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Dissertation

Title:
“The role of silent pauses in speech pathology”

“MSc Clinical Neuropsychology-Cognitive Neurosciences”

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Abstract

Pauses may be studied as an aspect of the temporal organization of speech, as well as an index of internal cognitive processes, like word selection and retrieval, monitoring, articulatory planning, and memory. There are studies demonstrating a specific pattern of pauses in normal speech, however evidence from pathological populations, and especially aphasia patients is sparse and restricted to small scale studies. The aim of the present study is threefold. First, to investigate possibly different patterns of pause distribution between healthy speakers and aphasics. Second, to examine distinct pause trends among individual patients. Third, to scrutinize possible associations between aphasic pause preferences and lesion characteristics. Our results indicate different distribution of pauses during connected speech between controls and aphasics. Moreover, different pause profiles are revealed when assessing individual patient data. Finally, these profiles seem to be related to indices of lesion extent and locus. Overall, our findings stress the importance of pauses as an integral part of language assessment in clinical populations, and further support their role in healthy language production as well as impaired speech output.

1. Introduction

Pauses have been labeled as the temporal component of speech. Despite the actual absence of words during pausing, it is considered that silence provides some important information about speaker's inner processing. On the basis of early studieson speech and reading, pauses were considered to serve breathing and articulation but also to reflect internal cognitive processes, not observable in any other way. Empty pauses –i.e. the longer empty gaps during speech usually referred to as silent pauses – graduallydrew the attention of both linguists and psychologists (see Rochester, 1973 for a review), and have been eventually treated as a measure of different cognitive functions such as word selection and/or retrieval, planning and memory, which may underlie the organization of spoken sentences (Kirsner, Dunn &Hird, 2005).

1.1.Pause definition

The definition of the term "pause" remains problematic from the very first studies up to this day. Inferences about different kind of pauses appear in psycholinguistic theoretical frameworks in the second half of twentieth century, as in Lounsbury's (1954) theoretical "Model of the Speaker". Lounsbury discriminated between two different pauses phenomena: brief junction pauses and longer hesitation pauses. However, it was Goldman-Eisler's (1968) experiments that had a great impact on further psycholinguistic research of speech. She recommended the threshold of 250 msec, as a criterion for distinguishing pauses into two qualitative categories that differ in duration, location and function, and thus may reflect different kinds of processes, as Lounsbury (1954) has proposed. Pauses shorter than 250 msec (short or articulation pauses) were considered to signify breathing and articulation, and consequently where treated as phenomena beyond psycholinguistic interest, while pauses longer than 250 msec (long or hesitation pauses) were assumed to reflect higher level cognitive processing as word seeking and sentence planning. Interestingly, inferences drawn from her first studies confirmed the appearance of longer pauses just before rare words. Even though the implementation of Goldman-Eisler's threshold was adopted by many researchers, it is not considered a gold standard, and methodological issues are not yet resolved in pausing research, as each study tends to use each own kind of threshold value (see Heike, Kowal& O'Connell, 1983, for a review).

Almost 50 years after Goldam-Eislers' statements for pauses' nature, a different methodological approach appeared. Based on research evidence derived from connected speech in normal speakers, Campione and Veronis (2002) advocated against a predetermined range threshold for defining pauses. They argued that threshold is dynamic and may be influenced by different variables, such as gender, age, educational level and health status. Consequent studies tend to adopt this new methodology (Kirsner, Dunn and Hird, 2005) and change the objective of pausing studies. Campione and Veronis (2002) conducted a large scale study on silent (empty) pauses, by analyzing data from two different speech styles (spontaneous speech and reading) and 5 different languages (English, French, Spanish, Italian and German). Their aim was to examine the effect of specific variables, like mother tongue and speech style, on pause distribution. They suggested that pauses during reading form a bimodal distribution, consisting of short and long pauses, in accordance with the time pattern that early studies have established, while in spontaneous speech they observed a third distribution of very long pauses. Additionally, distributions in reading seem to be similar across languages, with a significant difference only in Italian and Spanish, an outcome that the authors attribute to differentiated speech rate frequency. Interestingly, they did not find significant differences between genders, yet further research is needed for more robust conclusions. Beside the fact that their results displayed the dynamic nature of threshold, their major contribution is the notion that pauses are log-normally distributed, an argument supported by subsequent studies (Kirsner, Dunn &Hird, 2003; Kirsner, Dunn, Hird, Parkin, &Clark, 2002; Rosen, Kent, & Duffy, 2003). The aforementioned studies indicate the necessity of logarithmic transformation prior to parametric statistical analysis.

The new methodological approach does not indeed reject the initial notion for two different kinds of pause phenomena. On the contrary, it reinforces the hypothesis that pausing is an integral part of speech, reflecting its dynamic nature and indicating the temporal organization of various sub-linguistic cognitive processes, from lexical decision and planning to articulation of speech output. As Kirsner and colleagues (2002) argued, evidence from log-normal analysis may indicate the necessity to examine pauses in a different way, within the context of connected speech not only in normal populations but also in cases of communication disorders.

1.2.Previous studies in pathology

Different clinical populations of neurological background, as post-stroke aphasia (Kirsner, Hird and Dunn, 2005), Parkinson disease (Goberman and Elmer, 2005) and ALS (Green, Beukelman and Ball, 2004) have been tested in order to identify different patterns of pause distributions. Additionally, there are studies involving psychiatric patients with schizophrenia, in an attempt to localize brain activation in longer pauses during lexical decision in connected speech (Kircher et al., 2004). Of great interest is also an attempt to correlate pauses patterns with neuropsychological assessment in patients with Mild Cognitive Impairment and typically aging people (Rochford et al., 2012). Most of these studies provide indications that pauses distributions appeared significantly different between healthy participants and pathological populations. These results may lead to the conclusion that pauses could be an integral aspect of cognitive assessment in clinical practice and research, since pause-derived findings seem to be comparable with performance on psychometric measures.

1.3.Pauses and aphasia

Fluency is a critical factor to assess and categorize different types of aphasic disorders. Although pauses may be a measure of speech temporal organization related to fluency, only a few studies have yet taken them into consideration. Kirsner and Hird (2010) analyzed speech samples from three aphasic patients with different taxonomic profiles, in comparison to a normal speaker. They observed that pausing distributions could serve as a quantitative index of speech output, compatible with BDAE classifications. It could be therefore argued that pause analysis could contribute to a better understanding of language processing. This approach may be proved extremely useful in the case of aphasia, and also applied to other clinical populations in several languages besides English.

1.4.Barriers and Limitations in pause research

Despite the above indications that pauses may provide elucidating information concerning brain function during speech, there is only a small number of evidence based research investigating pausing in normal and pathological speech. As Kirsnerand colleagues (2002) fairly claim, there is an obvious gap with regard to pausing studies that could be attributed to several reasons. A major constraint refers to the cost of time. As mentioned in most of the studies, the proportion of time needed to process one minute of free speech is approximately forty minutes (Kirsnet et al., 2002), a conclusion that we verified in our study too. This is a major difficulty that prevents researchers from analyzing larger amounts of data and consequently examining the possible influence of more variables. A second issue concerns not only pauses but speech research in general. There are numerous factors influencing speech, which more than often are not easily controlled or even measurable. However, the major difficulty may be due to lack of a consensus for a standard methodology and, therefore a comparison between studies is practically unfeasible.

1.5.Current study's purpose

To our knowledge, there are only a small number of studies focusing on pauses in aphasia. We aim to investigate pausing duration distributions in Greek aphasic connected speech, in order to assess possible different patterns among patients and to further examine if the latter can be associated with specific lesion sites. Moreover, we attempt to compare pauses distribution between aphasics and normal speakers, in order to test the hypothesis that particular parameters –likeindices of central tendency and variance– maybe significantly affected by language disturbance due to brain pathology (Kirsner, Hird& Dunn, 2005).

2. Methodology

2.1. Participants

19 (7 women) patients with chronic aphasia following a left hemisphere stroke, 40-74 years old (Mean: 57.94, SD: 9.14), with 6-20 years of formal schooling (Mean: 12.28, SD: 3.75), were recruited. Aphasia was assessed with the short form of the Boston Diagnostic Aphasia Examination (BDAE-SF; Goodglass and Kaplan, 1972), adapted in Greek (Tsapkini, Vlahou, &Potagas, 2009). Patients with speech rate (words/minute) lower that 40 were excluded: a pilot preliminary study including only severely non-fluent individuals showed that their speech output pattern poses great limitations to subsequent analysis, due to extremely long intervals of silence between sparse, and rather short utterances, often corresponding to single words. Structural imaging data (CT or MRI) were obtained for each patient, and lesion sites were identified and coded for 16 predetermined left hemisphere areas: the inferior and middle frontal gyri, the precentral gyrus, the inferior, middle and superior temporal gyri, the inferior parietal lobule, including the angular and supramarginal gyri, the thalamus, the insula, the supplementary motor area, the internal and external/extreme capsule fasciculi, the head and tail of the caudate nucleus, the putamen, and the globus pallidus. The total number of affected cortical and subcortical areas served as an index of lesion extent. The control group consisted of 19 healthy adults (9 women), 45 to 86 years old (Mean: 63.95, SD: 10.60), with 6 to 16 years of formal schooling (Mean: 10.95, SD: 4.05), and no neurological or psychiatric history. The two groups were matched for age, gender, and years of formal schooling. All participants were right-handed, native Greek speakers.Informed consent was obtained from all participants prior to participation.

Table 1. Demographic characteristics of the two groups

	Aphasic patients (n=19)		Controls (n=19)		p
	Range	Mean (SD)	Range	Mean (SD)	
Age (years)	40-74	57.94 (9.14)	45-86	63.95 (10.60)	<.05[1]
Education (years)	6-20	12.28 (3.75)	6-16	10.95 (4.05)	<.05[1]
Gender (n)					
Men		12		10	<.05[2]
Women		7		9	

[1]Independend samples t-test
[2] Chi-square

2.2. Speech sampling analysis

Aphasic speech samples were derived from recordings of the stroke story interview during standard BDAE assessment. The control group consisted of the patients' care-givers. They were asked to provide a brief narration regarding the patient's history (i.e. the stroke incident and how it affected their lives); that was the speech sample equivalent to the stroke story. Speech samples were then transcribed, and silent pauses were annotated using ELAN (Wittenburg et al. 2006;Brugman and Russell, 2004) by two independent raters. On the basis of the methodology rationale put forward by Campione and Veronis (2002) and Hird and Kirsner(2010), all pauses were finally transformed to log values, using the ln algorithm, while no boundary threshold for pause range was implemented.

1. Results

Pausing duration distributions in connected speech were investigated in 19 Greek aphasicsand 19 healthy participants. A natural log transformation was made to msec values, prior to further analysis, as suggested by previous studies (Campione and Veronis, 2002). The bin size is 0.1 log units. Statistical analysis was made using the programR3.3.0. Results for the control (euphasic) and the aphasic group are presented in Table 2.

Table 2. Descriptive data in $\log_e(dt)$ for euphasic and aphasic group

	Aphasic patients (n=19)		Controls (n=19)	
	Short Pauses	Long Pauses	Short Pauses	Long Pauses
Mean	4.88	6.65	4.85	6.51
Standard Deviation	0.43	0.62	0.43	0.54
Λ	0.31		0.21	

As shown inFigure 1, the distribution of pauses is bimodal for both groups. That suggests the observed distributions are the result of the combination of two classes of short and long pauses (henceforth Csp and Clp, respectively), with medians of 4.85 (128 ms) and 6.51 (670 ms) in the log domain for the non-brain damaged participants and 4.88 (132 ms) and 6.65 (785 ms) for aphasics. The range of silent pauses was 3.87 - 8.87 log (48 ms-6000 ms) for the aphasic group and 3.69 – 8.18 log (40 ms-3550 ms) for the control group. No boundary thresholds for the detection of lowest and highest admissible pause duration value were implemented a priori; we included the lowest pause value that we detected, 48 ms for aphasics and 40 ms for normal speakers.

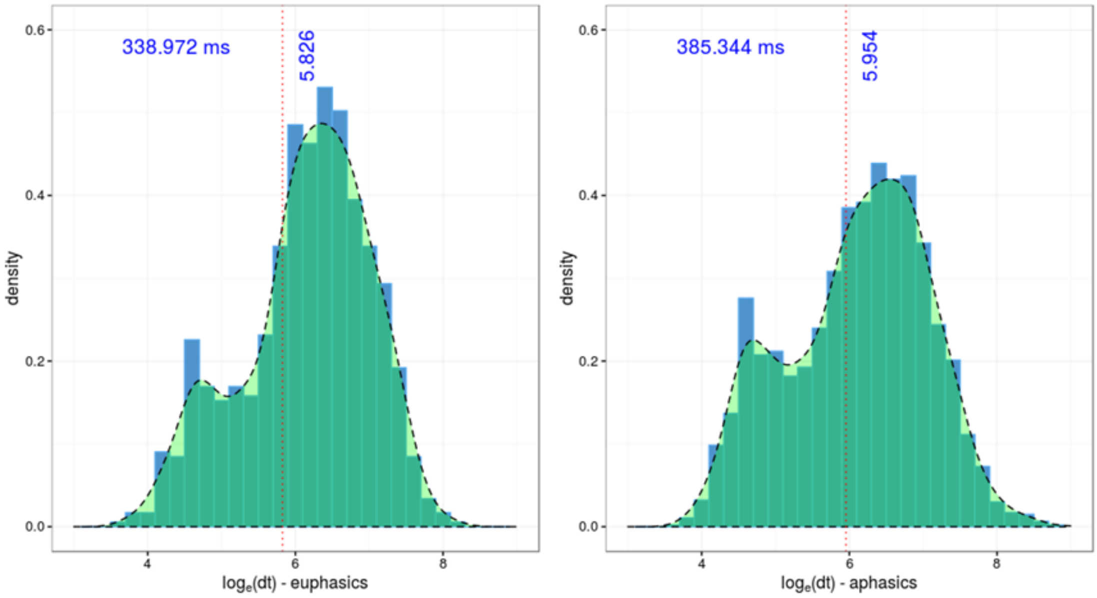

Figure 1. Pause duration distribution in $\log_e$(dt) for euphasic and aphasic group

In order to estimate the distribution threshold (i.e. the cut-off between the two classes of pauses), the Csp and Clp components of the bimodal distribution were modelled after their sample mean and standard deviation, and subsequently mixed using a weighting parameter λ (Oakes, 1999; Schlattmann, 2009). The λ parameter and cut-off wereestimated using the expectation-maximization algorithm (EM), while Monte Carlo simulations were implemented to estimate CIs (this method is described in Trang et al., 2015). The estimated cut-off value between Csp and Clp seems to be significantly lower for the control group (~ 339 ms) compared to aphasics (~ 385 ms).

The fact that both groups present a bimodal distribution indicates that short and long pauses are fundamental components of normal, but also pathological speech. It should be however noted that connected speech may be governed by different patterns in aphasics and healthy speakers, as illustrated inFigure 2: even if both distributions are bimodal, aphasics tend to demonstrate a higher peak for short pauses compared to controls, while the opposite trend is evident for long pauses.

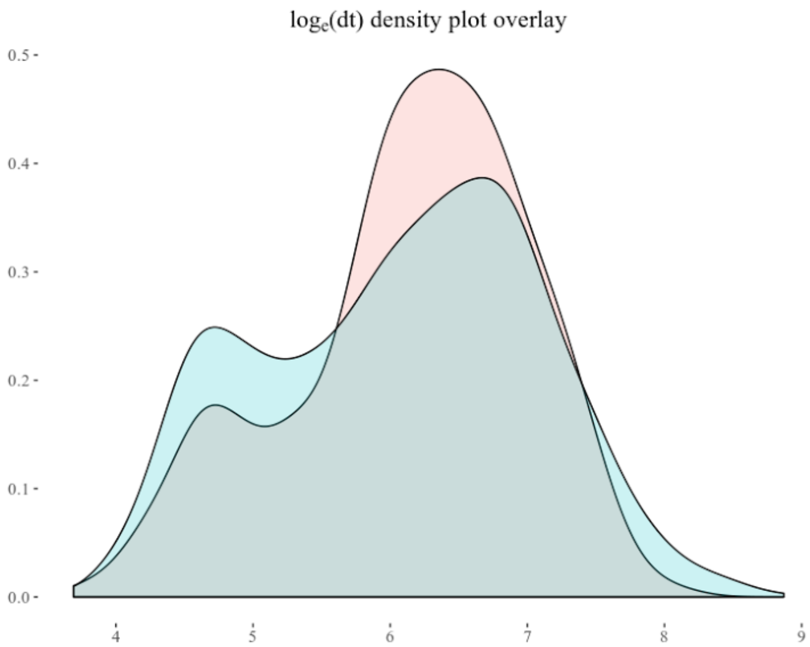

Figure 2. Pause duration distribution in log$_e$(dt) for normal (pink) and aphasic (green) group

In order to further assess different patterns within the aphasic group, we analyzed pause durations separately for each patient. As shown in Figure 3, the illustration of individual pause patterns, unveils the possible existence of two subgroups. Most patients (n=16) tend to produce more long than short pauses (henceforth AphLP). In contrast, 3 patients follow the opposite trend, with a much higher frequency for short, compared to long pauses (henceforth AphSP). A case by case investigation with regard to lesion loci was finally performed, in order to investigate differences between the aforementioned subgroups. Comparison of the two groups using the Mann-Whitney U test revealed significant differences between the two groups with regard to lesion extent ($p<.01$), with AphLP having more extensive lesions than AphSP. Moreover, slightly different lesion site trends were indicated: the frequency of lesions affecting specific regions, such as the insula and the superior temporal gyrus is higher for AphLP (see Table 3).

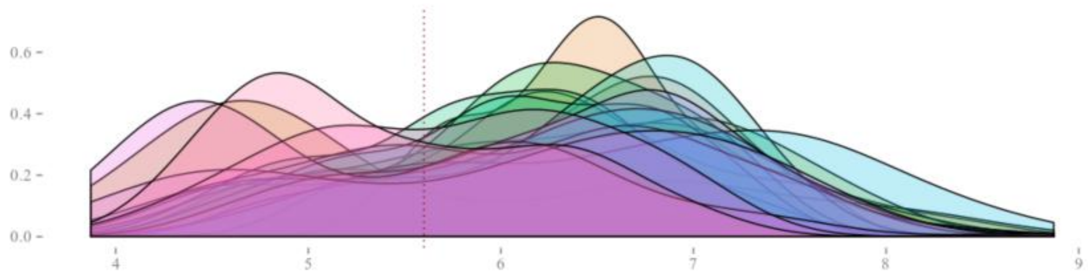

Figure3. Pause duration distribution in $\log_e$(dt) for aphasic group

Table 3. Individual lesion data for the aphasic group

ID	Gender	IC	EC	GP	Putamen	CNh	CNt	Thalamus	SMA	PrG	Insula	IFG	MFG	IPL	STG	MTG	ITG	LS
1	F	intact	intact	intact	intact	intact	intact	lesion	lesion	intact	Lesion	lesion	lesion	intact	intact	Intact	intact	5
2	F	intact	lesion	intact	intact	intact	intact	intact	intact	intact	lesion	intact	intact	lesion	lesion	lesion	lesion	5
3	F							Missing										-
4	M	intact	intact	intact	intact	intact	intact	intact	intact	intact	intact	intact	intact	lesion	lesion	lesion	lesion	4
5	M	intact	intact	intact	intact	intact	intact	intact	intact	intact	lesion	intact	intact	lesion	intact	intact	lesion	3
6	M	intact	intact	intact	lesion	intact	intact	intact	intact	lesion	lesion	lesion	lesion	intact	lesion	intact	intact	6
7	F							Missing										-
8		lesion	lesion	lesion	lesion	intact	intact	intact	intact	intact	lesion	lesion	intact	intact	lesion	lesion	intact	8
9	M	intact	lesion	intact	lesion	intact	intact	intact	intact	intact	lesion	lesion	intact	lesion	lesion	intact	intact	6
10	F	intact	intact	intact	lesion	lesion	lesion	intact	intact	lesion	lesion	lesion	intact	lesion	lesion	intact	intact	8
11	F	intact	intact	intact	lesion	lesion	lesion	intact	intact	lesion	lesion	lesion	intact	lesion	lesion	intact	intact	8
12*	M	lesion	intact	intact	intact	intact	lesion	intact	intact	intact	intact	intact	intact	intact	intact	intact	intact	2
13	M							Missing										-
14*	M	intact	intact	intact	intact	intact	intact	intact	intact	intact	lesion	intact	intact	lesion	intact	intact	intact	2

15	F	lesion	lesion	lesion	lesion	lesion	lesion	intact	intact	intact	lesion	intact	intact	lesion	lesion	intact	intact	9
16	M	intact	intact	intact	intact	intact	intact	intact	lesion	lesion	lesion	lesion	lesion	intact	intact	intact	intact	5
17	M	lesion	lesion	lesion	lesion	intact	intact	intact	intact	intact	intact	intact	intact	lesion	intact	intact	intact	5
18*	M	intact	intact	intact	intact	intact	intact	intact	intact	intact	intact	intact	intact	lesion	lesion	lesion	lesion	4
19	M	intact	lesion	intact	intact	intact	intact	intact	intact	intact	lesion	intact	intact	lesion	lesion	lesion	intact	5

IC: internal capsule; EC: external capsule; GP: globus pallidus; CNh: caudate nucleus head; CNt: caudate nucleus tail; SMA: supplementary motor area; PrG: precentral gyrus; IFG: inferior frontal gyrus; MFG: middle frontal gyrus; IPL: inferior parietal lobule; STG: superior temporal gyrus; MTG: middle temporal gyrus; ITG: inferior temporal gyrus; LS: lesion score

*patients in the AphSP subgroup

4. Discussion

The present study aimed to investigate pause distribution in aphasia. To the best of our knowledge, this is the first study in Greek. Although there have been studies in other languages, the relevant findings are sparse. Therefore, a study focused on Greek could aid in both understanding this aspect of aphasic speech in general and also providing useful data from another language.Our results indicate that the pause distributions of both populations are bimodal, consisting of two classes: short and long pauses. First and foremost, this indicates that silence pauses in Greek seem to follow the same pattern as presented in English (Hird and Kirsner, 2010) and French (Campione et Veronis, 2005), in normal speakers. That may lead to the assumption that pause pattern islanguage-independent. This may also be compatible with thenotion that pauses play an important role in cognitive processes that characterize speech organization and articulation, including planning, the retrieval of semantic and lexical information from memory, discourse monitoring, phonemic construction, and breathing (Kirsner, Dunn and Hird, 2005), by supporting the hypothesized universality of the aforementioned cognitive functions, at least in relation to silent pauses. It is suggested that pause durations provide an interface between observations of external behavior and the underlying cognitive processes. However, further research is essential, involving larger samples of connected speech of normal speakers, in order to clarify the exact role of pauses in cognitive processes during speech.

An indication of pauses' role though may appear in language disorders. A small number of studies in various pathologies have shown that pauses duration appears different frequencies of pause durations than control groups, however maintaining the bimodal pattern and consequently the existence of short and long pauses (Green et al., 2004; Hird & Kirsner,2010; Rochford et al., 2012; Rosen et al., 2003).Our data indicate that aphasics also form a bimodal distribution in pause duration, similar to that of healthy participants', in the sense that the frequency of long pauses is greater than the frequency of short pauses. However, the frequency of short pauses is much greater in the aphasic group, compared to controls. This findingmay shed light to the architecture of aphasic speech, since evidence on the subject is sparse, and mostly derived by small-scale studies. For example, Hird and Kirsner (2010) showed that some aphasics seem to prefer short pauses, a pattern also presented in their control group, while in one case of transcortical-motor non fluent aphasia, longer pauses are of higher frequency. However, their sample was small, consisting of only 3 patients.

On the other hand, our results are in accordance with Kirser and collegues (2004), who argued that normal speakers show a preference towards long pauses. The authors further argue that the latter occur mainly during word seeking or between sentences, and are associated with increased hemodynamic responses in a single region that spanned the banks of the posterior part of the left superior temporal sulcus (Brodmann Areas 22 and 39), at thejunction between the temporal and parietal lobes.

Furthermore a noteworthy result is the existence of two aphasic subgroups (AphLP and AphSP), which demonstrate different trends with regard to their preference for long or short pauses. This suggests variability within patients and may underlie different cognitive processes corresponding to different levels and/or types of language impairment. A preliminary attempt to further investigate this hypothesis was based on a case by case investigation of our patients in terms of lesion locus and extent. Our analysis clearly showed that there is a significant difference between AphLP and AphSP regarding lesion size, with the latter group presenting with much smaller lesions. Since long pauses have been associated with word selection/retrieval, planning, memory, and other functions that may underlie the organization of spoken sentences,this finding could reflect a breakdown of higher language-related cognitive processes due to lesions affecting several components the widely distributed perisylvian network, that is supposed to serve both linguistic and non-linguistic aspects of cognition. The increased frequency of specific lesion loci in AphLP may further support this notion, since the involved cortical regions have been proven to be an integral part of the neurological substrate of elaborate processes that require a constellation of executive, language, and memory functions.

5. Conclusion

Overall, we suggest that pause investigation may be applied to spontaneous speech analysis in communication disorders as well as other quantification measures of speech (speech rate, length of utterance and duration of speech segmentation). This step is feasible because log-normal analyses provide an appropriate basis for analyzing both pause and speech distributions. Additionally, pauses' locations could be also annotated, in order to specify silence duration before linguistic phenomena as clause boundaries, rare words and more importantly linguistic errors and repairs. As previous studies suggested, pausing during speech might be an important aspect of the translation of abstract preverbal thoughts into intelligible speech. However, to further elucidate the role of silence in speech organization, a larger sample size of spontaneous, typical and impaired, speech is desirable. As Levelt (1989) claimed, pauses own a major role in cognitive processes during speech planning; however, we are not still able to specify its exact nature.

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