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Qualitative Analysis of Naming Errors and of Responsiveness to Phonemic Cueing in Differentiating Logopenic and Non-Fluent Variants of Primary Progressive Aphasia

SUMMARY

Anomia, as a language impairment deficit, occurs in all variants of primary progressive aphasia (PPA). The study aimed at analysing error profile on confrontation naming in patients with logopenic (lvPPA) and non-fluent variant PPA (nfvPPA). Twelve individuals with lvPPA and 11 subjects with nfvPPA participated in the study. Patients with lvPPA exhibited more pronounced lexical-semantic deficits as well as phonological processing deficits (phonemic cues triggering neologisms). Type of naming errors and the patient's response to phonemic cueing is useful in the differential diagnosis of those two variants of PPA.

Key words: primary progressive aphasia, logopenic variant, non-fluent variant, naming, anomia

1. INTRODUCTION

According to the current diagnostic criteria, primary progressive aphasia is a language disorder of neurodegenerative aetiology that may manifest in 3 variants (Gorno-Tempini et al. 2011): non-fluent variant PPA (nfvPPA), logopenic variant PPA (lvPPA) and semantic variant PPA (svPPA) (Sitek et al. 2014a). Anomia,

"naming deficit or word-finding impairment" (Rutkiewicz-Hanczewska 2016, 405), is one of the language deficits in PPA that is present in all of its variants (Mesulam et al. 2009)[1]. Naming impairment is much more pronounced in lvPPA and svPPA than in nfvPPA (Hurley et al. 2012; Thompson et al. 2012). However, in each of the PPA variants, a different naming impairment profile is observed.

The efficient word-finding depends on the integrity of semantic, lexical and phonological processes (Tippett, Hillis 2015). Naming an object that is presented on confrontation naming task (naming objects presented visually: real objects, miniaturized objects, objects shown on line drawings, etc.) is possible also thanks to the involvement of visuospatial functions and memory (Raymer 2015). After analysis and synthesis of perceptual information it is compared to the semantic representation available in the cognitive system. This enables initiating further steps of word-finding. So as to pronounce the word, one has to select proper phonemes. Finally, thanks to motor aspects of expressive speech, the word can be correctly pronounced (Tippett, Hillis 2015). Thus, errors on confrontation naming may stem from visual perception impairment, generalized semantic memory deficits, lexical-semantic dysfunction, phonological impairment or speech apraxia. Naming impairment in nfvPPA is attributed to phonetic deficits associated with the processing and motor planning of the phonetic sequence. Phonological paraphasias[2] in lvPPA are associated with phonological coding. Words on naming tasks containing well articulated phonemes are also affected by substitution, addition and omission errors (Croot et al. 2012). In nfvPPA difficulties on naming tasks may manifest through phonemic paraphasias (Rohrer et al. 2010). However, articulation distortions are usually due to apraxia of speech (AOS) (Croot et al. 2012).

Word-finding difficulties[3] may be also observed in a selective form, affecting only some word classes. In nfvPPA verb naming is more affected, while in lvPPA noun-naming deficits are more pronounced (Hillis et al. 2004). Predominant word-finding in spontaneous speech are identified in lvPPA individuals (Gorno-Tempini et al. 2011).

Our study aimed at comparing the frequency of specific error types on confrontation naming in Polish-speaking patients with lvPPA and nfvPPA. It was hypothesized that the error profile in lvPPA patients will be compatible with pho-

[1] Extensive coverage of anomia, both for proper names and common words in aphasia can be found in a monograph by M. Rutkiewicz-Hanczewska (2016).

[2] "Phonological paraphasia resembles a target word, but does not co-create the dictionary resource of a given language. It is created as a result of the substitution of various sounds forming the finding word, e.g. *vanana* instead of *banana*" (Rutkiewicz-Hanczewska 2016, 409).

[3] Word-finding is "the process of searching for names, i.e. efficient naming based on the image of the clerk or its definition; [...] extracting names from the mental dictionary, recalling names, access to the mental dictionary" (Rutkiewicz-Hanczewska 2016, 409).

nological deficits and that due to this deficit those patients will not substantially benefit from phonemic cues[4]. Moreover, noun and verb naming was analysed based on data available from some of the patients.

2. PARTICIPANTS

Twenty-three patients with the clinical diagnosis of primary progressive aphasia, according to the diagnostic criteria by M. Gorno-Tempini et al. (2011), established in Memory Clinic at St. Adalbert Hospital, Copernicus PL Ltd. or Neurology Department of the same hospital between 2007 and 2017, participated in the study. Twenty patients were examined as outpatients and 3 individuals were assessed as inpatients. Twelve patients were diagnosed with lvPPA and 11 patients with nfvPPA. The other language assessment results were previously published (Sitek et al. 2014b; Sitek et al. 2015a; Sitek et al. 2015b; Sitek et al. 2015c). Also, the analysis of anomia severity, but not its profile, with reference to other aspects of language function were described by Kluj-Kozłowska et al. (in press).

In all patients the results from the first available language assessment were analysed. If the diagnostic process was initiated very early in the disease course (before 2 years elapsed from the symptom onset), the initial diagnosis was confirmed in further clinical follow-up. As the set of neuroimaging techniques and genetic testing was not consistent in the whole patient group, it is not presented in detail here. In most of the patients, magnetic resonance imaging (MRI) and single-photon emission computerized tomography (SPECT) were performed. However, if MRI could not be done due to contraindications, computed tomography (CT) was used. All patients fulfilled the level I criteria of PPA variant, two individuals fulfilled level III criteria. As the neuroimaging assessment was not homogenous in the whole group, the verification of level II criteria is not reported.

In both groups (lvPPA and nfvPPA) there were more women (see: Table 1). Due to the clinical profile of two syndromes age-matching was not possible. Among lvPPA patients there were more individuals with cognitive impairment.

3. METHODS

Different methods were used to assess word-finding in this study. In all participants noun naming was assessed. Additionally, in some of the patients verb naming was also examined.

[4] Phonemic cue is defined as a cue containing either the first phoneme or the first syllable of the word to be found, e.g. in the case of the word *helicopter* the cue *he* was the initial syllable. If the word was short, the first phoneme was used as a cue, e.g. *b* for the word *beaver*.

Table 1. Demographic and clinical characteristics of patients with logopenic (lvPPA) and non-fluent variants (nfvPPA) of primary progressive aphasia

	lvPPA n=12	nfvPPA n=11
Sex: F / M	8 / 4	9 / 2
Age	70±4*	65±9
Time since onset (years)	2.5 (1; 9) **	2 (0.5; 5)
Years of study	12 (9; 13)	13 (10;17)
CDR: normal (0) mild cognitive impairment (0.5) mild dementia (1) moderate dementia (2)	0*** 7 3 2	2 4 5 0

* median (±SD); ** Me (min. ; max.); *** number of cases
CDR, Clinical Dementia Rating Scale
Source: own research.

Noun naming was assessed with the use of:

- *Boston Naming Test* (BNT) (Kaplan et al. 2001) in 30-item or 15-item version;
- naming subtest from *Sydney Language Battery* (SydBAT) (Savage et al. 2013);
- noun naming from *Psycholinguistic Assessments of Language Processing in Aphasia (PALPA)* (Kay et al. 1996);
- naming task from *Addenbrooke's Cognitive Examination – Revised* (Mioshi et al. 2006) or *Addenbrooke's Cognitive Examination-III* (ACE-III) (Hsieh et al. 2013);
- naming common objects or animal figures according to *Progressive Aphasia Language Scale procedure* (Leyton et al. 2011);
- a set of 42 line drawings (6 drawings from each of the 7 semantic categories: animals, clothes, tools, body parts, fruit, vegetables, objects);
- a set of 48 drawings in gray-scale (8 drawings from 6 semantic categories: fruit, vegetables, furniture, tools, insects, vehicles).

Verb naming was examined with the use of:

- verb naming from *Boston Diagnostic Aphasia Examination* (BDAE) (Goodglass et al. 2001),
- verb naming from PALPA (Kay et al. 1996).

When it comes to BNT-15 and BNT-30, the improvement following semantic, phonemic and multiple-choice cues was computed as a percentage of correct

answers following a cue[5]. Detailed information on the naming tests' use was presented in Table 2.

Table 2. Comparison of the number of patients with the logopenic (lvPPA) and non-fluent variants (nfvPPA) of primary progressive aphasia examined with the use of specific naming tasks

	lvPPA	nfvPPA
BNT-15	5	6
BNT-30	4	3
Sydbat Naming-30	4	4
ACE-III/ACE-R Naming-12	8	6
BDAE naming	6	7
PALPA naming nouns	2	2
PALPA naming verbs	2	2
Set of line drawings / 40	1	0
Set of gray-scale drawings / 48	1	3
PALS Animal figures naming (10 or 13)	10	6
PALS Common objects naming / 10	9	6
Cambridge Semantic Battery naming	0	1

ACE – R (*Addenbrooke's Cognitive Examination – Revised*); ACE – III (*Addenbrooke's Cognitive Examination – III*); BDAE (*Boston Diagnostic Aphasia Examination*); BNT (*Boston Naming Test*); PALPA (*Psycholinguistic Assessments of Language Processing in Aphasia*); PALS (*Progressive Aphasia Language Scale)*; SydBAT (*Sydney Language Battery*)

Source: own research.

The following error types were used in the analysis:

1. Phonemic paraphasias – if in the patient's utterance there was a distortion of phoneme (syllable) or its substitution, omission or duplication;
2. Contamination – if the patient's utterance contained the elements coming from two subsequent words;
3. Neologisms – pseudowords, most often similar to word forms, but created by the patient and not existing in the Polish language system. When gen-

[5] When the target word was *comb*, the cue would be "used for fixing hair" (semantic cue was used when the patient's answer indicated misperception or the patient said that he/she could not recognize the object). If the answer was erroneous, but the object was correctly recognized, phonemic cue was given (first phoneme or first syllable). If all of these cues were inefficient, the examinee was presented with multiple choice e.g. for *comb – hair*, *rake*, *comb*, *brush.* Distractors could be either semantic, phonological or visual.

erating neologisms the patients may evidence limited criticism to naming impairment;
4. Verbal paraphasias (lexical) – identified, when the patient – instead of the target word – provided a different word that belongs to the Polish lexical system, but it is semantically unrelated to the target word;
5. Semantic paraphasias – identified if the patient – instead of the target word – provided a different word, belonging to the Polish lexical system and semantically related to the target word;
6. Circumlocutions – identified, if – instead of saying the target word – the patient described the meaning of the word, e.g. its use or its characteristic features;
7. Circumlocutions using paraphasias and jargon (multiword paraphasic error) – identified if the patient tried to describe the meaning of the target word, using incomprehensible words and phrases, that do not belong to the Polish language system;
8. Perceptual errors – naming errors stemming from misperception of the objects.

Apart from the error types specified above, other erroneous reactions were observed, such as: no reaction/no attempt of naming the object aloud and demonstration of the object use using pantomime and facial expression. As those answer types were not consistently rated during the assessment, they were excluded from further analysis. If the answer produced by the patient contained several error types, error type that clearly indicated phonological or lexical-semantic deficit was chosen. Thus, if the circumlocution contained phonemic paraphasia, only phonemic paraphasia was scored. Error types were independently rated by two raters (KKK and EJS). If the ratings were inconsistent, the final rating was established by the third rater. The examples of naming errors produced by patients with lvPPA and nfvPPA are provided in Table 3.

4. STATISTICAL ANALYSIS

The inter-rater consistency was computed with the use of Cohen's Kappa coefficient. Normality of data distribution was tested with the use of the Shapiro–Wilk W test and homogeneity of variance with the Brown–Forsythe test. The significance of inter-group differences was assessed with the use of either t-Student or the Mann–Whitney U tests, depending on the data distribution. Significance level was established at $p<0.05$.

Table 3. Examples of naming errors produced by the patients with logopenic (lvPPA) and non-fluent variants (nfvPPA) of primary progressive aphasia

ERROR TYPES	Stimulus	PATIENT RESPONSE*	PPA variant
Phonological errors			
phonemic paraphasia	helicopter (*helikopter*)	[*helikoptur*]	lvPPA
phonemic paraphasia	accordion (*akordeon*, *harmonia*)	[*harmeni*], [*harmunia*]	lvPPA
phonemic paraphasia	spoon (*łyżka*)	[*łeżka*], [*łużka*]	lvPPA
phonemic paraphasia	rolling pin (*wałek*)	[*wałtek*]	lvPPA
phonemic paraphasia	dragonfly (*ważka*)	[*rzadka*]	lvPPA
phonemic paraphasia	octopus (*ośmiornica*)	[*osiernica*]	lvPPA
contamination	tripod (*statyw*, *trójnóg*)	[*trojstoj*]	lvPPA
neologism	dandelion (*dmuchawiec*)	[*pucho*]	lvPPA
neologism	racket (*rakieta*)	[*lotka polotka*]	nfvPPA
neologism and germanism	electric drill (*wiertarka*)	[*bormaszyna, borownik*]	nfvPPA
circumlocution using paraphasia and jargon	battery (*bateria*)	[*do palesu*]**	lvPPA
Lexical and semantic errors			
verbal paraphasia	cactus (*kaktus*)	chestnut [*kasztan*]	lvPPA
verbal paraphasia	snail (*ślimak*)	bolete (mushroom) [*maślak*]*	lvPPA
semantic paraphasia	penguin (*pingwin*)	birdie [*ptaszek*]	lvPPA
semantic paraphasia	dinosaur (*dinozaur*)	lizard [*jaszczurka*]	nfvPPA
semantic paraphasia	muzzle (*kaganiec*)	(dog) collar [*obroża*]	nfvPPA
semantic paraphasia	sphinx (*sfinks*)	Poseidon [*Posejdon*]	nfvPPA

Table 3. Continued

Circumlocutions			
circumlocution	secateurs (*sekator*)	a man has to come and do something [*jakiś facet musi przyjść i coś zrobić*]	lvPPA
circumlocution	tie (*krawat*)	around and this masculine one [*dookoła i ten taki męski*]	lvPPA
circumlocution	saw (*piła*)	This is to cut, cutting, you take it in your hand, I don't know its name, I don't use it, my husband or son did something at it [*To się przecina, tnie się, w rękę to się bierze, nie wiem, jak to się nazywa, tym ja nic nie robię, to mąż przy tym, czy syn coś robił*]	lvPPA
circumlocution	pineapple (*ananas*)	This can be also eaten, it is delicious, I can cut it around and eat and I don't remember how much; it has to be washed thoroughly and then it, then eat and so on [*Też się je, smaczne jest, umiem obkroić wkoło i zjeść i też nie pamiętam ile; trzeba dużo sobie umyć i dopiero wtedy tego, i potem jeść i tak dalej*]	lvPPA
circumlocution	palette (*paleta*)	grandchildren paint it [*wnuki malują to*]	nfvPPA
circumlocution	sphinx (*sfinks*)	Roman this Apollo, no [*rzymski ten Apollo, nie*]	nfvPPA

* only circumlocutions, verbal and semantic paraphasias were translated to English, other responses were provided only in Polish

** ambiguous errors

Source: own research.

5. RESULTS

Inter-rater agreement Cohen's Kappa coefficient was 0.98. Due to marked heterogeneity in numbers of distinct naming errors in comparison to the sum of errors for the purposes of the statistical analysis the errors were grouped to obtain 4 error types: phonological (phonemic paraphasias, contaminations, neologisms), lexical-semantic errors (semantic and verbal paraphasias), circumlocutions and perceptual errors.

5.1. Comparison of the error types in patients with lvPPA and nfvPPA

When it comes to the defined error categories there were statistically significant differences in the distribution of lexical-semantic errors. Predominant problems were noted in the individuals with lvPPA (see Figure 1). There were no statistically significant inter-group differences in phonological, perceptual errors and circumlocutions. However, the maximum percentage of phonological and perceptual errors noted in patients with lvPPA was higher.

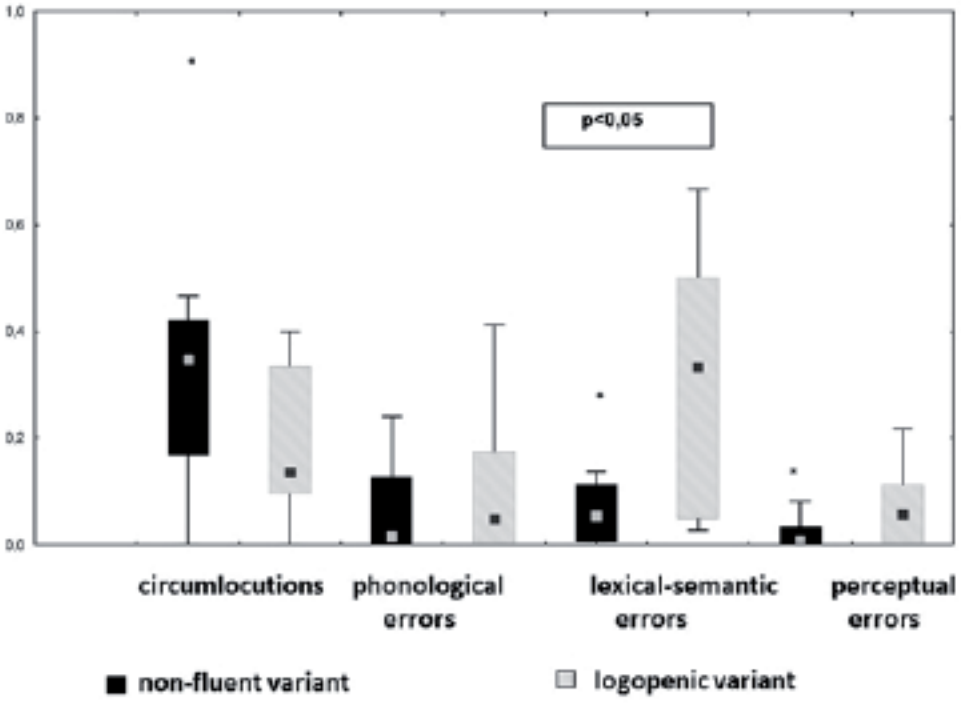

Figure 1. The comparison of error distribution in lvPPA and nfvPPA (point-median, box-percentiles, whiskers – the range of scores excluding the outliers)

The efficiency of phonemic cues was higher in nfvPPA than in lvPPA (see Figure 2). Phonemic cues triggered neologisms only in some individuals with lvPPA. In none of the patients with nfvPPA there were neologisms in response to phonemic cues. However, among individuals with logopenic variant, those reactions were frequent (see Figure 3).

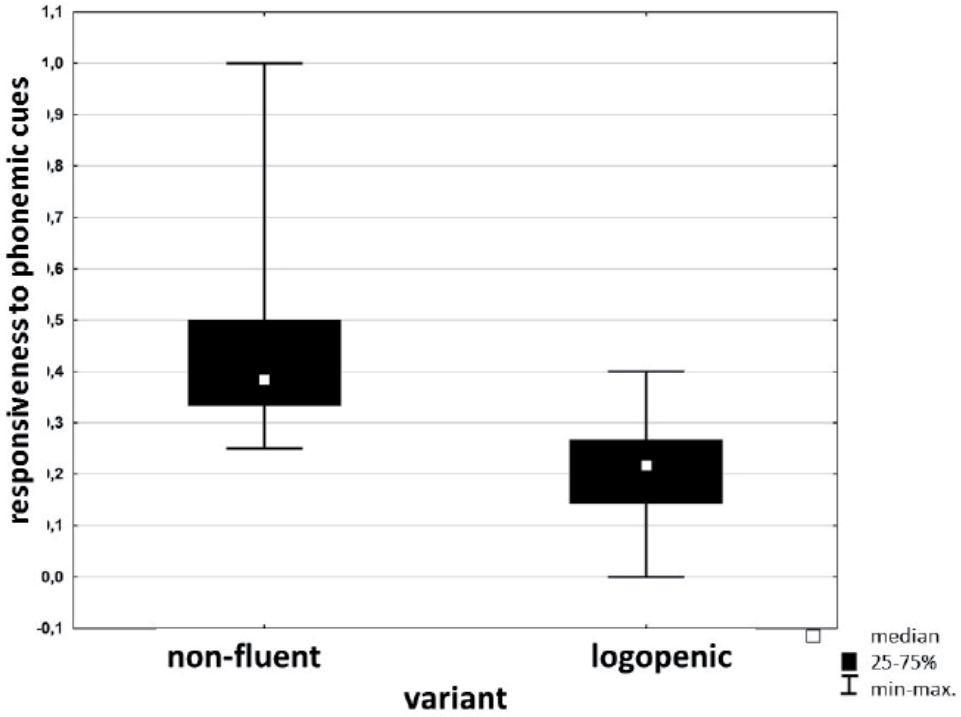

Figure 2. The responsiveness to phonemic cues in lvPPA and nfvPPA

5.2. Comparative analysis of word-finding: nouns from different semantic categories

Analysis of naming profile based on object naming and animal naming from Progressive Aphasia Language Scale (PALS) in 14 patients with PPA (9 with lvPPA and 5 with nfvPPA) showed their marked heterogeneity (see Figure 4). Most commonly the results obtained in both tasks differed by 1–3 points (in 10 patients) or the results on both tasks were the same (in 2 patients). However, in two patients greater difference was observed (4–5 points). Of note, in both cases the patient scored higher on naming objects than on naming animal figurines.

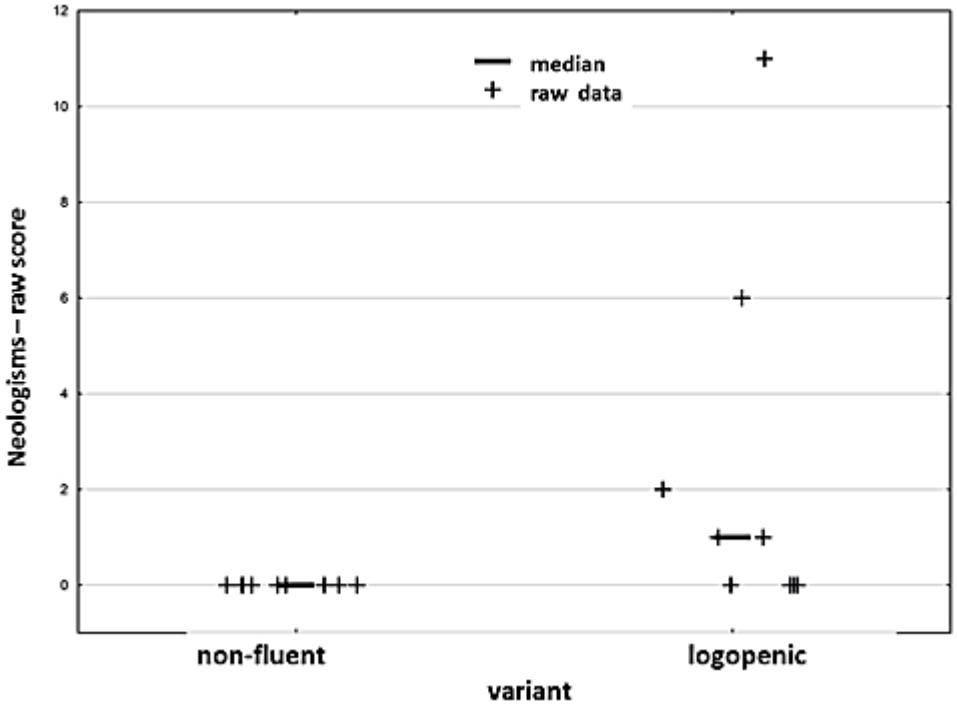

Figure 3. Number of neologisms in response to phonemic cues in lvPPA and nfvPPA – raw scores

5.3. Comparative analysis of noun and verb naming

As verb naming was assessed only in 13 patients (tasks from BDAE were conducted in 10 patients, task from PALPA in 2 patients ad both tasks in 1 patients), the results are provided as the percentage of correct responses. In 4 out of 7 patients with nfvPPA, in 57% of cases, the result profile was typical for nfvPPA, in 2 cases ceiling effect was noted (maximum scores on both tasks) and only in 1 person the result profile was atypical, higher scores in verb naming. In 4 out of 6 patients with lvPPA, 66% of those cases, the result profile was typical for this variant, verb naming score was higher than noun naming score. In 1 individual, both scores were the same and in 1 person noun naming score was higher. The comparison of noun and verb naming in lvPPA and nfvPPA is provided in Table 4.

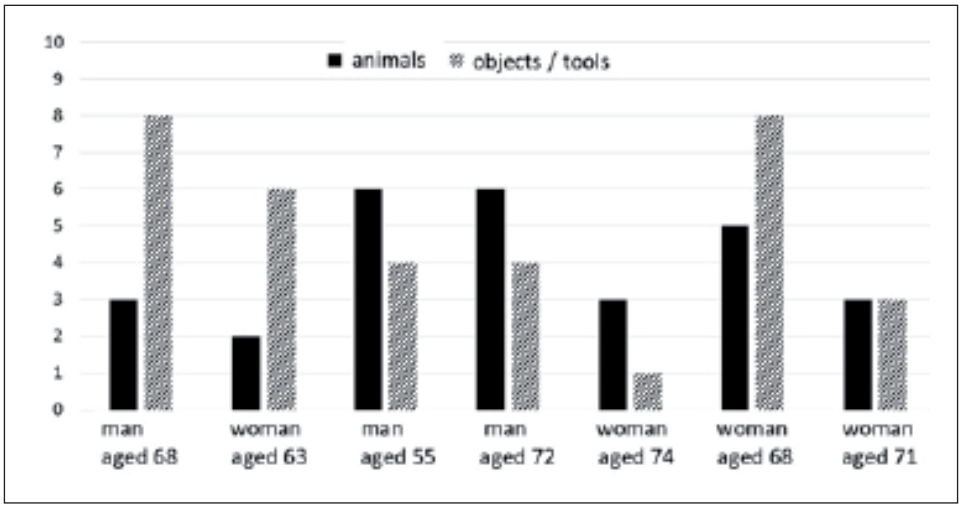

Figure 4. Naming profiles in lvPPA

Table 4. Percentage comparison of noun and verb naming in non-fluent (nfvPPA) and logopenic variants (lvPPA) of primary progressive aphasia and assessment of the presence typical naming profile for a given PPA variant (better noun naming in nfvPPA and verb naming in lvPPA)

	Case	Sex and age	Age at symptom onset	Verbs vs nouns (% correct)
nfvPPA patients	1	woman, aged 64	59 (?)	0% vs 66% (verbs < nouns)
	2	man, aged 65	62	66% vs 100% (verbs < nouns)
	3	woman, aged 60	59 (?)	100% vs. 83%
	4	woman, aged 81	79	50% vs 66% (verbs < nouns)
	5	woman, aged 75	70	100% vs 100%
	6	woman, aged 56	55	75% vs 92% (verbs < nouns)
	7	woman, aged 74	71	100% vs 92%
	8	woman, aged 60	58	86% vs 67%
lvPPA patients	1	woman, aged 68	64	66% vs 0% (verbs > nouns)
	2	man, aged 72	69	33% vs 33%
	3	woman, aged 76	74	83% vs 50% (verbs > nouns)
	4	man, aged 68	66	83% vs 66% (verbs > nouns)
	5	man, aged 68	59	42% vs 16% (verbs > nouns)
	6	woman, aged 63	62 (?)	72% vs. 76%

(?) probably the real duration of the disease is longer, incomplete information from the interview

Source: own research.

Table 5. Summary of characteristic features of word-finding deficits in lvPPA and nfvPPA

	lvPPA	nfvPPA
naming errors	very often	rare
awareness of deficits	usually significantly reduced	preserved for a very long time
word-finding: nouns (in spontaneous speech and naming tests)	severely disturbed (as in a typical fluent aphasia)	slightly reduced, or even initially preserved
word-finding: verbs (in spontaneous speech and naming tests)	better preserved than noun naming	more impaired than noun naming (as in a typical non-fluent aphasia)
speech fluency	initially preserved	in patients with apraxia of speech have been disturbed from the beginning
word accent	well preserved	in patients with apraxia of speech missing or atypical pattern of accentuation
phonemic paraphasias	secondary to phonological deficit	secondary to apraxia of speech
circumlocutions	long (with paragramatism)	short
perceptual errors	moderately frequent due to impaired visuo-spatial functions	very rare
perseverations	rare	frequent, at an advanced stage of the disease, when echolalia is present; dissociation between word and meaning
phonemic cues	ineffective	usually very effective
responsive naming	more impaired than confrontational naming due to comprehension deficits	at a similar level as confrontation naming
written confrontation naming	usually more impaired than oral word-finding	usually at a similar level as oral word-finding; in some patients with apraxia of speech at the beginning of the disease it may be easier to write down the word than to pronounce it

Source: own description.

6. DISCUSSION

In this study we compared word-finding difficulties in non-fluent and logopenic variants of PPA. As a result of comparative analysis it was evidenced that lexical-semantic errors occur more often in lvPPA. Studies conducted in English also show that semantic and verbal paraphasias are more frequent in lvPPA (Cerami, Cappa 2016). In nfvPPA naming errors are less frequent than in lvPPA. However, phonemic errors may predominate (Mack et al. 2013), that are most often attributed to speech apraxia (Croot et al. 2012). Phonemic errors may occur in both nfvPPA and lvPPA (Gorno-Tempini et al. 2011; Cerami, Cappa 2016). However, in lvPPA those errors are associated with phonological processing deficits. The patients have difficulties in connecting phonemes in strings and creating a phonological word representation (Mack et al. 2013). At the disease onset, the sentence repetition is affected, as it engages a phonological loop (as a subsystem of working memory). However, at more advanced disease stages, these problems appear when long words are concerned. In contrast, individuals with nfvPPA, in whom naming deficit is due to phonological coding impairment, demonstrate problems at the stage of transforming these representations into articulatory patterns. Thus, they frequently make few attempts to pronounce the word (Mack et al. 2013). While naming errors, known as phonemic paraphasias, are present in both PPA variants, their patomechanism is different (Croot et al. 2012).

According to the literature in English, circumlocutions are also frequent in lvPPA (Budd et al. 2010). In our study, circumlocutions did not differentiate between patients with lvPPA and nfvPPA. However, circumlocutions observed in both PPA variants were qualitatively distinct (see Table 5). Moreover, perceptual errors were more frequently observed in lvPPA, albeit this difference was not statistically significant.

Both patients with lvPPA and nfvPPA demonstrate phonological deficis (Henry et al. 2012). Phonemic cues are effective in word-finding facilitation mainly in nfvPPA (Mack et al. 2013). In our study, patients with lvPPA produced neologisms in response to phonemic cues, while this phemonon was not observed in any of the patients with nfvPPA. It is assumed that these problems evidence deficits in phonological and not lexical processing (Croot et al. 2012). Phonemic cues are ineffective not only in lvPPA but also in svPPA, where semantic deficits are accompanied by preserved phonological abilities. Patients with svPPA in response to phonemic cueing may provide random words (Sitek et al., in press), e.g. the cue "ca", when asked to name "camel" may trigger the answer "cabbage".

In our study, better verb naming was observed in lvPPA. This is consistent with the literature in English which showed less impaired object naming in nfvPPA (Hillis et al. 2004; Thompson et al. 2012). In narrative speech, more pauses and hesitation preceding nouns are observed in patients with lvPPA.

In nfvPPA similar problems concern verbs (Mack et al. 2015). The analysis of narrative speech showed higher percentage of nouns in phrases produced by the patients with nfvPPA than by the patients with lvPPA (Sitek et al. 2015a). Even before lvPPA was defined as a separate variant of PPA, greater difficulty in noun naming was seen in patients with fluent PPA than in non-fluent PPA (Hillis et al. 2004), which is in accordance with the pattern observed in patients with aphasia due to vascular aetiology.

The comparison of naming error types in patients with PPA and stroke-induced aphasia showed that error type is more dependent on the lesion location than its aetiology (Budd et al. 2010). Moreover, the pattern of anomia, e.g. difficulties with verb naming is also associated more closely with lesion location than its aetiology, as the patients with nfvPPA have similar impairment to patients with Broca's aphasia (Thompson et al. 2012). The severity of noun naming impairment is associated not only with the typical for svPPA left temporal pole atrophy but also with the left-sided atrophy in middle and posterior-inferior temporal gyrus, while the verb naming deficit is related to the atrophy within left parietal lobe (Race et al. 2013). In a study focusing on the relationship of cortical atrophy to naming and word comprehension deficits in 3 variants of PPA, it was demonstrated that lexical-semantic processes are mediated by the lateral surface of the temporal cortex, semantic representation engages both temporal poles and the lexical retrieval is associated with the left posterior temporal cortex. The integration of lexical-semantic processes requires the involvement of the area that lies between the aforementioned regions or the integrality of the white matter tracts linking the anterior and posterior part of the temporal lobe, which remains to be confirmed by tractography (Migliaccio et al. 2016). In our study, lexical-semantic paraphasias were more frequent in lvPPA than in nfvPPA. The atrophy profile typical for lvPPA incorporates indeed posterior part of the temporal lobe, which is engaged in lexical processing.

Category-specific naming disorder has been previously described mainly in svPPA and occasionally in nfvPPA (Reilly et al. 2011). The analysis of naming profiles on naming animal figurines and objects in our study suggests that the severity of the naming impairment may differ when distinct categories are concerned. Thus, the naming assessment in PPA requires the use of different stimuli, belonging to different semantic categories, preferably including living and non-living ones.

Our study had some limitations. We compared small groups of patients, which did not enable us to match them in terms of education level or time since symptom onset to the first assessment. As svPPA is particularly rare, we could not gather a subgroup with this variant. However, the profile of semantic impairment and neuroradiological changes in svPPA is very specific and the differentiation of nfvPPA from lvPPA is the most challenging in the clinic (Harciarek et al. 2014).

This underlines the practical implications of our results. As time of making diagnosis was variable, as was the severity of language impairment, the methodology of naming assessment was heterogenous. Verb naming was not tested in all participants. Also, we did not have audio recordings from each assessment that would enable the assessment of difficulties due to apraxia of speech. Moreover, the use of different stimuli for naming could potentially affect the frequency of phonological errors, that may depend on the length and complexity of the word (Petroi et al. 2014). It was also shown that reading pseudowords is more sensitive to phonological impairment than confrontation naming (Petroi et al. 2014), so our material could have been insufficient to demonstrate the predominance of phonological errors in lvPPA.The current analysis did not concern word-finding during narrative speech. Spontaneous speech samples from selected patients with nfvPPA and lvPPA were analysed in a previous paper (Sitek et al. 2015b). It was shown that the qualitative observation of short narrative speech sample is insufficient to correctly recognize PPA variant. Due to small sample size the analysis of subtypes of phonological errors was not feasible. In a study conducted with English-speaking patients in lvPPA, substitutions and omissions were predominant, while transposition were least frequent (Petroi et al. 2014). In this study, not only paraphasias on naming were included but also reading and repetition errors, which yielded more errors to analyse.

The summary of characteristic features of word-finding deficits in lvPPA and nfvPPA, based on the literature, current study and the authors' clinical practice, is presented in Table 5.

7. CONCLUSIONS

Qualitative analysis of naming errors in PPA patients showed the predominance of lexical-semantic errors in lvPPA. Also, in lvPPA phonemic cues lead to neologism production. This type of reaction did not appear in any of the patients with nfvPPA. Thus, neologism generation in response to phonemic cueing may be a specific marker of phonological deficit in lvPPA. Both, qualitative analysis of naming errors and the analysis of responsiveness to phonemic cueing may be useful in the differentiation of lvPPA and nfvPPA.

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