University of Padova

Department of Philosophy, Sociology, Education and Applied Psychology

Master's degree in Clinical, Social and Intercultural Psychology

Final dissertation

(Pragmatic-Communicative Impairment in Left and Right Hemisphere Stroke Patients)

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Academic Year: 2023/2024

Acknowledgements

I would like to express my gratitude to Professor Sara Mondini, my academic supervisor, for her support and guidance in getting this thesis, and my education, to where it is today. For creating this wonderful program, for helping me choose my future steps, and for her advice, I am very grateful.

I would also like to express my heartfelt gratitude to Dr. Giorgio Arcara, my supervisor at the San Camillo Neurorehabilitation Hospital, for his incredible support, patience, and guidance. I am fortunate to have such a dedicated and experienced supervisor, and his expertise has been invaluable in every step of this study. I am profoundly grateful, and could not have gotten this far without his help.

I would also like to thank Dr. Sara Lago, my dear colleague at San Camillo IRCCS, for her support, for her contributions to this research, and for her assistance.

I want to thank my parents, who have always supported and inspired me, and my siblings, for their love and encouragement.

Everyone who has helped me in any stage of this journey, be it through encouragement, a challenge to do better, inspiration through example, or practical assistance, has been invaluable in this process. I am so very grateful for all your contributions and involvement.

Abstract

Background:Communication deficits as a result of stroke can be loosely divided into aphasia, affecting structural language abilities, and pragmatic impairment, which refers to the ability to understand and use language properly depending on context for various communicative purposes, including being able to go beyond the literal meaning of words, infer intended meaning and produce adequate discourse (Domaneschi & Bambini 2020). While aphasia has famously been tracked to left-hemisphere damage, pragmatic deficits have been persistently conceptualized as belonging solely to the right hemisphere, despite increasing data to the contrary. Several recent neuropsychological studies and neuroimaging data demonstrate that non-literal language and communication abilities seem to have bilateral brain involvement, confirmed by frequent clinician reports to the same effect. The first research question aims to explore the effect of brain lesion lateralization on pragmatic communication in patients suffering from left and right hemisphere stroke using the APACS battery. The second aim is to investigate the correlation of pragmatic impairment with other cognitive impairments in both left and right hemisphere stroke patients. We expect to find pragmatic impairment in both right and the left hemisphere, and correlations of pragmatics with other neuropsychological domains across both hemispheres.

Methods: We took 52 consecutively enrolled Stroke patients, 26 with right hemisphere damage (RHD), and 26 with left hemisphere damage (LHD). To measure Pragmatics performance, we utilized The Assessment of Pragmatic Abilities and Cognitive Substrates (APACS), which assesses discourse and non-literal language. We first confronted APACS performance of stroke patients as a group (regardless of whether the lesion was left or right; n=52) with a sample of age-matched healthy controls (n=60).We then examined the differences in APACS performances between RHD and LHD patients. We also assessed APACS scores in comparison with other neuropsychological tests across both hemispheres, testing Theory of Mind (ToM), executive functioning, fluid intelligence, cognitive states, attention, and functional communication. For this, we used the following neuropsychological tests: Story-based Empathy Task (SET), Raven's Colored

Progressive Matrices (Raven), Phonemic Fluency and Semantic Fluency, Denomination on Description, Mini-Mental State Examination (MMSE), Attentional Matrices, and Communication Outcome after Stroke (COAST), carer and therapist.

Results: Stroke patients with lesions in either hemisphere performed significantly worse on APACS than controls (except in the humor subsection). LHD patients had worse performance on Interview and Figurative Language 2 subsections than RHD patients. For the neuropsychological tests taken separately, LHD patients had significantly worse performance for COAST Therapist, MMSE, and phonemic fluencies. When testing the correlations of APACS with other neuropsychological tests, the RHD patients had a more complex profile. Description subtest strongly correlated with the score of the COAST patient, Semantic fluency correlated with Humor and Figurative Language 2. SET correlated with Narratives, Figurative Language 1, Humor and Figurative Language 2. MMSE with Humor and Figurative Language 2, and Raven Matrices with Figurative Language 1, Humor and Figurative Language 2. The LHD patients were administered the same procedure, but there were no significant correlations surviving fdr correction in this case. However, when we consider the correlations between these neuropsychological tests and APACS composite scores in the LHD patients, there are significant correlations between SET and Pragmatic Comprehension and APACS Total. The strength of the correlations is not different across LHD and RHD samples. We can therefore conclude that the cognitive and pragmatic profile does not differ between the two samples.

Conclusion: These findings suggest that there is a bilateral hemisphere involvement in pragmatic abilities, which points to a need to adjust assessment and rehabilitation of LHD patients to include pragmatic abilities as well. The similar cognitive profiles correlating with APACS across both hemispheres indicate that pragmatic cognitive substrates are moderately interconnected with Theory of Mind and executive functioning, as well as general cognition levels. We finally present a call to a more holistic assessment approach, focusing on functional communication difficulties.

Keywords: Pragmatics, Communication, Stroke, Neuropsychological Assessment, Language

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CHAPTER 1: INTRODUCTION TO CEREBRAL VASCULAR DISORDERS AND LANGUAGE IMPAIRMENT: THE ROLE OF PRAGMATICS

1.1 Defining Stroke and Pragmatics

Stroke is one of the most important acquired causes of disabilities in motor and cognitive domains (Herpich & Rincon, 2020, Karamyan, 2023). Depending on stroke location and severity, stroke patients will often struggle with lingering impairments in physical, psychological, and/or social abilities, which frequently require significant rehabilitation (Peter Kim et al., 1999). Stroke is often accompanied by communication deficits, which can have a notable negative effect on patient quality of life (Peter Kim et al., 1999, Fridriksson and Argye, 2021, Teasell and Hussein, 2016). A well-documented phenomenon in stroke is simple aphasia following left-hemisphere damage, affecting formal areas of language such as syntax, lexicon, and phonetics (Peter Kim, et al.,1999, Sheppard and Rajani, 2021). More broadly, aphasic disorders account for general communication difficulties that frequently plague stroke patients and greatly affect the quality of their relationships and many everyday activities.(Rousseaux et al., 2010)

Some communications deficits following stroke pertain to the domain of Pragmatics, which is the ability to integrate language with context and to effectively communicate (Bambini, 2010, Angeleri., Bosco, Gabbatore et al., 2012). An important domain of pragmatics is that of figurative language, which conveys meaning through words or phrases that are not literally true. Metaphors, sarcasm, irony, joke production and comprehension and wordplay are typical examples of figurative language commonly used in daily life (Ruiz-Gurillo et al., 2013; Deighton et al., 2020) An appropriate pragmatic language behavior is characterized by the capacity to maintain a clear and coherent discourse, as well as to generate and understand figurative language. Grice (Grice, 1989) suggested four maxims to pragmatics as used in typical daily conversation; quality, quantity, relation/relevance, and manner, all together working to create appropriate discourse. For example, not telling a baker all about one’s detailed health woes unprompted, or giving monosyllabic responses to a friend inquiring about a vacation. In other words, this ability underpins the very essence of human communication, which relies so heavily upon shared context. When pragmatic abilities are impaired, as they frequently are in stroke patients, the ability to produce structurally and lexically sound sentences is entirely undermined by the fact that references are lost, metaphors are taken literally, and the patient neglects the basic rules of conversation (Deighton et al., 2020). This, naturally, can have a devastating effect on patient quality of life, affecting relationships and communication with caretakers.

1.2 Left vs. Right Hemisphere Debate in Pragmatics: An Overview

A traditional view of language disorders in clinical populations has suggested a clear-cut distinction between left and right hemisphere. Left hemisphere damage would lead to more "proper" structural language disorders (i.e. aphasia), while right hemisphere damage would lead to pragmatic disorders. Right hemisphere damage has indeed been linked to deficiencies in pragmatic communication, with patients presenting an impaired ability to produce a clear and coherent discourse, to adequately generate inferences and understand non-literal utterances, sarcasm, irony and metaphors (McDonald, 2000) . The studies identifying the right hemisphere as the site of pragmatic abilities go back to the sixties; perhaps originally, in order to not conflate them with the communication difficulties that would be present in patients with aphasia due to damage of Broca's and Wernicke's areas in the left hemisphere for most people (Joannette et al., 1990). Initially, the studies examined traumatic right brain injury (Joannette et al., 1990; Winner & Gardner, 1977; Joannette & Brownell, 1990), though then a large number of non-aphasic clinical populations with other pathologies, such as schizophrenia and MS, also presented with pragmatic impairments (Bambini, 2010; Stemmer, 2008). The left hemisphere studies have either focused on non-aphasic patients, which generally meant very minimal damage, or have been avoided entirely, as it would be difficult to study nonliteral language abilities in patients with aphasia (Ferstl, 2008). There has been a number of studies focusing on right hemisphere damage as related to nonliteral language, such as the sensitivity to verbal humor in right hemisphere-damaged patients (Brownell et al., 1983), sentence picture matching task for metaphor (Winner and Gardner, 1977), and proverb interpretation (Brundage, 1996). While there have been enough studies of right-hemisphere damage to demonstrate a clear correlation with pragmatic disability (Parola et al., 2016, Cutica et al., 2006), a careful inspection of the literature suggests that linking this impairment solely to the right hemisphere may be an oversimplification (Rousseaux, Daveluy & Kozlowski, 2010).

First of all, neuroimaging studies on figurative language processing seem to indicate a bilateral involvement of brain hemispheres. Indeed, left-hemisphere damage, while more famously responsible for aphasia, has also been increasingly linked to pragmatic impairments. Recent studies of aphasic adults' profiles reveal that their pragmatic impairments are not merely a consequence of deficits in structural language (Coelho & Flewellyn, 2003): in some cases, pragmatic language impairments related to global coherence have been shown to persist despite improvements in micro-linguistic skills. Moreover, Borod et al. examined discourse features such as conciseness, lexical selection, quantity, relevancy, specificity, and topic maintenance in brain-damaged subjects and controls (Borod et al., 2000) . People with left hemisphere damage showed more difficulties in pragmatic appropriateness than patients with right hemisphere damage, with positive emotional content facilitating performance. Another interesting study found that subjects with left hemisphere damage were significantly impaired relative to age-matched normal controls in non-verbal implicature processing (Kasher et al., 1999) . These results are bolstered by recent neuroimaging studies, with fMRI experiments demonstrating bilateral involvement of brain hemispheres during tasks exploring pragmatic abilities and figurative language (Bambini et al., 2011, Bohrn et al., 2012, Rapp et al., 2012, Spotorno et al., 2012).

Finally, this discrepancy has led to a still ongoing debate, as both sources of evidence have some limits. On the one hand, neuropsychological literature shows many inconsistencies in the right lateralization of pragmatic abilities: testing with pragmatic tasks only those patients that have right-hemisphere damage could be considered a bias (Zaidel et al., 2002), also taking into account that there is a lack of strong assessment tools for evaluating functional communication in aphasic patients. There has also been research on both hemispheres that, when it did assess left-hemisphere-damaged patients, only recruited those without aphasia, meaning that they skewed the patient selection to have less clinically severe cases for the left hemisphere. Naturally, this would create skewed results when measuring communication, only in this case it would present the left hemisphere patients as not having as many communication difficulties as they, on average, do. A meta review in 2008 (Ferstl, 2008) found that depending on the focus of the study, they might stress the involvement of the right hemisphere (Bookheimer, 2002; Mar, 2004) or the functions of the left fronto-medial and lateral PFC regions (Ferstl, in press). On the other hand, neuroimaging studies provide only correlational data and it is not clear if the bilateral involvement of brain hemispheres does really imply that these areas are crucial (or ancillary) for pragmatic abilities (Enrici et al., 2019,Cutica, Bucciarelli & Bara, 2006.)

1.2 Assessment of Pragmatics

There have been several tools used for assessing pragmatics in the past, such as the Right Hemisphere Communication Battery (Gardner and Brownell, 1986) and the Right Hemisphere Language Battery (Bryan, 1995), which primarily assess non-literal language competency. The Italian language versions with the same objectives are such tests as the Assessment battery for communication (ABaCo) (Angeler et al, 2012), Batteria sul Linguaggio dell'Emisfero Destro (BLED) (Rinaldi et al., 2004), and the Italian version of the Protocole Montréal d'Évaluation de la Communication (MEC) (Tavano et al., 2013). There also exist tests that measure patient discourse and conversation skills, such as Pragmatic Protocol (Prutting and Kirchner, 1987) and the Profile of Communicative Appropriateness (Penn, 1985). In this study, we will be using a test that combines the domain of non-literal language with that of discourse and conversation skills, the Test for the Assessment of Pragmatic Abilities and Cognitive Substrates, or APACs (Arcara & Bambini, 2016). This test has been previously used to assess pragmatic communication in schizophrenia (Bambini et al., 2016, Bambini et al., 2020), multiple sclerosis (Carotenuto et al., 2018, Lago et al., 2022), traumatic brain injury (Arcara et al., 2019), and ALS (Bambini et al., 2016). APACS consists of two parts: production assessment and comprehension assessment; and has a total of six tasks: interview, scene description, narratives, figurative language 1, humor, figurative language 2 (Arcara & Bambini, 2016).

In terms of assessing pragmatics historically, there have been a few stumbling blocks. Firstly, many tests assessing pragmatics are quite long (about 90 minutes), though APACS cuts that time more than in half with an average administration time of 35-40 minutes (Arcara & Bambini, 2016). Moreover, communicative deficits, while very common in a clinical level, are often ascribed to either formal language difficulties or social cognition deficits, rather than pragmatics. The cognitive substrates of pragmatics also seem to be related to several other cognitive domains, in particular Theory of Mind (ToM), or the ability to represent another's mental and emotional state internally (Premack and Woodruff, 1978), as well as executive functioning, which includes in it attention switching, working memory, set-shifting, inhibition, planning and flexibility (McDonald, 2008; Stemmer, 2008). For example, there is neuroimaging evidence that some of the same brain regions (the medial prefrontal cortex (mPFC) (Amodio et al., 2006, Krall et al., 2015; Kobayashi et al., 2006), and the bilateral temporo-parietal junction (TPJ) (Kobayashi et al., 2007; Frank et al., 2015)) are involved in both Pragmatics and ToM. Also, executive functions like attention are needed to some degree when participating in pragmatic aspects of language, so it might not be clear if deficits are related to executive dysfunction or pragmatics, as with many testing domains (Champagne-Lavau & Joanette, 2009; Barkley, 2001; Lezak et al., 2012; Mondini et al., 2022). While these functions do not fully account for pragmatics, there is enough interplay to create a puzzle in regards to the cognitive substrates of pragmatics in the literature (Champagne-Lavau et al., 2007), though pragmatic behavior itself and communication difficulties in clinical settings are indeed prevalent enough to merit a serious approach to diagnosis and rehabilitation (Stemmer, 2008).

Purpose and Interests of This Study: Two Hypotheses

As of now, there is much contradiction between the traditional conceptualization of lateralized communication difficulties and what has been observed in clinical settings and neuroimaging data. If indeed post-stroke pragmatic difficulties are bilateral, the persisting attribution of pragmatic deficits solely to right hemisphere brain damage can lead to improper rehabilitation goals, dismissal of pragmatic deficit symptoms, and ineffective treatment outcomes. It is therefore important to clarify the degree to which the lateralization of stroke damage plays a role in pragmatic deficits. Not only can this clarification then play a role in rehabilitation plans for individual stroke patients, an updated conceptualization of pragmatic deficits can be applied to other types of brain damage, such as traumatic brain injury, MS, ALS, and more. Finally, adding nuance to yet another dichotomous assumption in neuropsychology can help erode the lingering misapprehension that the brain is neatly divisible into functional segments, each of which is responsible for a single area of expertise, rather than the interconnected system it is emerging to be. We therefore put our first aim as exploring the possible differences in the pragmatic profiles of left and right stroke patients, or more simply, the differences in APACS performances between the two groups. We hypothesize that there will be some pragmatic impairment in the left hemisphere as well as the right hemisphere, despite traditional assumptions in the literature attributing pragmatic abilities to the right hemisphere.

Beyond the first aim, we are interested in whether pragmatic abilities correlate with other aspects of cognition in different ways across patient groups. The areas of interest in their possible correlation with Pragmatics are empathy and Theory of Mind (ToM) (here measured with SET, the Story-Based Empathy neuropsychological test), general cognition levels (Raven 47 test), attention (Attentional Matrices), phonemic and semantic fluency in production (Phonemic and Semantic Fluency tests), verbal comprehension (Denomination on Description), and finally, the perception of communication difficulties by therapist and carer (COAST patient and carer). There have already been studies linking pragmatics to other cognitive domains like declarative memory, working memory, attention, executive functions, and social cognition; all have been found to correlate (Rowley et al., 2017). We had access to enough neuropsychological tests by the same patients we tested for APACS to run our own correlations, also adding Theory of Mind and empathy domains, as well as testing for perception of communication difficulties. Of particular interest in this research is the correlations that pragmatics might have with Theory of Mind (ToM). There have been a number of studies claiming that pragmatics in general is underpinned by or at least intertwined with Theory of Mind, or the ability to take in another's perspective, utilizing also knowledge of the world and memory (Frank, 2018, Bambini et al., 2016). Based on this research, we expect to find correlations of APACS pragmatic performance with other neuropsychological tests, especially those measuring Theory of Mind and executive functioning.

In the present study, our aims are twofold: first, to explore the effect of brain lesion lateralization on pragmatic abilities of patients suffering from left and right hemisphere stroke by using comprehensive tests, applied to consecutively enrolled stroke patients. The second aim is to investigate the correlation of this impairment with other cognitive impairments in both left and right hemisphere stroke patients. We hypothesize that pragmatic impairment will be found in both hemisphere stroke patients, and that these pragmatic impairments will correlate with some other neuropsychological tests, particularly Theory of Mind and executive functions.

CHAPTER 2: RESEARCH METHODS

2.1 Participants

We took 52 stroke patients, consecutively enrolled, with inclusion criteria of:

- Age > 18 years
- Stroke either to the left or the right hemisphere
- Absence of previous relevant psychiatric or neurological conditions (other than those defining membership to the experimental group)
- Ability to sign an informed consent form
- Being a native speaker of Italian.

Exclusion criteria were:

- Presence of disabilities that could prevent the participation to the study
- Insufficient knowledge of Italian
- Refusal to take part in the study
- Comorbidity of multiple clinical conditions that would result in membership in multiple experimental groups
- Comorbidity with other neurological conditions
- Presence of psychiatric conditions.

Of these, 26 patients had left hemisphere stroke damage, and 26 had right hemisphere stroke damage. Of the 26 left hemisphere patients, 13 had aphasia, and of these 13, 2 patients were nonverbal.

Table 1. Demographics and t-tests results for the stroke and control groups.

Variable	df	t	p	Stroke Mean (SD)	Controls Mean (SD)
Age	110	-1.627	0.107	65.13 (11.46)	61.67 (11.07)
Education	109	1.6378	0.1044	9.90 (4.23)	11.25 (4.4)

2.2 Materials

Patients were assessed for pragmatic abilities using Assessment of Pragmatic Abilities and Cognitive Substrates APACS, and other neuropsychological tests which consist of the following: SET (Story-Based Empathy), COAST patient and carer, MMSE (Mini-Mental State Examination), Denomination on Description, Verbal Fluency (Phonemic and Semantic), Raven 47, and Attentional Matrices.

2.2.1 APACS

In order to assess the pragmatic abilities of patients and controls, we used the Assessment of Pragmatic Abilities and Cognitive Substrates (APACS) (Arcara & Bambini, 2016). The APACS test examines the two primary domains of pragmatics: discourse and non-literal language. The test is administered to Italian patients, and combines traditional tasks with refined Italian-language linguistic material (Arcara & Bambini, 2016). The test is divided into two main sections, one for production assessment and the other for comprehension assessment, consisting of a total of 6 tasks. The authors derived three composite scores from these tasks. APACS consists of the following six sections, to be described in detail below: interview, scene description, narratives, figurative language 1, humor, figurative language 2 (Arcara & Bambini, 2016).

<u>Interview</u>: The interview section aims to assess the ability of patients to engage in semi-structured conversation, focusing on four autobiographical topics and noting both areas of verbal pragmatics such as speech, informativeness, and information flow, as well as a paralinguistic dimension. Grammar and vocabulary errors are marked, as is the frequency of communication difficulties, and these are converted into scores for a maximum of 44.

<u>Scene Description:</u> The scene description tasks assesses expressive abilities in a more structured way, with participants asked to describe main elements of the scenes in ten photographs of

everyday life situations. The correct or incorrect identification of salient elements in each photograph is annotated, for a maximum score of 48.

Narratives: In the narratives task, participants are assessed in their ability to comprehend discourse and fundamental narrative elements, presenting six real article-based stories and 4-6 comprehension questions ranging from global topics to figurative expressions used. There is one open question about the topic of the story, yes/no questions about particular elements, and verbal explanation questions for non-literal expressions in the stories. Accuracy of the questions is scored, for a maximum score of 56.

Figurative language 1: This task provides 15 figurative expressions (5 highly familiar idioms, 5 novel metaphors, 5 common proverbs), and assesses the ability to infer non-literal meaning through 3 multiple-choice explanations. Each item is scored 0 or 1, and the section has a maximum score of 15.

Humor: This task assesses verbal humor comprehension ability through multiple-choice questions; seven stories are provided, with three possible endings, of which one is the correct, humorous ending that plays with literal or polysemous meanings, or presents an unexpected, non-explicit scenario. Each item is scored 0 or 1 based on accuracy, for a maximum total score of 7.

Figurative language 2: This task tests the verbal explanation of 15 figurative language items, with the subject describing the meaning of each expression. Responses are scored as 2 for a good description, 1 for an incomplete explanation, and 0 for paraphrasing or providing a literal explanation, for a maximum total score of 30.

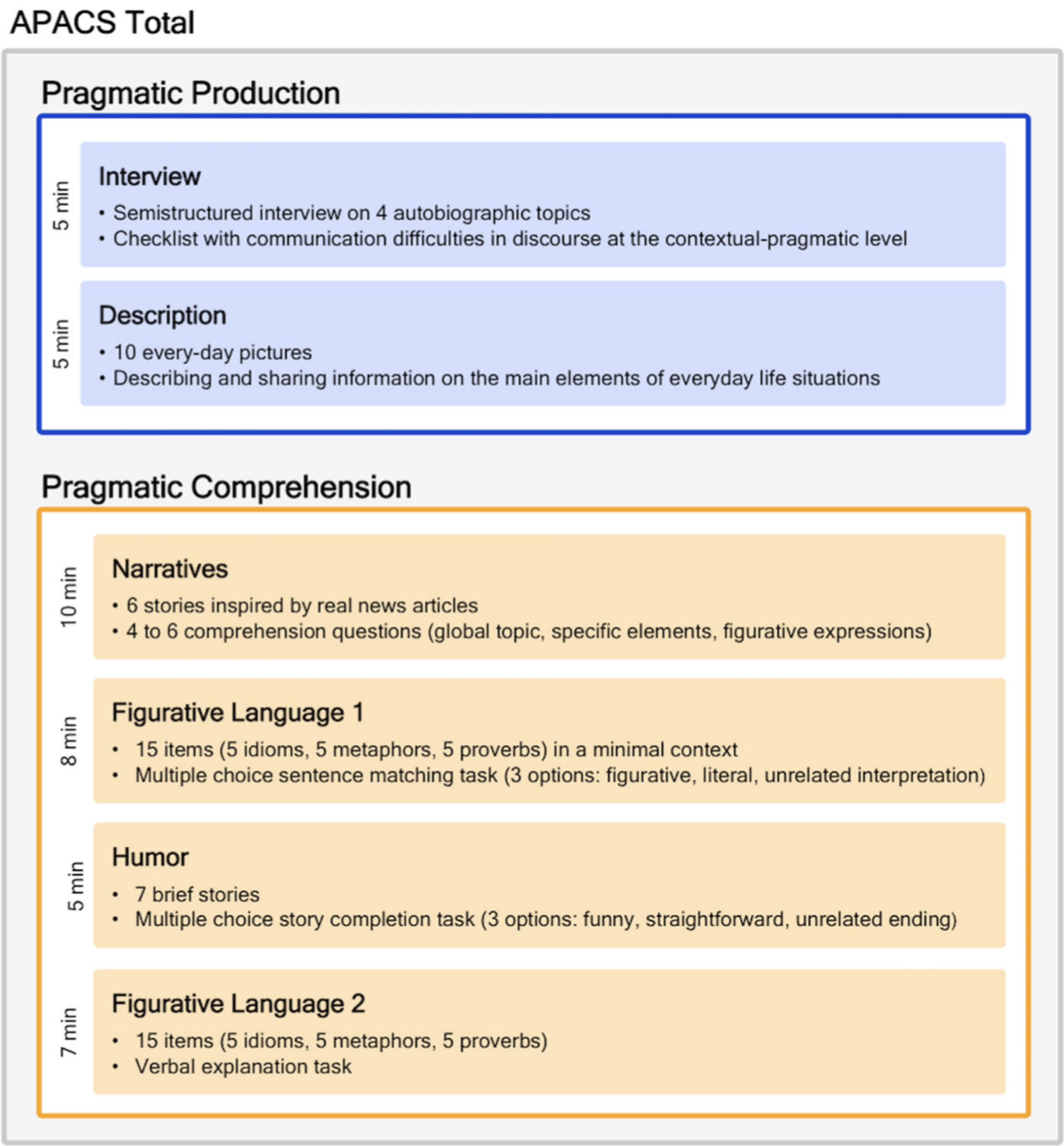

Figure 1:This figure shows the structure of the APACS test. APACS consists of two sections: Production (in blue), which has two tasks, and Comprehension (in orange), which has four tasks. Taken from Arcara and Bambini (2016).

2.2.2 Other Neuropsychological Tests

All participants took a variety of other psychological tests we thought were useful to explore the cognitive profile in the patient groups, namely: SET (Story-Based Empathy), COAST patient and carer, MMSE (Mini-Mental State Examination), Denomination on Description, Verbal Fluency (Phonemic and Semantic), Raven 47, and Attentional Matrices.

Story-based Empathy Task (SET) (Dodich et al., 2015) is a non-verbal measure of social cognition assessing both affective and cognitive Theory of Mind (ToM).

Raven's Colored Progressive Matrices (Raven 47) (Carlesimo et al., 1996) is a non-verbal test of fluid intelligence, assessing ability to solve novel tasks with abstract reasoning and logic. It is somewhat related to executive functioning, according to some studies (Roca et al., 2012)

Phonemic Fluency and Semantic Fluency (also known as Verbal Fluency tests (Italian version: Novelli et al., 1986) measures lexical retrieval/object naming performance, as well as executive function (Lezak et al., 2012.)

- In Phonemic Fluency, the subject is asked to produce as many words as they can during a set time frame (for example, two minutes), starting with a given letter. E.g., "say as many words as you can that start with the letter "N").
- In the Semantic Fluency tests, the same task was given, only participants had to name words belonging to certain simple categories. For example, "Say as many words as you can that belong to the category "plants".) in which the examinee is asked to produce as many words as possible during a limited time frame (e.g., 2 minutes). (Lezak et al., 2012, Novelli et al., 1986)

Denomination on Description, also known as Naming on Verbal Description (Novelli et al., 1986), involves the test administrator providing verbal descriptions to relatively common words, and the patient is required to name the word described.

Mini-Mental State Examination (MMSE), (Folstein et al., 1975) This is one of the most commonly used tests for assessing cognitive state in patients, with a first part which has questions testing orientation, memory, and attention, and the second part presenting questions testing verbal and written ability.

Attentional Matrices (Della Sala et al., 1992) assess selective attention deficits in the visual modality of patients.

Communication Outcome after Stroke (COAST), carer and therapist (Italian version by Bambini et al., 2017), are scales that measure functional communication and its impact on the quality of life (Bambini et al., 2017), used in our study to investigate whether difficulties in communication as perceived by the patient or the therapist can correlate with APACS)

These tests, if significantly correlated with APACS, can point to non-linguistic impairment, which would be significant for LHD patients in particular, as well as illuminate potential mechanisms/domains involved in pragmatic skills and communication difficulties more broadly.

2.3 Data Analysis

All statistical analyses were performed with R (R core team, 2023). As regards Aim1, we first compared performances between patients and healthy controls, and then between the left and right hemisphere group by means of independent samples t-tests, effect size was calculated as Cohen’s d. P-values are reported both uncorrected and using False Discovery Rate (Benjamini & Hochberg, 1995). For Aim 2, meanwhile, we explored the associations between the cognitive and pragmatic profile by means of Pearson’s correlations. We finally tested whether the differences between the correlation coefficients were actually significant across groups using z-test to compare correlation as implemented in the psych R package (Revelle, 2023).

CHAPTER 4: RESULTS

Hypothesis 1: APACS Results Across Hemispheres

As per the first aim, we first confronted APACS performance of stroke patients as a group (regardless of whether the lesion was left or right; n=52) with a sample of age-matched healthy controls (n=60). The groups were matched for age and education as measured by independent t-tests (see Table 1) and reasonably matched for gender as measured by a Chi-squared test (36 females in the control group, 21 in the stroke group; X-squared = 3.54, p = 0.06). This is ok given the limited influence that gender has on APACS performance (Arcara & Bambini, 2016).

Table 1. Demographics and t-tests results for the stroke and control groups.

Variable	df	t	p	Stroke Mean (SD)	Controls Mean (SD)
Age	110	-1.627	0.107	65.13 (11.46)	61.67 (11.07)
Education	109	1.6378	0.1044	9.90 (4.23)	11.25 (4.4)

We confronted APACS performance between stroke and healthy controls by means of independent samples t-tests (Table 2 and Figure 1). P values were FDR corrected.

Table 2. Comparison of APACS performance of stroke patients and healthy controls.

APACS subtest	df	t	Cohen's d	p	p.fdr	Mean Stroke (SD)	Mean Controls (SD)
Interview	108	-11	-2	$p < 0.001$	$p < 0.001$	35.96 (5.15)	43.25 (1.35)

Scenes	110	-7,4	-1,4	$p < 0.001$	$p < 0.001$	42.83 (4.61)	47.53 (1.64)
Narratives	110	-6,1	-1,2	$p < 0.001$	$p < 0.001$	46.23 (6.26)	52.08 (3.72)
Figurative Language 1	110	-2,8	-0,53	0,006	0,0068	13.44 (1.53)	14.17 (1.21)
Humor	110	-1,6	-0,3	0,110	0,110	5.48 (1.6)	5.93 (1.39)
Figurative Language 2	109	-8,8	-1,7	$p < 0.001$	$p < 0.001$	18.94 (4.48)	25.78 (3.71)
APACS Production	108	-10	-2	$p < 0.001$	$p < 0.001$	0.86 (0.09)	0.99 (0.02)
APACS Comprehen sion	109	-5,4	-1	$p < 0.001$	$p < 0.001$	0.79 (0.12)	0.9 (0.09)
APACS Total	107	-8,6	-1,6	$p < 0.001$	$p < 0.001$	0.82 (0.09)	0.94 (0.05)

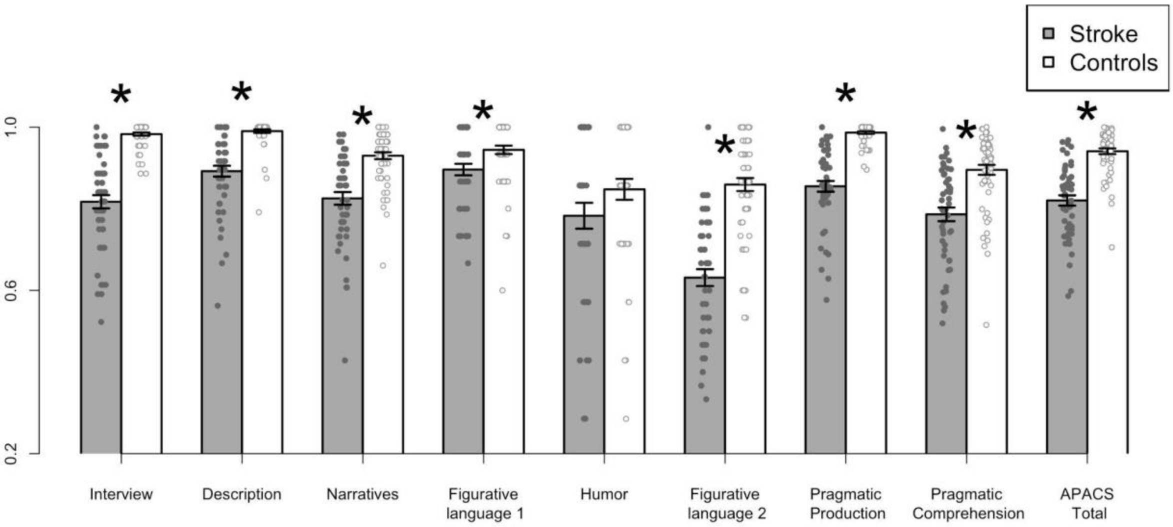

Figure 2. Comparisons of APACS performance between stroke patients and healthy controls.

As we can see from the table and figure, patients had significantly lower performances on all APACS subtests (except Humor) and composite scores, as expected.

We then compared left and right hemisphere stroke patients. The groups were matched for age and education as measured by independent t-tests (see Table 3) and for gender as measured by a Chi-squared test (11 females in the left hemisphere group, 10 in the right hemisphere group; X-squared = 0.00, p = 1.00).

Table 3. Demographics and t-tests results for the left and right hemisphere stroke groups.

Variable	df	t	p	Left Hemisphere Stroke Mean (SD)	Right Hemisphere Stroke Mean (SD)
Age	50	0.44	0.66	64.42 (10.79)	65.85 (12.25)
Education	49	-0.76	0.45	10.36 (4.16)	9.46 (4.33)

Table 4. Comparison of APACS performance of left and right hemisphere stroke patients.

APACS Subtest	df	t	Cohen's d	p	p.fdr	Left Hemisphere Stroke Mean (SD)	Right Hemisphere Stroke Mean (SD)
Interview	48	-3,3	-0,92	0,0018	0,016	33.76 (4.91)	38.16 (4.48)
Scenes	50	-0,27	-0,074	0,790	0,890	42.65 (4.73)	43 (4.57)
Narratives	50	-0,48	-0,13	0,630	0,810	45.81 (4.1)	46.65 (7.93)
Figurative Language 1	50	-1,2	-0,33	0,240	0,430	13.19 (1.52)	13.69 (1.52)
Humor	50	-0,086	-0,024	0,930	0,930	5.46 (1.77)	5.5 (1.45)
Figurative Language 2	49	-2,8	-0,77	0,008	0,036	17.28 (3.99)	20.54 (4.4)
APACS Production	48	-2	-0,55	0,054	0,160	0.83 (0.09)	0.88 (0.09)
APACS Comprehension	49	-1,1	-0,3	0,290	0,430	0.77 (0.11)	0.8 (0.13)
APACS Total	47	-1,6	-0,44	0,120	0,270	0.8 (0.09)	0.84 (0.09)

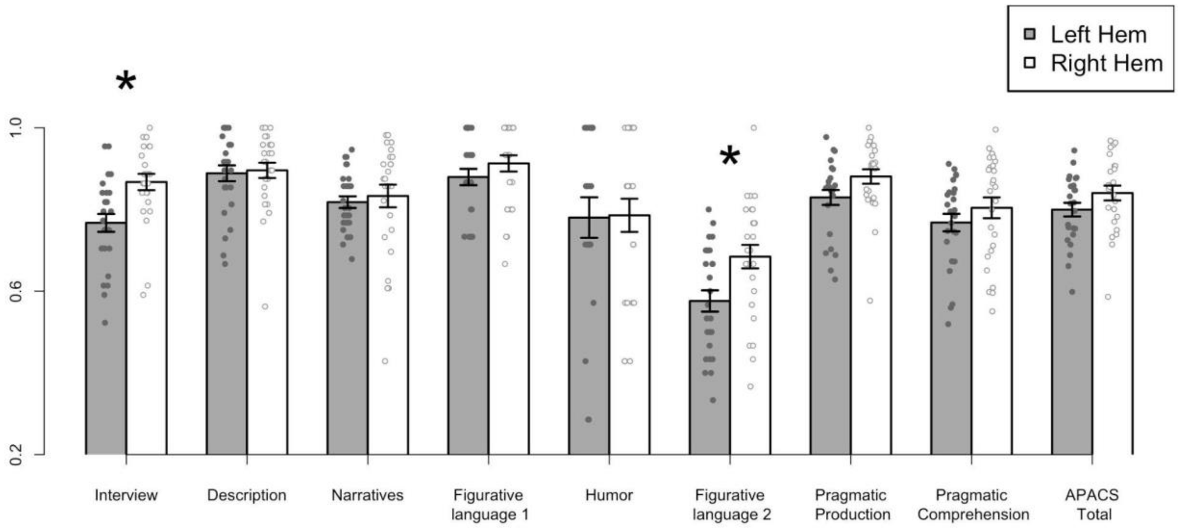

Figure 3. Comparison of APACS performance of left and right hemisphere stroke patients.

Left hemisphere stroke patients had significantly lower performances compared with right hemisphere stroke patients on the Interview and Figurative Language 2 subtests.

We note that these subtests are the ones where participants can talk more freely, so we can hypothesize that left hemisphere patients are more prone to language deficits. This may be the reason why they have lower scores on Interview and Figurative language 2, while performance on other tests is comparable between the two groups. These considerations are addressed more in depth by the analyses performed for Aim 2, where we will compare the cognitive profiles and explore the correlations between pragmatic and cognition in the two patient groups. The poor left hemisphere performance on APACS matches our hypothesis that both hemispheres would have impaired pragmatic skills.

Hypothesis 2: Correlations of APACS with Other Neuropsychological Tests

As per the second aim, we investigated the correlation of the pragmatic impairment with other cognitive impairments in both left and right hemisphere stroke patients.

For each test, the number of observations (participants that completed the test) was different across groups (see Table 5).

Table 5. Number of observations for each test in the left and right hemisphere damage group.

Neuropsychological Test	LHD	RHD
APACS	24	25
COAST Therapist Total	26	18
MMSE	20	25
RAVEN 47	23	25
Attentional Matrices	23	26
Denomination on Description	4	25
Phonemic Fluency	11	26
Semantic Fluency	11	26
SET Total	26	26
Coast Patient	26	19

First of all, we compared performances between the left and right hemisphere group in all these tests, by means of independent samples t-tests, as we did previously.

Table 6. Comparisons of neuropsychological tests performance between left and right hemisphere stroke patients.

Neuropsychological test	df	t	Cohen's d	p	p.fdr	Mean LHD (SD)	Mean RHD (SD)
SET Total	50	1,9	0,53	0,062	0,093	14.69 (2.71)	13.23 (2.8)
COAST Patient	43	-1,9	-0,54	0,059	0,093	60.96 (12.17)	67.89 (11.42)
COAST Therapist	42	-4,5	-1,3	p < 0.001	p < 0.001	60.42 (12.79)	74.5 (3.94)
MMSE	43	-2,2	-0,6	0,037	0,092	26.25 (2.59)	27.8 (2.24)
Denomination on Description	27	-3	-0,82	0,0064	0,029	33.5 (3.24)	36.26 (1.44)
Phonemic Fluency	35	-2,1	-0,59	0,041	0,092	16.45 (11.33)	23.73 (8.72)
Semantic Fluency	35	-0,53	-0,15	0,600	0,600	29.18 (10.98)	31.23 (10.73)
RAVEN47	46	1,3	0,37	0,190	0,240	28.91 (5.63)	26.92 (4.79)
Attentional Matrices	47	-0,87	-0,24	0,390	0,440	28.3 (12.92)	31.12 (9.61)

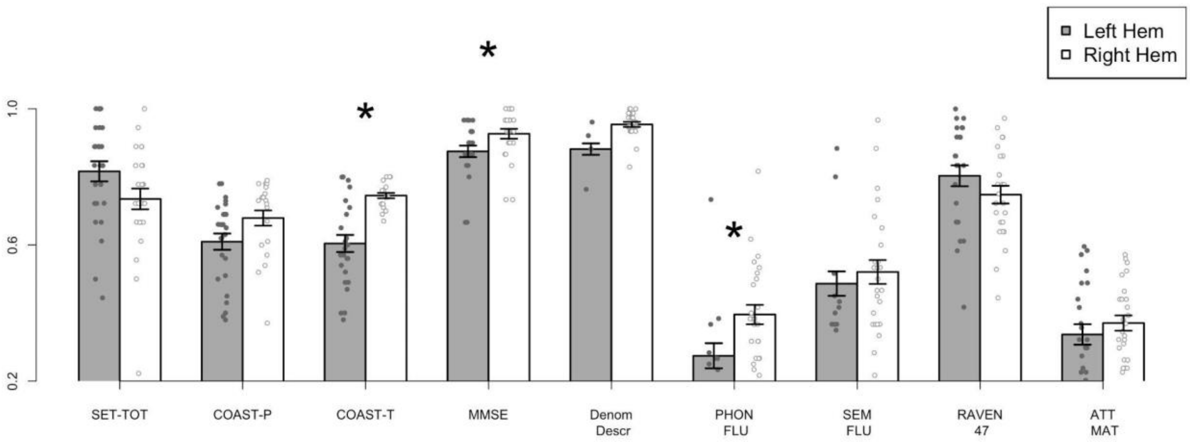

Figure 4. Comparisons of neuropsychological test performance between left and right hemisphere stroke patients.

Left hemisphere stroke patients had significantly lower scores in the COAST Therapist, MMSE and phonemic fluencies.

To better characterize the pragmatic and cognitive profile across the two patients groups, we investigated whether and how performance in the neuropsychological tests was associated with APACS performance through Pearson's correlations separately by lesion group.

For right hemisphere stroke patients, Figure 5 represents the correlation matrix between APACS subtests and the neuropsychological tests. Significant correlations ($p<0.05$ fdr corrected) are reported in the figure and we can see that there are significant positive correlations ranging between 0.5 to 0.61, that can be interpreted as moderate to strong correlations.

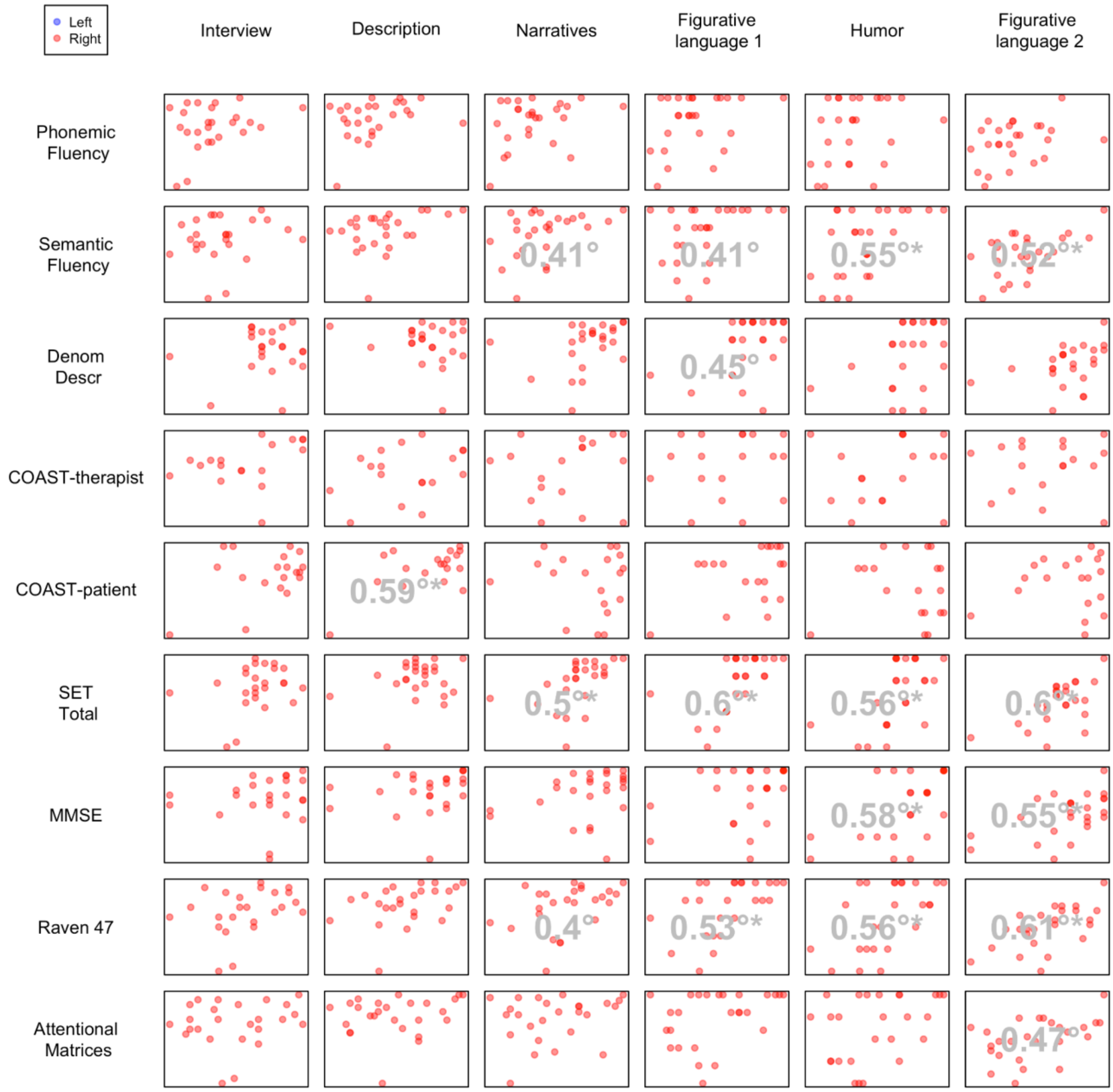

*Figure 5. Scatterplot showing all correlations between APACS subtests and neuropsychological tests performance for the right hemisphere group. Correlation coefficients with an uncorrected p<0.05 are marked with °, while coefficients with p values surviving fdr correction are marked with *.*

The same neuropsychological tests (except COAST patient) that correlated with APACS subtests also correlated with APACS composite scores (fig6).

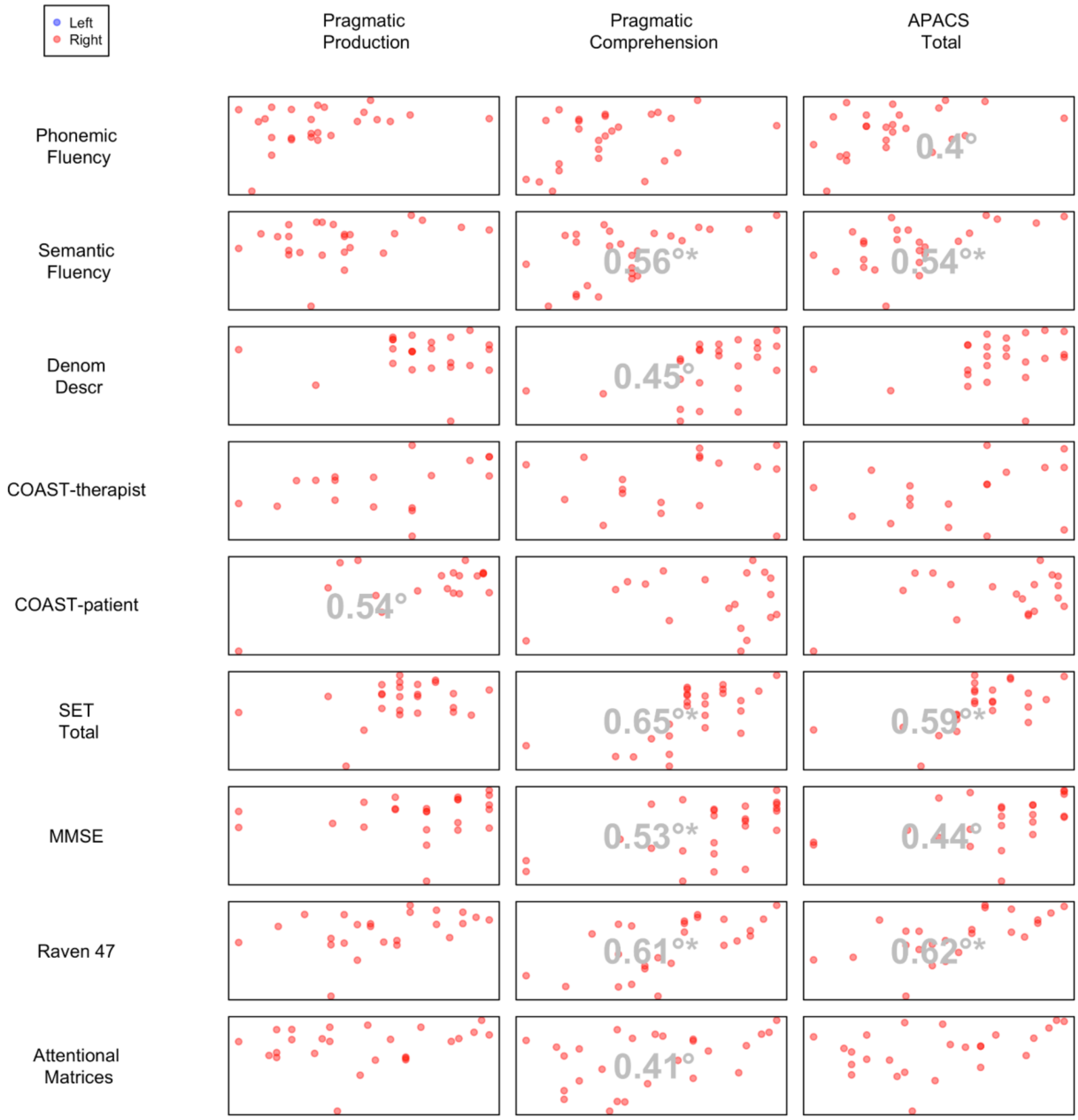

*Figure 6. Scatterplots showing all correlations between APACS composite scores and neuropsychological tests performance for the right hemisphere group. Correlation coefficients with an uncorrected p<0.05 are marked with °, while coefficients with p values surviving fdr correction are marked with *.*

The same procedure was applied to left hemisphere stroke patients. There were no significant correlations surviving fdr correction in this case (fig7).

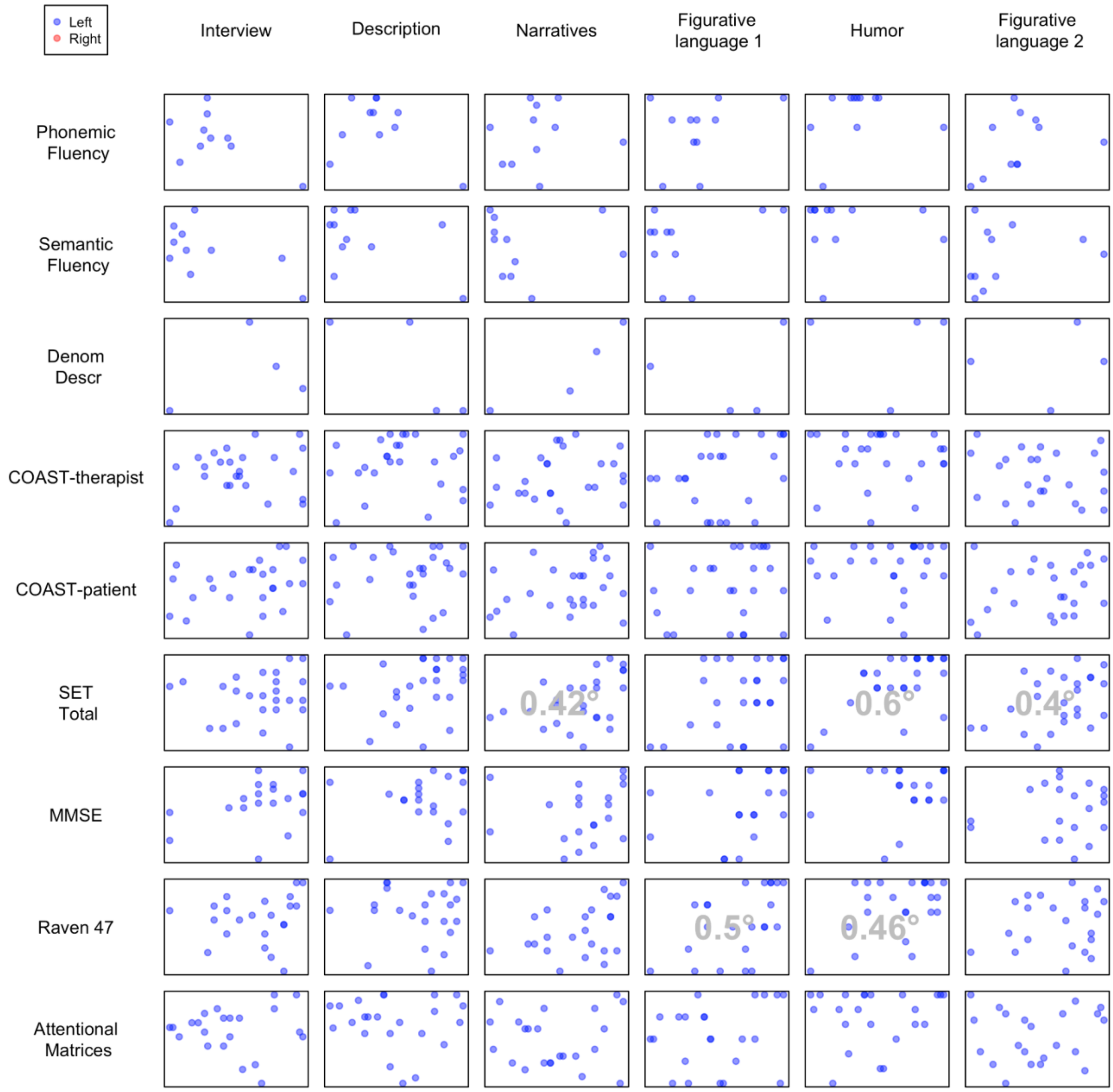

Figure 7. Scatterplots showing all correlations x between APACS subtests and neuropsychological tests performance for the left hemisphere group. Correlation coefficients with an uncorrected p<0.05 are marked with °, while coefficients with p values surviving fdr correction are marked with *.

However, if we consider the correlations between these neuropsychological tests and APACS composite scores in the LHD patients, there are significant correlations between SET and Pragmatic Comprehension and APACS Total (fig8).

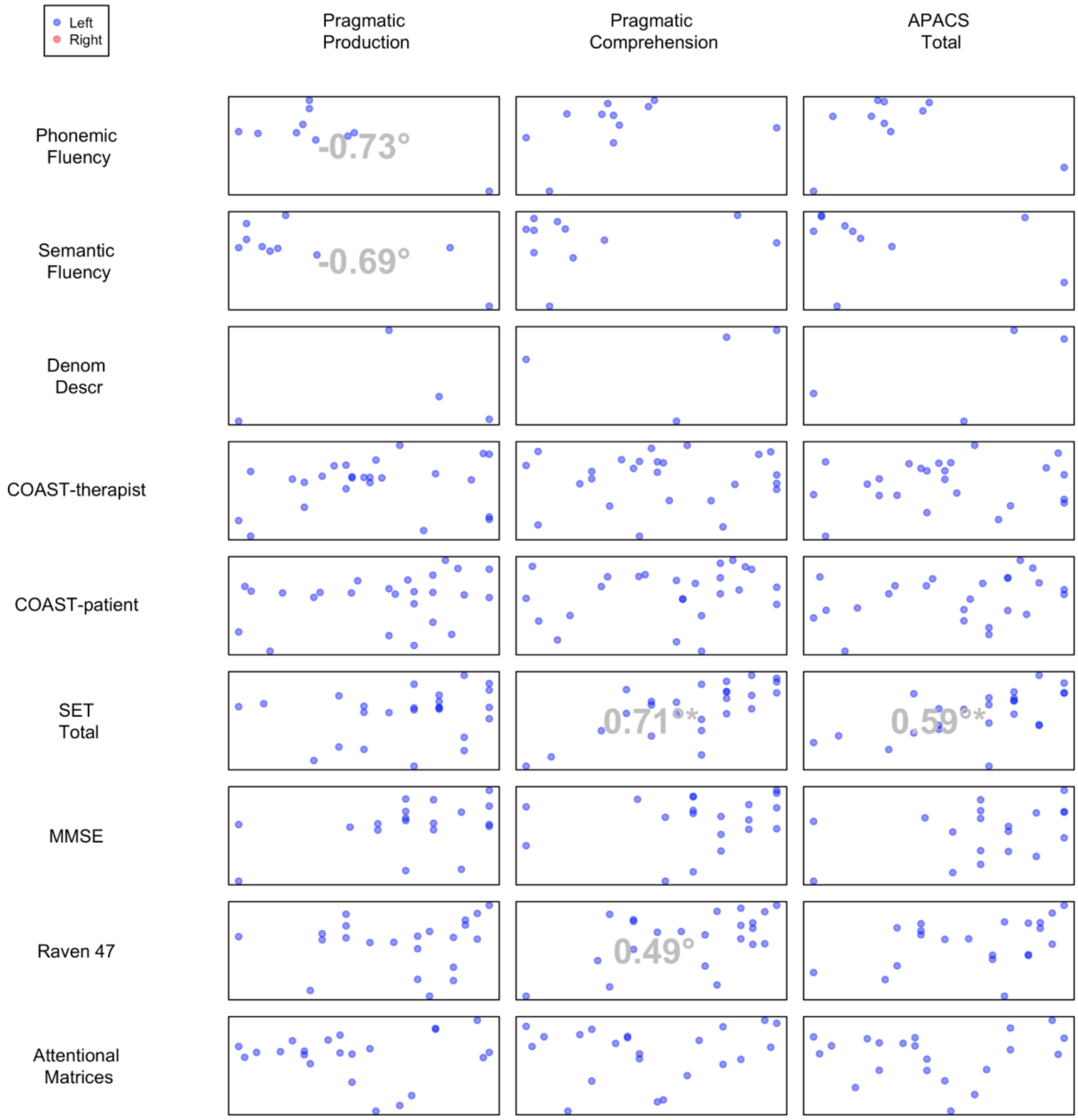

*Figure 8. Correlation matrix between APACS composite scores and neuropsychological tests performance for the left hemisphere group. Correlation coefficients with an uncorrected p<0.05 are marked with °, while coefficients with p values surviving fdr correction are marked with *.*

So at a first glance we can see that these correlations identified a more complex profile for right hemisphere stroke patients.

For this group, Description subtest is strongly correlated with the score in the COAST patient, probably indicating that the patient's level of satisfaction with his/her communication abilities might mediate the person's ability to describe the scenes. Semantic fluency correlated with Humor and Figurative Language 2. SET correlated with Narratives, Figurative Language 1, Humor and Figurative Language 2. MMSE with Humor and Figurative Language 2, and Raven Matrices with Figurative Language 1, Humor and Figurative Language 2.

However, we also have to test for significant differences between the two groups' correlation coefficients. We do this because the (significant) correlations we observe for the right hemisphere group could be no different in terms of strength from those we (not) observe for the left hemisphere group.

When we test for these differences, we can see that there are none surviving fdr correction (see Table 7). In other words, there are some correlations between pragmatics and other cognitive abilities when we test them separately within a group, but the strength of these correlations is not different across samples.

Therefore, we can conclude that the cognitive and pragmatic profile does not differ between the two samples.

Table 7. Differences between the significance of left and right correlation coefficients.

APACS subtest	**NPSY Test**	**r stroke LEFT**	**r stroke RIGHT**	**p**	**p.fdr**	**n stroke LEFT**	**n stroke RIGHT**
Interview	Phonemic Fluency	-0,58	0,29	0,03	0,61	10	25
	Semantic Fluency	-0,62	0,18	0,04	0,61	10	25
	Denomination on Description	0,36	0,13	0,81	0,99	4	24

	COAST Therapist	0,19	0,37	0,58	0,99	25	18
	COAST Patient	0,3	0,39	0,75	0,99	25	19
	SET Total	0,09	0,28	0,51	0,99	25	25
	MMSE	0,37	0,09	0,38	0,99	19	24
	RAVEN47	0,13	0,32	0,54	0,99	22	24
	Attentional Matrices	0,03	0,15	0,68	0,99	22	25
Description	Phonemic Fluency	-0,37	0,32	0,08	0,75	11	26
	Semantic Fluency	-0,46	0,37	0,03	0,61	11	26
	Denomination on Description	-0,8	-0,16	0,36	0,99	4	25
	COAST Therapist	0,07	0,3	0,48	0,99	26	18
	COAST Patient	0,13	0,59	0,09	0,75	26	19
	SET Total	0,3	0,25	0,84	0,99	26	26
	MMSE	0,31	0,22	0,77	0,99	20	25
	RAVEN47	-0,01	0,37	0,19	0,99	23	25

	Attentional Matrices	-0,07	0,19	0,40	0,99	23	26
Narratives	Phonemic Fluency	0,12	0,32	0,62	0,99	11	26
	Semantic Fluency	0	0,41	0,28	0,99	11	26
	Denomination on Description	0,92	0,36	0,24	0,99	4	25
	COAST Therapist	0,16	0,11	0,89	0,99	26	18
	COAST Patient	0,27	-0,07	0,28	0,99	26	19
	SET Total	0,42	0,5	0,74	0,99	26	26
	MMSE	0,14	0,28	0,65	0,99	20	25
	RAVEN47	0,4	0,4	1,00	1,00	23	25
	Attentional Matrices	0,01	0,23	0,47	0,99	23	26
Figurative Language 1	Phonemic Fluency	0,33	0,33	0,99	1,00	11	26
	Semantic Fluency	0,35	0,41	0,86	0,99	11	26
	Denomination on Description	0,16	0,45	0,75	0,99	4	25

	COAST Therapist	0,37	0,11	0,42	0,99	26	18
	COAST Patient	0,17	0,4	0,45	0,99	26	19
	SET Total	0,36	0,6	0,29	0,99	26	26
	MMSE	0,34	0,36	0,95	0,99	20	25
	RAVEN47	0,5	0,53	0,92	0,99	23	25
	Attentional Matrices	0,19	0,35	0,58	0,99	23	26
Humor	Phonemic Fluency	0,21	0,29	0,84	0,99	11	26
	Semantic Fluency	0,01	0,55	0,14	0,93	11	26
	Denomination on Description	0	0,39	0,69	0,99	4	25
	COAST Therapist	-0,03	0,19	0,50	0,99	26	18
	COAST Patient	0,09	-0,01	0,74	0,99	26	19
	SET Total	0,6	0,56	0,85	0,99	26	26
	MMSE	0,12	0,58	0,09	0,75	20	25
	RAVEN47	0,46	0,56	0,65	0,99	23	25
	Attentional Matrices	0,11	0,36	0,38	0,99	23	26

Figurative Language 2	Phonemic Fluency	0,37	0,35	0,95	0,99	11	26
	Semantic Fluency	0,24	0,52	0,41	0,99	11	26
	Denomination on Description	0,17	0,37	0,83	0,99	4	25
	COAST Therapist	-0,16	0,03	0,58	0,99	25	18
	COAST Patient	0,24	0,11	0,68	0,99	25	19
	SET Total	0,4	0,6	0,37	0,99	25	26
	MMSE	0,11	0,55	0,12	0,88	20	25
	RAVEN47	0,14	0,61	0,07	0,75	22	25
	Attentional Matrices	0,08	0,47	0,17	0,99	22	26
APACS Production	Phonemic Fluency	-0,73	0,33	0,00	0,28	10	25
	Semantic Fluency	-0,69	0,3	0,01	0,30	10	25
	Denomination on Description	0,1	-0,02	0,90	0,99	4	24
	COAST Therapist	0,17	0,4	0,45	0,99	25	18

	COAST Patient	0,25	0,54	0,28	0,99	25	19
	SET Total	0,21	0,29	0,79	0,99	25	25
	MMSE	0,4	0,16	0,43	0,99	19	24
	RAVEN47	0,09	0,38	0,33	0,99	22	24
	Attentional Matrices	0,01	0,19	0,55	0,99	22	25
APACS Comprehension	Phonemic Fluency	0,34	0,37	0,95	0,99	11	26
	Semantic Fluency	0,16	0,56	0,25	0,99	11	26
	Denomination on Description	0,3	0,45	0,87	0,99	4	25
	COAST Therapist	0,03	0,14	0,75	0,99	25	18
	COAST Patient	0,23	0,09	0,66	0,99	25	19
	SET Total	0,71	0,65	0,71	0,99	25	26
	MMSE	0,2	0,53	0,23	0,99	20	25
	RAVEN47	0,49	0,61	0,60	0,99	22	25
	Attentional Matrices	0,1	0,41	0,29	0,99	22	26

APACS Total	Phonemic Fluency	-0,11	0,4	0,22	0,99	10	25
	Semantic Fluency	-0,25	0,54	0,05	0,68	10	25
	Denomination on Description	0,61	0,29	0,69	0,99	4	24
	COAST Therapist	0,12	0,28	0,62	0,99	24	18
	COAST Patient	0,3	0,34	0,88	0,99	24	19
	SET Total	0,59	0,59	1,00	1,00	24	25
	MMSE	0,38	0,44	0,82	0,99	19	24
	RAVEN47	0,39	0,62	0,34	0,99	21	24
	Attentional Matrices	0,08	0,39	0,30	0,99	21	25

To summarize, in line with Hypothesis 1, both hemisphere stroke patients performed significantly worse on APACS than controls (except in humor subsection). Importantly, left hemisphere stroke patients even had significantly worse performance on Interview and Figurative Language 2 subsections than right hemisphere patients, while scoring relatively the same on all other patients. In other words, RHD patients did not score worse than LHD patients at any time in APACS. The LHD poor performance in the Interview and Figurative Language 2 subsections because these sections require patients speaking more freely, so any aphasia of the LHD patients may account for this.

In regards to Hypothesis 2, there were correlations with other neuropsychological tests for both hemispheres, though the right hemisphere patients presented a more complex profile. On the neuropsychological tests taken separately, LHD patients had significantly worse performance for COAST Therapist (measuring therapist evaluation of patient's communication difficulties, MMSE (mini-mental state examination), and phonemic fluencies (word production starting with given letter). When testing the correlations of APACS with other neuropsychological tests, the RHD patients had a more complex profile, on first glance. Description subtest is strongly correlated with the score in the COAST patient, probably indicating that the patient's level of satisfaction with his/her communication abilities might mediate the person's ability to describe the scenes. Semantic fluency correlated with Humor and Figurative Language 2. SET correlated with Narratives, Figurative Language 1, Humor and Figurative Language 2. MMSE with Humor and Figurative Language 2, and Raven Matrices with Figurative Language 1, Humor and Figurative Language 2.

The LHD patients were administered the same procedure, but there were no significant correlations surviving fdr correction in this case. However, if we consider the correlations between these neuropsychological tests and APACS composite scores in the LHD patients, there are significant correlations between SET and Pragmatic Comprehension and APACS Total. There are some correlations between pragmatics and other cognitive abilities when we test them separately within a group, but the strength of these correlations is not different across LHD and RHD samples. We can therefore conclude that the cognitive and pragmatic profile does not differ between the two samples.

CHAPTER 5: DISCUSSION

As to Aim 1, which was to explore possible differences in pragmatic scores between left and right hemisphere stroke patients, we found not only that left hemisphere stroke patients had equal impairment in APACS scores, which was in line with Hypothesis 1, but even that they performed worse on some APACS tasks, i.e., the Interview and Figurative Language 2. The first demonstrates that left hemisphere patients do show significant pragmatic deficits, equal or even greater in some cases than RHD patients. In a clinical sense, this is highly significant because it implies that patients with stroke in both hemispheres have trouble understanding messages, irony, humor, and metaphor. This impairment of pragmatic behavior is not often assessed or diagnosed in LHD patients (McDonald, 2000), which means that any communication difficulties are usually attributed solely to aphasia. Both diagnosis and treatment are therefore missing a vital link of the clinical profile for left hemisphere patients.

The fact that LHD patients did have more difficulty with the Interview and Figurative Language 2 subsets, which are the subtests where patients can talk more freely, can be explained by the fact that LHD patients are more prone to formal language deficits (Heine et al., 2014); however, LHD patients performed evenly with RHD patients in all other APACS subsets. This poor pragmatic performance in the left hemisphere is important simply for its appearance, no less strong than for the right hemisphere, contradicting traditional assumptions of the right hemisphere being the main and sole producer of pragmatic cognitive function and behavior (Joannette et al., 1990, Winner & Gardner, 1977, McDonald, 2000). For clinical purposes, we posit that the underlying cognitive substrates of pragmatics is less urgent here than the fact that LH patients do present deficits in pragmatic behavior, and it is this behavior that must be assessed, accounted for, and rehabilitated (Wilson, 2002, Nordio et. al., in press).

It is in Aim 2 that we saw the more nuanced results, and more complex cognitive profiles for both groups of patients. The goal of comparing APACS scores to neuropsychological tests of other domains was to see if there might be a correlation with cognitive functions other than aphasia, and according to Hypothesis 2, we expected to find some correlations. There have already been studies linking pragmatics to other cognitive domains like declarative memory, working memory, attention, executive functions, and social cognition; all have been found to correlate (Rowley et al., 2017). There have also been studies strongly linking pragmatic abilities with Theory of Mind (ToM), (Frank, 2018)

We first individually tested cognitive domains such as test verbal fluency (phonemic fluency, semantic fluency, denomination of descriptions), communication difficulty perception by both therapist and patient (COAST), general cognition (Raven), empathy and ToM (SET), and general cognitive impairment (MMSE). Testing in these domains separately from pragmatics revealed fairly even results, with LHD patients predictably scoring worse on some of the more language-based tests such as Phonemic Fluency (measuring word production), COAST-therapist (measuring therapist perception of communication difficulties), and MMSE (which has a language skills section), but surprisingly not on Semantic fluency or denomination description subtests, (though this was probably due to having very few left hemisphere patients tested in this domain), nor significantly better on nonverbal tests such as Raven's Matrices and SET. The latter is relevant because it points to ToM, empathy, and general cognition being equally affected by stroke across hemispheres. For ToM, in particular, there has been a similar bias in literature attributing ToM solely to the right hemisphere, whereas other studies have demonstrated it to also be found in the left hemisphere (Jospe et. al., 2022, Shamay-Tsoory et. al., 2004)

For correlations of these cognitive domains with pragmatics in the right hemisphere, our findings revealed a complex profile of pragmatic (APACS) scores correlating significantly with Theory of Mind and empathy (SET), and general cognition (Raven 47), in line with Hypothesis 2. For the left hemisphere, the results were less unilateral, with no correlations surviving fdr corrections, somewhat challenging Hypothesis 2. Importantly, however, when testing for the strength of correlation, the difference was fairly even between the two groups, leading us to conclude that the cognitive and pragmatic correlation profiles do not differ between LHD and RHD patients. In this perspective, LHD patients showed correlations of APACS with SET and Raven 47, which measure empathy, Theory of Mind, and general cognition (while not surviving fdr correction, the correlation was not significantly different from the RHD score correlations in these domains with APACS). The fact that these domains were correlated with APACS with approximately the same strength bilaterally points to pragmatics being something related to all three, with participation from both hemispheres. Moreover, SET is nonverbal, as is Raven, and their deficit correlations with APACS for both hemispheres further demonstrate a different mechanism for Pragmatics than mere formal language difficulty (Dodich et al., 2015; Carlesimo et al., 1996).

The lack of significant difference between the cognitive and pragmatic profiles across hemispheres is also important because it offers further evidence that formal language difficulties in

LHD patients do not account entirely for pragmatic deficits. While LHD patients did score generally lower than RHD in domains requiring more free speech such as COAST-therapist (which tests therapist satisfaction with the patient's communication, which makes sense given that 13 of the LHD patients were also aphasic, with two of these patients nonverbal), MMSE (which has a language skills section) and Phonemic fluency (which measures word production, again reflecting the aphasic scores), these low scores did not then significantly correlate with APACS, leading to the conclusion that pragmatics is a domain separate from formal language, and individually affected by stroke damage (Arcara & Bambini, 2016).

In Hypothesis 2, we hypothesized that Theory of Mind would be one of the neuropsychological domains correlating with APACS across hemispheres, and we found support for it in our results. The correlation of Pragmatics to Theory of Mind in both hemispheres is particularly interesting, because not only has there been research dismissing the over-attribution of ToM to the right hemisphere (Herzig et al., 2012; Jospe et al., 2022; Shamay-Tsoory et al., 2004) much as for pragmatics, but some have even gone so far as to say that pragmatic ability and ToM are an intertwined cognitive domain (Frank, 2018; Tonini et al.. 2023; Bischetti et al, 2023; Canal, et al., 2022; Lecce et al., 2019). Theory of Mind, or ToM, refers to the ability to attribute mental states such as beliefs and intentions to self and/or others (Dennett, 1980). One current theory posits that Pragmatics and Theory of Mind are fundamentally overlapping functions, supported by both developmental and neurological research (Frank, 2018). Since the SET test is nonverbal, it is possible to assess ToM with it across both hemispheres, regardless of aphasia. In our analysis of SET scores between hemispheres, LH patients scored evenly with RH in SET, suggesting at least that ToM or empathy are not solely found in RH. The fact that SET correlated with APACS in patients with damage with either hemisphere (if slightly weaker in LH) does seem to indicate Pragmatics and ToM to have a fairly strong link, bilaterally.

Another cognitive domain of interest we hypothesized would correlate with pragmatics was executive functioning, which was found to correlate with some tests but not others. There was correlation for the phonemic fluency task, which is frequently used to assess executive functioning and global cognitive abilities in patients with MS (Lezak et al., 2012), but not for the semantic fluency task, which may be explained by the fact that there were few patients for this task in the LH condition. There has been a link in literature between fluid intelligence and executive functioning as well, so the significant correlation of Raven47 with APACS in this cognitive domain may point to executive function as well (Roca et al., 2012). However, neither attentional matrices nor the MMSE correlated significantly with APACS, and these both measure the attention switching aspect of executive functioning. These mixed correlations in executive functioning, the same across hemispheres, may point to pragmatic abilities being only partially interconnected with executive functioning. There is a plethora of literature postulating a link between executive functions and communication and social behavior (Champagne-Lavau & Joanette, 2009; Barkley, 2001), given that executive functions are what allow people to adapt their attention and abilities to context, and adapt to the rules of each conversation in different contexts (Champagne-Lavau & Joanette, 2009).

Implications for Diagnosis and Treatment

There is difficulty knowing sometimes what, precisely, neuropsychological tests measure and do not, how effectively they truly show us the neuropsychological domain they purport to examine. We cannot truly trace the thoughts and cognitive substrates in the mind as they happen, or measure the true experience of the mind; the only thing we can measure is the behavior, the practical difficulties patients might have, the way in which certain impairments might present themselves in action (Frith, 2017). As an example, Verbal fluency tasks are clinically mostly used to measure executive functioning rather than language ability, though clearly name retrieval and lexical fluency are necessary for a good performance. Indeed, most neuropsychological tests also require a degree of good executive functioning, attention, and correct motivation, and might be skewed significantly by poor mood, low motivation, attention or verbal difficulties, and any number of adjacent conditions and circumstances (Lezak et. al., 2012; Mondini et. al., 2022).

Pragmatic cognitive functioning has been demonstrated in literature to be at least partially independent as a domain, both interconnected/correlated with other neuropsychological domains (Arcara & Bambini, 2016; Rowley et. al., 2017) . Pragmatics has been shown in literature to be interconnected with domains such as ToM and executive functioning, but also only moderately correlating, indicating that it is also an independent domain as well (McDonald, 2008; Stemmer, 2008). It may be difficult or even futile, therefore, to attempt to fully disentangle this cognitive domain in clinical settings, given the interrelated nature of so many cognitive substrates. There is also research demonstrating the clinical effect of communication difficulties in lowering mood, impairing social standing, burdening caregivers, and creating a loss of autonomy (el-Wahsh et al., 2020), but also the effect of mood and fatigue on these exact communication abilities (deBiagi et al., 2020), creating a vicious cycle (Nordio et al., in prep). This might create a downward spiral of communication deficits impairing general functioning, mood, and motivation, which in turn negatively affect communication and rehabilitation attempts. In such a scenario it is difficult to disentangle the various mechanisms involved in poor performance, and perhaps not necessary (Wilson, 2002).

Given the interconnected nature of communicative behaviors as seen in the literature and this study, we suggest a holistic approach to assessment and treatment, proposed by Barbara Wilson, 2002. As Wilson posits, simply knowing the precise diagnosis of a cognitive domain is not enough to create an effective rehabilitation procedure (Wilson, 2002). Patients across both hemispheres present with pragmatic difficulties, separate enough from formal language difficulties, ToM, and executive functioning to merit assessment and diagnosis, but also often interconnected enough that treatment plans should focus on rehabilitating as many aspects of these domains as possible, in a holistic, practical approach. Some pros of a holistic approach include patient involvement, and tackling together the many contributing factors to impaired communication, rather than attempting to target specific cognitive substrates and potentially ignoring other contributing elements. We therefore suggest that in assessing stroke patients, at least the Figurative Language 1 subset of APACS (being relatively short yet effective) be administered to both right and left hemisphere patients, and that diagnosis and rehabilitation approaches be tailored to target functional communication difficulties rather than theoretical, frequently updated, and sometimes outdated, notions about the cognitive substrates of pragmatics.

Conclusion

In conclusion, we first assessed left hemisphere-damaged and right hemisphere-damaged stroke patients in their performance on APACS, checking if there is a lateralization of pragmatic abilities. We found that left hemisphere damaged patients performed equally poorly or worse (in the tasks containing more free discourse) on the APACS test than right hemisphere damaged patients, indicating that pragmatic impairment with stroke may be bilateral. We also assessed the correlation of scores of APACS with other neuropsychological tests, and found moderate correlation with Theory of Mind and executive functioning. The correlation coefficient differences between the cognitive profiles of left and right hemisphere patients in neuropsychological tests vs APACS revealed no significant lateral difference in cognitive profiles. We therefore posit that pragmatic abilities are not as lateralized as often implied in literature, and find support for the position that pragmatic abilities are interconnected yet separate with other cognitive domains across hemispheres. We conclude by calling for more testing of pragmatics, particularly for left hemisphere damaged patients, and by suggesting a more holistic approach to assessment, diagnosis, and treatment which addresses practical communication difficulties rather than individual cognitive substrates. This study contributes to the growing understanding of higher-level cognitive functions involved in pragmatics and their impairment in stroke and lateralized brain damage, emphasizing the importance of assessing communication difficulties in all patients. The implications of this research extend to the development of more holistic, targeted interventions for pragmatic and general communication difficulties post-stroke, as well as for other brain injuries and damage, in clinical practice. Overall, this thesis provides insights into the field of neuropsychology and paves the way for future research on pragmatic abilities in stroke and other brain injuries.

Supplementary Materials

The Supplementary Materials for this thesis can be accessed online at:

https://drive.google.com/drive/folders/16ouSCeYr5X48BAEo8vRPC3-rAEHGHW52?usp=sharing

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