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ORIGINAL ARTICLE

Preliminary validation of the apraxia battery for adults-second edition (ABA-2) in Greek patients with dementia

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Abstract

Background Apraxia is considered a supportive feature in Alzheimer's disease (AD) patients. It has been reported that patients with frontotemporal dementia (FTD) may present apraxia, especially in the buccofacial area. The Apraxia Battery for Adults (ABA-2) is a brief and practical battery for praxis impairment and has been validated in Greek post-stroke patients.
Aim To validate and evaluate ABA-2 test, translated and culturally adapted, in a sample of Greek demented patients.
Patients and methods Patients diagnosed with FTD ($n=20$) and AD ($n=20$) were included in the study. Age-, gender-, and education- matched healthy controls ($n=20$) were also tested. All participants completed Adenbrooke's Cognitive Examination-Revised (ACE-R), Frontal Rating Scale (FRS), Frontal Behavioral Inventory (FBI), and ABA-2 battery. Sensitivity and specificity of ABA-2 were calculated, as well as its consistency and statistical significance for diagnosing apraxia.
Results The ABA-2 was able to differentiate demented patients from healthy controls with a sensitivity of 77.5% and specificity of 95%. Its validity was confirmed with Cronbach's alpha coefficient > 0.7, indicating satisfactory internal reliability. Statistically significant differences were found when comparing total ABA-2 score ($p<0.0001$), as well as 3 out of 6 subtests of ABA-2, between the two study groups. Age, gender and education were not correlated with ABA-2 score.
Conclusion ABA-2 is a valid, reliable and sensitive battery to differentiate demented patients from healthy individuals in the Greek population. We propose the modification of ABA-2 to a 5-subtest tool, to be administered as a bed-side test.

Keywords Apraxia · Frontotemporal dementia · Alzheimer's disease · ABA-2

Introduction

Detection of dementia and verification of its specific type remains a challenge for the clinician at early clinical presentation, despite unambiguous criteria. The clinical heterogeneity and slow progression of cognitive decline impedes early diagnosis [1, 2]. Clinical studies focus on early recognition of mental deficits and aiming even at preclinical stages of the disease [3]. Recent research on manifestations of dementia recognizes apraxia as a core feature of higher cognitive functions disorientation [4].

Praxis is the ability to plan and execute purposeful movements based on stored representations and previously learned skills, while apraxia refers to the disability of carrying out these movements, despite intact motor and sensory systems, coordination, comprehension and cooperation [5–11]. Several subtypes of apraxia are known with the majority of them identified as limb apraxia, buccofacial apraxia, and apraxia of speech (AOS) [6, 12–15]. Deficits in

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praxis are considered a supportive feature for the diagnosis of Alzheimer's disease (AD) [16] and primary progressive aphasia (PPA), especially for the non-fluent variant (nfv-PPA) [17]; however, they are still underrepresented in the corresponding diagnostic criteria. Recent studies suggest the presence of apraxia in patients suffering from behavioral variant frontotemporal dementia (bvFTD) in middle disease stages [18]. Nowadays, impairments in praxis are considered an object of observation for specialists, without a clear, further evaluation of the abnormal findings.

In the past, multiple batteries have been developed to diagnose impairments of praxis in patients suffering from stroke, to confirm the dominant role of the left hemisphere in the praxis circuit (KAS-R, STIMA, Van Heugten Apraxia Test, FABERS) [19–22]. Observation, assessment and evaluation of apraxia in demented patients has recently become a matter of discussion and investigation, leading to new, brief tools (DATE) for the differentiation of dementia syndromes [23].

Apraxia Battery for Adults (ABA-2) is a test designed by Brownell and Dabul, in 2000 [24]. It is an individually administered test for the evaluation of the presence and the degree of apraxia. Until recently, it was widely used in patients suffering from stroke. It consists from six subtests and covers a wide range of apractic disturbances (AOS, buccofacial and limb apraxia). Its simplicity and ease of application and scoring, even by unskilled staff (doctor or nurse), are the most appealing features for usage as a bedside battery.

The current study describes a preliminary validation of ABA-2 in a sample of Greek population and explores its psychometric properties, in a community sample of 20 healthy control (HC) adults and a group of 40 patients suffering from dementia (AD and FTD).

Patients and methods

Patients

A total of 40 patients (20 women, 20 men), with a mean age of 70.13 years (range = 58–79, SD = 5.59) and less than 5 years after the first symptom-onset of neurodegenerative disease were recruited in the study. All individuals were examined in the Second Neurology Department of AHEPA University Hospital of Thessaloniki, Greece, either as inpatients or outpatients. Patients' interview included personal perception of their current physical and cognitive status, history taking, neurological examination and neuropsychological assessment using Adenbrooke's Cognitive Examination-Revised (ACE-R) [25] for corroboration of cognitive decline and assessment of its severity. Caregivers of patients were asked to complete the Frontal Rating Scale (FRS) [26] and Frontal Behavioral Inventory (FBI) [27, 28] to measure the severity of behavioral disturbances and confirm the possible clinical diagnosis. Structural brain imaging, mainly computed tomography (CT) or magnetic resonance imaging (MRI) when available, and blood tests were assessed to exclude an organic disability and reach the final diagnosis of FTD ($N = 20$) and possible AD ($N = 20$) according to the current criteria [17, 29, 30], by two independent, expert neurologists. Exclusion criteria included head injury, brain lesions, stroke or severe cerebrovascular disorder, epilepsy, hydrocephalus, alcoholism, major mental illness, other pathology, or medication causing motor dysfunction. Additionally, individuals suffering from mild cognitive impairment (MCI) were also excluded. Twenty age-, gender- and education- matched individuals, aged 63–83 years old (M = 70.05, SD = 5.73), with no neurodegenerative disease, meeting the above exclusion criteria were also screened and recruited as HC. The latter group did not undergo any structural imaging.

All patients and caregivers were informed in writing and orally about the objectives and methodology of the study and gave signed informed consent prior to inclusion in the study. In cases where patients gave oral consent but were unable to sign, written informed consent was given only by the caregivers. This study was non-interventional and was not obligatory for safety data to be collected. Approval was given by the local university committee and the principles of the Helsinki Declaration were followed.

ABA-2

All participants were tested for apraxia, using the ABA-2 tool. ABA-2 consists of 6 subtests designed to evaluate specific domains of praxis-related cognitive function and specifically buccofacial apraxia, AOS, and limb apraxia. In subtest 1, the patient is being asked to repeat monosyllabic, disyllabic and trisyllabic combinations as fast as possible within a predetermined time limit, an act called diadochokinesia. This subtest is examining voluntary control over speech. Subsequently, according to the subtest 2 (two parts, A and B), the examinee repeats similar words that grow in number of syllables, an exercise to confirm the ability of the patient to sequence the correct number of syllables in the appropriate order. The following task (subtest 3) consists of two parts, in which 10 oral commands are given by the examiner to the patient and are expected to be performed, either with the usage of his/her hands (e.g. snap your fingers), in part A, or with buccofacial muscles (e.g. show me how you kiss somebody), in part B. Subtest 4 is used to examine the latency time and utterance time for polysyllabic words. The patient is being asked to name ten objects shown in pictures. Both latency and utterance time should be measured and recorded but only utterance time is being taken in consideration to determine the severity of

apraxia. Next, 10 polysyllabic words are orally presented to the examinee and he/she is asked to repeat each one of them three times (subtest 5). This task highlights any disturbances in word production in consecutive attempts. Lastly, in subtest 6 the patient's automatic speech, spontaneous speech, and reading ability is being observed and any disturbance in speech behavior is recorded. The results of subtest 6 are being used for therapeutic purposes only. Therefore, they were not included in the present study analysis.

Translational and cultural adaptation of the ABA-2 in the Greek population has already been done by the Technological Educational Institute of Epirus, School of Health and Welfare Professions, Department of Speech and Language Therapy [31], to be used in post-stroke patients. Deviations from the original battery are found in subtests 2, 4 and 5 so that representative syllables, words and phrases adapted to the Greek language can be used. Subtests 1, 3, and 6 from the original instrument were translated into Greek, item per item, and used without any further changes.

Statistical analysis

The Cronbach's alpha and item-to-total correlation coefficients were used to assess internal consistency of the battery (minimum acceptable value = 0.7). Distribution of numerical variables was tested using the Kolmogorov–Smirnov test. Numerical variables with normal distribution are presented as mean ± standard deviation (SD), while those with non-normal distribution are presented as median (range). The qualitative variables are presented in absolute numbers and percentages.

Comparisons between numerical variables were performed using the Student's test (parametric) or Mann–Whitney test (nonparametric). Categorical data were analyzed using the Pearson's chi squared or the Fisher's exact test. Multivariate binary logistic regression analysis was used to identify any factors (age, gender, education, disease duration and ACE-R score) associated with ABA-2 outcome.

All statistical analyses were performed using the SPSS statistics version 25.0 (SPSS Inc., Chicago, IL).

Results

Mean score of ACE-R was 62.93 (SD = 17.30) for the demented group and 96.55 (SD = 3.56) for non-demented individuals. FBI and FRS were used for differentiating FTD from AD. Mean scores of FBI were 16.35 (SD = 9.40) and 4.35 (SD = 4.09) for FTD and AD patients, respectively, and FRS showed significantly lower scores in FTD group, compatible with the clinical diagnosis.

Descriptive statistics of demographic characteristics for the ABA-2 of both groups are presented in Table 1. No significant differences between HC and dementia patients were found in matters of age (70.05 ± 5.73 and 70.13 ± 5.59 respectively, $p = 0.710$) and gender (60% and 50% respectively, $p = 0.585$). Additionally, education did not significantly differ between the two groups ($p = 0.093$). Moreover, ACE-R score was compared between HC and patients demonstrating statistically significant difference (96.55 *vs.* 62.93, $p < 0.001$); thus, confirming the clinical status of the examined individuals.

Table 1 Characteristics of patients

	HC ($n = 20$) n (%)	Patients ($n = 40$) n (%)	p values
Age* (years)	70.05 ± 5.73	70.13 ± 5.59	0.710
Gender			
Male	8 (40%)	20 (50%)	0.585
Female	12 (60%)	20 (50%)	
Education (years)	11.30 ± 3.57	9.97 ± 4.69	0.271
ACE-R	96.55 ± 3.56	62.93 ± 17.30	**< 0.001**

*Data presented as mean ± standard deviation

We calculated the Cronbach's α coefficients for each subtest to determine the optimal test form for demented patients. Six items of the subtest "Increasing Word Length-A" were removed due to zero variance. Moreover, following a step-by-step approach to exclude items, two items of the Greek version of ABA-2 were deleted from the subtest "Increasing Word Length-B" to achieve the highest Cronbach's α coefficient (0.752). Therefore, these two subtests were merged to one (Increasing Word Length) that included 13 items. In the evaluation of Cronbach's α of the subtest "Repeated trials", 5 items were removed due to zero variance, while the remaining items had a very low (< 0.0) corrected item-total correlation. No other modification was made to the subtests. The α coefficients for each subtest separately ranged from 0.752 to 0.977. Internal consistency of the total ABA-2 was satisfactory as measured by Cronbach's alpha (Cronbach's $\alpha = 0.833$).

Sensitivity of the test was satisfactory and specificity was high (77.5% and 95%, respectively). Moreover, positive predictive value (PPV) and negative predictive value (NPV) were calculated (PPV = 96.88%, NPV = 67.86%).

The cut-off values that were used to discriminate healthy from pathological outcome were according to the ABA-2 original article [24] and are shown in Table 2, as well as the mean ± SD score of the subtest for each group. When comparing the outcome of each subtest between the two groups (HC and dementia patients), subtests 1 (diadochokinetic rate), 2 (increasing word length), and 3A (limb apraxia) showed statistically significant differences ($p < 0.0001$, $p < 0.0001$, and $p = 0.011$, respectively), indicating better results for differentiating pathological and healthy individuals. The results for

Table 2 Scores for ABA-2 subtest for healthy control (HC) and demented patients

	ABA-2 subtests					
	Diadochokinetic rate	Increasing word length	Limb apraxia	Oral apraxia	Latency time and utterance time for polysyllabic words	Repeated trials
Control (mean ± SD)	36.55 ± 3.44	0.20 ± 0.52	50.00 ± 0.0	50.00 ± 0.0	0 ± 0	30.00 ± 0
Patients (mean ± SD)	28.08 ± 9.24	2.35 ± 2.48	46.48 ± 6.94	47.85 ± 7.02	2.50 ± 6.63	29.83 ± 0.78
Pathological score cut-off	≤ 25	≥ 2	≤ 43	≤ 43	≥ 16	≤ 27

Table 3 Outcomes of ABA2 subtests in healthy control (HC) and demented patient groups

	HC		Patients		
	Healthy	Pathological	Healthy	Pathological	*p* values
Diadochokinetic rate	20 (100)	0	20 (50)	20 (50)	**< 0.0001**
Increasing word length	19 (95)	1 (5)	17 (42.5)	23 (57.5)	**< 0.0001**
Limb apraxia	20 (100)	0	30 (75)	10 (25)	**0.011**
Oral apraxia	20 (100)	0	36 (90)	4 (10)	0.187
Utterance time for polysyllabic words	20 (100)	0	36 (90)	4 (10)	0.187
Repeated trials	20 (100)	0	38 (95)	2 (5)	0.441
ABA-2 total	19 (95)	1 (5)	9 (22.5)	31 (77.5)	**< 0.0001**

Data are presented as *n* (%). Statistically significant *p* values are shown in bold

subtests 3B, 4 and 5, revealed a higher frequency of pathological score (10%, 10%, and 5%, respectively) in the patient group, compared to that in the HC group (0% for all); however, these differences were not statistically significant. Finally, the overall ABA-2 score was significantly lower in the demented group ($p < 0.0001$) (Table 3). Taking into account the very low percentage (5%) of the patients that had pathological score according to the subtest 5, as well as the data from the Cronbach's a test (5 items with zero variance and low corrected item-total correlation of the remaining 5 items), we suggest that the subtraction of this test could improve the practical usage of the ABA-2 test by making it more simple and faster, while slightly improving its internal reliability (0.837).

To examine the potential contribution of demographic variables to ABA-2 outcome, a binary logistic regression analysis was performed. It was demonstrated that male gender had a correlation with pathological ABA-2 score, however, not statistically significant (OR = 0.848, $p = 0.831$). Age and education were not shown to be associated with ABA-2 pathological outcomes (OR = 0.948, $p = 0.423$; OR = 1.072, $p = 0.469$) (Table 4).

Table 4 Multivariate binary logistic regression analysis to identify significant determinants for ABA-2 outcome in patients

	OR	95% CI	Df	*p* values
Age	0.948	0.831–1.081	1	0.423
Gender (male/female)	0.848	0.187–3.852	1	0.831
Education	1.072	0.887–1.296	1	0.469

Discussion

This is the first study to validate ABA-2 in a sample of patients with clinically defined AD and FTD in Greece. Assessment of apractic deficits is considered necessary when clinically approaching a patient with dementia [18, 30, 32, 33]. Many diagnostic batteries have been used, each one evaluating a specific apraxia type. Although accurate, these batteries fail to evaluate all aspects of apractic disturbances, they are time consuming, and therefore, not

suitable for everyday clinical practice [19–22, 34]. There is an emerging need for a reliable cognitive assessment tool with sufficient reliability, sensitivity and specificity, which may provide widespread evaluation of apraxia. The ABA-2 can be used as a bed-side test without the need of staff trained in neuropsychology and its wide usage may assist in the recognition of all clinical aspects of a dementia syndrome. Additionally, the patterns of praxis disturbances that emerge from its implementation might play a crucial role in the differential diagnosis process.

The Greek version of ABA-2 was shown to have high sensitivity and specificity when administered in demented individuals and it was able to discriminate demented patients from HC. Therefore, ABA-2 could be used as a screening tool, added to the routine clinical and neuropsychological assessment of a newly diagnosed patient or during the follow-up of the clinical course of an already demented patient.

Comparison of the ABA-2 outcome between HC and demented patients showed statistically significant differences for the total ABA-2 test and the subtests of "diadochokinetic rate", "increasing word length" and "limb apraxia", while "oral apraxia", "latency time and utterance time for polysyllabic words" and "repeated trials" did not reach statistical significance. When examining diadochokinesia, sequential motor rates were found to be reduced compared to HC, probably due to increased pauses for word finding, as mentioned in previous studies [35]. "Increasing word length" subtest showed abnormal findings in specific words with more complex sounds. This highlights a difficulty in praxis movements of demented patients when more demanding tasks are asked to be executed. Regarding limb apraxia, it is worth to mention that deficits were noticed in all demented individuals, underlying the need for its evaluation in AD as well as in FTD patients. Contrary to our findings, a previous study in Greek patients suffering from stroke demonstrated statistically significant differences between patients and HC in all the subtests of ABA-2 [31]. This may be explained by the coexistence of aphasic symptoms in patients with stroke and their effect on comprehension of commands that require non-verbal movements of the buccofacial area, resulting to abnormal findings in oral apraxia trials [36]. Likewise naming of objects seems to be more severely affected in stroke patients, leading to accompanying disorders in praxis.

Based on the Cronbach's alpha analysis, the test was slightly modified by removing 6 and 2 items from the subtests 2A and 2B, respectively, and merging these two subtests to one. The total ABA-2 displayed very satisfactory internal reliability. When examining each subtest separately, all of them showed high reliability. In the "Repeated trials" subtest, half of the items had zero variance, while the rest of them had low corrected item-total correlation value (< 0.3). Moreover, it was the subtest with the lowest rate of true positive outcomes, indicating that this subtest could be deleted. This was also confirmed by the mildly elevated Cronbach's alpha value when subtest 5 was deleted. Hence, based on our results, we suggest the deletion of this subtest, as well as "Inventory of Articulation Characteristics of Apraxia" subtest, which is used only for providing further information about speech disorders of the examinee and is not used in the overall quantitative assessment. A shorter version of ABA-2, by removing these subscales, could serve to an easier and less demanding approach of the patient, but further investigation in order to confirm our findings are considered necessary. Gender, age, and education did not contribute to the total ABA-2 outcome.

Recent studies support the hypothesis of unique apraxia profiles in different dementia types [18]. ABA-2 has the advantage of including all aspects of major apraxia disturbances in its subtests (limb, non-verbal, and verbal apraxia) and therefore it could be considered a useful and reliable tool for evaluation of praxis deficits, in large samples of demented patients. The patterns of praxis disturbances that emerge from its implementation might play a crucial role in the differential diagnosis of individuals suffering from FTD and AD. Further investigation on this field is considered necessary for confirmation of its differentiating abilities.

There are limitations in our study. Firstly, there was neither genetic testing nor histological analysis for confirmation of the clinical diagnosis. Moreover, limited number of patients were enrolled in the study; thus, further research with larger samples should be conducted, including different subgroups of dementia, to calculate ABA-2 scores separately for each type. This could lead to more detailed apractic disturbances and different results, depending on the subtype of dementia. For example, previous studies have found mixed results in speech rate in semantic variant PPA (svPPA) patients, compared to HC and other types of PPA [37–39]. On the other hand, participation of patients with AD and FTD and the usage of a battery that investigates all fields of praxis deficits could serve to strengthen the results.

In conclusion, the ABA-2 instrument demonstrated desirable properties for detecting praxis disturbances among demented patients. A short version can be used as a bedside test and serve in the clinical evaluation of cognitive impairment. It provides an easily applicable option, even to unskilled staff, for screening an underrated neuropsychological aspect of demented individuals. Global cognitive examination cannot be replaced by apraxia screening, as apraxia can be present without dementia, but can serve in the neuropsychological evaluation and therapeutic approach of the patient. Finally, our study gives rise to further future investigations about the discriminant ability of praxis disturbances among different types of dementia.

Author contributions All authors contributed to the study conception and design. Material preparation and data collection were performed by GP, DP, PI and EK. Analysis was performed by KN and AGP. The first draft of the manuscript was written by GP and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials The datasets generated during and analysed during the current study are available from the corresponding author on reasonable request.

Code availability Not applicable.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

Ethical approval Approval was obtained from the ethics committee of Aristotle University of Thessaloniki, Greece. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Consent to participate Informed consent was obtained from all individual participants included in the study.

Consent for publication Patients signed informed consent regarding publishing their data.

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