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Language profile in different kinds of apraxia in post-stroke patients

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Abstract

Background: Stroke affects all aspects of communication of patients by causing disorders of motor control (dysarthria or apraxia) or language (dysphasia) or both. The aim of this study is to evaluate language skills in patients post-stroke presented with comorbidity with different types of apraxia.

Methods: An analytical cross-sectional study was carried out, and a number of 58 stroke adults with comorbid apraxic manifestations of various types were included after assessing them using the protocol of motor programming skills that was extracted from thesis titled "Assessment protocol of motor programming skills after cerebrovascular insults" from October 2016 to July 2018. They were subjected to the interview and personal history taking, and a modified comprehensive aphasia test to determine their language profile.

Results: Patients with verbal apraxia showed difficulty with tasks tapping verbal fluency, repetition, and picture description. The language deficits in ideational apraxia patients included cognition tasks, verbal fluency, sentence comprehension, and naming. Constructional apraxia patients showed language deficits in word comprehension, complex word repetition, and naming. Limb apraxia showed greater deficits on tasks tapping working memory and processing speed while buccofacial apraxia was accompanied by fewer language deficits in reading and repeating complex words.

Conclusion: Heterogeneous language profile was found in different types of apraxia.

Keywords: Apraxia, Aphasia, Stroke, Reading, Writing

Background

Cerebrovascular disease is a general term encompassing different disturbances of the vascularization of the brain. The majority of deaths due to cerebrovascular diseases are due to stroke [1].

Every 2 s, someone in the world has a stroke; there were almost 17 million incidences of first-time strokes worldwide in 2010 [2]. Stroke is the second most common cause of death in the world, causing around 6.7 million deaths each year, taking a life every 5 s [3]. Almost 1 in 8 deaths worldwide are caused by stroke [3].

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Approximately 2 million patients worldwide every year suffer from cerebrovascular diseases as a result of cerebral hemorrhage, cerebral infarction, and subarachnoid hemorrhage. Even if the patient's life is saved, the after-effects experienced by stroke victims are a grave problem [4]. The residual impairment in a number of functions fundamental for everyday activities, such as movement programming and execution, sensorimotor integration, language, and other cognitive functions, has a chronic impact on the overall level of functioning and quality of life [5].

Communication may be impaired following cerebrovascular insults as a result of disorders of motor control (dysarthria and dyspraxia) or language (dysphasia) or both [6].

Communication is usually affected after CVI. Communication is affected in the form of aphasia,

dysarthria, and apraxia. Each type of communication disorder may affect the patient separately and may be combined. This study assesses the combination between aphasia and apraxia in post-CVI patients and if there is an effect of apraxia on the language of the patients in order to put a specified detailed rehabilitation program that will help improve the quality of life of this kind of patients.

The long-term outcomes of strokes have been taught to be essentially irreversible, and it is a common belief that the adult brain has no significant ability for self-repair or reorganization following injuries resulting in neuronal death, such as CVAs. However, it is not uncommon in clinical practice to see slow but consistent recovery over a period of weeks and months following lesions underlying seemingly stabilized neurological deficits [7].

Aphasia, a term which is used interchangeably with dysphasia, is defined as an acquired impairment of the components of the language system (semantics, syntax, phonology, morphology, and pragmatics). The language limitations include both expressive and receptive modalities (comprehension, speaking, reading, and writing) to varying degrees [8].

Praxis means action which refers to the ability to perform complex learned motor actions in response to verbal command, imitation, or pantomiming [9].

The brain's left hemisphere is responsible for skilled movement planning of both right and left arms, while corpus callosum mediation occurred in this latter limb [10].

Apraxia is a higher-order motor disorder impairing the ability to correctly perform skilled, purposive movements as the result of neurological disorders most commonly stroke, dementia, and movement disorders. It is increasingly recognized that Apraxia negatively influences activities of daily living [11].

Acquired apraxia consists of various types of apraxia among them: limb apraxia, ideational and ideomotor apraxias, buccofacial apraxia, dressing and constructional apraxia, and acquired verbal apraxia [12].

There is co-morbidity between dysphasia and apraxia in post-stroke patients [13]. However, to our knowledge, there is no Egyptian study done to clarify if there is an effect of the presence of apraxia on the language skills in the population of post cerebrovascular insults.

The manuscript was extracted from thesis titled "Assessment protocol of motor programming skills after cerebrovascular insults" [14].

The aim of this study was to determine if there is a specific language profile in patients post-stroke presented with comorbidity with different types of apraxia in order to help establish the needed program for their rehabilitation.

Methods

This study was an analytical cross-sectional study that has been carried out on post-stroke patients aged more than 18 years who attended the phoniatric outpatient clinic in Kasr Al Aini and Benha university hospitals in the period from October 2016 to July 2018. After obtaining an oral informed consent, fifty-eight post-stroke adults with apraxic manifestations that were revealed after being assessed by the protocol of motor programming skills [15] were included in the study The assessment protocol of motor programming skills is composed of different tasks to assess different types of apraxia (limb apraxia, verbal apraxia, buccofacial apraxia, ideational and ideomotor apraxias, and constructional, dressing, and swallowing apraxias). The patients included had different types of apraxia in addition to their language and communication impairment. The sample included 54 patients with verbal apraxia, 23 with ideational apraxia, 13 with constructional apraxia, 26 with limb apraxia, 45 with bucco-facial apraxia and less than 4 with ideomotor apraxia, 2 with dressing apraxia, and 1 with swallowing apraxia. Because of the very few number and percentage of patients with ideomotor, swallowing and dressing apraxia, they were excluded from the statistical analysis as it was not expected to reveal any significant findings. Forty-eight patients of the sample had combined apraxia while 10 patients had single type of apraxia.

Patients were selected from adults who suffered from language and speech difficulties after cerebrovascular insults. Patients with insults of more than 6-month duration were selected to ensure full neurological stabilization of their condition.

The exclusion criteria included were as follows: the presence of other central neurological lesions or dementia before the current stroke, addiction, presence of severe physical weaknesses that might interfere with active patient's participation with the administered tasks, severe aphasia patients in the first 6 months of the cerebrovascular insult in addition to illiterate patients.

Patients were subjected to the protocol of assessment that included the following: interview and personal history taking including name, age, sex, marital status, handiness, literacy level, and occupation. Then, the patients were subjected to the modified comprehensive aphasia test [16]. It was carried out on the apraxic patients to assess the receptive and expressive language abilities in the patients diagnosed as having apraxic manifestations. The test consists of 34 subtests divided into three parts: the Cognitive screen, the Language Battery, and the Disability Questionnaire. The first section is the cognitive screen which includes 6 items: line bisection, semantic and recognition memories, word fluency, gesture use, and arithmetic. The second section is the language

battery which is subdivided into 2 parts; the first part assesses language comprehension as regards understanding spoken words, sentences, and paragraphs and understanding written words and sentences. The second part assesses the expressive abilities as regards repetition (repetition of words, complex words, pseudowords, numbers, and sentences), naming pictures and actions, spoken picture description, reading (words, complex words, function words and non-words), and writing (copying, writing picture names, dictation, and picture description by writing).

The protocol of motor programming skills that was used to pick up the post-stroke patients with apraxic manifestations included the following: *limb apraxia tasks* that were divided to receptive tasks which assess the ability of the patient to understand gestures produced by the assessor and the patient was asked to explain the purpose of the gesture or explains verbally what the assessor was doing, and expressive tasks which assess the ability of the patient to perform a gesture either by imitation or pantomiming (giving the orders to the patient verbally).

The gestures included were divided into meaningless such as "Put your thumb on your nose," intransitive (communicative) such as "Use a phone in the absence of the tool itself," and transitive (tool related) such as "use a key."

Verbal apraxia was assessed by various tasks including:

- Diadochokinesis that consists of two items: the rate and accuracy with increasing speed.
- The ability to repeat words that measures the ability of the patient to repeat certain words (6 words divided into three groups with 2 words in each group) heard from the assessor. These words were graded in difficulty from simple monosyllabic words, bisyllabic words, then to tri- and tetrasyllabic words.
- The ability to repeat words of increasing length which were assessed by asking the patient to repeat a series of words increasing in length. The patient was given two series that were the most sensitive series found while applying the pilot study.
- Latency time which measured the time taken by the patient to name familiar objects or pictures like scissors and a cup.
- Inventory of articulation characteristics of apraxia which assessed the patient's spontaneous speech, picture description, reading, and automatic speech.

Buccofacial apraxia assessed the non-speech non-swallowing oral motor function of the patient including the functions of the following structures: lips, face, tongue, jaw, soft palate and pharynx.

Ideational apraxia tasks assessed the ability of the patient to plan the sequence of a multi-task and assesses the ability to extract the idea of performance from the task.

Ideomotor apraxia tasks assessed d the patient's ability to translate the idea into a motor act in the three conditions: at rest, imitation, and in passive manner. It consisted of two parts:

- The first part consisted of five gestures in which the patient was asked to imitate immediately the assessor. For example: raising one's hand.
- The second part included multiple object use where the patient was asked to operate; two objects, e.g., a torch.

Constructional apraxia tasks assessed the ability of the patient to *assemble two shapes using matches.* The first one is a simple square and the second is a more complex one which is a square with diagonals.

Dressing apraxia task assessed the ability of the patient to dress. In addition to swallowing apraxia which was assessed by bedside assessment. The bedside assessment included 2 parts:

- *Dry assessment:* which is an observational checklist that included 7 items: if the patient had normal posture, had the ability to control his own secretions, did not show drooling, had the ability to chew and ingest food smoothly, had completed oral evacuation and clearing of the oral cavity post swallow, was safe and had no signs of aspiration such as cough and gurgly voice after swallow, and had normal tongue movement with no searching movement.
- *Meal eating and self-feeding:* introducing the three different food consistencies which are the fluids, semisolids, and solids. Each consistency was tested spontaneously, with elicitation and upon imitation.

During the assessment, the patient was put under several challenges such as doing the action spontaneously, on imitation and on command, and to perform unpurposeful and purposeful tasks. The purposeful tasks were divided into transitive (tool related) and intransitive (communicative) tasks that might help to induce apraxic errors.

The assessment was done in two settings about 30–45 min each.

Patients who showed apraxic manifestations were included in the study.

Results

The current study was conducted on the 58 selected Egyptian post-stroke adults who had apraxic manifestations in addition to language and communication

deficits. The males constitute 55.2% while females constitute 44.8% of normal subjects. In post-CVI patients, males constitute 65.5% while females constitute 34.5%. The lesion was left-sided in 89.7% of post CVI cases while 6.9% were right-sided with left handedness and the lesion was bilateral in 3.4% of cases. 5.2% of cases had both expressive aphasia and dysarthria while the rest had expressive aphasia.

Demographic data

Figure 1 shows that 82.8% of patients had combined apraxia while 17.2% had single type of apraxia.

Figure 2 shows that the common combination is between verbal apraxia and buccofacial apraxia.

Figure 3 shows that 93.1% of patients had verbal apraxia, 39.7% of patients had ideational apraxia, 22.4% had constructional apraxia, 44.8% had limb apraxia,

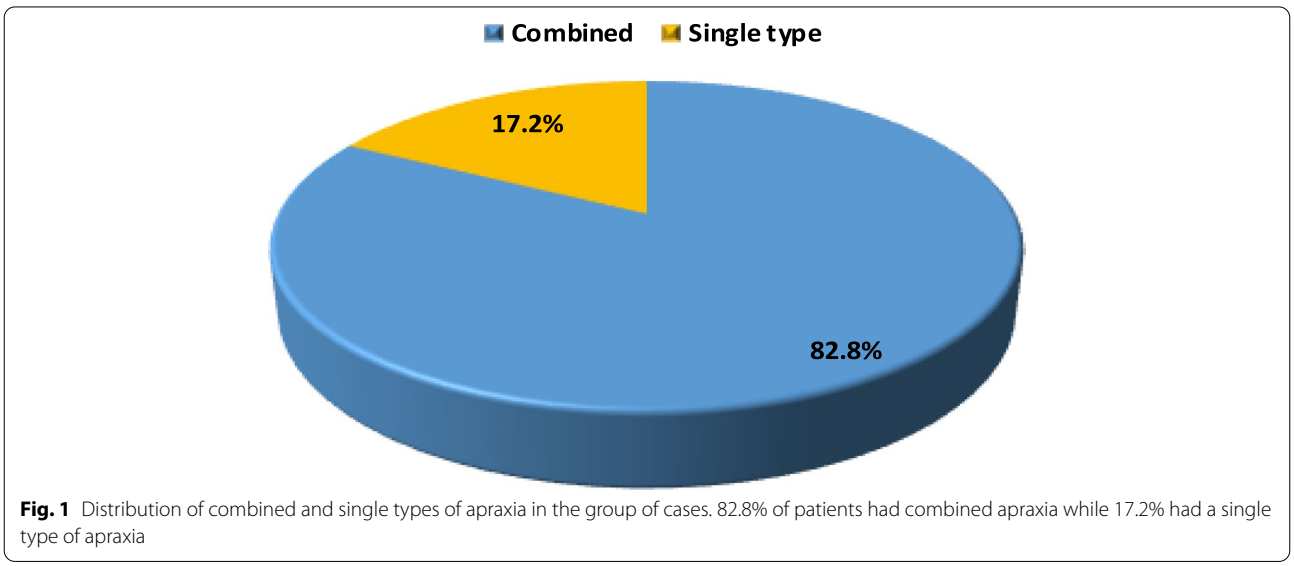

Fig. 1 Distribution of combined and single types of apraxia in the group of cases. 82.8% of patients had combined apraxia while 17.2% had a single type of apraxia

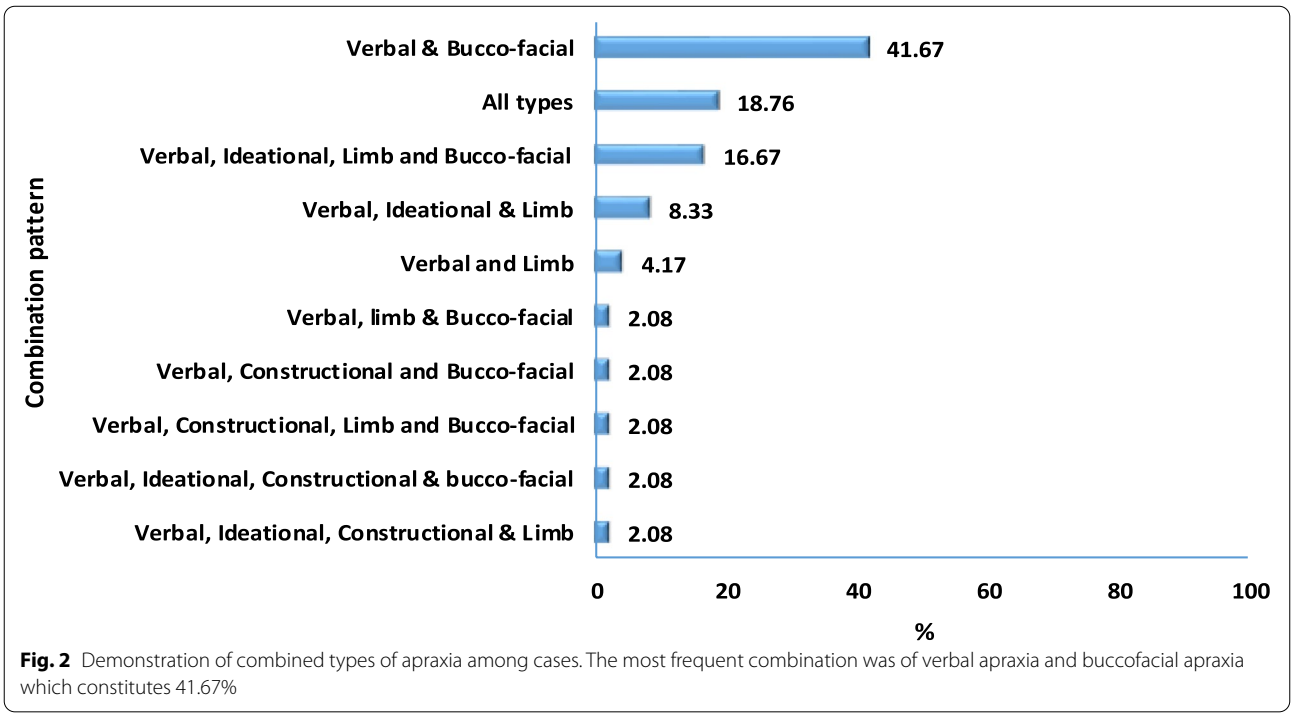

Fig. 2 Demonstration of combined types of apraxia among cases. The most frequent combination was of verbal apraxia and buccofacial apraxia which constitutes 41.67%

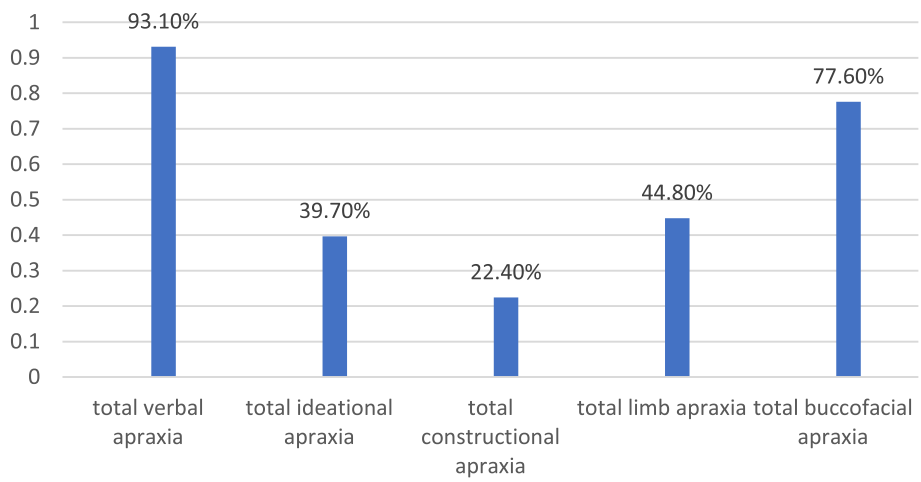

Fig. 3 Distribution of different types of apraxia among cases. 93.1% of patients had verbal apraxia, 39.7% of patients had ideational apraxia, 22.4% had constructional apraxia, 44.8% had limb apraxia, and 77.6% had buccofacial apraxia.

77.6% had bucco-facial apraxia, and less than 1% had ideomotor, dressing, and swallowing apraxia

Table 1 that was statistically analyzed using the median shows that there was significant difference between patients with verbal apraxia and patients without verbal apraxia in the following scores of aphasia test word fluency, repetition of digit strings, sentence repetition, and spoken and written picture description. Table 1 that was statistically analyzed using the mean reveals that there was no significant difference between patients with verbal apraxia and patients without verbal apraxia in the scores of aphasia test except for repetition of words.

Table 2 that was statistically analyzed using the median shows that there was a significant difference between patients with ideational apraxia and patients without ideational apraxia in the scores of aphasia test in word fluency, semantic and recognition memories, arithmetic, spoken word, sentence and paragraph comprehension, written word comprehension, repetition of digit strings, sentence repetition, naming tasks, spoken picture description, and reading and writing tasks. Table 2 that was statistically analyzed using the mean reveals that there was a significant difference between patients with ideational apraxia and patients without ideational apraxia in the scores of aphasia test in sematic and recognition memories, arithmetic, spoken word, sentence and paragraph comprehension, repetition of digit strings, sentence repetition, naming tasks, reading words, and writing tasks.

Table 3 that was statistically analyzed using the median shows that there was a significant difference between patients with constructional apraxia and patients without constructional apraxia in the scores of aphasia test in word fluency, spoken word and paragraph comprehension, repetition of complex words, digit strings and sentences, naming sub-items, and spoken picture description. Table 3 that was statistically analyzed using the mean reveals that there was a significant difference between patients with constructional apraxia and patients without constructional apraxia in the scores of aphasia test in spoken word comprehension, spoken sentence, and spoken paragraph comprehension repetition of digit string, sentence repetition, naming objects and actions, spoken picture description, reading words, writing copying and words, and dictation.

Table 4 that was statistically analyzed using the median shows that there was a significant difference between patients with limb apraxia and patients without limb apraxia in the scores of aphasia test in word fluency, semantic and recognition memories, arithmetic, spoken word, sentences and paragraph comprehension, naming tasks, spoken picture description, and writing tasks. Table 4 that was statistically analyzed using the mean revealed that there was a significant difference between patients with limb apraxia and patients without limb apraxia in the scores of aphasia test in semantic and recognition memories, arithmetic, spoken word, sentence and paragraph comprehension, and naming and writing tasks.

Table 5 that was statistically analyzed using the median shows that there was a significant difference between patients with buccofacial apraxia and patients without buccofacial apraxia in the scores of aphasia test in gesture object use, written sentences comprehension, reading

Table 1 Comparison between patients with verbal apraxia and without verbal apraxia regarding scores of aphasia test. Table 1 (a) that was statistically analyzed using the median shows that there was a significant difference between patients with verbal apraxia and patients without verbal apraxia in the scores of aphasia test except for word fluency, repetition of digit strings, sentence repetition, and spoken and written picture description. Table 1 (b) that was statistically analyzed using the mean reveals that there was a significant difference between patients with verbal apraxia and patients without verbal apraxia in the scores of aphasia test except for repetition of words

a.

Items of aphasia test	Results of cases with verbal apraxia		Mode	Results of cases without verbal apraxia		Mode	
	Median	Range		Median	Range		*P* value
Bisection of line	0	(0–1)	4	0	(0–0)	0	0.965
Semantic memory	10	(0–10)	2	10	(10–10)	10	0.261
Verbal fluency for words	4	(0–25)	0	13	(9–18)	13	0.013*
Recognition memory	10	(0–10)	3	10	(10–10)	10	0.288
Gesture object use	12	(2–12)	4	12	(12–12)	12	0.824
Arithmetic skill	2	(0–6)	11	5	(3–6)	5	0.161
Comprehension of spoken words	30	(0–30)	4	30	(30–30)	30	0.236
Comprehension of spoken sentences	32	(0–32)	2	32	(32–32)	32	0.189
Comprehension of spoken paragraphs	2	(0–4)	0	3	(2–4)	3	0.543
Comprehension of written words	30	(0–30)	3	30	(30–30)	30	0.239
Comprehension of written sentences	32	(0–32)	4	24	(16–32)	24	0.953
Words repetition	32	(0–32)	11	32	(32–32)	32	0.524
Repetition of complex words	6	(0–6)	4	6	(6–6)	6	0.348
Non-word repetition	6	(0–10)	2	6	(6–6)	6	0.646
Repetition of digits	6	(0–14)	0	9	(8–10)	9	0.035*
Repetition of sentences	6	(0–12)	3	11	(10–12)	11	0.029*
Naming (objects)	10	(0–48)	4	30	(12–48)	30	0.236
Naming (actions)	5	(0–10)	11	10	(10–10)	10	0.089
Spoken description of pictures	7	(0–28)	4	28	(4–28)	28	0.018*
Reading at level of words	20	(0–48)	2	34	(20–48)	34	0.384
Reading at level of complex words	6	(0–6)	0	4	(2–6)	4	0.658
Reading at level of function words	6	(0–6)	3	3	(0–6)	3	0.863
Reading at level of non-words	6	(0–10)	4	3	(0–6)	3	0.686
Writing by copying	27	(0–27)	11	27	(27–27)	27	0.189
Writing of picture names	21	(0–21)	4	21	(21–21)	21	0.285
Dictation	28	(0–28)	2	28	(28–28)	28	0.207
Picture description by writing	7	(0–28)	0	24	(10–26)	24	0.02*

b.

Items of aphasia test	Results of cases with verbal apraxia		Results of cases without verbal apraxia		Independent *t* test	
	Mean	SD	Mean	SD	*T*	*P* value
Bisection of line	0.02	0.15	0	0	0.61	0.54
Semantic memory	8.36	3.237	7.6	3.519	0.75	0.455
Verbal fluency for words	6.4	6.23	3.9	4.89	1.42	0.16
Recognition memory	7.79	3.848	7	4.195	0.678	0.50
Gesture object use	11.86	0.52	11.38	2.5	1.199	0.236
Arithmetic skill	2.8	2.597	2.4	2.58	0.53	0.61
Comprehension of spoken words	26.4	5.456	24.5	8.779	1.008	0.318
Comprehension of spoken sentences	26.05	8.04	25.13	10.275	0.36	0.719

Table 1 (continued)

Comprehension of Spoken paragraph	2.29	1.566	2.6	1.89	−0.696	0.489
Comprehension of written words	23.39	10.857	22.91	12.534	0.12	0.902
Comprehension of written sentences	23.45	11.77	23.82	13.43	−0.086	0.93
Word repetition	29.81	7.306	23.13	14.028	2.375	0.021*
Repetition of complex words	5.1	1.985	3.88	2.579	1.923	0.060
Non-word repetition	6.79	3.36	5.13	3.86	1.614	0.112
Digits repetition	6	3.155	5.38	4.77	0.581	0.56
Repetition of sentences	7.24	3.9	6.25	4.78	0.810	0.42
Naming (objects0	21	21.999	18.75	23.58	0.341	0.734
Naming (actions)	5.71	4.89	4.38	5.123	0.920	0.361
Spoken description of pictures	12.79	11.503	6.81	9.347	1.854	0.069
Reading at level of words	24.45	22.547	25.67	23.967	−0.157	0.876
Reading at level of complex words	3.58	2.905	3.17	2.887	0.418	0.678
Reading at level of function words	3.45	3.01	3.17	2.887	0.287	0.776
Reading at level of non-words	4.18	3.917	3.17	2.887	0.818	0.418
Writing by copying	16.55	12.173	22.5	10.5	−1.501	0.141
Writing of picture names	13.6	9.924	17.5	8.17	−1.206	0.235
Dictation	18.03	12.785	23.33	10.899	−1.272	0.211
Picture description by writing	10.88	10.597	12	8.893	−0.326	0.746

complex, and function words. Table 5 that was statistically analyzed using the mean revealed that there was a significant difference between patients with buccofacial apraxia and patients without buccofacial apraxia in the scores of aphasia test in complex word repetition, reading complex words, and reading non-words.

Data management and statistical analysis were done using SPSS vs.25. Numerical data was summarized using means and standard deviations. Categorical data was summarized as numbers and percentages. All apraxia scores were compared between two groups using Mann-Whitney *U* test. Categorical data was compared using chi-square test.

All *P* values were two sided. *P* values less than 0.05 were considered significant.

Discussion

Language and praxis are the most lateralized functions in the human brain. There is a striking overlap involving the left frontal and parietal lobes. Their co-occurrence is very frequent [17].

In this study, the lesion was left-sided in 89.7% of the included post CVI cases. Meador et al. [18] found that among the right-handed population, apraxia is mostly caused by injury to the left hemisphere. The incidence of apraxia is reportedly 34–51% after left-hemisphere stroke and 6–10% after right-hemisphere stroke. This led to the notion that acquired memory of manual praxis, known as action lexicon or praxicon, is generally stored in the left hemisphere. If praxicons are stored in the left hemisphere as a result of right-handedness, the praxicons of left-handers should be stored in the right hemisphere. In fact, the incidence of apraxia in left-handers is not high after right-hemisphere injuries. Thus, based on clinical observations, praxis usually appears to be represented in the left hemisphere, irrespective of handedness, and only in less cases is represented bilaterally, or lateralized to the right hemisphere [18].

In the current study, the most frequent combination was the combination between verbal apraxia and buccofacial apraxia as they share the same muscles and it constitutes 41.67% of cases. New et al. [19] also found that many patients with verbal apraxia also have buccofacial apraxia and this co-occurrence is mostly indicating that verbal and buccofacial apraxia share the same control mechanisms [20].

Many studies reported various combinations such as Ozsancak et al. [21] who found orofacial apraxia frequently coexists with limb apraxia. However, orofacial and limb apraxia can be dissociated, suggesting that the neural systems underlying these disorders are at least partially separable.

Vanbellingen et al. [22] showed that ideational and ideomotor apraxia usually co-exists with limb apraxia because of the same parietal representation.

Table 2 Comparison between patients with ideational apraxia and without ideational apraxia regarding scores of aphasia test. Table 2 (a) that was statistically analyzed using the median shows that there was a significant difference between patients with ideational apraxia and patients without ideational apraxia in the scores of aphasia test in word fluency, semantic and recognition memories, arithmetic, spoken word, sentence and paragraph comprehension, written word comprehension, repetition of digit strings, sentence repetition, naming tasks, spoken picture description, and reading and writing tasks. Table 2 (b) that was statistically analyzed using the mean revealed that there was a significant difference between patients with ideational apraxia and patients without ideational apraxia in the scores of aphasia test in sematic and recognition memories, arithmetic, spoken word, sentence and paragraph comprehension, repetition of digit strings, sentence repetition, naming tasks, reading words, and writing tasks

a.

	Results of cases with ideational apraxia		Mode	Results of cases without ideational apraxia		Mode	
	Median	Range		Median	Range		*P* value
Bisection of line	0	(0–1)	0	0	(0–0)	0	0.217
Semantic memory	8	(0–10)	8	10	(0–10)	10	0.003*
Verbal fluency for words	0	(0–15)	0	7	(0–25)	7	0.024*
Recognition memory	6	(0–10)	6	10	(0–10)	10	0.001*
Gesture object use	12	(2–12)	12	12	(10–12)	12	0.575
Arithmetic skill	0	(0–6)	0	4	(0–6)	4	0.002*
Comprehension of spoken words	20	(0–30)	20	30	(18–30)	30	<0.001**
Comprehension of spoken sentences	18	(0–32)	18	32	(16–32)	32	<0.001**
Comprehension of spoken paragraphs	2	(0–4)	2	4	(0–4)	4	0.002*
Comprehension of written words	22	(0–30)	22	30	(0–30)	30	0.044*
Comprehension of written sentences	20	(0–32)	20	32	(0–32)	32	0.186
Word repetition	32	(0–32)	32	32	(0–32)	32	0.798
Repetition of complex words	6	(0–6)	6	6	(0–6)	6	0.163
Repetition of non-word	6	(0–10)	6	6	(0–10)	6	0.511
Digit repetition	4	(0–10)	4	8	(0–14)	8	0.007*
Repetition of sentences	6	(0–12)	6	10	(0–12)	10	0.022*
Naming (objects)	0	(0–48)	0	48	(0–48)	48	0.001*
Naming (actions)	0	(0–10)	0	10	(0–10)	10	<0.001**
Spoken description of pictures	0	(0–23)	0	22	(0–28)	22	0.001*
Reading at level of words	0	(0–48)	0	48	(0–48)	48	0.036*
Reading at level of complex words	0	(0–6)	0	6	(0–6)	6	0.095*
Reading at level of function words	0	(0–6)	0	6	(0–6)	6	0.143
Reading at level of non-words	0	(0–6)	0	6	(0–10)	6	0.072*
Writing by copying	13	(0–27)	13	27	(0–27)	27	0.035*
Writing of picture names	3	(0–21)	3	21	(0–21)	21	0.007*
Dictation	4	(0–28)	4	28	(0–28)	28	0.014*
Picture description by writing	1	(0–20)	1	19	(0–28)	19	0.005*

b.

	Results of cases with ideational apraxia		Results of cases without ideational apraxia		Independent *t* test	
	Mean	SD	Mean	SD	*T*	*P* value
Bisection of line	0.04	0.21	0.00	0.00	1.239	0.220
Semantic memory	6.35	4.07	9.3	1.97	−3.745	0.001**

Table 2 (continued)

Verbal fluency for words	3.61	5.19	7.11	6.09	−2.27	0.027
Recognition memory	5.43	4.50	8.97	2.76	−3.714	0.001**
Gesture object use	11.57	2.09	11.83	0.57	−0.71	0.480
Arithmetic skill	1.57	2.33	3.50	2.47	−2.970	0.004**
Comprehension of spoken words	21.65	8.02	28.69	3.07	−4.71	0.001**
Comprehension of spoken sentences	20.4	10.1	29.31	5.16	−4.41	0.001**
Comprehension of spoken paragraphs	1.57	1.59	2.9	1.48	−3.29	0.002**
Comprehension of written words	20.3	10.83	24.52	11.22	−1.147	0.258
Comprehension of written sentences	20.00	11.92	25.03	11.98	−1.273	0.210
Word repetition	28.87	7.55	27.37	11.34	0.557	0.58
Repetition of complex words	4.35	2.31	5.03	2.14	−1.15	0.255
Non-word repetition	5.9	3.74	6.60	3.45	−0.718	0.476
Digit repetition	4.35	2.87	6.8	3.8	−2.64	0.011*
Repetition of sentences	5.65	3.65	7.8	4.27	−2.009	0.049*
Naming (objects)	9.39	18.4	27.60	21.81	−3.30	0.002**
Naming (actions)	2.35	4.21	7.31	4.42	−4.267	0.001**
Spoken description of pictures	5.26	7.69	15.00	11.54	−3.555	0.001**
Reading at level of words	14.15	20.63	29.09	22.31	−2.079	0.044*
Reading at level of complex words	2.3	3.04	3.94	2.7	−1.766	0.085
Reading at level of function words	2.3	3.04	3.81	2.85	−1.578	0.122
Reading at level of non-words	2.3	3.04	4.56	3.7	−1.926	0.061
Writing by copying	12.38	12.88	20.47	10.89	−2.141	0.038*
Writing of picture names	8.54	10.3	17.16	8.14	−2.977	0.005**
Dictation	11.38	13.75	22.87	10.24	−3.063	0.004**
Picture description by writing	4.46	7.3	13.9	9.85	−3.117	0.003**

Apraxia is mainly a production defect: Lipmann [23] assumed that gesture information passes through a conceptual stage located in the left occipitotemporal cortex, followed by a production stage where the appropriate motor programs are selected in the sensory motor areas [24]. So, it is difficult to assess apraxia with sever sensory/receptive aphasia [25]. This was one of the exclusion criteria for patients in this study.

Results of aphasia tests in patients with verbal apraxia with or without other types of apraxia showed the following results as compared to patients without verbal apraxia: regarding *the cognitive screen:* apraxic patients showed only lower performance with significant difference in items of *verbal fluency scores* which requires recall of items such as animals and things that begin with sound /S/ in 1 min and that could be attributed to the high linguistic requirements of the test and it was also a challenging task because of its nature of being time limited. *The receptive section:* apraxic patients showed no significant difference in all the subtests and that could be attributed to the lesser need of coordination in this task than that required in the expressive section. *Repetition section*: apraxic patients showed significant differences in the scores of repetition of sentences and digit strings because the patients might have a working memory and a short-term memory deficits. This is in agreement with Ortiz and Martins [26]. Regarding *the expressive section, reading, and writing*: apraxic patients showed non-significant difference in their scores that means that all cases had impaired expressive language, reading, and writing.

Table 3 Comparison between patients with constructional apraxia and without constructional apraxia regarding scores of aphasia test. Table 3 (a) that was statistically analyzed using the median shows that there was a significant difference between patients with constructional apraxia and patients without constructional apraxia in the scores of aphasia test in word fluency, spoken word and paragraph comprehension, repetition of complex words, digit strings and sentences, naming sub-items, and spoken picture description. Table 3 (b) that was statistically analyzed using the mean reveals that there was a significant difference between patients with constructional apraxia and patients without constructional apraxia in the scores of aphasia test in spoken word comprehension, spoken sentence, and spoken paragraph comprehension repetition of digit string, sentence repetition, naming objects and actions, spoken picture description, reading words, writing copying and words, and dictation

a.

	Results of cases with constructional apraxia		Mode	Results of cases without constructional apraxia		Mode	
	Median	Range		Median	Range		*P* value
Bisection of line	0	(0–1)	0	0	(0–0)	0	0.063
Semantic memory	10	(0–10)	10	10	(0–10)	10	0.137
Verbal fluency for words	0	(0–25)	0	7	(0–18)	7	0.02*
Recognition memory	10	(0–10)	10	10	(0–10)	10	0.113
Gesture object use	12	(2–12)	12	12	(10–12)	12	0.848
Arithmetic skill	0	(0–6)	0	3	(0–6)	3	0.07
Comprehension of spoken words	20	(0–30)	20	30	(14–30)	30	0.016*
Comprehension of spoken sentences	18	(0–32)	18	32	(12–32)	32	0.028
Comprehension of spoken paragraphs	0	(0–4)	0	4	(0–4)	4	<0.001**
Comprehension of written words	21	(0–30)	21	30	(0–30)	30	0.239
Comprehension of written sentences	21	(0–32)	21	32	(0–32)	21	0.459
Word repetition	32	(0–32)	32	32	(0–32)	32	0.246
Repetition of complex words	4	(0–6)	4	6	(0–6)	6	0.027*
Non-word repetition	6	(0–10)	6	6	(0–10)	6	0.151
Digit repetition	4	(0–12)	4	6	(0–14)	6	0.026*
Repetition of sentences	4	(0–12)	4	8	(0–12)	8	0.037*
Naming (objects)	0	(0–48)	0	16	(0–48)	16	0.005**
Naming (actions)	0	(0–10)	0	10	(0–10)	10	<0.001**
Spoken description of pictures	0	(0–26)	0	14	(0–28)	14	0.006**
Reading at level of words	0	(0–48)	0	20	(0–48)	20	0.301
Reading at level of complex words	0	(0–6)	0	6	(0–6)	6	0.257
Reading at level of function words	0	(0–6)	0	6	(0–6)	6	0.317
Reading at level of non-words	0	(0–6)	0	6	(0–10)	6	0.229
Writing by copying	0	(0–27)	0	27	(0–27)	27	0.092
Picture names by writing	0	(0–21)	0	21	(0–21)	21	0.074
Dictation	0	(0–28)	0	28	(0–28)	28	0.078
Picture description by writing	0	(0–21)	0	12	(0–28)	12	0.074

Table 3 (continued)

b.

	Results of cases with constructional apraxia		Results of cases without constructional apraxia		Independent *t* test	
	Mean	SD	Mean	SD	*T*	*P* value
Bisection of line	0.08	0.28	0.00	0.00	1.903	0.062
Semantic memory	6.62	4.1	8.6	2.9	−1.955	0.056
Word fluency	3.3	7.24	6.4	5.43	−1.688	0.097
Recognition memory	5.85	4.79	8.07	3.55	−1.833	0.072
Gesture object use	11.23	2.77	11.87	0.51	−1.485	0.143
Arithmetic skill	1.69	2.43	3.02	2.57	−1.662	0.102
Comprehension of spoken words	21.23	9.58	27.24	4.66	−3.153	0.003**
Comprehension of spoken sentences	20.62	11.62	27.29	7.03	−2.574	0.013*
Comprehension of spoken paragraphs	0.92	1.32	2.80	1.50	−4.070	0.001**
Comprehension of written words	17.00	14.90	24.26	10.35	−1.505	0.140
Comprehension of written sentences	17.67	16.12	24.47	11.27	−1.297	0.202
Word repetition	26.00	11.89	28.53	9.41	−0.805	0.424
Repetition of complex words	3.69	2.43	5.07	2.07	−2.027	0.047
Non-word repetition	5.08	3.71	6.69	3.46	−1.456	0.151
Digit repetition	4.00	3.65	6.36	3.50	−2.118	0.039*
Repetition of sentences	4.92	4.21	7.56	3.98	−2.076	0.042*
Naming (objects)	7.38	18.03	24.13	22.11	−2.497	0.015*
Naming (actions)	1.08	2.90	6.58	4.74	−3.960	0.001**
Spoken description of pictures	4.00	9.16	13.2	10.96	−2.756	0.008**
Reading at level of words	16.00	24.79	26.1	22.36	−1.020	0.314
Reading at level of complex words	2.00	3.10	3.69	2.8	−1.356	0.182
Reading at level of function words	2.00	3.10	3.59	2.91	−1.237	0.223
Reading at level of non-words	2.00	3.10	4.21	3.69	−1.386	0.173
Writing by copying	9.00	13.94	19.54	11.15	−2.089	0.043*
Writing of picture names	7.0	10.84	15.85	8.9	−2.201	0.033*
Dictation	9.3	14.46	21.08	11.46	−2.255	0.029*
Picture description by writing	4.8	8.54	12.15	10.04	−1.69	0.098

So the effect of verbal apraxia is mainly on the tasks that needed processing and co-ordination of the spoken language. This in agreement with Terband et al. [27] who stated that verbal apraxia mainly affect expression and verbal fluency.

Results of aphasia test in patients with ideational apraxia with or without other types of apraxia showed the following results as compared to patients without ideational apraxia: Regarding *the cognitive screen*: apraxic patients showed a significant difference in the scores of semantic and recognition memories and arithmetic tasks and this can be attributed to the difficulty and limitation in their working memory and cognitive abilities after brain insult. This is in agreement with Jackson [28] who found that patients with ideational apraxia are unable to perform a skilled activity because they have lost

Table 4 Comparison between patients with limb apraxia and without limb apraxia regarding scores of aphasia test. Table 4 (a) that was statistically analyzed using the median shows that there was a significant difference between patients with limb apraxia and patients without limb apraxia in the scores of aphasia test in word fluency, semantic and recognition memories, arithmetic, spoken word, sentences and paragraph comprehension, naming tasks, spoken picture description, and writing tasks. Table 4 (b) that was statistically analyzed using the mean reveals that there was a significant difference between patients with limb apraxia and patients without limb apraxia in the scores of aphasia test in semantic and recognition memories, arithmetic, spoken word, sentence and paragraph comprehension, and naming and writing tasks

a.

	Results of cases with limb apraxia		Mode	Results of cases without limb apraxia		Mode	
	Median	Range		Median	Range		*P* value
Bisection of line	0	(0–1)	0	0	(0–0)	0	0.267
Semantic memory	10	(0–10)	10	10	(0–10)	10	0.026*
Word fluency	0	(0–25)	0	8	(0–18)	8	0.044*
Recognition memory	9	(0–10)	9	10	(0–10)	10	0.009**
Gesture object use	12	(2–12)	12	12	(10–12)	12	0.444
Arithmetic skill	0	(0–6)	0	3	(0–6)	3	0.006**
Comprehension of spoken words	22	(0–30)	22	30	(18–30)	22	<0.001**
Comprehension of spoken sentences	18	(0–32)	18	32	(16–32)	32	<0.001**
Comprehension of spoken paragraphs	2	(0–4)	2	4	(0–4)	4	0.028*
Comprehension of written words	27	(0–30)	27	30	(0–30)	30	0.208
Comprehension of written sentences	27	(0–32)	27	32	(0–32)	32	0.672
Word repetition	32	(0–32)	32	32	(0–32)	32	0.9
Repetition of complex words	6	(0–6)	6	6	(0–6)	6	0.37
Non-word repetition	6	(0–10)	6	7	(0–10)	7	0.229
Digit repetition	4	(0–14)	4	7	(0–10)	7	0.176
Repetition of sentences	6	(0–12)	6	8	(0–12)	8	0.251
Naming (objects)	0	(0–48)	0	32	(0–48)	32	0.003**
Naming (actions)	0	(0–10)	0	10	(0–10)	10	0.002**
Spoken description of pictures	0	(0–26)	0	22	(0–28)	22	0.001**
Reading at level of words	0	(0–48)	0	48	(0–48)	48	0.084
Reading at level of complex words	0	(0–6)	0	6	(0–6)	6	0.163
Reading at level of function words	0	(0–6)	0	6	(0–6)	6	0.241
Reading at level of non-words	0	(0–6)	0	6	(0–10)	6	0.099
Writing by copying	13	(0–27)	13	27	(0–27)	27	0.046*
Writing of picture names	3	(0–21)	3	21	(0–21)	21	0.009**
Dictation	4	(0–28)	4	28	(0–28)	28	0.018*
Picture description by writing	1	(0–21)	1	20	(0–28)	20	0.002*

b.

	Results of cases with limb apraxia		Results of cases without limb apraxia		Independent t test	
	Mean	SD	Mean	SD	*T*	*P* value
Bisection of line	0.04	0.2	0.00	0.00	1.112	0.271
Semantic memory	7.00	3.89	9.09	2.41	−2.511	0.015*
Word fluency	4.38	6.48	6.81	5.35	−1.564	0.124
Recognition memory	6.19	4.3	8.69	3.24	−2.518	0.015*
Gesture object use	11.62	1.96	11.8	0.59	−0.540	0.591
Arithmetic skill	1.85	2.46	3.45	2.47	−2.446	0.018*
Comprehension of spoken words	22.31	7.85	28.81	2.96	−4.331	0.001**
Comprehension of spoken sentences	21.23	10.01	29.5	4.95	−4.102	0.001**

Table 4 (continued)

Comprehension of spoken paragraphs	1.85	1.69	2.81	1.51	−2.296	0.025
Comprehension of written words	22.13	10.44	23.93	11.67	−0.512	0.612
Comprehension of written sentences	22.25	11.71	24.29	12.39	−0.535	0.596
Word repetition	29.23	7.15	26.94	11.78	0.870	0.388
Repetition of complex words	4.54	2.23	4.94	2.2	−0.680	0.499
Non-word repetition	5.77	3.4	6.78	3.65	−1.081	0.284
Digit repetition	5.38	3.99	6.19	3.35	−0.834	0.408
Repetition of sentences	6.38	4.0	7.44	4.26	−0.96	0.34
Naming (objects)	12.00	20.37	27.19	21.68	−2.726	0.009*
Naming (actions)	3.08	4.71	7.19	4.40	−3.431	0.001**
Spoken description of pictures	5.42	7.81	15.78	11.48	−3.920	0.001**
Reading at level of words	17.50	22.24	28.79	22.25	−1.630	0.11
Reading at level of complex words	2.63	3.07	3.93	2.7	−1.479	0.146
Reading at level of function words	2.63	3.07	3.79	2.85	−1.281	0.207
Reading at level of non-words	2.63	3.07	4.62	3.82	−1.791	0.08
Writing by copying	13.4	13.04	20.72	10.64	−2.028	0.049*
Writing names of pictures	9.56	10.46	17.48	7.86	−2.872	0.006**
Dictation	12.75	13.95	23.32	9.7	−2.953	0.005**
Picture description by writing	4.88	7.86	14.66	9.57	−3.487	0.001**

the conceptual ability to organize the actions required to achieve their goal. The patients also showed significant difference in the verbal fluency item. The nature of the task was challenging as it is time limited. *The receptive section*: apraxic patients showed significant difference in the scores of spoken word, sentence, and paragraph comprehension. These tasks are negatively impaired by the effect of the recognition and working memory. *The expressive section*, *reading, and writing sections*: apraxic patients showed significant difference in their scores and this could be attributed to inability of the patients to find the idea of the task. *Repetition section*: apraxic patients showed no significant difference in the scores of word repetition while they showed lower performance with significant difference in the items of sentence repetition and repetition of digit strings. This could be attributed to the need of integration between the auditory input and spoken outputs which hinder performance in addition to the limited working memory skills and verbal reasoning present in the ideational apraxia as mentioned in a previous study by Ortiz and Martins [26]. So, the effect of ideational apraxia on patient's performance as shown in the aphasia test in the current study is mainly in comprehension, reading, writing, and some expressive abilities. In contrary to verbal apraxia which did not affect comprehension and receptive section.

Results of aphasia test in patients with constructional apraxia with or without other types of apraxia showed the following results as compared to patients without constructional apraxia: Regarding *the cognitive screen:* apraxic patients showed only significant difference in the verbal fluency item because of the nature of the task being time limited causing more challenges in addition to the effect of the combination between constructional apraxia and verbal apraxia as shown in the current study Fig. 3. Regarding *the receptive and expressive sections:* apraxic patients showed significant difference in these tasks. This could be attributed to that most constructional apraxia patients under the study were combined with other types of apraxia and also attributed to that verbal command makes the task more challenging because of the more co-ordination needed in addition to the association between constructional apraxia and comprehension that was found in the literature as in a study by Laeng [29] who found that in left-hemisphere insult, constructional apraxia is associated with the presence of receptive language impairment and affected comprehension, and the more severe the receptive disorder, the more likely constructional apraxia will occur. Although the patients under study had predominantly expressive difficulty, but some degree of comprehension was affected. Correlating the findings with the radiological results and the brain lesions is recommended in for future studies.

Results of aphasia test in patients with limb apraxia with or without other types of apraxia showed the following results as compared to patients without limb apraxia: patients with limb apraxia showed lower performance in tasks of *the cognitive screen* (scores of semantic,

Table 5 Comparison between patients with buccofacial apraxia and without buccofacial apraxia regarding scores of aphasia test. Table 5 (a) that was statistically analyzed using the median shows that there was a significant difference between patients with buccofacial apraxia and patients without buccofacial apraxia in the scores of aphasia test in gesture object use, written sentences comprehension, reading complex, and function words. Table 5 (b) that was statistically analyzed using the mean reveals that there was a significant difference between patients with buccofacial apraxia and patients without buccofacial apraxia in the scores of aphasia test in complex word repetition, reading complex words, andreading non-words.

a.

	Results of cases with buccofacial apraxia		Mode	Results of cases without buccofacial apraxia		Mode	
	Median	Range		Median	Range		P value
Bisection of line	0	(0–1)	0	0	(0–0)	0	0.591
Semantic memory	10	(0–10)	10	9	(0–10)	9	0.172
Word fluency	3	(0–25)	3	5	(0–16)	5	0.571
Recognition memory	10	(0–10)	10	10	(0–10)	10	0.891
Gesture object use	12	(2–12)	12	12	(10–12)	12	0.012*
Arithmetic skill	2	(0–6)	2	2	(0–6)	2	0.602
Comprehension of spoken words	30	(0–30)	30	30	(14–30)	30	0.531
Comprehension of spoken sentences	32	(0–32)	32	22	(10–32)	22	0.386
Comprehension of spoken paragraphs	2	(0–4)	2	2	(0–4)	2	0.441
Comprehension of written words	30	(0–30)	30	30	(16–30)	30	0.184
Comprehension of written sentences	30	(0–32)	30	32	(12–32)	30	0.04*
Word repetition	32	(0–32)	32	32	(32–32)	32	0.051
Repetition of complex words	6	(0–6)	6	6	(4–6)	6	0.055
Non-word repetition	6	(0–10)	6	6	(2–10)	6	0.205
Digit repetition	6	(0–12)	6	6	(4–14)	6	0.21
Repetition of sentences	6	(0–12)	6	8	(0–12)	6	0.476
Naming (objects)	0	(0–48)	0	16	(0–48)	0	0.386
Naming (actions)	0	(0–10)	0	10	(0–10)	0	0.104
Spoken description of pictures	12	(0–28)	12	7	(0–28)	12	0.862
Reading at level of words	34	(0–48)	34	20	(0–48)	34	0.813
Reading at level of complex words	3	(0–6)	3	6	(0–6)	3	0.047*
Reading at level of function words	2	(0–6)	2	6	(0–6)	2	0.044*
Reading at level of non-words	2	(0–10)	2	6	(0–6)	2	0.19
Writing by copying	27	(0–27)	27	27	(0–27)	27	0.967
Writing of picture names	21	(0–21)	21	21	(0–21)	21	0.28
Dictation	28	(0–28)	28	28	(0–28)	28	1
Picture description by writing	18	(0–26)	18	5	(0–28)	18	0.53

b.

Items of aphasia test	Results of cases with buccofacial apraxia		Results of cases without bucccofacial apraxia		Independent *t* test	
	Mean	SD	Mean	SD	*T*	*P* value
Bisection of line	0.02	0.15	0.00	0.00	0.53	0.595
Semantic memory	8.27	3.32	7.77	3.35	0.475	0.637
Word fluency	5.6	6.3	6.08	4.70	−0.240	0.811
Recognition memory	7.53	4.02	7.69	3.73	−0.128	0.899

Table 5 (continued)

Gesture object use	11.78	1.49	11.5	0.88	0.550	0.585
Arithmetic skill	2.82	2.71	2.3	2.06	0.581	0.564
Comprehension of spoken words	26.00	6.7	25.54	5.95	0.223	0.824
Comprehension of spoken sentences	26.18	8.8	24.46	8.09	0.628	0.53
Comprehension of spoken paragraphs	2.49	1.55	2.00	2.00	0.939	0.352
Comprehension of written words	21.94	11.97	28.4	4.67	−1.588	0.120
Comprehension of written sentences	21.94	12.65	29.78	6.67	−1.784	0.082
Word repetition	26.8	11.06	32.00	0.00	−1.684	0.098
Repetition of complex words	4.44	2.4	5.85	0.56	−2.071	0.043*
Non-word repetition	5.98	3.73	7.5	2.60	−1.408	0.165
Digit repetition	5.38	3.56	7.38	3.60	−1.785	0.080
Repetition of sentences	6.7	4.35	7.85	3.31	−0.868	0.389
Naming (objects)	20.18	23.18	21.08	19.57	−0.127	0.899
Naming (actions)	4.76	5.00	7.38	4.35	−1.716	0.092
Spoken description of pictures	11.78	11.82	8.9	8.73	0.807	0.423
Reading at level of words	25.11	23.65	23.44	19.39	0.195	0.846
Reading at level of complex words	3.00	2.89	5.33	2.00	−2.281	0.028*
Reading at level of function words	2.89	2.96	5.33	2.00	−2.334	0.024*
Reading at level of non-words	3.56	3.9	5.3	2.00	−1.311	0.197
Writing by copying	18.08	12.36	18.33	10.72	−0.056	0.956
Writing names of pictures	13.67	9.92	18.67	7.00	−1.420	0.163
Dictation	18.69	13.1	22.56	9.1	−0.832	0.41
Written description of pictures	12.25	10.3	6.89	8.24	1.444	0.156

recognition and verbal memories and arithmetic) indicating the limited working memory and processing speed of these patients. They showed also lower performance in *the receptive and expressive sections.* These findings could be explained by the augmented effect of combination between aphasia and limb apraxia. Current cognitive models for praxis highlighted the close relationship between language and action. Scholars in the field of language evolution declared the debate about whether human language evolved from the primitive hand gesture based communication [17].

Repetition section: apraxic patients showed no significant difference in the scores of all sub-items due to minimal effect of limb apraxia on repetition. Apraxic patients showed lower performance and significant difference in the scores of *writing section* due to difficult co-ordination in hand muscles producing difficult grip, while no significant difference was found in *reading section* because the co-ordination of the oral muscles that is required for reading might be intact. There was no significant difference as regards gesture object use. This finding is not expected. Applying the test on larger scale might clarify the subtle differences.

Results of aphasia test in patients with buccofacial apraxia with or without other types of apraxia showed the following results as compared to patients without buccofacial apraxia: regarding the *cognitive screen:* apraxic patients showed no significant difference in the scores of semantic and recognition memories and arithmetic while they showed significant difference only in the scores of gesture object use. *The receptive section:* apraxic patients showed significant difference in the scores of written sentences' comprehension. These findings are not expected in case of buccofacial apraxia and cannot be attributed to the combination with other types as limb apraxia or verbal apraxia. As in case of combination with limb apraxia,

no significant difference was found in the current study regarding gesture object use as shown previously in Table 4 and its combination with verbal apraxia does not have any impact on the findings of affected gesture object use and the written sentences comprehension. Therefore, applying the protocol of assessment on larger sample size might clarify the current findings.

However, there is a significant difference between cases of buccofacial apraxia and those without buccofacial apraxia in reading complex and functional words and in repeating complex words. These findings can be attributed to the combination between buccofacial and verbal apraxia as shown in the current study. This combination is common in the literature as in the studies of Whiteside et al. [30] as they shared the same musculature

Conclusion

From the research findings, it is concluded that there is heterogeneity of language profile in various cases of apraxia. The effect of verbal apraxia is mainly on the tasks that needed processing and coordination of the spoken language. The language deficits in ideational apraxia patients included limited performance in cognition tasks, verbal fluency, sentence comprehension, and naming. Constructional apraxia patients showed language deficits in word comprehension, complex word repetition, and naming. Limb apraxia showed greater influence on tasks tapping working memory and processing speed. Buccofacial apraxia showed limited performance with significant difference in reading complex and functional words and in repeating complex words. Full appraisal of the co-existence and the specific language profiles in patients with comorbid dysphasia and apraxia may have a direct impact on the efforts towards setting and tailoring the patient's rehabilitation programs and may open the window to better understanding of the two conditions in post-stroke patients.

Limitation of the current study

Although the current study was an attempt to analyze the language profile in patients with different types of apraxia, but it showed some limitations. It was difficult to carry out the language test on isolated apraxia types as the study showed more than 80% of the patients had combined types of apraxia. Conveying the study on a larger scale of post-cerebrovascular insult patients is warranted to confirm the results. Correlating the language profile of the apraxic cases with their radiological findings is recommended. Validation of the study againest other tests of apraxia used on the Egyptian population as the Arabic version of Apraxia Battery of Adults is recommended [31].

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Authors' contributions
AS shared in the design of the protocol and revised the written manuscript. DM formulated the idea of the protocol. OE shared in designing the protocol, formulated and interpreted the results, wrote the manuscript, and is the corresponding author who contacted the journal. AF shared in designing the protocol and writing and revision of the manuscript. The author(s) read and approved the final manuscript.

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

Declarations

Ethics approval and consent to participate
The study has been approved by the institutional research ethics committee of the Otolaryngology Department of Cairo University in October 2016 with a unique protocol number of 1-150316 before the experiment was started and that has been conducted in accordance with the principles set forth in the Helsinki Declaration. Informed consent was obtained from all patients.

Consent for publication
Not applicable

Competing interests
The authors declare no competing interests.

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