Individual variability in attention and language performance in aphasia: a study using Conner's Continuous Performance Test

Journal:	*Aphasiology*
Manuscript ID	Draft
Manuscript Type:	Paper
Date Submitted by the Author:	n/a
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Keywords:	Aphasia, Stroke, cognition, language disorders, attention variability

RUNNING TITLE: Attention, variability and Aphasia

Individual variability in attention and language performance in aphasia: a study using Conner's Continuous Performance Test

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ABSTRACT

Aims. To study the possible relationship between moment-to-moment intra-individual fluctuations in attention and their possible relationship with language disorders. We have employed a comprehensive test of basic attention functions (Conner's Continuous Performance Test II).

Methods & Procedures. 24 controls and 21 people with aphasia matched by age and sex took part in a evaluation design using phonological processing subtests, (phonological discrimination, word and pseudoword repetition), lexical access subtests (auditory lexical decision, spoken word-to-picture matching and naming) and semantic association subtests (object-action association, semantic associates and odd-one-out). We studied the association between indices of intra-individual variability in response time in Conner's Continuous Performance Test II and linguistic performance in both groups.

Outcomes & Results. People with aphasia showed increased response times and also increased intra-individual variability in response speed. Moreover, only in this group, response speed variability was significantly associated to speech discrimination and with performance in semantic association tasks. Indices of intra-individual variability predicted performance in linguistic tasks in people with aphasia, even after accounting for language performance in related tasks.

Conclusion. The current results provide additional support to evidence suggesting a relationship between attention skills and some aspects of linguistic performance in people with aphasia, and draw attention to the putative importance of processing speed instability.

Key words: Aphasia, stroke, cognition, language disorders, attention variability.

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INTRODUCTION

Language has been traditionally regarded as a highly domain specific process (Fedorenko, Behr, & Kanwisher, 2011). However, many current brain models of language processing emphasize a multifunctional perspective whereby a constant and dynamic interaction exists among neural networks subserving cognitive, affective, and praxic functions with neural networks specialized for lexical retrieval, sentence comprehension, and discourse processing (Blumstein & Amso, 2013; Cahana-Amitay & Albert, 2014; Fedorenko & Thompson-Schill, 2014). In fact, there is a growing interest in understanding the complex relationships among language and attention in the context of aphasic deficits (Connor, Albert, Helm-Estabrooks, & Obler, 2000; Murray, 2012, Villard & Kiran, 2016). There are lines of evidence which converge to suggest not only that attentional difficulties are pervasive in people with aphasia (PWA) (Erickson, Goldinger, & Lapointe, 1996; Laures, 2005; Lee & Pyun, 2014) but also that there exist an influence of attentional capacities over language and communication skills (Connor et al., 2000).

First, there is considerable moment to moment intra-individual variability in linguistic performance among PWA (Hula & McNeil, 2008; McNeil & Pratt, 2001). This variable pattern of performance is suggestive of an intermittent breakdown in the access to linguistic representations (e.g. Caplan, Waters, DeDe, Michaud, & Reddy, 2007). Moreover, competing auditory information decrease performance in PWA both in linguistic and in non-linguistic tasks (Erickson et al., 1996; Murray, Holland, & Beeson, 1997, 1998; Murray, 2000), suggesting a diminished ability to maintain attention and to access linguistic knowledge when distracting information is present. Additionally, the results of language therapy seems to be influenced to some extent also by non-linguistic cognitive deficits (Murray, Keeton & Karcher, 2005; Lambon Ralph, Snell, Fillingham, Conroy, & Sage, 2010).

Mc Neil and colleagues (Hula & McNeil, 2008; McNeil & Pratt, 2001) suggest a close relationship between attention and aphasic symptoms. They consider aphasia as a disorder in the pool of resources providing access to linguistic knowledge. Clinical studies support this position only partially. Murray (2012) observed a substantial association between scores in clinical attention tests and linguistic and communication measures. Congruently with previous experimental data (Erickson et al., 1996; Hunting-Pompon, Kendall, & Moore, 2011; Murray et al., 1997, 1998), large correlations were found among linguistic measures and attention. However, although attention and language disorders were clearly related at a group level, results by Murray (2012) did not support a "strong" relationship between attention and aphasia, where aphasic deficits are mainly driven by attentional difficulties. Some PWA failed to show attentional disturbances, despite their evident language problems. Actually, some studies have failed to found a reliable relationship between aphasia severity and attentional impairment (Lee & Pyun, 2014).

Hence, tough the existence of a relationship between attention and aphasia seems well established, the nature and extension of such relationship seems more elusive. Research is warranted on the actual features of attention which influence language performance in aphasia. In fact, attention is not an unitary construct, and an adequate model about the relationship between attention and aphasic disturbances should consider the role of different attentional dimensions. Attention might be regarded as a hierarchic construct, with complex attentional functions supported by the more basic types (see Villard & Kiran, 2016, for a recent review). Clinical models of attention converge on the basic features of this hierarchy. One of the most basics types of attention might be the capacity to focus attention on some target stimulus for enhanced processing, followed by the ability to sustain this attention over time, and the most complex types of attention might imply divide or alternate attention among tasks or sets of stimuli (Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991; Sohlberg & Mateer, 1987). Villard & Kiran (2016) as well as McNeil and colleagues (Hula & McNeil, 2008; McNeil & Pratt, 2001) highlight the importance of intra-individual variability in PWA. Intra-individual variability evidences an inability to maintain constant levels of attention and performance across time. It might operate at multiple time scales, from intra session (i.e., moment-to-moment) to between session (i.e., day-to-day) variability (Villard & Kiran, 2016). Many neurological conditions have been found to be related with increased intra-individual variability in response speed (MacDonald, Nyberg, & Bäckman, 2006).

While intra-individual variability has been traditionally considered a hallmark of aphasia (McNeil & Pratt, 2001), little research has addressed specifically whether response speed inconsistency might provide interesting clinical information regarding language performance. Laures (2005) found increased response speed variability in PWA. Also, response speed inconsistency was found to be the principal reason for aphasic participants to miss targets during auditory vigilance tasks, often failing to respond during the specified time window. Although Laures found overall RT to correlate negatively with the Aphasic Quotient of the Western Aphasia Battery, variability of RT and its relationship with linguistic symptoms was not specifically considered. More recently, Villard & Kiran (2015) have emphasized also increased between session (i.e. day to day) intra-individual variability in PWA. These previous results underscore the relevance of a more detailed knowledge of the consequences of response speed instability for linguistic performance.

The present study aims to provide more detailed evidence on the relationship among aphasic symptoms and basic components of attention, and in particular to explore the relationships among intra-individual variability in processing speed and different linguistic tasks. Attention was assessed using Conner's Continuous Performance Test II (C-CPT) (Conners, 2002). One of the advantages of C-CPT is that it provides a comprehensive number of indices related to distinct dimensions of attention. Recent studies which includes brain damaged adults alongside with other populations showing attentional disturbances have found a factorial structure on C-CPT that includes at least the following four factors (Egeland & Kovalik-Gran, 2010a, 2010b): focused attention (i.e., maintaining one specific task goal and responding consistently), sustained attention (i.e., maintaining performance level across time, avoiding fatigue), impulsivity (i.e., avoiding inappropriate responses to nontarget stimuli) and vigilance (maintaining alertness and performance independently of an slow or fast rate of stimulation). Tough more complex components such as divided and alternating attention are not considered, the factors measured by C-CPT are easy to integrate with most models of clinical disturbances of attention (Mirsky et al., 1991; Sohlberg & Mateer, 1987).

Crucially, response speed variability across different levels of attention is also an important information provided by C-CPT. The main point when considering response speed variability is not whether responses are rapid or accurate, but whether the time to respond is consistent among trials. C-CPT includes indices of response speed variability related to focused attention, sustained attention and vigilance.

With regard to language performance, in the current study we have used different tasks to evaluate phonetic discrimination, repetition, lexical access, naming and nonverbal semantic association skills (see below for detailed tasks descriptions). Tough semantic association tasks measure semantic skills non verbally, the ability to access, select and compare semantic knowledge (semantic executive skills) might contribute importantly to aphasic comprehension deficits (Robson, Sage, & Lambon Ralph, 2012). Further, we aimed to avoid that attentional disturbances present in our sample were produced by frontal damage. Because prefrontal cortex is the main regulator of attentional control, and many aphasic symptoms are related to frontal damage, a seeming association between attention and language might be driven by the breakdown of close but independent brain networks. Hence, we excluded from our sample PWA showing radiological evidence of frontal damage. All the experimental participants had lesion/s localized in posterior (temporo-parietal) brain areas.

Taking into account the evidence on the relationship between attention and language in individuals with Aphasia (Erickson et al., 1996; Hunting-Pompon et al., 2011; Murray et al., 1997, 1998; Murray, 2000, 2012), the aim of this paper is to further explore the importance of intra-individual variability in attention and its impact on language performance. Here we will focus on moment-to-moment fluctuations in focused attention as measured by intraindividual indices of response time variability provided by C-CPT. We expected to find increased intraindividual variability in response time in PWA, in line with previous results by Laures (2005). Further, we expect to find correlations among intraindividual variability in attention and phonological, lexical and semantic processing tasks in PWA. Finally, using linear regression, we expected measures of intra-individual variability in attention to contribute to predict performance in linguistic tasks beyond the contribution of other measures of attention (accuracy, mean response time) and beyond performance in other linguistic tasks. The revealed contributions from intraindividual variability would thus help us delineate how basic attentional deficits contribute to constraint certain linguistic operations in PWA.

METHODS

Participants

Twenty one people suffering from post-stroke aphasia (PWA, 12 male, 9 female, mean age 52.9 ± 14.9) and twenty four age-matched neurologically unimpaired controls (10 male, 14 female, mean age 53.3 ±15.1) participated in the study. PWA were recruited from Speech and Language Therapy programs from CEADAC (Spanish National Reference Centre for Brain Injury), Torrejón´s University Hospital and Medical Rehabilitation Center at Madrid (Spain) and were selected if they were native Spanish speakers, have suffered from a single stroke of the Left Middle Cerebral Artery resulting in a language disturbance, have no premorbid history of neurological or mental impairments and volunteer to participate. Demographic data of PWA is presented on Table 1. A convenience control sample composed by Spanish speaking volunteers matched in age and educational level was recruited from the community through word of mouth.

PLEASE INSERT TABLE 1 ABOUT HERE

Linguistic Tasks

Linguistic tasks used in the current study measured different components involved in language use (namely phonological, lexical and semantic processing) and are routinely used in clinical settings.

a) Phonological processing:

Our phonological processing tasks measured the areas of phonological discrimination and repetition of words and pseudowords.

Phonological Discrimination (PhonDisc). The Pseudoword Phonological Discrimination task of Spanish test EDAF (Evaluación de la Discriminación Auditiva y Fonológica) (Brancal, Alcantud, Ferrer, & Quiroga, 2007) was used. Each trial consists on hearing a recorded set of three one-syllable pseudowords. The subject task was to ascertain whether all three were equal or someone differed from the others. Maximum score was 28.

Word Repetition (WRep) and Pseudoword Repetition (PWRep). Both subtests were taken from Spanish Aphasia´s Test Barcelona (Peña Casanova, 2010, 2011) consisting of 10 and 8 items, respectively.

c) Lexical processing:

Auditory Lexical Decision (ALD). This subtest was taken from the Spanish test BETA (Batería para la evaluación de los trastornos afásicos) (Cuetos & González-Nosti, 2009). The participant has to decide whether each stimulus is a word or a nonword, for a maximum score of 32.

Spoken Word-to-Picture Matching (SWPM). This subtest was taken from Spanish test EPLA (Valle & Cuetos, 1995), which is an adaptation of PALPA (Kay, Lesser, & Coltheart, 1992). The subject was asked to choose the right image depicting an auditory word among an array including lexical, semantic and visual foils. Maximum score in the task was 40.

Boston Naming Test (BNT). A shortened version of the Boston Naming Test was used. Participants were asked to name aloud a subset of the original black and white pictures that demonstrated an adequate reliability and high correlation with the original test

(Fernández-Blázquez et al., 2012). Because of time constraints and fatigue, only 39 participants (18 PWA and 21 controls) performed this task.

d) Semantic processing:

Object-Action Association (O-A). Subject is asked to pair the picture of an object with that of a related action. There are 4 possibilities for each item, including one semantic and one visually similar foil. This and all the following semantic processing tasks were taken from the Spanish test BETA (Cuetos & González-Nosti, 2009) and the maximum score for each one was 30.

Semantic Associates (SA). Similarly to the previous task, and similar to the Pyramid and Palm Trees Test (Howard & Patterson, 1992), the subject is asked to pair the picture of an object with another one semantically related among 4 possibilities, including a semantic and a visually similar distractors.

Odd-One-Out (O-O-O). The task here consists in pointing to the only one element which is not semantically related to all the rest depicted in a 4 item array for each semantic category.

Conner's Continuous Performance Test II (C-CPT)

The Conner's Continuous Performance Test II (C-CPT) consists of 360 trials where different letters appear visually, one at a time, on a computer's screen. Participants are required to respond by pressing the spacebar every time a stimulus appears, except when letter “X” is displayed. The task includes 6 blocks, each consisting of 3 sub-blocks with different Inter-Stimulus Interval (ISI) of 1, 2 and 4 , presented in different order for each block. Each stimulus is displayed for 250 ms, for a total time of 14 minutes to complete the task.

The C-CPT provides several different summary measures including the following:

Commission errors: occurs when a response is given after a "X" stimulus appears because as per the test instruction, no response should be given, omission errors: occurs when a response is not given to a target "non-X" stimulus, mean hit reaction time (hit RT), overall hit RT standard error (hit RT SE), variability of hit RT SE across sub-blocks (RT variability), responses within the first 100 ms post-stimulus (perseverations), discrimination between targets and non-targets according to signal-detection-theory (d'), whether response criterion is more or less liberal (response style), hit RT change across the 6 task blocks as the test progresses (hit RT block change), hit RT Standard Error change across the 6 task blocks (hit RT SE block change), hit RT change depending on Inter stimulus Interval; letters can appear at 1,2 or 4 second interval (hit RT ISI change) and hit RT Standard Error change depending on ISI (hit RT SE ISI change).

According to recent comprehensive factor analysis (Egeland & Kovalik-Gran, 2010a, 2010b), C-CPT scores might be grouped into at least four different dimensions of attention: focused attention, sustained attention, impulsivity, and vigilance. Measures related to focused attention include omissions, perseverations, and overall indices of RT inconsistency (hit RT SE and RT variability). Sustained attention is reflected in response speed consistency across blocks: hit RT block change and hit RT SE block change. Impulsivity is related to a fast hit RT, commission errors and a liberal response style. Finally, vigilance is related to a consistent response speed independently of a fast or slow ISI: hit RT ISI change and hit RT SE ISI change. Here we have not included a fifth putative dimension: change in control (i.e., increasing impulsivity in responses with time on task). While increases in impulsivity with time on task might be expected on some attentional disturbances (e.g. on some kinds of attention deficit hyperactive disorder, Egeland & Kovalik-Gran, 2010b), we have no reason to suspect that it plays any important role in PWA.

RESULTS

Table 2 shows the results of the between-groups contrast in demographic variables, and table 3 shows differences in C-CPT indices. Differences in linguistic tasks are displayed in figure 1. Non-parametric tests (Mann-Whitney U) were used to compare numerical variables because of anormal distribution of data. Categorical data were compared trough Chi-square tests. There was no significant difference in demographic characteristics such as age, sex and education.

PLEASE INSERT TABLE 2 ABOUT HERE

People with aphasia showed a lower performance in C-CPT variables related to variability in focused attention (Hit RT SE, RT variability, perseverations) and an increased response time. Regarding linguistic tasks, PWA scored significantly lower than controls in WRep (Mann-Whitney U = 163.5; p = .004), PWRep (Mann-Whitney U = 102.5: p < .001), SWPM (Mann-Whitney U = 162.5; p = .016), BNT (Mann-Whitney U = 82.5; p = .001) and SA (Mann-Whitney U = 138.5; p = .006). Differences approach significance in PhonDisc (Mann-Whitney U = 169.5; p = .078), O-A (Mann-Whitney U = 138.5; p = .052) and O-O-O (Mann-Whiney U = 165; p = .069).

PLEASE INSERT TABLE 3 ABOUT HERE

PLEASE INSERT FIGURE 1 ABOUT HERE

Next, we performed multiple correlation analysis among demographic variables, C-CPT scores, and linguistic tasks, both in PWA and in controls separately. Sperman's rho was used because of the non-normal distribution of data. Table 4 shows the correlation among demographic variables (age, and months post stroke onset) and C-CPT indices in PWA and among age and C-CPT indices in controls. In PWA, age was correlated with sustained attention (Hit RT block change and Hit RT SE block change) and vigilance indices (Hit RT ISI change). Time post stroke onset did not seem to influence C-CPT scores. In controls, age was found to be associated to indices of variability in focused attention (Hit RT SE, RT variability and perseverations) and response time.

PLEASE INSERT TABLE 4 ABOUT HERE

Table 5 shows the correlation among demographic variables (age and time post stroke onset) and linguistic performance in people with aphasia and among age and linguistic performance in controls. In people with aphasia, age was negatively associated with WRep, and ALD. Time post stroke onset and WRep were positively associated. In controls, age correlated negatively with performance in BNT.

PLEASE INSERT TABLE 5 ABOUT HERE

More crucially for our current purposes, tables 6 and 7 displays the correlation among C-CPT scores and linguistic tasks in people with aphasia and controls, respectively. In PWA we observed large negative significant correlations between phonological discrimination scores and focused attention indices and moderate-to-large negative significant correlations between C-CPT indices of focused attention and linguistic tasks measuring semantic skills, particularly with the Odd-one-out task. Figure 2 shows scatterplots of the relationship of RT variability with PhonDisc, SA and Odd-one-out and of the relationship of perseverations with semantic tasks. Results in PWA also showed significant negative correlations between commission errors and O-A and between RT and O-O-O, and a positive correlation between O-A and HitRT block change. Some sporadic significant correlations among attentional performance and linguistic tasks also arise in controls, but they were not as clear-cut as they were in PWA.

PLEASE INSERT TABLE 6 ABOUT HERE

PLEASE INSERT TABLE 7 ABOUT HERE

PLEASE INSERT FIGURE 2 ABOUT HERE

Table 8 displays Sperman's rho correlations among linguistic tasks in PWA. Phonological tasks showed close associations. Semantic association task showed also strong associations among them. Lexical tasks, on the other side, did not show close correlations among them, possibly reflecting that they tap on different linguistic demands. BNT show some association with phonological and semantic tasks, while SWPM correlated significantly mainly with semantic association tasks.

PLEASE INSERT TABLE 8 ABOUT HERE

Table 9 shows the results of stepwise linear regressions for PWA using linguistic tasks as dependent variables and the rest of linguistic and attentional indices as predictors. Only those linguistic tasks where attention indices emerged as significant predictors are reported. Hit RT variability alone emerged as a significant predictor of Phonological discrimination, explaining almost a 50% of variance. RT variability is also a significant predictor of lexical decision in conjunction with SWPM. Perseverations (i.e., out-of-range responses) helped to explain performance in SWPM and semantic association tasks in conjunction with other language tasks.

PLEASE INSERT TABLE 9 ABOUT HERE

DISCUSSION

The current study aimed to provide evidence on the relationship between moment-to-moment variability in attention and linguistic performance in PWA. Intraindividual variability was measured by a standard clinical test of attention, C-CPT, which provides indices of response time variability across different attention functions: vigilance, focused attention, and sustained attention. Our sample of PWA show impairments in focused attention which become evident when looking at measures of intraindividual variability (and also of response speed). Further, it seems of particular interest that variability in focused attention correlate with performance in phonological discrimination and semantic association tasks for PWA. Finally, linear regression analysis show that intraindividual variability in focused attention in PWA explain different amounts of variance in language performance, beyond the contribution of other linguistic and nonverbal semantic tasks.

From a clinical point of view, then, the current results are in agreement with the idea that attention is an important mediator of language disturbances shown by PWA (Connor et al., 2000; Murray, 2012; Villard & Kiran, 2016).Moreover, they highlight the importance of considering a detailed assessment of attention in PWA, including moment-to-moment fluctuations (Villard & Kiran, 2016).

Focused attention is one of the most basic attentional components, involving the ability to select some specific target item for enhanced processing (Mirsky et al., 1991). It seems to be impaired in a variety of conditions such as ADHD, affective disorders, schizophrenia, brain injury and developmental language disorders (Egeland & Kovalik-Gran, 2010b). So, focused attention deficits in PWA seem quite expectable. Notwithstanding, some previous results have found people with aphasia to display normal-like performance in basic attention tasks, with difficulties only arising in selective or divided attention (Erickson et al., 1996; Hunting-Pompon et al., 2011) or under automatically-driven attention (Hunting-Pompon et al., 2011).

Our present results show that basic focused attention deficits in PWA might be detected when tested with a comprehensive instrument such as C-CPT. In particular, differences with the control sample did not arise in the most basic index of focused attention (commission errors) but in more subtle indices of response speed inconsistency. In a previous study using vigilance tasks, Laures (2005) find PWA to respond to target stimuli outside the time range allowed by the task on some trials, thus loosing the target and responding incorrectly to the following non-target stimulus. This same variability in response speed seems to be reflected here in RT inconsistency indices (Hit RT SE and RT variability) and in the high number of "perseveration" errors made by PWA. Considering that C-CPT tags as perseverations abnormally fast responses (sooner than 100 ms post-stimulus), C-CPT perseverations mostly correspond to anomalous slow responses failed to execute within the previous stimulus time window, just like in Laures study.

Moment to moment variability in processing efficiency has been previously suggested to play a decisive role in aphasic performance (Hula & McNeil, 2008; McNeil & Pratt, 2001, Villard& Kiran, 2016). Our current results thus highlight, in line with Laures report, the putative relevance of intra-individual variability in response speed in PWA. While response speed variability has gained increased interest as a marker of neurocognitive impairment (MacDonald et al., 2006) it seems to have been surprisingly overlooked in aphasia research.

More important to our current purposes, performance in C-CPT indices of focused attention, including response speed variability, were highly associated with performance in some linguistic tasks for PWA. In particular, we found moderate to high correlations with phonological discrimination and semantic association tasks in PWA, but not in controls. This is in agreement with a recent study using principal component analysis of the performance of PWA in a wide set of linguistic and cognitive tasks (Butler, Lambon Ralph, & Woollams, 2014). In this study, phonological discrimination in pseudowords and a semantic association task were found to load in a common factor with other non-linguistic cognitive tasks.

Phonological discrimination and semantic processing deficits have been described as distinct but crucial contributors to language comprehension in aphasia (Robson, Sage, et al., 2012). Recent evidence also shows that a direct influence of phonological discrimination difficulties in comprehension is evidenced in people with Wernicke's aphasia when properly evaluated and classified (Robson, Keidel, Lambon Ralph, & Sage, 2012), and, generally speaking, phonological discrimination difficulties might at least play a contributory role in aphasic comprehension deficits (Blumstein et al., 1977). Neuroimaging studies have shown how attention modulates activity over primary and secondary sensory areas (Jaencke et al., 1999) thus enhancing speech discrimination skills. With regard to semantic association tasks, they seem to depend on executive semantic skills that retrieve, compare and manipulate semantic information. These executive semantic processing skills depend on a distributed fronto-temporo-parietal network comprising both semantic and domain-general components (Whitney et al., 2012). Intra-individual variability in focused attention might therefore constraint the capacity to retrieve, compare and manipulate semantic information, as reflected by our current results. In this regard, previous studies have shown performance in tests of semantic association in people with aphasia seems to be influenced by non linguistic cognitive skills (Butler et al., 2014; Jefferies, 2006).

In our current study, both phonological discrimination and semantic association tasks involve the necessity to compare a set of highly similar stimuli and make decisions based on subtle differences. For the phonological discrimination task, a phonetic contrast make a minimal phonological difference among highly similar pseudowords. In semantic association tasks, the semantic characteristics of different elements must be analyzed and compared. Thus, it seems that PWA failures in focused attention might exacerbate difficulties selecting and identifying crucial linguistic features in order to distinguish among highly similar items, both in the phonological and in the semantic domain.

Moreover, the relevance of focused attention variability for language performance is highlighted by the results of stepwise linear regression analysis. Response speed variability explained a significant amount of variance, particularly in phonological discrimination, but also in the lexical decision task. It is noteworthy that response speed variability does not directly correlate to lexical decision performance, but once lexical comprehension problems indexed by SWPM are allowed to enter the model, a significant percentage of the remaining variability in lexical decision is accounted by variability in response time. Perseverations (i.e., out-of-range responses) contributed to explain variance in SWPM and semantic association tasks. The amount of variance contributed uniquely by perseverations to semantic association tasks in linear regression analysis is very low. However, it might be due to the fact that all semantic association tasks were closely related, and all them are closely associated to perseveration (see tables 6 and 8). Then, once the other semantic association tasks (which in turn are related to perseverations) are allowed to enter the model, there is little amount of variance left to account.

The present results are thus in accordance with a "weak" version of the influence of attention in aphasia (Murray, 2012), where attentional deficits may exacerbate aphasic symptoms, but not with a "strong" version where aphasic symptoms are driven by attentional impairments (Hula & McNeil, 2008). In particular, the current data serve to highlight the role of moment-to-moment variability as a modulator of performance in linguistic tasks (Villard & Kiran, 2016).

Notwithstanding, our present results are based on a limited and quite heterogeneous sample of PWA. The interaction of different attention- and language-related brain networks depending on neural damage seems a promissory area of research (Cahana-Amitay & Albert, 2014). However, the possible relationship patterns among attentional skills and aphasic symptoms depending on the damage of different brain networks can not be addressed within the current study. Here we have focused on patients suffering from posterior lesions. Tough previous research has found that PWA with frontal and posterior lesions are similarly affected by divided attention (Murray et al., 1997), future research might explore in a more detailed way how different dimensions of attention (focused, selective, sustained, executive) are related to different aphasic symptoms and neural damage.

Finally, the influence of variability in focused attention over language tasks might also have implications for the clinical management of PWA. A longitudinal analysis of interventions addressing attentional problems and its influence over linguistic performance might be quite interesting. Previous results have shown how non-linguistic difficulties influence the recovery of language skills (Lambon Ralph et al., 2010) and how interventions over attention might be helpful for linguistic recovery (Helm-estabrooks, Connor, & Albert, 2000).

Overall, the present study provide additional support to the current evidence suggesting that attentional capacities are an important moderator of language performance in people with post-stroke aphasia (Connor et al., 2000; Murray, 2012). Further, our results show basic difficulties in focused attention in PWA, evidenced in response speed inconsistency. In this regard, moment-to-moment variations in the efficiency of processing have been repeatedly reported in aphasia and are thought to contribute importantly to aphasic symptoms (Hula & McNeil, 2008; McNeil & Pratt, 2001). Intra-individual variability in response speed thus emerged as possible interesting index of attentional disturbances in PWA and as a mediator of language performance.

TABLES

Table 1. Demographic characteristics of PWA

Participant	Sex	Age	Education	MPSO	Stroke type	Aphasia type
PWA1	M	46	Superior	19	Ischemic	Anomic
PWA2	F	22	Secondary	4	Hemorragic	Anomic
PWA3	F	32	Superior	5	Ischemic	Fluent
PWA4	F	79	Elementary	8	Ischemic	Fluent
PWA5	M	52	Superior	4	Ischemic	Anomic
PWA6	M	55	Superior	63	Ischemic	Anomic
PWA7	F	40	Secondary	9	Ischemic	Anomic
PWA8	F	41	Elementary	10	Hemorragic	Fluent
PWA9	F	40	Superior	5	Hemorragic	Fluent
PWA10	M	50	Secondary	6	Hemorragic	Fluent
PWA11	M	44	Secondary	6	Ischemic	Anomic
PWA12	M	71	Elementary	3	Ischemic	Fluent
PWA13	M	72	Superior	23	Hemorragic	Sensory
PWA14	M	72	Elementary	4	Ischemic	Fluent
PWA15	F	59	Secondary	26	Ischemic	Fluent
PWA16	F	77	Elementary	2	Ischemic	Fluent
PWA17	M	48	Elementary	8	Ischemic	Fluent
PWA18	M	51	Secondary	7	Ischemic	Anomic
PWA19	M	50	Secondary	9	Hemorragic	Anomic
PWA20	M	49	Secondary	7	Hemorragic	Anomic
PWA21	F	60	Secondary	3	Hemorragic	Fluent

MPSO: Months Post Stroke Onset

Table 2. Comparison of demographic characteristics between groups.

	PWA	Controls	Statistic	d.f.	p-value
Age (Mean ±SD)	52.9 ±14.94	53.3 ±15.15	251.5[a]		.99
Sex (Male:female)	12:9	10:14	1.07[b]	1	.30
Education (Primary/secondary/superior)	6/9/6	10/4/10	3.74[b]	2	.15

[a]Mann-Whitney U; [b]Chi-square; d.f.: degrees of freedom

Table 3. Comparison between groups in C-CPT performance.

C-CPT indices	PWA Mean (±SD)	Controls Mean (±SD)	Mann-Whitney U	p-value
Focused attention				
Omissions	20.10 (26.79)	11.04 (15.82)	216	.411
Hit RT SE	12.39 (12.43)	5.97 (3.62)	116	**.002**
RT variability	17.74 (20.22)	8.88 (7.23)	163	**.043**
Perseverations	3.24 (5.07)	0.88 (1.70)	148	**.012**
Sustained attention				
Hit RT block change	-0.015 (0.04)	-0.005 (0.02)	227.5	.575
Hit RT SE block change	-0.022 (0.08)	-0.038 (0.06)	232	.649
Impulsivity				
Commissions	14.48 (7.21)	11.29 (7.09)	198	.217
Hit RT	524 (169)	422 (78)	149	**.019**
Response style	1.21 (1.70)	1.65 (2.79)	236	.716
Vigilance				
Hit RT ISI change	0.053 (0.08)	0.015 (0.04)	185	.126
Hit RT SE ISI change	-0.001 (0.16)	-0.029 (0.08)	236.5	.724

Table 4. Correlation among demographic variables and C-CPT performance

	PWA		Controls
C-CPT indices	Age	MPSO	Age
Focused attention			
Omissions	0.365	-0.161	0.278
Hit RT SE	0.295	-0.184	0.790^{***}
RT variability	0.266	-0.049	0.793^{***}
Perseverations	0.229	0.018	0.546^{**}
Sustained attention			
Hit RT block change	-0.728^{***}	0.101	0.017
Hit RT SE block change	-0.574^{**}	0.034	-0.072
Impulsivity			
Commissions	0.113	0.024	0.264
Hit RT	0.260	-0.191	0.583^{**}
Response style	0.293	0.027	-0.059
Vigilance			
Hit RT ISI change	-0.473^{*}	-0.243	-0.433^{*}
Hit RT SE ISI change	-0.332	-0.291	0.104

MPSO: Months post stroke onset. $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$

Table 5. Correlation among demographic variables and linguistic tasks

	PWA		Controls
Linguistic tasks	Age	MPSO	Age
Phonological Processing			
PhonDisc	-0.418	0.153	-0.234
WRep	-0.439*	0.453*	0.090
PWRep	-0.397	0.205	-0.008
Lexical Processing			
ALD	-0.508**	0.060	-0.235
SWPM	-0.251	-0.023	-0.134
BNT	-0.328	0.143	-0.431*
Semantic Processing			
O-A	-0.428	-0.025	-0.152
SA	-0.385	-0.040	-0.157
O-O-O	-0.292	0.099	-0.258

MPSO: Months post stroke onset. *p < .05; **p < .01.

Table 6. Correlations among C-CPT indices and linguistic tasks in PWA.

	Phonological Processing			Lexical Processing			Semantic Processing		
	PhonDisc	WRep	PWRep	ALD	sWPM	BNT	O-A	SA	O-O-O
Focused attention									
Omissions	-0.540*	-0.441*	-0.392	-0.189	-0.131	-0.084	-0.420	-0.407	-0.470*
Hit RT SE	-0.580**	-0.305	-0.422	-0.410	0.046	-0.163	-0.221	-0.359	-0.439*
RT Variability	-0.609**	-0.264	-0.385	-0.416	-0.079	-0.096	-0.334	-0.496*	-0.500*
Perseverations	-0.423	-0.281	-0.299	-0.366	-0.129	-0.165	-0.514*	-0.456*	-0.580**
Sustained attention									
Hit RT block change	0.294	0.201	0.149	0.387	0.414	0.277	0.490*	0.319	0.283
Hit RT SE block change	0.127	0.244	0.238	0.153	0.410	0.249	0.257	0.271	0.132
Impulsivity									
Commissions	-0.398	-0.127	-0.080	-0.007	-0.109	-0.028	-0.589**	-0.425	-0.322
Hit RT	-0.408	-0.251	-0.270	-0.193	-0.125	-0.373	-0.170	-0.266	-0.483*
Response style	0.002	-0.035	0.053	-0.345	0.036	0.456	-0.230	-0.155	0.051
Vigilance									
Hit RT ISI change	-0.173	-0.086	-0.051	0.367	-0.158	-0.147	-0.130	-0.047	-0.237
Hit RT SE ISI change	-0.210	0.048	0.038	0.039	-0.236	-0.172	-0.133	-0.089	-0.234

$^{*}p < .05$; $^{**}p < .01$.

Table 7. Correlations among C-CPT indices and linguistic tasks in controls.

	Phonological Processing			Lexical Processing			Semantic Processing		
	PhonDisc	WRep	PWRep	aLD	SWPM	BNT	O-A	SA	O-O-O
Focused attention									
Omissions	0.017	0.076	0.358	-0.387	0.030	0.020	0.263	-0.073	-0.119
Hit RT SE	-0.328	-0.286	0.037	-0.202	-0.059	-0.346	-0.153	-0.155	0.101
RT Variability	-0.146	0.015	0.131	-0.397	-0.274	-0.206	0.055	-0.148	-0.073
Perseverations	-0.157	-0.208	0.184	-0.274	0.111	-0.237	-0.061	-0.130	0.254
Sustained attention									
Hit RT block change	0.257	0.351	-0.025	-0.144	-0.105	0.443*	0.014	0.107	-0.017
Hit RT SE block change	-0.055	0.242	-0.217	0.620**	0.097	0.157	-0.085	0.163	0.041
Impulsivity									
Commissions	0.124	0.076	0.005	-0.391	0.030	0.214	0.242	-0.190	0.434*
Hit RT	-0.492*	-0.256	0.017	0.091	0.200	-0.647**	-0.448*	-0.237	-0.326
Response style	0.006	0.316	0.113	-0.123	0.037	0.111	0.214	-0.056	-0.116
Vigilance									
Hit RT ISI change	0.079	-0.347	0.023	-0.031	-0.141	0.142	-0.014	0.106	0.102
Hit RT SE ISI change	-0.299	-0.347	0.294	0.142	-0.030	-0.298	-0.509*	-0.280	-0.235

*p < .05; **p < .01.

Table 8. Correlations among linguistic tasks in PWA.

	PhonDisc	WRep	PWRep	aLD	SWPM	BNT	O-A	SA
WRep	0.583^{**}							
PWRep	0.613^{**}	0.846^{***}						
aLD	0.146	0.088	0.189					
SWPM	0.104	-0.011	-0.149	-0.013				
BNT	0.357	0.487^{*}	0.486^{*}	-0.041	0.254			
O-A	0.166	0.101	0.016	0.240	0.595^{**}	0.240		
SA	0.254	0.128	0.155	0.270	0.568^{**}	0.152	0.798^{***}	
O-O-O	0.351	0.330	0.299	0.137	0.423	0.652^{**}	0.716^{***}	0.748^{***}

$^{*}p < .05$; $^{**}p < .01$; $^{***}p<.001$

Table 9. Results of stepwise linear regression analysis in PWA with attention scores emerging as significant predictors of language performance.

	Model				Variables entered			
Dependent variable	Adjusted R^2	F	df	p-value	Variable	Change in R^2	Beta	p-value
PhonDisc	0.466	15.862	1,16	.001	RT variability	0.498	-0.706	.001
aLD	0.489	9.149	2,15	<.01	SWPM	0.389	0.450	<.05
					RT variability	0.161	-0.437	<.05
SWPM	0.782	21.372	3,14	<.001	O-A	0.471	1.060	<.001
					Perseverations	0.291	0.673	.001
					BNT	0.059	0.265	.05
O-A	0.916	63.141	3,14	<.001	S-A	0.771	0.422	<0.01
					SWPM	0.116	0.475	<.001
					Perseverations	0.045	-0.339	<.01
O-O-O	0.909	43.532	4,13	<.001	S-A	0.715	0.540	<.001
					BNT	0.096	0.352	<.001
					Perseverations	0.094	-0.420	<.01

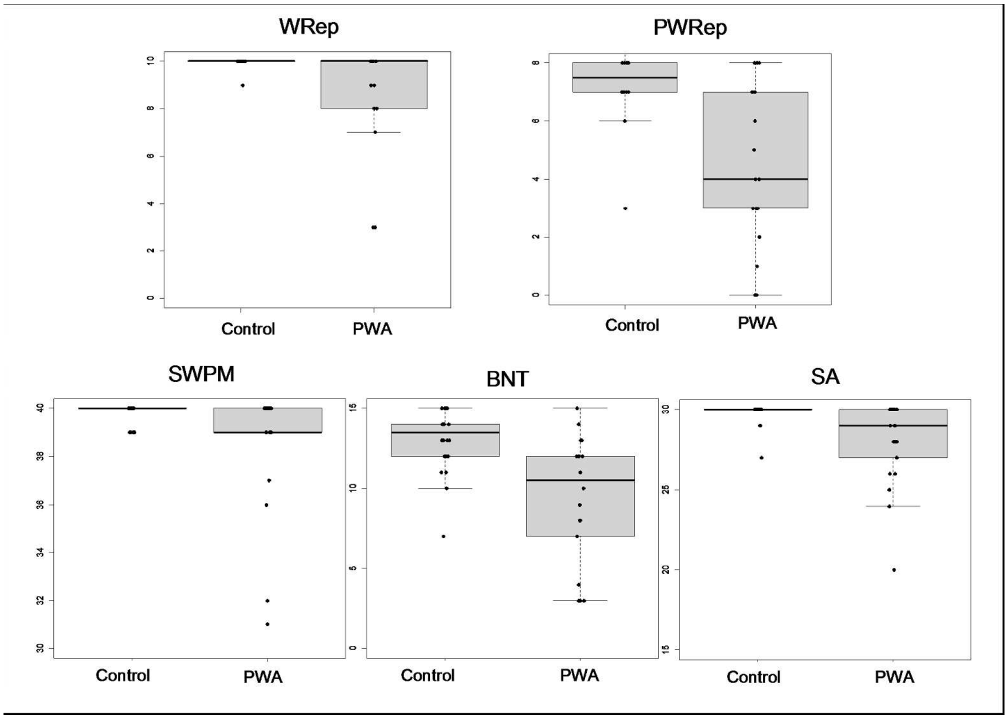

Figure 1. Dot plots of the performance of PWA and controls on linguistic tasks showing reliable group differences.

200x143mm (300 x 300 DPI)

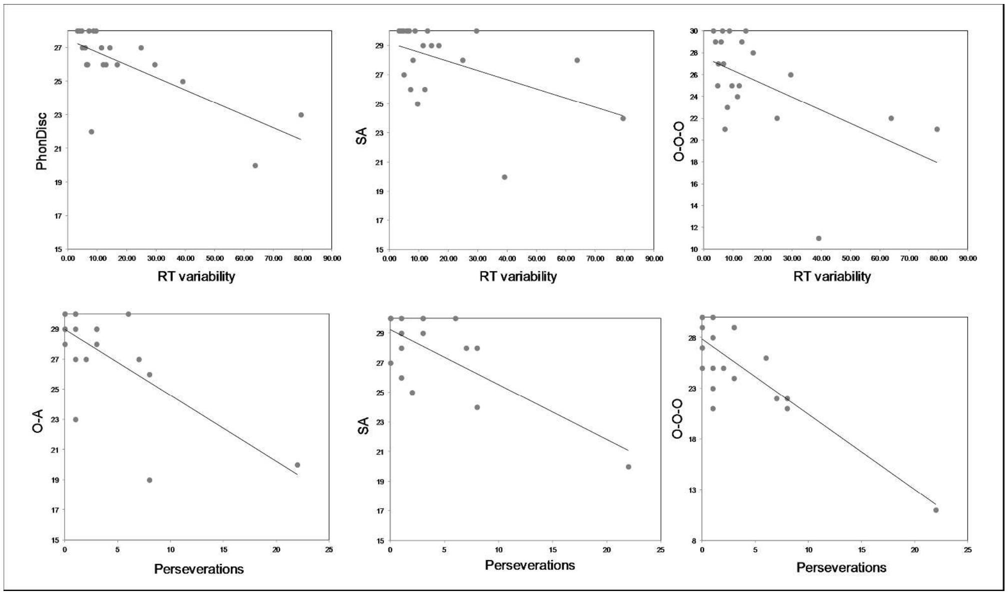

Figure 2. Scatterplots showing the relationship of Hit RT variability with PhonDisc, SA and O-O-O tasks (upper row) and the relationship of Perseverations with O-A, S-A and O-O-O tasks (lower row).

260x152mm (300 x 300 DPI)

REFERENCES:

Blumstein, S. E., & Amso, D. (2013). Dynamic Functional Organization of Language: Insights From Functional Neuroimaging. *Perspectives on Psychological Science : A Journal of the Association for Psychological Science*, *8*(1), 44–8. http://doi.org/10.1177/1745691612469021

Brancal, M. F., Alcantud, F., Ferrer, A. M., & Quiroga, M. E. (2007). *Evaluación de la discriminación auditiva y fonológica* (2nd ed.). Barcelona: Ediciones Lebón.

Butler, R. a, Lambon Ralph, M. a, & Woollams, A. M. (2014). Capturing multidimensionality in stroke aphasia: mapping principal behavioural components to neural structures. *Brain*, *137*(12), 3248–3266. http://doi.org/10.1093/brain/awu286

Cahana-Amitay, D., & Albert, M. L. (2014). Brain and Language: Evidence for Neural Multifunctionality. http://doi.org/10.1155/2014/260381

Caplan, D., Waters, G., DeDe, G., Michaud, J., & Reddy, A. (2007). A study of syntactic processing in aphasia I: Behavioral (psycholinguistic) aspects. *Brain and Language*, *101*, 103–150. http://doi.org/10.1016/j.bandl.2006.06.225

Conners, C. K. (2002). *Conners' continuous performance test (CPTII). Technical guide and software manual.* North Tonawanda, NY: Multi Health System.

Connor, L. T., Albert, M. L., Helm-Estabrooks, N., & Obler, L. K. (2000). Attentional Modulation of Language Performance. *Brain and Language*, *71*(1), 52–55. http://doi.org/10.1006/brln.1999.2210

Cuetos, F., & González-Nosti, M. (2009). *BETA. Batería para la Evaluación de los Trastornos Afásicos*. Madrid: EOS.

Egeland, J., & Kovalik-Gran, I. (2010a). Measuring Several Aspects of Attention in One Test: The Factor Structure of Conners's Continuous Performance Test. *Journal of Attention Disorders*, *13*(4), 339–346. http://doi.org/10.1177/1087054708323019

Egeland, J., & Kovalik-Gran, I. (2010b). Validity of the Factor Structure of Conners' CPT. *Journal of Attention Disorders*, *13*(4), 347–357. http://doi.org/10.1177/1087054709332477

Erickson, R. J., Goldinger, S. D., & Lapointe, L. L. (1996). Auditory Vigilance in Aphasic Individuals: Detecting Nonlinguistic Stimuli with Full or Divided Attention. *BRAIN AND COGNITION*, *30*, 244–253.

Fedorenko, E., Behr, M. K., & Kanwisher, N. (2011). Functional specificity for high-level linguistic processing in the human brain. *Proceedings of the National*

Academy of Sciences, *108*(39), 16428–16433. http://doi.org/10.1073/pnas.1112937108

Fedorenko, E., & Thompson-Schill, S. L. (2014). Reworking the language network. *Trends in Cognitive Sciences*, *18*(3), 120–6. http://doi.org/10.1016/j.tics.2013.12.006

Fernández-Blázquez, M. a, Ruiz-Sánchez de León, J. M., López-Pina, J. a, Llanero-Luque, M., Montenegro-Peña, M., & Montejo-Carrasco, P. (2012). Nueva versión reducida del test de denominación de Boston para mayores de 65 años: aproximación desde la teoría de respuesta al ítem. *Revista de Neurologia*, *55*(7), 399–407. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/23011858

Helm-Estabrooks, N. (2002). Cognition and aphasia: a discussion and a study. *Journal of Communication Disorders*, *35*, 171–186.

Helm-estabrooks, N., Connor, L. T., & Albert, M. L. (2000). Nancy Helm-Estabrooks, Lisa Tabor Connor, and Martin L. Albert. *Brain and Language*, *74*, 469–472.

Howard, D., & Patterson, K. (1992). *The Pyrams and Palm Trees Test: a test for semantic access from words and pictures*. Bury St. Edmunds: Thames Valley Test Company.

Hula, W. D., & McNeil, M. R. (2008). Models of attention and dual-task performance as explanatory constructs in aphasia. *Seminars in Speech and Language*, *29*(212), 169–187. http://doi.org/10.1055/s-0028-1082882

Hunting-Pompon, R., Kendall, D., & Moore, A. B. (2011). Examining attention and cognitive processing in participants with self-reported mild anomia. *APHASIOLOGY*, *25*, 6–7. http://doi.org/10.1080/02687038.2010.542562

Jefferies, E. (2006). Semantic impairment in stroke aphasia versus semantic dementia: a case-series comparison. *Brain*, *129*(8), 2132–2147. http://doi.org/10.1093/brain/awl153

Kay, J., Lesser, R., & Coltheart, M. (1992). *PALPA: Psycholinguistic assesment of language processing in aphasia*. London: Lawrence Erlbaum.

Lambon Ralph, M. A., Snell, C., Fillingham, J. K., Conroy, P., & Sage, K. (2010). Predicting the outcome of anomia therapy for people with aphasia post CVA: Both language and cognitive status are key predictors. *NEUROPSYCHOLOGICAL REHABILITATION*, *20*(2), 289–305. http://doi.org/10.1080/09602010903237875

Laures, J. S. (2005). Reaction time and accuracy in individuals with aphasia during auditory vigilance tasks. *Brain and Language*, *95*, 353–357. http://doi.org/10.1016/j.bandl.2005.01.011

Lee, B., & Pyun, S.-B. (2014). Characteristics of cognitive impairment in patients with post-stroke aphasia. *Annals of Rehabilitation Medicine*, *38*(6), 759–765.

http://doi.org/10.3760/cma.j.issn.0376-2491.2012.03.002

MacDonald, S. W. S., Nyberg, L., & Bäckman, L. (2006). Intra-individual variability in behavior: links to brain structure, neurotransmission and neuronal activity. *Trends in Neurosciences*, *29*(8), 474–480. http://doi.org/10.1016/j.tins.2006.06.011

McNeil, M. R., & Pratt, S. R. (2001). Defining aphasia: Some theoretical and clinical implications of operating from a formal definition. *Aphasiology*, *15*(10-11), 901–911. http://doi.org/10.1080/02687040143000276

Mirsky, A. F., Anthony, B. J., Duncan, C. C., Ahearn, M. B., & Kellam, S. G. (1991). Mirsky et al 1992 NP AUT Attn Neuro. *Neuropsychology Review*, *2*(2), 109–145.

Murray, L. L. (2000). The Effects of Varying Attentional Demands on the Word Retrieval Skills of Adults with Aphasia, Right Hemisphere Brain Damage, or No Brain Damage. *Brain and Language*, *72*, 40–72. http://doi.org/10.1006/brln.1999.2281

Murray, L. L. (2012). Attention and other cognitive deficits in aphasia: Presence and relation to language and communication measures. *American Journal of Speech-Language Pathology*, *21*(2), 51–65. http://doi.org/10.1044/1058-0360(2012/11-0067)

Murray, L. L., Holland, A. L., & Beeson, P. M. (1997). Auditory Processing in Individuals With Mild Aphasia: A Study of Resource Allocation. *JSLHR Journal of Speech, Language, and Hearing Research JSLHR*, *40*(40), 792–808.

Murray, L. L., Holland, A. L., & Beeson, P. M. (1998). Spoken Language of Individuals With Mild Fluent Aphasia Under Focused and Divided-Attention Conditions. *Journal of Speech, Language, and Hearing Research JSLHR American Speech-Language-Hearing Association Journal of Speech, Language, and Hearing Research*, *4198*(213), 213–227.

Peña Casanova, J. (2005). *Test Barcelona Revisado* (2nd ed.). Barcelona: Masson.

Robson, H., Keidel, J. L., Lambon Ralph, M. A., & Sage, K. (2012). Revealing and quantifying the impaired phonological analysis underpinning impaired comprehension in Wernicke's aphasia. *Neuropsychologia*, *50*(2), 276–288. http://doi.org/10.1016/j.neuropsychologia.2011.11.022

Robson, H., Sage, K., & Lambon Ralph, M. A. (2012). Wernicke's aphasia reflects a combination of acoustic-phonological and semantic control deficits: A case-series comparison of Wernicke's aphasia, semantic dementia and semantic aphasia. *Neuropsychologia*, *50*(2), 266–275. http://doi.org/10.1016/j.neuropsychologia.2011.11.021

Sohlberg, M. M., & Mateer, C. a. (1987). Effectiveness of an attention-training program. *Journal of Clinical and Experimental Neuropsychology*, *9*(2), 117–130.

http://doi.org/10.1080/01688638708405352

Valle, F., & Cuetos, F. (1995). *EPLA: Evaluación del procesamiento lingüístico en la afasia*. Hillsdale, NJ: Lawrence Erlbaum.

Villard, S., & Kiran, S. (2015). Between-session intra-individual variability in sustained, selective, and integrational non-linguistic attention in aphasia. *Neuropsychologia*, *66*, 204–212. http://doi.org/10.1016/j.neuropsychologia.2014.11.026