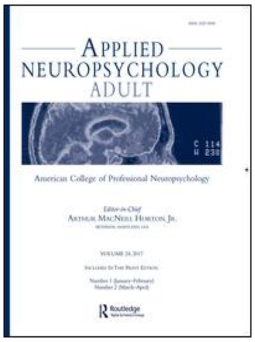

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Cognitive functioning in chronic post-stroke aphasia

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ABSTRACT

There is a minimal amount of knowledge regarding the cognitive abilities of people with aphasia. We evaluated the performance of individuals with chronic aphasia (AP) and control participants without aphasia (CP) with left hemisphere stroke in a battery of nonverbal cognitive tests and its relationship with aphasia severity, comprehension abilities, and speech fluency in a prospective cross-sectional study. Cognitive evaluation comprised 10 nonverbal tests. Scores were converted to age and education adjusted standard scores. Forty-eight AP and 32 CP were included. AP average scores were below normal range in three tests: Camel and Cactus Test, immediate recall of 5 Objects Test and Spatial Span. The mean test scores were significantly lower in AP than in CP, except in four tests. Aphasia severity and verbal comprehension ability correlated significantly with semantic memory, constructive abilities and attention/processing speed tests. Subjects with nonfluent aphasia had lower scores than CP in memory, executive functions and attention tests, while subjects with fluent aphasia showed lower scores in memory tests only. On average half of the individuals with aphasia exhibit results within the normal range. Nonetheless, their performance was worse than that of controls, despite the fact that many tests do not correlate with the severity of language disorder.

KEYWORDS
Aphasia; assessment; cognition; neuropsychological evaluation; nonverbal evaluation

Introduction

It is well recognized that stroke survivors have a high prevalence of cognitive disorders (Ballard, Rowan, Stephens, Kalaria, & Kenny, 2003; Oksala et al., 2009), which impacts daily life functioning (Nys et al., 2007) and carries an additional risk of dementia (Lee, 2011; Prince et al., 2013; Kalaria et al., 2016; Lee et al., 2016). However, it is not clear how this applies to individuals with aphasia, despite the high prevalence of language disorders in stroke patients (Flowers et al., 2016). Most studies on cognitive performance following stroke excluded subjects with aphasia (Ballard et al., 2003; Jaillard, Grand, Le Bas, & Hommel, 2010; Srikanth et al., 2003), or severe aphasia (Lin et al., 2016; Oksala et al., 2009), as the loss of communication abilities interferes with standard cognitive testing. These data are in agreement with conceptual beliefs postulating that language and cognition cannot be separated (Arendt, 1978). The dorsolateral prefrontal cortex, for instance, underpins executive function, but also includes the thematic component of verb representations (Nadeau, 2012). Thus, a given region may be involved in several domains. The co-activation between a given region and other brain areas results in distinct neural networks which underpin different functions.

Nonetheless, several clinical observations indicate that some distinction exists between language and cognition but it is hard to disentangle language from other cognitive domains. Impairments in language expression or comprehension have a negative impact on the demonstration of other cognitive abilities that are mediated by the language code and this can have negative consequences for patients management and rehabilitation (Murray & Coppens, 2017), unless they undertake a specific cognitive evaluation.

Despite numerous studies examining nonverbal cognitive abilities in people with aphasia (e.g., Fillingham, Sage, & Lambon Ralph, 2006; Fucetola, Connor, Strube, & Corbetta, 2009; Helm-Estabrooks, 2002; McNeill et al., 2004; McNeill et al., 2011; Murray, 2004; Hula, McNeil, & Sung, 2007; Hula & McNeil, 2008; Kalbe, Reinhold, Brand, Markowitsch, & Kessler, 2005; Lambon-Ralph, Snell, Fillingham, Conroy, & Sagem, 2010; Lang, 1989; Lang & Quitz, 2012; Murray, 2012; Peach, 2012; Soares-Ishigakil, Cera, Pieri, & Ortiz, 2012; Vallila-Rohter & Kiran, 2013; Villard & Kiran, 2015; Yeung and Law, 2010), the relationship between language, and specifically the relation between comprehension, speech fluency and the severity of aphasia,

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and other cognitive domains in aphasia remains elusive. A recent review (Fonseca, Ferreira, & Martins, 2016) corroborated the controversy of this issue, by revealed contradicting findings, with some studies indicating that aphasia may be associated with a variety of cognitive deficits (notably, visuospatial functions, attention, memory, and reasoning) whereas others report normal cognitive performance in memory and executive functions (Helm-Estabrooks, Bayles, Ramage, & Bryant, 1995) and in attention (Erikson, Goldinger, & Lapointe, 1996) in patients with aphasia.

Given this debate and the paucity of clear data on this topic, this study aims to evaluate the cognitive performance of persons with aphasia and how overall aphasia severity, verbal comprehension abilities and speech fluency relate to performance on various cognitive tasks that are not strictly dependent on language. This is an important goal as the impact of different linguistic components upon cognition has not yet been explicitly addressed.

Materials and methods

Study design

In this observational, cross-sectional, prospective study we compared performance of participants with aphasia (AP) and control participants without aphasia (CP) with single ischemic lesions of the left hemisphere in a range of cognitive tasks selected in order to minimize language dependency.

Participants

Patients in the chronic period of first-ever ischemic stroke of the left hemisphere, with or without aphasia, were recruited from five hospitals in the district of Lisbon. Patients were contacted by their neurologist or speech and language therapist, explaining the purpose of the study and were invited to participate on a voluntary basis. An informed consent was signed by the patient or a relative. Participants were observed by their clinicians who confirmed the following inclusion criteria: (a) age ≥50 years; (b) a minimum of 4 years of school education; (c) single ischemic stroke of the left hemisphere confirmed by imaging (CT or MRI); (d) time post stroke ≥6 months; and (e) no evidence of dementia (clinical diagnosis). Participants were excluded if they had new symptomatic lesions, history of alcohol or drug addiction, other neurological or psychiatric disease or severe medical illness. The goal of selecting patients with left hemisphere lesions without aphasia as controls was to minimize the effect of the lesion side and site, and to control for possible cognitive impairment due to the left hemisphere lesion, independently from the language disorder. Patients with right hemisphere lesions would be likely to present a different cognitive profile.

The protocol was approved by the Joint Ethics Committee of the Faculty of Medicine, University of Lisbon and North Lisbon Hospital Centre.

Material

All subjects were evaluated by a single speech and language therapist with a standardized language battery (Castro-Caldas, 1979) to exclude or confirm the diagnosis of aphasia and rate its severity.

All patients were then submitted to a battery of neuropsychological tests that did not require language production, directed to evaluate three cognitive domains: memory, executive functions, and attention and speed processing. The battery included 10 tests. In the memory domain, the tests used were: 5 Objects Memory Test (which assesses episodic memory, that is immediate and delayed recall; Papageorgiou, Economou, & Routsis, 2014), Spatial Span of Wechsler Memory Scale III, WMS III (a measure of immediate memory), Memory of faces both immediate and delayed recall (Wechsler Memory Scale II); and Camel and Cactus Test (a semantic association memory test; Bozeat, Lambon-Ralph, Patterson, Garrard, & Hodges, 2000). To evaluate executive functions, we used the Tower of Hanoi (a measure of planning and problem-solving; Shallice, 1982), Matrix reasoning of Wechsler Abbreviated Scale of Intelligence, WASI (which evaluates abstract reasoning), Clock drawing and Motor initiative of the Lisbon Battery for Assessment of Dementia, BLAD (a graphical patterns switching test; Garcia, 1984). Even though the clock drawing test can be used for different purposes (such as, cognitive screening, visual and constructive ability, etc.), it was selected here to assess executive functions (Juby, Tench, & Baker, 2002). To evaluate attention and speed processing we used the following tests: Symbol Search of WAIS (a test for sustained attention and processing speed) and the Letter Cancellation Task of BLAD (to assess visual attention; Garcia, 1984).

Test selection was made based on a minimum component of language, previous use in populations with aphasia (Fonseca et al., 2016) and the existence of age and education adjusted normative data for Portuguese population. Tests were always administered in the same order. Raw scores were converted to standard scores (Z scores), adjusted for age and education according to normative values. Participants were instructed to use either the right or the left hand to perform tapping and other tasks involving a motor response.

Language was assessed by a comprehensive language battery, the Lisbon Aphasia Assessment Battery (Castro-Caldas, 1979). The battery includes tests of verbal fluency, object naming, word and sentence comprehension, word repetition and the Token test version of 22 items (De Renzi & Vignolo, 1962). Aphasia severity was measured by the Aphasia Quotient (AQ) corresponding to the arithmetic mean of the percentage score obtained in the 4 core tests (fluency, object naming, word repetition and sentence comprehension subtests) and rated as severe (AQ scores from 0 to 34), or moderate/mild (35 to 99). Verbal comprehension was measured in a composite comprehension score (CCS) ranging between 0 and 24, corresponding to the sum of object identification (ranging between 0 and 16) and sentence comprehension (ranging between 0 and 8).

Participants were also evaluated with the Modified Barthel Index (Araújo, Ribeiro, Oliveira, & Pinto, 2007) of autonomy in activities of daily living and mobility, and the Stroke Aphasic Depression Questionnaire (Rodrigues, Santos, & Leal, 2006) to assess depressive symptomatology.

Statistical analyses

Statistical analysis was performed using the software Statistical Package for Social Sciences (version 21.0). We used descriptive statistics to characterize the sample. Due to the relatively small number of patients in each group and because the data in the two groups did not follow the normal distribution and had heterogeneous variances, we used the nonparametric Mann-Whitney U test to compare performance of the groups with and without aphasia. In addition, Spearman correlations tested associations between test performance and verbal abilities. Results were considered significant for $p < .05$. As nonparametric tests tend to be more conservative than the parametric counterparts, we opted for not correcting for multiple comparisons as this would increase the risk of type II errors.

Results

Demographic data, functional autonomy, and language abilities

A total of 80 subjects were included, of which 48 were patients with aphasia (AP) and 32 were control patients (CP). As described in Table 1, there were no significant differences between groups in age, gender handedness and education. Although both groups were in the chronic stage of stroke, AP had significantly less time post-onset than CP. The CP group had significantly higher scores in the Modified Barthel Index, indicating a higher functional autonomy and higher scores in the SAD-Q, indicating a significantly lower presence of depressive symptoms.

Most ($N = 29$, 60.4%) participants with aphasia had nonfluent speech, 12 (25%) had severe aphasia, and 20 (41.7%) had impaired comprehension, with a CCS <24. Patients had different types of aphasia diagnosis, with a predominance of anomic (25%) and global aphasia (22.9%) followed by transcortical motor (18.8%), Broca (10.4%), mixed transcortical (10.4%), Wernicke (6.3%), transcortical sensory (4.2%), and conduction aphasia (2.1%).

Language evaluation confirmed the absence of aphasia in CP (Table 1), despite the presence of minor language or motor speech disorders, namely on word retrieval and complex auditory verbal comprehension in the Token test that were not compatible with a diagnosis of aphasia.

Cognitive performance

Age and education adjusted Z scores by test and group are presented in Table 2. The percentage of subjects in each group that obtained scores below normal range (i.e., $Z \leq -1.5$) is also presented. The majority of AP had low scores in the semantic association memory Camel and Cactus Test (60.5%), in the 5 Objects Memory Test for immediate recall of the objects location (54.2%) and in the immediate memory Spatial Span Test of WMS (50%). Compared with CP, AP subjects had significantly lower scores in all tests except in tests of Memory of Faces (delayed recall), Symbol Search of WAIS, Tower of Hanoi and Matrix reasoning of WASI (Table 2).

We evaluated the impact of aphasia severity, verbal comprehension and speech fluency on the cognitive performance of people with aphasia. We found a significant correlation between the Aphasia Quotient and the scores obtained in the Camel and Cactus Test (semantic association), Memory of Faces (delayed episodic memory recall), Clock Drawing of BLAD (executive function) and Symbol Search of WAIS (attention and speed processing). Verbal comprehension abilities also correlated with performance on those tests, except for Memory of Faces, that is, delayed recall. In addition, it correlated with performance on the Spatial Span of WMS and the Cancellation Task of BLAD (Table 3).

As the patients with aphasia and the control group showed a significant difference in depressive symptomatology, revealed by significantly higher scores in the depression scale (SAD-Q) for the AP group, it was important to rule out the hypothesis that any differences

Table 1. Demographic, autonomy, depression data, and results in language tests.

	Max Score	AP ($N = 48$) Mean ± *SD*	CP ($N = 32$) Mean ± *SD*	Test	*P*	95% Confidence Interval
Age (years)		64.1 ± 10.8	66.3 ± 7.2	U = 926.000	0.12	−6.29;1.73
Gender (M:F) (42:38)		22:26	20:12	$\chi^2 = 2.139$	0.17	−0.39;0.06
Education		9.3 ± 5.4	10.2 ± 5.6	U = 836.500	0.48	−3.36;1.59
Handedness (R:L) (77:3)		47:1	30:2	$\chi^2 = 3.701$	0.16	−0.29;0.08
Time post-onset (days)		1403.2 ± 2050.9	1668.7 ± 1738.9	U = 1.001.000	0.02	−1143.81;612.66
Modified Barthel Index	100	88.5 ± 17.0	95.9 ± 12.2	U = 987.500	0.01	−13.90;−0.91
MBI - Personal autonomy	53	47.2 ± 8.1	51.7 ± 3.9	U = 1.004.500	0.00	−7.21;−1.81
MBI – Mobility	47	41.4 ± 10.3	44.3 ± 8.8	U = 936.000	0.03	−7.32;1.53
SAD-Q	63	16.6 ± 9.7	13.0 ± 9.3	U = 539.000	0.05	−0.85;7.91
Speech fluency (NF/F)		29/19	1/31	$\chi^2 = 26.889$	<0.001	−0.73;−0.42
Fluency rating	5	3.1 ± 1.3	4.8 ± 0.3	$\chi^2 = 57.854$	<0.001	−2.15;−1.35
Naming	16	7.3 ± 6.0	16 ± 0.0	U = 1.520.000	<0.001	−10.48;−7.02
Comprehension	24	21.1 ± 4.2	24 ± 0.1	U = 1.253.000	<0.001	−4.12;−1.68
Word repetition	30	20.9 ± 16.6	30 ± 0.0	U = 1.232.000	<0.001	−14.01;−7.08
Token Test	22	8.7 ± 6.6	18.8 ± 2.9	U = 1.363.500	<0.001	−12.32;−7.78
AQ	100	59.9 ± 27.7	98.8 ± 2.9	U = 1.534.000	<0.001	−46.99;−30.81

Notes. MBI = Modified Barthel Index; SAD-Q = Stroke Aphasic Depression Questionnaire; NF = Nonfluent; F = Fluent; AQ = Aphasia Quotient.

Table 2. Cognitive performance in AP and CP groups.

	AP ($N = 48$)	CP ($N = 32$)	Test	*P*	95% Confidence interval
5 Objects Memory Test: Immediate recall	−2.5 ± 3.0 (54.2)	−0.5 ± 1.6 (25)	U = 1.168.500	<0.001	−3.02;−0.98
5 Objects memory test: Delayed recall	−0.4 ± 1.7 (16.7)	−0.4 ± 1.5 (18.8)	U = 952.000	0.054	−0.81;0.68
Spatial span of WMS	−1.2 ± 1.5 (50)	−0.2 ± 1.6 (25)	U = 1.038.000	0.008	−1.72;−0.37
Memory of faces of WMS: Immediate recall	−0.2 ± 1.2 (0)	0.9 ± 1.7 (0)	U = 1.022.000	0.004	−1.75;−0.44
Memory of faces of WMS: Delayed recall	0.0 ± 1.3 (4.2)	0.4 ± 1.4 (3.1)	U = 862.500	0.197	−1.04;0.19
Camel and Cactus Test	−2.9 ± 3.3 (60.5)	−0.4 ± 0.7 (6.3)	U = 1.080.500	<0.001	−3.74;−1.40
Tower of Hanoi	0.5 ± 1.7 (14.6)	0.1 ± 1.1 (0)	U = 575.500	0.695	−0.26;1.09
Matrix reasoning of WASI	−0.5 ± 1.2 (4.8)	−0.4 ± 0.7 (0)	U = 895.000	0.211	−0.53;0.33
Clock drawing of BLAD	0.6 ± 0.9 (7.5)	1.0 ± 0.3 (0)	$\chi^2 = 17.78$	0.013	−0.75;−0.13
Motor initiative of BLAD	0.0 ± 1.2 (21.1)	0.5 ± 0.4 (6.3)	$\chi^2 = 17.98$	0.003	−0.88;−0.07
Symbol search of WAIS	−0.5 ± 1.2 (7.1)	0.1 ± 1.3 (0)	U = 767.500	0.060	−1.19;−0.00
Cancellation task of BLAD	0.1 ± 1.1 (19.6)	1.0 ± 1.2 (6.3)	U = 980.000	0.001	−1.45;−0.38

Notes. Mean Z scores and standard deviations are presented by test and group. Numbers in brackets represent the percentage of participants with low scores ($z \leq -1.5$) compared to age and education norms for controls.

in cognitive performance could be explained by depressive symptoms. Pearson correlations demonstrated that there was not a significant association between the severity of aphasia (AQ) and the values of the depression scale (SAD-Q) ($r = -0.245$ $p = 0.101$) nor between the global cognitive performance (as indexed by the average of all tests) and SAD-Q ($r = -0.245$ $p = 0.100$).

Finally, we split the group of patients with aphasia in three subgroups: subjects with fluent speech ($N = 19$), subjects with nonfluent speech and nonglobal aphasia ($N = 18$) and subjects with global aphasia ($N = 11$). This allowed us to directly evaluate the impact of speech fluency upon other cognitive domains and also to tap, although in an indirect way, into the effects of lesion location. Patients with global aphasia, with probable

Table 3. Correlations between aphasia severity (AQ) and comprehension score (CCS) and cognitive performance.

		AQ		CCS	
	N	Spearman correlation	*p*	Spearman correlation	*p*
5 Objects Memory Test					
Immediate recall	48	−0.005	0.973	0.058	0.694
Delayed recall	48	0.161	0.273	0.015	0.917
Spatial span of WMS	48	0.220	0.132	0.375	0.009**
Memory of Faces of WMS					
Immediate recall	46	0.039	0.799	0.107	0.478
Delayed recall	46	0.800	<0.001**	0.265	0.075
Camel and Cactus Test	43	0.629	<0.001**	0.686	<0.001**
Tower of Hanoi	42	−0.223	0.156	−0.140	0.378
Matrix reasoning of WASI	48	0.056	0.706	0.103	0.485
Clock drawing of BLAD	42	0.406	0.008**	0.366	0.017*
Motor initiative of BLAD	40	0.010	0.952	0.074	0.652
Symbol search of WAIS	38	0.365	0.024*	0.443	0.005**
Cancellation task of BLAD	42	0.276	0.077	0.423	0.005**

Note. *Correlation is significant for $\alpha = .05$ (2-tailed).
**Correlation is significant for $\alpha = .01$ (2-tailed).

Table 4. Comparison of cognitive performance obtained by AP fluent, AP Nonfluent and Nonglobal, and Global AP and CP.

	AP Fluent (*N*=19) (Max;Min)	AP Non-Fluent/Non-Global (*N*=18) (Max;Min)	Global AP (N = 11) (Max;Min)	CP (*N*=32) (Max;Min)	Test*	*P*	95% Confidence interval
5 Objects Memory Test							
Immediate recall	−2.9 ± 3.0	−1.6 ± 3.0	−3.1 ± 2.7	−0.5 ± 1.6	U = 440.500	**0.003**	−2.10;−0.52
	(−7.78;1.28)	(−9.86;0.54)	(−7.86;0.24)	(−5.78;0.54)	U = 411.000	**0.010**	−1.60;−0.18
	(63.2)	(31.6)	(72.7)	(25)	U = 298.500	**<0.001**	1.55;−0.19
Delayed recall	−0.7 ± 2.2	−0.2 ± 1.4	−0.2 ± 1.1	−0.4 ± 1.6	U = 343.000	0.298	−1.01;0.08
	(−5.78;0.54)	(−5.16;0.54)	(−2.46;0.35)	(−5.78;0.54)	U = 365.500	0.089	−0.80;0.16
	(21.1)	(10.5)	(18.2)	(18.8)	U = 225.500	0.171	−0.78;0.22
Spatial span of WMS	−1.4 ± 1.1	−0.7 ± 1.4	−1.7 ± 1.9	−0.2 ± 1.6	U = 423.000	**0.010**	−0.90;0.07
	(−3.31;1.32)	(−4.12;1.50)	(−4.12;1.99)	(−2.57;2.26)	U = 336.500	0.326	−0.81;0.14
	(52.6)	(15.8)	(45.5)	(21.9)	U = 263.000	**0.014**	−0.71;0.34
Memory of faces of WMS							
Immediate recall	−0.0 ± 1.1	−0.1 ± 1.3	−0.6 ± 1.3	0.9 ± 1.7	U = 383.000	**0.031**	0.16;1.19
	(−2.00;1.40)	(−2.25;2.00)	(−2.75;1.20)	(−3.00;5.00)	U = 389.000	**0.041**	0.05;1.09
	(5.6)	(15.8)	(30)	(6.3)	U = 241.500	**0.014**	0.07;1.22
Delayed recall	0.3 ± 1.3	0.1 ± 1.3	−0.8 ± 1.3	0.4 ± 1.4	U = 305.500	0.581	0.16;1.00
	(−1.60;2.30)	(−2.00;2.30)	(−2.60;1.30)	(−2.30;3.00)	U = 319.000	0.529	0.00;0.80
	(5.6)	(5.3)	(30)	(3.1)	U = 234.500	**0.026**	−0.27;0.69
Camel and Cactus Test	−1.3 ± 2.3	−2.5 ± 2.4	−6.1 ± 3.9	−0.4 ± 0.7	U = 299.000	**0.252**	−0.53;0.23
	(−7.8;1.3)	(−8.87;0.15)	(−13.94;−1.28)	(−1.99;0.81)	U = 456.500	**<0.001**	−1.37;−0.44
	(37.5)	(61.1)	(90)	(6.3)	U = 317.00	**<0.001**	−1.02;−1.64
Tower of Hanoi	0.2 ± 1.7	0.6 ± 1.6	1.4 ± 1.9	0.1 ± 1.2	U = 269.000	0.467	−0.33;0.42
	(−1.19;3.68)	(−1.19;3.46)	(−0.72;4.74)	(−1.19;3.46)	U = 218.500	0.748	−0.22;0.52
	(0)	(0)	(0)	(0)	U = 72.500	**0.045**	−0.08;0.89
Matrix reasoning of WASI	−0.8 ± 0.8	−0.3 ± 1.1	−0.2 ± 1.8	−0.4 ± 0.7	U = 390.500	0.054	−0.65;−0.16
	(−2.20;1.14)	(−2.00;2.17)	(−2.14;3.20)	(−1.29;1.33)	U = 295.000	0.887	−0.55;0.00
	(15.8)	(5.3)	(27.3)	(0)	U = 193.500	0.631	−0.52;0.19
Clock drawing of BLAD	0.8 ± 0.9	0.6 ± 0.8	0.3 ± 1.2	1.0 ± 0.3	χ^2 = 12.229	0.057	0.82;1.17
	(−1.67;1.18)	(−1.18;1.18)	(−1.67;1.18)	(−0.33;1.18)	χ^2 = 13.870	**0.008**	0.77;1.11
	(6.3)	(0)	(20)	(0)	χ^2 = 11.745	**0.019**	0.74;1.14
Motor initiative of BLAD	0.1 ± 0.8	0.5 ± 0.5	−0.8 ± 1.8	0.5 ± 0.4	χ^2 = 12.930	**0.005**	0.32;0.59
	(−1.37;0.67)	(−1.37;0.67)	(−3.41;0.67)	(−1.37;0.67)	χ^2 = 6.459	0.091	0.52;0.59
	(0)	(0)	(27.3)	(0)	χ^2 = 16.736	**0.005**	0.21;0.66
Symbol search of WAIS	0.1 ± 1.2	−0.7 ± 1.1	−1.2 ± 0.4	0.1 ± 1.3	U = 218.500	0.971	−0.26;0.55
	(−2.20;2.00)	(−2.00;2.00)	(−1.60;−0.60)	(−2.20;2.40)	U = 365.500	**0.050**	−0.52;0.28
	(14.3)	(22.2)	(28.6)	(6.3)	U = 179.500	**0.011**	−0.59;0.29
Cancellation task of BLAD	0.3 ± 0.9	0.3 ± 1.3	−0.4 ± 0.7	1.0 ± 1.2	U = 313.500	0.058	0.53;1.22
	(−1.54;1.41)	(−2.34;3.05)	(−1.25;0.78)	(−1.15;4.03)	U = 386.500	**0.016**	0.40;1.21
	(0)	(5.6)	(0)	(0)	U = 274.000	**<0.001**	0.43;1.21

Notes. Mean Z scores and standard deviations are presented by test and group. Numbers in brackets represent the percentage of participants with low scores (z < −1.5) compared to age and education norms for controls.
*Top line refers to comparisons with fluent, middle line with nonfluent/nonglobal aphasia and bottom line with global aphasia.

extensive lesions pre and post-Roland gyrus, differed in all domains when compared to CP (Table 4). Subjects with fluent aphasia, with probable lesions post-Roland gyrus, performed at the level of CP except in three memory tests (5 Objects Memory Test with immediate recall, Spatial Span of WMS and Memory of Faces with immediate recall). In contrast, subjects with nonfluent and good comprehension aphasia (with probable lesion in pre-Roland gyrus) differed in memory (Camel and Cactus Test, 5 Objects Memory Test with immediate recall, Memory of Faces with immediate recall), executive function (Clock drawing), and attention (Cancellation task of BLAD).

Discussion

Language is intimately related with other cognitive domains, including memory, executive function and attention. A recurrent debate is whether language may be disentangled from other cognitive domains. The assessment of cognitive functions in aphasia may offer important insights into this discussion, as it clarifies the extent to which people may reason, remember and solve problems without the integral support of language capacities.

Cognitive evaluation in this sample of subjects with chronic aphasia showed that many individuals (ranging from 40 to 100%, in the different tests) performed above −1.5 standard deviation of the mean in different tests. This confirms prior evidence showing that subjects with aphasia may demonstrate normal nonverbal cognitive performance (Erikson et al., 1996; Fonseca et al., 2016; Helm-Estabrooks et al., 1995) and, thus, constitutes a strong argument against the exclusion of these individuals from clinical studies of cognitive decline. However, their performance was consistently impaired in memory tests, notably the semantic Camel and Cactus test, the immediate recall of 5 objects and the memory span test, despite the careful choice of those tests as being predominantly nonverbal.

Among all cognitive tests, the Camel and Cactus test (nonverbal version) presented the most severe impairment. This measure of associative semantic memory requires individuals to select, among four options (e.g., a picture of a tree, a sunflower, a cactus—the correct response—and a rose), the one that is semantically associated with the target image (i.e., camel). Semantic memory is known to be closely related to language and therefore some impairment may be expected when aphasia is present. An interesting goal for future research includes finer-grained analyses of potential qualitative differences in the pattern of deficit between individuals with aphasia and those with a disorder of semantic memory (Jefferies & Lambon Ralph, 2006).

The 5 objects episodic memory test is mainly a test of visual memory that requires the encoding and retrieval of the position of 5 objects displayed in a space in front of the patient. Previous studies have shown that performance in this test is not influenced by education, age or gender (Papageorgiou et al., 2014). However, the test seems to be sensitive to language impairment, at least in the immediate recall condition. Importantly, in the 5 minutes delayed recall the AP group showed normal performance. This pattern of dissociation with a better delayed recall compared to immediate memory has also been described in vascular cognitive impairment when compared to patients with dementia due to Alzheimer's disease (Braate, 2006). The difference between the immediate (5 objects test and spatial span test) and the delayed recall conditions may be related to a fluctuating attention or, in the case of individuals with aphasia, to the damage of fronto-parietal networks supporting working memory in middle cerebral artery infarcts.

AP subjects presented less motor autonomy than CP, due to the presence of hemiparesis, with 24 patients showing right hemiparesis/hemiplegia and 24 denoting minimum or no motor impairment. To minimize the impact of motor impairments on performance, all subjects were allowed to use the nonparetic limb in cognitive tasks requiring a motor response. Even though the AP group had significantly lower results in some tasks that required motor movements (e.g., Cancellation Task, Clock Drawing Task), this effect was not systematic, with no significant differences emerging in 5 Objects Memory Test: delayed recall, Tower of Hanoi, Matrix Reasoning, and Symbol Search Test.

Some test scores presented a significant correlation with aphasia severity and verbal comprehension. Increased aphasia severity was associated with worse performance in semantic memory (Camel and Cactus Test), executive functions (Clock Drawing) and processing speed (Symbol Search). Lower verbal comprehension was also associated with worse test performance in the primary memory tests (Spatial Span) and attention (Cancellation Task). Helm-Estabrooks et al., (1995, 2000) demonstrated a relationship between auditory comprehension and attention in a single case study of a patient who had a significant improvement of auditory comprehension following stimulation with attention and concentration tasks (sustained, selective and alternating attention, symbol cancellation, trail-making, repeated graphomotor patterns, and sorting tasks). However, the relationship between cognitive performance and aphasia severity is not linear in most cognitive tests. This has also been described by other authors (Helm-Estabrooks, 2002), who could not predict the integrity of nonlinguistic skills of attention, memory, executive function and visuospatial abilities on the basis of aphasia severity. As opposed to that, other studies (Lang & Quitz, 2012), reported a memory gradient in subjects with aphasia, declining gradually from verbal to nonverbal content reflecting aphasia severity. The latter, included 49 people with aphasia and found that they generally perform worse than people without aphasia, even if they present similar cerebral lesions. El Hachioui et al. (2014) assessed 147 patients with acute aphasia and the most frequently observed impairment concerned visual memory (83% at 3 months and 78% at 1 year). Kauhanen et al. (2000) compared 25 subjects with aphasia with patients with dominant hemisphere lesion without aphasia ($N = 21$). The battery used was different from the one used in the present study yet, patients with aphasia had lower scores in all three tests reflecting visual memory and in the test of visuoconstructive functions at three months. It is worth noting that, despite the frequent prevalence of post-stroke depression in aphasia (Aström, Adolfsson, & Asplund, 1993), the cognitive profile described here and in previous studies is not necessarily associated with depression. In a study by Kauhanen et al. (2000) there were no significant differences in the cognitive scores of patients with aphasia with minor or major depression and those without depression. In our study, we also found no significant correlations between the severity of aphasia (AQ) or global cognitive performance and the values of the depression scale. Thus, the lower scores obtained by AP in cognitive tests when compared to CP, are unlikely to be explained by the presence of depressive symptoms in the AP group.

Interestingly, speech fluency also had differential effects in performance. Subjects with fluent speech had lower scores compared to the control group in three memory tests (i.e., Visual Span, 5 Objects, and Faces immediate memory). In contrast, subjects with nonfluent types of speech and good comprehension differed from the control group in the three cognitive domains: memory (Camel and Cactus Test, 5 Objects, and Faces immediate recall), executive functions (Clock drawing) and attention (Cancellation task). Such differences may reflect the effect of lesion site. Although there are exceptions, in general there is a good correlation of nonfluent discourse with anterior lesions and fluent discourse with posterior lesion (Borovsky, Saygin, Bates, & Dronkers, 2007; Hope, Seghier, Leff, & Price, 2013; Kreisler et al., 2000; Price, Seghier, & Leff, 2010; Yang, Zhao, Wang, Chen, & Zhang, 2008). Despite the reduced number of studies on the impact of the lesion location upon nonverbal cognitive performance in aphasia, our findings challenge previous data showing no relationship between performance on memory tests and lesion location (e.g., Kasselimis et al., 2013).

Compared with control patients (i.e., individuals with left hemisphere lesions without aphasia), patients with aphasia had significantly lower scores in all tests except in the Memory of Faces (delayed recall), Symbol Search of WAIS, Tower of Hanoi, and Matrix reasoning of WASI. The lower scores found in subjects with aphasia can have different explanations. One possibility is the use of verbal strategies in memory, reasoning and problem solving tasks. Another possibility is the interruption of systems supporting those functions as a consequence of the lesion in the language network. While episodic memory functions activate the medial temporal lobe, a structure that can be largely spared in middle cerebral artery stroke, there is a strong overlap between networks supporting language comprehension and semantic memory (Martin & Chao, 2001) or working memory (Chein, Ravizza, & Fiez, 2003). Consistent with this view, patients with damage to the left prefrontal cortex have difficulty retrieving words in phonological and semantic fluency tests, even in the absence of a frank aphasia (Baldo & Shimamura, 1998). Similarly, patients with damage to the temporal lobes often have difficulty naming objects and retrieving information about object-specific characteristics (Hodges, Salmon, & Butters, 1992). In addition, functional imaging studies of semantic processing revealed activity in broad expanses of the left prefrontal, parietal and posterior temporal lobes, including ventral and lateral regions of temporal cortex (Demonet et al., 1992). It is also possible that the different scores obtained by the two groups may result from different lesion size and sites in the left hemisphere, since lesion size is one of the strongest predictors of stroke severity in the acute period (Martins et al., 2016). The goal of selecting a group of patients with left hemisphere lesion without aphasia as the control group was to minimize the effect of the lesion side. We reasoned that choosing two groups of patients with left hemisphere lesions would result in a more similar pattern of cognitive dysfunction than that observed for subjects with right hemispheric lesions. However, the fact that control patients had no language impairment may indicate that they have smaller lesions or that the lesions are on the periphery of the left hemisphere language network. Lastly, it is worth noting that there was a significant difference between the two groups in the number of days post stroke and this difference in recovery time might have an influence in the tests' results. However, we believe that this is unlikely, as the difference was of nine months, which is presumably not relevant in patients in the chronic period post stroke, with an average of 47 months post stroke in the case of AP and 56 months post onset in CP.

We acknowledge some limitations to this study. Despite the careful selection of tests with a minimal verbal load, according to previous studies in patients with aphasia (Fonseca et al., 2016), one cannot guarantee that the tests are entirely nonverbal, as the instructions were verbal, and the resolution strategies may also be verbalized. A second limitation is the lack of imaging data, which prevents us from correlating lesion size or specific lesion patterns with results obtained in the neuropsychological battery. Third, we acknowledge that the sample of individuals included is rather small and heterogeneous with a large variety of aphasia diagnosis. Importantly, however, it represents the variety usually found in the clinical practice of a speech therapist. Finally, we do not have a baseline evaluation in order to check for improvement of test performance with time or further decline towards a dementia stage.

Conclusion

We conclude that about 50% of people with aphasia are likely to obtain values within normal range in a detailed neuropsychological assessment, tackling predominantly nonverbal domains. However, they tend to perform worse than individuals with a left hemispheric lesion without aphasia namely patients with aphasia recovered. Three tests seem to be particularly prone to worse performance: semantic memory tests (semantic association), episodic memory and immediate memory, which may reflect either shared networks between those functions and language or the reliance on linguistic strategies to use those abilities. Further studies are needed to disentangle the effect of lesion size from the effect of aphasia. Several studies have related specific cognitive domains and language processing. However, this constitutes one of the first approaches for understanding overall cognition in aphasia, a factor that may have an impact on patients' autonomy, recovery and rehabilitation, and that so far has not been systematically investigated. Although speech and language therapists often observe patients' cognitive difficulties, direct evaluation of nonverbal cognition may help to understand the overall cognitive pattern of performance and inform planning for therapeutic strategies.

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Conflicts of interest

All author states that there is no conflict of interest.

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