at the initial testing stage.

Notes: WAB: Western Aphasia Battery; DAST: Dyslexia Adults Screening Test

At the retest stage, there was an improvement of the results in the WAB and DAST tasks, as expected, but the patients with dominant AD/ADg and Non-Aphasia remained unaltered (Table 3).

Further analysis was carried out in the DAST test results of patients with dominant AD/ADg (ARQ ≥1) to investigate their weaknesses in specific areas related to reading and writing skills, which in turn could reflect clear patterns of AD/ADg, distinct of Aphasia. At the initial testing stage, the most frequent 'very strong' and 'strong' ARQ was recorded in three tests of attainment (One Minute Reading, One Minute Writing, and Two Minute Spelling[1]) and the diagnostic test of Rapid Naming. At the retest stage, 'very strong' and 'strong' ARQ persisted in the same tests. The ARQ means, as they were recorded in the DAST tests of attainment and diagnostic tests, are shown in table 4.

Interestingly, using the Paired Sample Test analysis, no statistically significant differences were observed in the ARQ mean values of the DAST tests between the initial testing and retest stage (Table 5).

		DAST			*N*
		High	**Low**	**No**	
WAB	Very severe	2	0	0	2
Severe	0	0	0	0	
Moderate	3	0	0	3	
Mild	5	0	0	5	
No Aphasia		**5**	4	0	9
N		15	4	0	19

Table 3: Combined results of WAB and DAST at the retest stage.

Notes: WAB: Western Aphasia Battery; DAST: Dyslexia Adults Screening Test

DAST tests		ARQ Means		Mean differences	Standard Deviation	Standard Error Mean	95% Confidence interval of the difference		p
		Initial testing Stage	Retest Stage				Lower	Upper	
Tests of Attainment	One Minute Writing	3.40	4.00	-.60	.55	.24	-1.28	.080	.070
	One Minute Reading	3.40	3.20	.20	1.09	.49	-1.16	1.56	.70
	Two Minute Spelling	3.00	3.50	-.50	2.08	1.04	-3.81	2.81	.66
Diagnostic Tests	Rapid Naming	3.40	3.40	.00	1.41	.632	-1.75	1.76	1.00
	Phonemic Segmentation	2.40	2.80	-.40	1.14	.51	-1,81	1,02	.48
	Verbal Fluency	2.40	2.60	-.20	1.48	.66	-2.04	1.64	.78
	Backwards Digit Span	2.00	2.40	-.40	1.14	.51	-1,81	1,02	.48
	Nonverbal Reasoning	2.00	2.00	.00	1.58	.78	-1.96	1.96	1.00
	Nonsense Passage Reading	1.75	2.00	-.25	1.71	.85	-2.97	2.47	.79
	Semantic Fluency	1.60	2.00	-.40	1.52	.68	-2.28	1.48	.59

Table 4: Differences in the ARQ means of the DAST tests between the initial testing and retest stage.

Paired Sample Test (2-tailed). No statistically significant differences are observed; ARQ= 'At Risk' Quotation.

DAST tests	Initial testing stage		Retest stage	
	r	*p*	*r*	*p*
One Minute Reading - One Minute Writing	1.00**	.00		
One Minute Reading - Nonsense Passage Reading	1.00**	.00		
One Minute Writing - Nonsense Passage Reading	1.00**	.00		
Backwards Digit Span - Verbal Fluency	0.93*	.02		
Two Minute Spelling - Phonemic Segmentation			1.00**	.00
Phonemic Segmentation - Semantic Fluency			1.00**	.00

Table 5: DAST tests with statistically significant correlations in initial testing and retest stage.

Note: Paired Sample Test (2-tailed). Significant correlations are labeled with * for p < .05 and ** for p < .01.

The paired comparisons between different items of the DAST test revealed the following statistically significant correlations: (1) at the initial testing stage, between One Minute Reading and One Minute Writing (*p* =,000), One Minute Reading and Nonsense Passage Reading (*p* =,000), One Minute Writing and Nonsense Passage Reading (*p* =,000), and Backwards Digit Span and Verbal Fluency (*p* =,022) and (2) at the retest stage, between Two Minute Spelling and Phonemic Segmentation (*p* =,000) and Phonemic Segmentation and Semantic Fluency (*p* =,000) (Table 5).

Aiming to examine whether DAST tests of attainment and diagnostic tests affect the overall ARQ score, we used linear regression analysis, although no statistically significant correlations were observed.

Discussion

Several studies have shown that in AD and ADg the damages could be found in visual, phonological, or semantic system of the reading network [21]. On the other hand, Aphasia is not restricted to semantic damage, but it also comprises damage to the mental lexicon, which appears to be the major factor for surface dyslexia [22]. In individuals with Aphasia speech production, speech comprehension, reading, writing, repetition, and naming skills are affected, whereas in individuals with AD the reading ability is mainly affected, while in ADg the writing ability [6].

An accurate identification and classification of well-specified weaknesses after a brain damage is of great importance in order to implement as early as possible oriented, well-adjusted, and effective rehabilitation of impaired cognitive skills, leading to brain's reorganization [23].

In the present study we investigated whether the clinical profile of AD and ADg differentiates from the general profile of Aphasia, taking into consideration the data obtained by the testing stages and the rehabilitation program. As a result, we attempted to define and analyze unique AD/ADg patterns, examining those (language and non-language) cognitive skills that are strongly affected in AD/ADg reading and writing disorders.

Concerning the patients with the clinical diagnosis of Aphasia, our results showed that presented impairments in both the interpretation ability and the enunciation of linguistic symbols, including:

- Reading, writing, and speaking problems,
- Loss of language comprehension, especially for morphemes and large syntactic units,
- Failure in the use of syntactic rules,
- Linguistic detriments exceeding impairments of other cognitive functions, and
- Reduced vocabulary.

On the other hand, for the patients diagnosed with AD/ADg only impairments in automatic reading and writing, rapid naming, spelling, and phonological processing, were detected. Evidently, the results demonstrate that these two categories of patients were well separated, confirming the absence of direct and predictable relationship between AD/ADg and Aphasia [24]. It is worth noting that for the patients who were initially diagnosed with AD/ADg, the reevaluation after six months of systematic speech and language rehabilitation revealed identical reading and writing deficits to the baseline examination.

The finding that the six-month systematic rehabilitation proved not enough to modify the status of reading and writing difficulties, is crucial for the appreciation of these disorders' prevalence as well as the necessity for implementation of long-term, accurate, and well-adapted rehabilitation strategies [25]. Our results are consistent with previous studies reporting the strong relationship between initial severity and outcome, while the reevaluation after a proper period can affirm the prognosis' estimation.[26] While our findings suggest that AD can be differentiated very early from aphasia, they also show that a 6-month rehabilitation speech program was not effective for the patients with AD. This is probably due to the fact that these patients followed the department's general treatment protocol, which was mainly adapted to aphasia. Therefore, the results emphasize that intervention programs, must be based on an accurate and prompt diagnosis of the communication deficits, in order to be well designed and tailored to the individual's impairments.

An important question concerned whether the AD/ADg patterns compose a distinct entity and, in some extent, contribute to the circumscription of AD types. Thus, further analysis was carried out to better characterize patients' linguistic disorders [27], while the results underscored main difficulties in the domains of nonsense passage reading, verbal fluency, working memory, phonology, spelling, and semantic fluency. Moreover, dominant difficulties were observed in reading, writing, spelling, and rapid naming.

Looking more closely at the results, we noted that the statistically significant correlations between these domains not only strengthen the occurrence of the affected skills per se, but they underline a complex system of strong interactions between them and the cognitive mechanisms (see Figure 1). The main affected skills are reading, writing, spelling, and rapid naming, whereas highly correlated are reading with writing. Concomitantly, spelling is highly correlated with phonological process, which is also significantly correlated with semantic fluency. Likewise, high correlation is observed between working memory and verbal fluency, while relevant correlations are observed between reading and writing with nonsense passage reading.

Figure 1: An interpretative model of strong interactions between affected domains in patients with AD/ADg.

Interpreting all these deficits and their interactions, we believe that they are attributed to multi-level deficits occurring in one or more interacting parts of a complex lexical retrieval route of the reading process [28-31]. However, considering that the results revealed predominant impairments in reading and writing irregular words, this seems to potentially mirror surface dyslexia and dysgraphia deficits [28,32].

Interestingly, the results indicated a more complex network of impairments concerning both real-word reading and writing speed and accuracy, as well as irregular-word spelling speed and accuracy. Instead, nonword reading and spelling accuracy and phonological awareness remained intact [33]. Of high importance is that although surface dyslexia is determined in English language by an impaired ability to read irregular words, with a relatively well-preserved ability to read regular words and nonwords [34], a comparison between English and Greek language permits a contrast of morphological effects in addition to orthographic transparency.

According to the observation that in Greek language there is a stronger involvement of the phonological code in lexical access [35], the Greek language is considered more highly regular for reading in phonotactic structure than other languages. Similarly, it is highly consistent in terms of orthography–phonology mappings, as it is characterized by a high degree of correspondence between vowel and consonant graphemes, an articulatory simplicity and, mainly, an open consonant-vowel syllable structure, with few exceptions [33,36]. Although the orthography is relatively transparent at the grapheme-phoneme level [37], there is a rich morphological system that results in many words with derivational and inflectional affixes [38], in average-size vowel and consonant inventories, complex syllable structure, and lexical stress [39]. Additionally, the correct spelling depends on the principles of morphology and etymology, which is a prerequisite for the orthography of stems, whereas suffixes follow the grammar rules [40,41].

As indicated, these studies support the existence of 'dissociable symptoms of acquired dyslexia and dysgraphia in different languages' [25], stressing the different languages' orthographic systems between Greek and English. However, the results of the current study are discussed in terms of the cognitive Dual Route Cascaded (DRC) model [42], of reading, as it has been used to explain acquired reading disorders in English. Based on DRC it could be highly supported that the brain damages of patients with T/nT-BDs, reflect to deficits regarded to the output of the orthographic input lexicon into the phonological output lexicon. In addition to semantic, phonological/sound, and orthographical patterns, an affected intermediate mental lexicon containing whole word forms, failed to map word entries in the orthographic lexicon. Hence, as it is shown through the correlations between spelling and phonological processing, due to the difficulties in reading, writing, spelling irregular words, the patients were forced to rely on nonlexical procedures, resulting to the regularization of these words [22,34,43].

An additional finding worth interpreting, is the correlations observed between reading, writing, and nonsense passage reading, in which the patients were asked to read aloud a passage that contained real words along with nonsense words. Considering that these patients did not occur strong difficulties in reading nonwords, we attempted to explain why reading and writing could be correlated with nonsense passage reading. According to the DRC model, it seems that the patients followed the same procedure with that of reading and writing real words, even when they were trying to read the nonsense passage, as follows: they activated the Grapheme Phoneme Correspondence (GPC) route, according to which they were following phonological rules of matching the remained leftmost letters of words, available to the route. Besides, trying to read the whole passage in the same way, they activated orthographic units to generate phonemic activation from the lexical route. However, since the neighbors, although nonwords, had common phonemes with the real words, the patients who considered them real words, they did not change the procedure, resulting in plausible difficulties with nonwords.

Similarly, the multiple correlations between latent neurocognitive mechanisms, such as phonological processing and semantic fluency as well as between working memory and verbal fluency are also well explained by the lexical semantic route of DRC model, showing that an activation of phonology model interacts with a system of semantic representations [25,42].

Aiming to justify the findings of this study, it should be mentioned that plausibly the difficulties presented could reflect the existence of anomic Aphasia, since language processing impairments (naming, phonological lexicon output) with co-occurring impairments in cognitive domains, such as executive function, verbal short-term memory, visuo-spatial skills have been well documented [28,44,45]. However, this assumption is attenuated in this study, given that the patients with surface dyslexia do not express any non-language deficits [46], while their repetition, comprehension, reading, and writing skills remained intact [47].

A main assumption that we could conjecture is that the recorded combined difficulties could potentially indicate patterns of

both AD and ADg since, besides to reading, there were also involved difficulties in writing and spelling [7,48]. Indeed, difficulties were detected in both reading and writing in dictating irregular words [49,50], which also indicated impairments in the orthographic lexicon, reflected unified patterns of both acquired surface dyslexia and dysgraphia.

Limitations

The main limitation for the generalization of the results is the small sample size. However, it is important to highlight that all patients underwent an acute brain insult after which they were evaluated with common scales and treated in the same way. In addition, as the sample was composed of heterogeneous patients in terms of the neurological disease etiology and aphasia type, limitations regarding the non-homogeneity of the sample were taken into account.

However, to differentiatelly interpret AD/ADg patterns from those of Aphasia, we examined the profiles of only a small sample of 5 patients, those who, according to WAB and DAST results, were classified as non-aphasic (e.g., without motor speech impairments). Although this inclusion criterion was a limitation to the generalizability of our findings, in fact, it was a selection that ensured the homogeneity of our sample and enhanced the clarity of our findings.

Conclusions

To summarize, the findings of this study underscore the identification of unique patterns of surface AD/ADg as distinct diagnostic profiles than that of Aphasia, in Greek patients with T/nTBDs. Moreover, they show that AD and ADg patterns are well established at a very early stage after brain disorders and persist even after a six-month rehabilitation program. This emphasizes the importance of developing as early as possible, effective AD/ADg oriented treatments, well-adapted to individuals' disabilities.

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