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Research paper

Non-linguistic abilities in aphasia

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ABSTRACT

Background: Understanding the pattern of non-linguistic abilities in aphasia has been a controversial question. We hypothesized that only some aphasia patients, particularly patients with fluent forms of aphasia and global aphasia, would present deficits in non-linguistic abilities.
Methods & procedures: We studied 200 vascular aphasia patients (119 men and 81 women; mean age = 57.37 years, SD = 15.56) at the Cognitive Communicative Speech Language Pathology Unit at the Clinical Hospital University of Chile (Santiago, Chile). The mean time post onset was 6.57 months (SD = 12.94). The Spanish versions of Western Aphasia Battery Revised (SWAB-R) and the Spanish version of the Boston Diagnostic Aphasia Examination (SBDAE) were administered. We used the SWAB-R Part 1 to determine the aphasia severity (Aphasia Quotient: AQ). SWAB-R Part 2 was used to study nonverbal abilities; a Non-Linguistic Quotient (NLQ) was calculated. The SBDAE was used in determining the type of aphasia.
Outcomes & results: Deficits were particularly evident in Global, Mixed non-fluent, and Transcortical Motor aphasia, followed by Wernicke and Transcortical Sensory aphasia. Deficits were mildest in Amnesic, Conduction, and Broca aphasia. Correlation between linguistic and non-linguistic deficits were found to be statistically significant.
Conclusion: Our results support previous studies: non-linguistic abilities can be affected in aphasia, but there is an important variability. Some aphasia patients can present non-linguistic deficits. Verbal and nonverbal deficits are significantly correlated, suggesting some communality in their brain organization.

1. Introduction

Interpreting the pattern of non-linguistic abilities in aphasia has been an ongoing controversial question (e.g., Bay, 1964,1974; Zangwill, 1964). This is an issue that was broadly discussed primarily during the 1970s and 1980s; later, during the years that followed some studies approached this question in more detail.

An important number of studies have used the Raven's Colored Progressive Matrices as a measure of nonverbal abilities in aphasia (e.g., Bailey, Powell, & Clark, 1981; Basso, Capitani, & Luzzatti, 1981; Gainotti, D'erme, Villa, & Caltagirone, 1986; Kertesz & McCabe, 1975; Villardita, 1985; Zaidel, Zaidel, & Sperry, 1981). Regardless of the specific characteristics of each one of these studies the major conclusion of these initial reports is that aphasia is sometimes, but not always, associated with low scores in the Raven's Colored Progressive Matrices as a measurement of nonverbal ability. Low scores are more frequently observed in Global and Wernicke aphasia.

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In addition to the Raven's Colored Progressive Matrices, other tests have been used to evaluate nonverbal abilities in patients with aphasia (e.g., De Renzi, Faglioni, Savoiardo, & Vignolo, 1966; Haas, Vogt, Schiemann, & Patzold, 1982). As an example, Borod, Carper, and Goodglass (1982) administered the Performance tests of the Wechsler Adult Intelligence Scale (WAIS) to 98 right-handed males, with unilateral left-hemisphere damage. Differences among the aphasia types were examined using the Performance IQ (PIQ), sub-scores for spatial organization subtests (Block Design and Object Assembly), and for verbalizability (Picture Completion and Picture Arrangement). It was found that there were significant group differences for each WAIS score. Correcting for auditory Comprehension, group differences were eliminated on the verbalizable subtests, but not on the spatial organization subtests. In general, difficulties in non-verbal ability tests were more significant in severe forms of aphasia.

During the 21st century, several studies have analyzed nonlinguistic abilities in individuals with aphasia. Helm-Estabrooks (2002) selected 13 patients with left hemisphere strokes and administered four linguistic and four non-linguistic tests. No significant association was disclosed between linguistic and non-linguistic abilities, and between non-linguistic abilities and educational level, age, or time post onset. They presented as a general conclusion that sometimes non-linguistic tests are affected in aphasia, but an important variability in test scores is observed. Blazková-Ctrnáctá, Kalvach, Preissová, and Müllerová (2004) studied 41 persons with brain stroke and correlate the level of aphasia using the Western Aphasia Battery with intelligence scores using the nonverbal Raven's and verbal Euro-ADAS tests. Correlations between both types of tests were positive and statistically significant. The authors suggested that aphasia is associated with an intellectual disturbance. In a similar type of study, Baldo, Paulraj, Curran, and Dronkers (2015) observed that the degree of language impairment is correlated with the degree of impairment on complex reasoning tests (e.g., Wisconsin Card Sorting Test and Raven's Progressive Matrices). Furthermore, Kang, Jeong, Moon, Lee, and Lee (2016) suggested that patients with more severe aphasia present greater disturbances in cognitive functions. Interestingly, Fedorenko and Varley (2016) found that patients with global aphasia, regardless the almost complete absence of language, are able to add and subtract, solve logic problems, think about another person's thoughts, appreciate music, and successfully navigate in their environments. The authors concluded that many aspects of thought involve different cerebral areas from those involved in language.

Marinelli, Spaccavento, Craca, Marangolo, and Angelelli (2017) selected 189 patients with severe aphasia and administered the Cognitive Test Battery for Global Aphasia. Three different subgroups of patients with different types and severity of their cognitive disorders were observed. The groups differed in relation to their residual linguistic skills, in particular comprehension and literacy skills. Fonseca, Raposo, and Martins (2018) found that patients with non-fluent aphasia get low scores on memory tests, executive functions, and attention, while patients with fluent aphasia get low scores only on memory tests. However, implicit learning is severely affected in patients with aphasias associated with agramatism (Broca aphasia) (Schuchard & Thompson, 2014). These patients also present serious difficulties in the organization of temporal sequences (Manning & Franklin, 2016).

Various additional deficits have been reported in individuals with aphasia, including, digit retention, drawing of a clock, visual memory, executive functions, and praxis (Bonini & Radanovic, 2015). On the other hand, it has been observed that nonverbal cognitive tests can predict verbal abilities in patients with aphasia suggesting that language and non-linguistic cognitive processes are often interrelated (Wall, Cumming, & Copland, 2017).

Disturbances in non-linguistic skills are associated with the site and lateralization of the pathological process. Recently, Schumacher, Halai, and Lambon-Ralph (2019) administered diverse standardized nonverbal neuropsychological tests and several language tests to 38 individuals with chronic post-stroke aphasia. Behavioral data were studied using rotated principal component analyses, first separately for the nonverbal and language tests, then in a combined analysis including all tests. Three orthogonal components for the nonverbal tests were extracted, interpreted as: shift-update, inhibit-generate, and speed. Three components were also found for the language tests: phonology, semantics, and speech quanta. The shift-update component was associated with a posterior left temporo-occipital and bilateral medial parietal cluster; the inhibit-generate component was mainly associated with left frontal and bilateral medial frontal regions; and the speed component with several small right-sided fronto-parieto-occipital clusters. These results suggest that a wide range of brain areas are involved in attention and executive functioning, and that these non-linguistic domains play a role in the abilities of patients with chronic aphasia.

Taken together all these studies suggest that nonverbal abilities may be affected in aphasia; however, an important variability is observed: whereas in some patients, evident nonverbal deficits are found, in other patients, performance is found to be within normal limits.

It is not easy, however, to understand why nonverbal abilities are frequently decreased in aphasia. Several hypotheses could be proposed; (a) tests that are assumed to be nonverbal are also partially verbal tests; (b) the decrement in nonverbal abilities may reflect some right hemisphere decreased activation due to the left hemisphere pathology; or (c) language represents an additional resource to solve nonverbal problems and, hence, the people with aphasia are at disadvantage in regard to the normal speaking individuals (Ardila & Rubio-Bruno, 2018). Evidently, it is not easy to be sure what would be the correct explanation. But anyhow, the frequent assumption that aphasia does not affect intellectual abilities should be taken with caution.

Departing from previous studies we hypothesized that only some aphasia patients, particularly patients with more severe forms of aphasia would present deficits in non-linguistic abilities. Furthermore, it was anticipated that the severity of non-verbal ability disturbances would be correlated with the aphasia severity. Considering that information about the impact of demographic variables on non-linguistic abilities in aphasia has not been clarified yet, it was also hypothesized that patients' demographic characteristic would affect the performance in nonverbal tests.

The current study advances our understanding of the pattern of cognitive abilities in aphasia. It also contributes to the comprehension of the effect some demographic variables on intellectual abilities in the aphasia syndrome. We used a large sample of 200 participants, and consequently, we assume that our results are solid.

2. Methods

2.1. Participants

We assessed and treated the aphasia patients in the Cognitive Communicative Speech- Language Pathology Unit at the Clinical Hospital University of Chile in Santiago of Chile (*Unidad de Patología del Habla y Lenguaje Cognitiva Comunicativa del Departamento de Neurología y Neurocirugía del Hospital Clínico de la Universidad de Chile*). Our unit receives the patients presenting speech and language disorders associated with stroke. We have been registering aphasia patients over a period of 11 years (2008–2019). This study was initiated with prior approval from the Institutional Ethics Committee.

In the Unit there is a database with 1404 entries. To select the patients included in this report, we used the following procedure: initially, we collected all the patients that were assessed using the Spanish revised version of Western Aphasia Battery (SWAB-R) (González, Hornauer-Hughes, Leyton, Neumann, & Vera, 2015; translated and adapted to Spanish by González, 2008), and the Boston Diagnostic Aphasia Examination, Spanish version (SBDAE) (Goodglass, 2005). We found 915 patients out of 1404 (65.17%) qualified. In a second stage, only those patients having the initial evaluation with the SWAB-R Part 1 and Part 2 were selected (504 patients). From those patients with a vascular etiology were selected, corresponding to 231/504 entries (45.83%). Finally, the following inclusion criteria was used: (1) adult (> 18 years) literate participants with aphasia due to first-ever left hemisphere stroke; (2) conscious (according to WHO definition) at the time of language assessment; and (3) native Spanish speakers. We also used the following exclusion criteria: (1) aphasia caused by intracranial hemorrhage; (2) pre-morbid psychiatric pathologies; (3) pre-morbid dementia with significant cognitive disturbances, congruent with a dementia process; (4) Significant non-linguistic cognitive disturbance impairing the language evaluation. From this 231-patient sample, 31 were removed from the study because did not fulfill the inclusion criteria. The final sample for the current study included 200 vascular aphasia patients.

Handedness was determined based on the direct clinical observation and/or a brief questionnaire answered by a close family member or by the patient him/herself, when it was possible. We had 195 (97.50%) right-handed, and 5 (2.5%) left-handed participants. In our aphasia sample, there were 119 men and 81 women with a mean age of 57.37 years (SD = 15.56). Our participants had a mean level of education of 13.52 years (SD = 4.08) corresponding to approximately high school, according to the Chilean education system. The mean time post-onset that they were evaluated was 6.57 months (SD = 12.94) after the aphasia onset. All the patients had localized strokes according to CT or MRI scans.

2.2. Language examination

Two different aphasia test batteries were administered: the Spanish version of the Western Aphasia Battery Revised (SWAB-R) and the Boston Diagnostic Aphasia Examination, Spanish version (SBDAE).

(1a) SWAB-R Part 1. It was used to determine the aphasia severity. We only used four subtests: Spontaneous Speech, Auditory Verbal Comprehension, Repetition, and Naming. An Aphasia Quotient (AQ) is calculated based in these four scores. The AQ was calculated using the following formula: AQ= (Spontaneous speech 20 + comprehension 200/20 + repetition 100/10 + naming 100/10)/x 2. This is the standard procedure recommended in the WAB-R Manual. According to the AQ, aphasia severity is interpreted as follows: 0–25 = very severe, 26–50 = severe, 51–75 = moderate, and 76–above = mild. In our sample the mean AQ was 59.26 (SD = 30.03).

(1b) SWAB-R Part 2. This is a supplementary instrument, which was used to study nonverbal abilities. We used the following subtests: Praxis, Drawing, Block Design, Calculation, and Raven's Colored Progressive Matrixes. Using these subtests, a Non-Linguistic Quotient (NLQ) was calculated. The following formula was used: NLQ= (Praxis 60 + Drawing 30 + Block Design 9 + Calculation 24 + Raven's Colored Progressive Matrixes 37) x 1.25/2. It means, that the maximum score in Praxis was 60, in Drawings it was 30, etc. The total score is multiplied by 1.25 and divided by two. This procedure was developed with the purpose of comparing verbal and nonverbal abilities.

(2) The SBDAE was used in determining the type of aphasia. We selected the SBDAE for determined the type of aphasia because it includes not only a quantitative but also a qualitative analysis of the aphasia groups. In our current study, the distribution of the aphasia types was the following: Global = 11 patients (5.50%), Broca = 31 (15.50%), Wernicke = 30 (15.00%), conduction = 22 (11.00%), transcortical sensory = 17 (8.50%), transcortical motor = 3 (1.50%), and amnesic or anomic = 54 (27.00%), mixed non-fluent = 32 (16.00%). Mixed non-fluent aphasia, refers to those patients with a significantly impaired expressive language and auditory comprehension deficits (below 50%). In Broca aphasia Auditory Comprehension is above 50% and in global aphasia below 25%. Usually, two different examiners participate in the patients' assessment. The inter-rater reliability in aphasia diagnosis was 0.98.

3. Results

Table 1 presents the scores in the different SWAB-R Part 2 non-linguistic subtests, according to the aphasia type. The SDs were frequently high with regard to the means scores, indicating the heterogeneity of the scores. Praxis ability was decreased in all the aphasia types, especially, Global aphasia and Mixed non-fluent aphasia. Drawing and Block design was low not only in Global, but also in Wernicke aphasia. Calculation was decreased in the transcortical aphasias, Global aphasia, and Mixed non-fluent aphasia. Finally, Raven's Colored Progressive Matrices was decreased in all the aphasia types, especially Global.

Table 1
Scores in the different SWAB-R Part 2 subtests according to the aphasia type. ANOVAS and Tukey's test for multiple comparisons were used. Transcortical motor aphasia group was excluded because it was too small (n = 3).

Total (197)	Broca (31)	Wernicke (30)	Conduction (22)	Transc. Sensory (17)	Amnesic (54)	Global (11)	Mixed non-fluent (32)	F	p
Praxis (0/60) (SD)	45.90 (10.09)	37.70 (12.29)	49.64 (7.31)	45.24 (9.66)	52.09 (5.43)	15.45 (13.71)	27.78 (9.69)	42.93	0.001
Drawing (0/30) (SD)	20.02 (5.54)	16.20 (7.75)	20.98 (6.07)	18.38 (4.05)	21.61 (5.56)	5.59 (6.16)	14.88 (7.54)	13.21	0.001
Block design (/9) (SD)	7.71 (2.15)	6.60 (2.86)	7.46 (2.06)	6.82 (1.81)	7.20 (2.65)	2.82 (3.52)	6.75 (2.51)	5.72	0.001
Calculation (0/24) (SD)	20.77 (5.41)	14.73 (7.74)	20.36 (4.85)	15.24 (6.55)	20.11 (4.62)	4.91 (6.16)	13.78 (6.06)	17.03	0.001
Raven's CPM (/36) (SD)	26.65 (8.48)	20.83 (7.85)	25.64 (7.16)	20.41 (7.16)	25.72 (7.11)	11.82 (9.92)	22.88 (7.81)	7.12	0.001

Table 2 presents the pairs of groups that were different from each other.

Table 3 presents the AQ values and NLQ scores in the different types of aphasia. As expected, according to the AQ score, the most severe type of aphasia was Global aphasia, and the least severe was Amnesic aphasia. NLQ was affected in all the types of aphasia although in Amnesic, Conduction, and Broca the scores were relatively higher indicating a smaller nonverbal cognitive impairment. NLQ was most affected in Global and least affected in Amnesic aphasia. Interestingly, in Transcortical Sensory and Conduction aphasia no significant differences between the AQ and NLQ were observed, indicating similar difficulties in verbal and nonverbal abilities. In Amnesic aphasia, nonverbal impairments (NLQ) were higher than verbal impairments (AQ).

The different subtests included in the NLQ were correlated with the AQ score in order to find the potential communality between verbal and nonverbal abilities. It was found that all the correlations were positive and statistically significant ($p < 0.001$) The highest correlation was with Praxis ($r = 0.797$) and the lowest with Block design ($r = 0.279$). The overall correlation between NLQ and AQ was 0.687. AQ score correlated 0.544 with Drawing, 0.572 with Calculation, and 0.339 with Raven's CPM.

The contribution of demographic variables to the non-linguistic deficits were also analyzed. Table 4 presents the correlations between the different SWAB-R Part 2 and the demographic variables. Age negatively while education positively correlated with the scores in all the subtests, whereas Time post onset correlated the scores in the Praxis subtest.

The effect of sex was also analyzed. Using an unpaired *t*-Student test no significant difference was observed in any of the non-verbal tests (Table 5).

The global verbal (AQ) and nonverbal (NLQ) impairments were further correlated with the demographic variables. Table 6 presents the correlations between the two analyzed quotients and the demographic variables. For age and education statistically significant correlations were found with NLQ but not with AQ. Age correlated negatively and education positively with NLQ. Time post onset mildly correlate with AQ.

4. Discussion

Overall, our results support previous studies: non-linguistic abilities can be affected in aphasia, but there is an important variability. Deficits were particularly evident in Global, Mixed Non-fluent, and Transcortical Motor aphasia, followed by Wernicke

Table 2
Significant differences ($p < 0.001$) in pairs of groups of aphasia in the different nonverbal tests.

Praxis
Broca, Conduction, Amnesia > Wernicke, Global, MNF
Transcortical sensory, Wernicke > Global, MNF
MNF > Global
Drawings
Broca, Conduction > Global, MNF
Amnesic > Wernicke, Global, MNF
Transcortical sensory, Wernicke, MNF > Global
Block design
Broca, Conduction, Amnesic, Transcortical sensory, Wernicke, MNF > Global
Calculation
Broca > Wernicke, Transcortical Sensory, Global, MNF
Conduction > Wernicke, Global, MNF
Amnesic > Wernicke, Global, MNF, Transcortical Sensory
Transcortical sensory, Wernicke > Global
MNF > Global
Raven's Colored Progressive Matrices
Broca, Conduction, Amnesic, Transcortical sensory, Wernicke, MNF > Global

Table 3
SWAB-R AQ and NLQ scores according to the aphasia type. Paired *t*-Student test was used to determine the significance level.

Aphasia Types (197)	AQ (/100) (SD)	NLQ (/100) (SD)	t	p
Broca (31)	67.01 (24.14)	75.66 (15.18)	**2.05**	**0.0494**
Wernicke (30)	47.83 (18.40)	58.13 (21.77)	**2.94**	**0.0064**
Conduction (22)	71.03 (13.68)	77.55 (13.17)	1.603	N.S.
Transc. Sensory (17)	67.07 (19.39)	66.01 (14.41)	0.312	N.S.
Amnesic (54)	87.67 (9.37)	79.21 (12.60)	**4.94**	**0.0001**
Global (11)	4.23 (2.72)	25.37 (19.25)	**3.99**	**0.0026**
Mixed non-fluent (32)	23.61 (13.75)	53.79 (15.88)	**9.30**	**0.0001**

Table 4
Correlations of Spearman between the different SWAB-R Part 2 and the demographic variables.

Variables (n = 200)	Praxis	Drawing	Block design	Calculation	Raven's CPM
Age	−0.30**	−0.433**	−0.419**	−0.338**	−0.559**
Education	0.177*	0.303**	0.305**	0.333**	0.430**
Time post onset	**−0.22****	−0.058	0.037	−0.106	−0.004

*P < 0.05; **P < 0.001.

Table 5
Scores obtained by men and women in the different nonverbal tests. No significant difference was observed when using an unpaired *t*-Student test.

Variables (n = 200)	Man (119)	Woman (81)	t	p
Praxis /60 (DS)	42.17 (14.47)	41.77 (13.83)	0.197	N.S.
Drawing /30 (DS)	17.94 (7.61)	18.28 (7.10)	0.323	N.S.
Block design /9 (DS)	7.14 (2.57)	6.44 (2.83)	1.809	N.S.
Calculation /24 (DS)	17.67 (6.55)	16.16 (7.68)	1.493	N.S.
Raven's CPM /36 (DS)	24.09 (8.25)	22.02 (8.75)	1.697	N.S.

Table 6
Spearman Correlations between the different SWAB-R quotients and the demographic variables.

Variables (n = 200)	AQ	NLQ
Age	−0.120	**−0.459****
Education	0.041	**0.323****
Time post onset	**−0.171***	−0.099

*P < 0.05; **P < 0.001.

and Transcortical Sensory aphasia. Non-linguistic impairments were mildest in Amnesic, Conduction and Broca aphasia.

It was found that the distribution of deficits across the aphasia subtypes depended upon the specific nonverbal task. However, difficulties were generally more evident in Global, Transcortical motor, and Mixed non-fluent aphasia. It should be emphasized that patients with Global and Mixed non-fluent aphasia present extensive pathologies.

The non-linguistic test most affected in our aphasia patient was Praxis whereas the least affected was Block Design. The close association between aphasia and apraxia has been emphasized since long time ago by different authors (e.g., Vingerhoets et al., 2013) and a significant percentage of patients with aphasia also present apraxia (Benson & Ardila, 1996). Nonetheless, it is important to bear in mind that typical praxis assessment also involves auditory comprehension ability (understanding of commands) and hence, it is not an exclusively “non-linguistic” assessment task. Block Design, on the other hand, is a typical nonverbal test, assessing constructional abilities. These constructional abilities are considered to be lateralized to the right hemisphere (Arrigoni & De Renzi, 1964; Gainotti & Trojano, 2018) and consequently, distant from the classical brain areas involved in language. It is understandable that correlation with language deficits is low.

Only two demographic variables were significantly associated with NLQ: age and education level. Education positively correlated while age negatively correlated with all the subtest scores contributing to the NLQ. It is well known that language ability is significantly associated with education level (Ardila et al., 2010) and decreases with aging (Wright, 2016). Hence, it is not surprising that NLQ scores were positively correlated with education and negatively correlated with age. However, men obtained higher scores than women in two subtests: Block design, and Raven Colored Progressive Matrixes. Time post onset negatively correlated with the Praxis test.

Quite surprisingly, we found a solid and highly significant correlation between aphasia severity (AQ) and disturbances in nonverbal cognition (NLQ), suggesting an important communality and association between verbal and nonverbal abilities. We found that frequently aphasia patients –particularly patients with global aphasia– are impaired in nonverbal abilities, including a diversity of skills such as praxis, drawing, block design, calculation, and progressive matrixes. These impairments were significantly correlated with the linguistic deficits, and were highest in Global aphasia.

Interesting to note, non-linguistic deficits have been shown to correlate with quality of life in people with aphasia (Nicholas, Hunsaker, & Guarino, 2017) and recovery in chronic poststroke aphasia patients (Gilmore, Meier, Johnson, & Kiran, 2019). The general suggestion is that in cases of aphasia it is important to assess not only the language characteristics, but also the non-linguistic abilities. These abilities may inform about the patient's quality of life, and represent a significant predictor for future language recovery.

Finally, it is important to bear in mind that the current study has a diversity of limitations, including but not limited to: the specific characteristics of our sample, the restricted assessment procedure, the idiosyncrasies of the patients' language, and the heterogeneity of the time post onset of the current aphasia sample. We only included vascular aphasia patients with left-hemisphere pathologies, only two aphasia test batteries were administered, and all patients were speaker of a single language. Moreover, aphasia classification was based on a single test battery. Furthermore, in a few cases aphasia was associated with such severe nonverbal deficits that it was simply impossible to pinpoint the aphasia type and severity; these patients were not included in our sample, introducing a potential bias into the sample.

Author statement

Rafael Gonzalez contributed in collecting the sample, performing the statistical analyses, and interpreting the results.
Macarena Rojas contributed in collecting the sample, performing the statistical analyses, and performing the literature search.
Alfredo Ardila contributed writing the introduction and the discussion sections, and interpreting the results.

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