International Conference on Character and Sustainable Education (ICoCSE) Proceedings
Vol.1, 2024, pp. 95-105

Analyzing Phonological Errors in Non-Fluent Aphasia: An Acoustic Analysis

I Ketut Wardana

Faculy of Teacher Training and Education, Universitas Mahasaraswati Denpasar, Denpasar, Indonesia

Corresponding Email: ketutwardana71@unmas.ac.id

Abstract

This study investigated the phonological error patterns in the speech of a patient with non-fluent aphasia, focusing on the nature and types of sound deficits, syllabic structures, and language abilities. Utilizing a quantitative-descriptive case study design, the research aims to analyze KW's consonant and vowel production errors, categorize their severity, and assess the decline in his speech abilities. Various language tasks, including word and picture naming, comprehension questions, and oral reading, were administered and recorded for acoustic analysis. Transcriptions were made using the International Phonetic Alphabet (IPA) to capture phonological deviations. Results revealed a total of 44 phonological errors, predominantly substitutions (31), along with distortions, additions, and omissions. Notable patterns included frequent substitutions of complex consonant sounds and vowel alterations, indicating challenges in articulating sounds, particularly in high-complexity positions. Acoustic measurements demonstrated significant differences in formant values and articulation duration compared to typical speech. These findings highlight the intricate nature of phonological impairments in non-fluent aphasia, emphasizing the need for tailored therapeutic interventions to improve speech production. The study contributes to the understanding of aphasia-related speech difficulties and provides a framework for further exploration of phonological errors in similar cases.

Keywords: phonological errors, mon-fluent aphasia, acoustic analysis, speech production

INTRODUCTION

Aphasia is a language disorder that often occurs due to brain injury, particularly after a stroke. One of the most common types of aphasia is non-fluent aphasia, where patients experience difficulty speaking fluently, although their language comprehension is relatively intact. In non-fluent aphasia, such as in the case of Broca's aphasia, phonological errors frequently occur, including misarticulation, substitution, and sound omission. Therefore, it is essential to understand the forms, types, and levels of sound errors based on acoustic analysis. The identification and analysis of these phonological errors are crucial for understanding the limitations in the patient’s language production and for providing insights into more effective clinical interventions (Goodglass & Kaplan, 2001).

The research tradition on aphasia focuses on descriptive linguistic approaches, observing patterns of errors that appear in the patient's language production. However, research using an acoustic approach to analyze phonology in aphasia is still relatively limited (Kent, 2015). The acoustic approach provides deeper insights into the physical characteristics of the sounds produced by aphasia patients, such as frequency, intensity, and sound duration (Turner *et al*., 2017). This method enables researchers to identify errors that may not be detected through conventional observation and helps to understand the extent of the disturbance at the sound production level (Aichert & Ziegler, 2013).

Although acoustic research in the context of aphasia is increasingly developing, most previous studies have been limited to qualitative analysis without in-depth integration of acoustic data with the specific phonological errors experienced by non-fluent aphasia patients (Balasubramanian *et al*., 2015). More comprehensive research that combines the analysis of phonological errors with acoustic data is still needed to provide a more holistic picture of phonological disorders in aphasia. Furthermore, there is still a gap in the literature regarding the specific methods used to categorize and interpret acoustic results in the context of phonological errors (Buchwald & Miozzo, 2012). Therefore, more systematic studies using an acoustic approach to decode phonological errors in greater detail in non-fluent aphasia patients are needed.

This study aims to identify the forms of sound errors in the aphasia patients being investigated, explain the types of phonological errors, and categorize the levels of sound errors produced by the patients. By understanding these categories, the severity of dysfunction in the language production areas involved can be concluded. This research combines an in-depth acoustic and phonological approach to analyze sound production errors in non-fluent aphasia patients. Thus, the results of this study are expected to make a significant contribution to the development of more specific and effective therapeutic interventions.

To explain this issue theoretically and empirically, this study synthesizes theories related to aphasia, phonological analysis, and acoustic analysis. Non-fluent aphasia, such as Broca's aphasia, is a form of language disorder caused by brain damage, particularly in the left frontal region associated with language production (Dronkers, 1996). Patients with non-fluent aphasia tend to have difficulty speaking fluently, even though they can understand conversations. A key characteristic of this type of aphasia is the presence of phonological errors, including misarticulation, substitution, omission, or addition of sounds in speech production (Goodglass & Kaplan, 2001). Studying these phonological errors is essential for understanding the cognitive and motor impairments underlying patients' language limitations.

Phonology in Non-Fluent Aphasia

Phonology is a branch of linguistics that studies the structure and sound patterns in language. In non-fluent aphasia, phonological errors can involve various types of impairments, including the inability to string sounds together correctly. Non-fluent aphasia patients often experience phoneme distortion or changes in syllable patterns (Ziegler *et al*., 2010). These errors may be due to motor planning issues, articulation problems, or disruptions in the internal phonological representation that guides speech production. The phonological theory related to non-fluent aphasia refers to several approaches, including Levelt's Model of Speech Production (Levelt, 1999). This model proposes that speech production involves three main stages: conceptualization (selecting the idea to convey), formalization (creating the phonological representation), and articulation (producing the physical sound). In non-fluent aphasia patients, disruptions in the formalization and articulation stages often result in sound production errors.

Acoustic Approach to Analyzing Phonological Errors

Acoustic analysis offers a quantitative approach to understanding the physical properties of sounds produced in speech. In the context of non-fluent aphasia, this analysis includes measuring parameters such as fundamental frequency, duration, intensity, and formants (Kent & Read, 2002). Acoustics provides empirical data on how far the patient's sound production deviates from the normal standard, allowing for more precise identification of phonological errors (Ball & Rahilly, 2013). A study by Turner *et al*. (2017) showed that non-fluent aphasia patients tend to have significant variations in vowel and consonant duration, as well as reduced intonation control, which can worsen the intelligibility of their speech. Acoustic analysis also allows researchers to identify phenomena that may not be detected through auditory observation alone, such as minor distortions or frequency drops that do not align with normal patterns (Aichert & Ziegler, 2013).

According to Simanjuntak (1990) & Shane (1992), the phonological process consists of three stages: lexical representation, phonological representation, and phonetic representation. In generative phonology, three key components are used for fundamental analysis; (1)

underlying Representation (UR): This is the mental or basic representation of sounds, notated as / /; (2) Phonological Rules: These rules govern how sounds are altered or changed; and (3) Phonetic Representation (PR): This refers to the actual spoken form of sounds, notated as [ ].

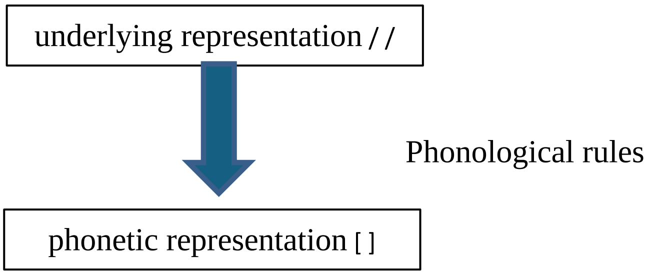

Figure 1. Model of Analysis of Generative Phonology

From these rules, Schane (1992) explains that generative phonology is a mental mechanism that governs sound processes in all languages. Phonological processes involve alterations in sound segments when morphemes combine to form words. These sound changes can occur in different environments, such as at the beginning, middle, or end of a word, or between vowels, particularly when the second vowel is stressed. Sound changes can be categorized into four types of phonological processes: assimilation, syllable structure modification, weakening and strengthening, and neutralization Goldrick & Rapp (2007). In Broca's aphasia, phonological disorders are often related to semantic difficulties, especially challenges with naming and repeating words or sentences.

The Relationship Between Phonology and Acoustics in Aphasia

Linking phonological theory with acoustic analysis can expand our understanding of the mechanisms behind phonological errors in aphasia patients. Phonological theory explains errors in cognitive and linguistic terms, while acoustics provides objectively measurable data about the quality of the sounds produced. Combining these two approaches offers a more comprehensive insight into how the impaired brain processes and produces speech. Modular phonological theories, such as the one proposed by Goldrick & Rapp (2007), suggest that errors in sound production are often caused by disruptions in the interaction between the phonological and articulation modules. Acoustic data can support this claim by providing physical evidence of production errors, such as reduced vocal control or abnormal intensity.

In this context, research on decoding phonological errors based on acoustic analysis can help expand the understanding of the most appropriate interventions for each patient based on the specific error patterns they experience. There are three research questions addressed in this study:

1. What are the forms of sound errors analyzed through PRAAT?
2. What types of phonological errors are present in the speech of aphasia patients?
3. How are the severity levels of sound errors in aphasia patients categorized?

METHOD

Research Design

This study employed a quantitative-descriptive case study approach, which is particularly well-suited for in-depth analysis of specific phenomena in a single participant. The focus was to analyze phonological errors in both consonant and vowel production, categorize the severity of these errors, and explore the decline in informant speech. A case study design allows for the detailed examination of complex disorders like non-fluent aphasia, where individual variability in symptom presentation is high (Creswell & Poth, 2018).

Participant

The study involved a single participant, KW, a 70-year-old retired elementary school teacher. KW is right-handed and developed non-fluent aphasia following a cerebral vascular accident (CVA), which caused a lesion in the anterior fissure of the Rolandic area in the left hemisphere of the brain. KW's participation in the study focused on his ability to produce speech in response to various phonological tasks.

Instruments

This study utilized a series of language tests to evaluate KW's language abilities, which included word naming, where KW was asked to name words presented in a list; picture naming, where KW was shown pictures and asked to name the visible objects; and answering questions related to specific contexts to assess comprehension and language production. Additionally, KW was asked to read a text aloud, allowing for the analysis of speech production and fluency. All sessions of conversation and testing were recorded using high-quality digital recording equipment to ensure clarity and adequate sound quality, and these recordings were subsequently analyzed acoustically. Each recording was transcribed phonetically and phonemically using the International Phonetic Alphabet (IPA) to capture any errors and variations in sound production, making this process essential for accurately identifying phonological errors.

Data analysis

First, all of KW's speech samples, which included tasks such as word naming, picture naming, question answering, and oral reading, were recorded and then transcribed both phonetically and phonemically using the International Phonetic Alphabet (IPA). This transcription process was critical in identifying deviations from expected phonological outputs, including misarticulations, omissions, substitutions, and distortions, allowing for thorough phonological error analysis (Ball & Rahilly, 2013).

Following this, the recorded speech was analyzed using PRAAT software (Boersma & Weenink, 2022), which enabled detailed acoustic measurements. Key acoustic parameters such as fundamental frequency (F0) to examine pitch variation, formant frequencies (F1, F2, F3) to assess vowel articulation and resonance, duration to measure how long KW sustained both consonants and vowels, intensity to gauge the loudness of produced sounds, and voice onset time (VOT) to evaluate the timing of voicing in plosive consonants were measured. These acoustic measurements helped identify subtle variations in KW's speech that would be difficult to detect through auditory analysis alone.

The phonological errors were then classified into specific categories, including misarticulations (incorrect sound production), substitutions (replacing one phoneme with another), deletions (omitting sounds, particularly in final consonants or unstressed syllables), additions (inserting extra sounds that disrupt phonological sequences), and distortions (changes in articulation due to motor control issues). The types of errors were further analyzed based on their distribution within the words—whether they occurred in the initial, medial, or final positions—revealing patterns in KW's difficulties with certain sounds. The severity levels were then cross-referenced with the acoustic measurements, providing an objective basis for classifying the phonological errors (Aichert & Ziegler, 2013).

RESULTS AND DISCUSSION

The forms of phonological errors

The results of this study show that KW had difficulty pronouncing words and naming pictures correctly. Below are 10 examples of vowel and consonant sound errors from a total of 44 errors produced by the subject, KW.

Table 1. The forms of vowel and consonant errors

No	Targeted words	Meaning	Uttered sounds	Types of errors
1	tomat /ipah/	'tomato'	[opat]	Deletion//assimiltion
2	Uled /uləd/	'caterpillar'	[oles] [olef]	substitution
3	Aluh /alUh/	'easy'	[lul….alluh]	Addition
4	Toke /tokè/	'gecko	[tuke]	substitution
5	Keket /kèket/	'bush'	[keiket]	Addition
6	Oleg /oleg/	'dance'	[olleʔ]	substitution
7	Roko /roko/	'cigarette'	[lokoh]	substitution
8	Katos /katos/	'hard'	[hastuh]	substittution
9	Kapak /kapak/	'axe'	[hapah]	substittution
10	Papat /papat/	'four'	[papas]	substittution

In the pronunciation of 65 words, there were 44 vowel and consonant sound errors, consisting of 31 substitutions, 7 distortions, 4 additions, and 2 omissions. The consonant sounds /p/, /r/, and /s/ were replaced by [l] in 3 cases across all positions. The consonant sounds /d/, /t/, /k/, /h/, and /ɲ/ were substituted with /s/ in 8 cases across all positions. The sound /g/ was replaced by [ʔ] and [d] in 3 cases at the end of words, and the sounds /s/, /k/ were replaced by [h] in 3 cases at the beginning and end of words. The sound /ɲ/ became [n] and [s] in 2 cases at the beginning and middle of words, while /y/ was substituted with [j] in 1 case at the beginning of a word and /y/ was replaced by [ɲ] in 2 cases in the middle of words. The sound /s/ was substituted by [k] in 2 cases at the beginning of words, /g/ was replaced by [k] in 1 case, /t/ was replaced by [b] in 1 case at the end of a word, /p/ was replaced by /k/ in 2 cases, and /u/ and /e/ were substituted with [o] in 2 cases at the beginning and end of words. In terms of distortions, the sound /u/ became [a] in 3 cases, and /p/ was replaced by [l] in 4 cases. There were 2 cases of adding /i/ and 2 cases of adding /o/, while /k/ was omitted in 2 cases. The phonological processes and rules in these word pronunciations are presented in Table 2.

Table 2. Phonological rules of consonant errors

Sound targeted	meaning	Uttered sounds	Phonological rules
/papat/	'four'	[papas] ▼	/t/ [s] /. #
/[təbu/	'sugar cane'	[təboh] ▼	/u/ [o] / · #
/məɲan/	'sandal wood'	[menan] ▼	/ɲ/ [n]/V · V
/kipas/	'fan'	[ipas] ▼	/k/ ϕ / #·

From the data examples above, it can be observed that the patient has difficulty articulating sounds with high complexity, both at the beginning and end of words. Voiceless stop sounds at the end of words were replaced with fricative sounds. Meanwhile, voiceless velar sounds were omitted at the beginning of words. This indicates that the more complex the level of sound articulation, the more likely the sound is to undergo substitution. Table 3 below shows the vowel sound substitutions found in the patient's speech.

Table 3. The direction of vowel articulation errors

No	Arah pergantian	Analisis fonetik	Analisis fonologis
1	/i/ ▼ [e] [siap] /seap/ 'chicken'	The tongue anticipates the [a] vowel sound earlier, affecting the accuracy of the high vowel [i] pronunciation (Ladefoged, 2004).	Sound high vowel sound weakens the middle vowel occurs as the speech organs anticipate the following low vowel /a/ (Schane, 1992).
2	/i/▼ [a] [ipah] /aleh/ 'in law'	The tongue height in the coarticulation of [i] and [p] is affected as the lips fail to block the airflow, allowing it to pass through both sides of the tongue (Ladefoged, 2004).	A high sound becoming a low sound before a lateral sound can be described as a conceptual error (Schane, 1992).
3	/ə/▼ [u] [gələm] /kuləb/ 'sick'	The blade of the tongue moves backward and rises after a voiceless sound, and the pharyngeal space slightly narrows (Jurafsky & Martin, 2007).	The shift from a mid-sound to a high-back sound due to the surrounding environment occurs when the sound [e] changes to [u] after a voiceless velar sound (Schane, 1992).
4	/ə/▼ [o] / batə / 'bata' [da ebat oh] "brick"	Gerakan lidah ke belakang dan nilai F3 sedikit rendah yang menunjukkan bibir agak membulat (Ladefoged, 2004)	Pelemahan bunyi [e] menjadi [o] di akhir kata karena kehadiran bunyi glottal di posisi akhir (Schane, 1992)
5	/ə/ ▼ [a] /rebab/ 'biola' [papa]	Penurunan lidah di suku pertama akibat karena organ wicara pengantisipasi bunyi hambat tak bersuara (Jurafsky&Martin (2007)	Pergantian bunyi getar [r] oleh bunyi /p/ di awal kata akibat bunyi yang tersimpan MJP yaitu [pa] sehingga terjadi pengulangan (Gandour, 2013)
6	/ə/▼ [e] /uləd/'ulat' [oles]	Lidah ke langit keras sehingga rahang bawah menurun, udara keluar melalui bibir merentang karena mengantisipasi bunyi frikatif berikutnya (Ladefoged, 2004)	Bunyi [ə] menjadi [e] akbat lingkungan bunyi tak bersuara yang mana target fonemnya [ə] diikuti oleh bunyi bersuara (Schane, 1992)
7	/u/ ▼ [U] /bulu/'bulu' [ulUh]	Pengendoran bunyi tinggi akibat dari ketidakcermatan pada gerakan lidah akibat antisipasi bunyi lain pada posisi tertentu (Ladefoged, 2004)	Pelemahan bunyi tegang menjadi bunyi kendor akibat dari adanya tutupan bunyi glottal di akhir kata (Schane, 1992)
8	/u/▼ [o] /madu/ 'madu' [mado]	Pelemahan bunyi tinggi ke bunyi lebih rendah akibat posisi lidah menurun sehingga bibir menjadi tidak membulat diposisi akhir (Ladefoged, 2004)	Bunyi vokal tinggi bulat belakang menjadi bunyi tengah belakang apabila berada di posisi akhir. Ini merupakan proses pergantian akibat lingkungan bunyi (Schane, 1992)
9	/o/ ▼ [u] /katos// 'keras'[hastuh]	Pelemahan bunyi /o/ terjadi karena naiknya lidah belakang dan membulatnya bibir akibat glotis menghimpit alur udara (Ladefoged, 2004)	Proses asimilasi terjadi ketika bunyi /o/ mengambil ciri bunyi /u/ akibat diikuti oleh bunyi glottal diposisi akhir (Schane, 1992)
10	/u/▼ [U] /juju/ 'kepiting' [julUh]	Gerakan lidah setelah bunyi lateral kebelakang dan sedikit naik dan bibir tidak membulat secara penuh akibat gesekan udara di glottis (Ladefoged, 2004)	Bunyi tegang menjadi bunyi kendor apabila berada di posisi akhir tertutup dan juga disebabkan bunyi yang mendahuluinya yaitu bunyi lateral (Schane, 1992)
11	/a/▼ [e]	Ketidaksempurnaan pelafalan bunyi[a] di suku kata kedua akibat	Bunyi rendah belakang menjadi bunyi tengah depan karena terdapat

	/manas ‘nenas’ [manles]	lidah menutupi rongga mulut depan dan terjadi himpitan udara di area palate aveolar (Ladefoged, 2004)	penyisipan bunyi lateral dan tutupan bunyi alveolar frikatif di akhir kata (Schane, 1992)
12	/a/▼ [o] /wayah/ ‘tua’ [aoh]	Kesulitan pelafalan bunyi /a/ pada suku kata kedua akibat kegagalan lidah terangkat mendekati langit-langit keras dan sedikit kebelakang dan diakhiri oleh geseran di glottis (Ladefoged, 2004)	Terdapat proses pelesapan bunyi /w/ di awal kata dan pelesapan bunyi /y/ sebelum bunyi /a/ dan pergantian [a] menjadi [o] di suku kata kedua (Schane, 1992.

From the Table 1, it can be understood that the most noticeable sound alteration from the vowels [e], [u], [o], and [a] into the sound [ə]. This could be due to the articulation occurring in a neutral position. The most distant change is the transformation of /i/ into [a] at the beginning of a word, while the shorter lines indicate sound simplification, such as the shift from +tense to +lax or the lengthening of the vowel [e] to [I]. The direction of movement from high vowels to low vowels (black lines) and from low vowels to high vowels (red lines) represents one form of vowel sound configuration. However, there is a process of vowel weakening in open syllables, which affects the substitution of the voiceless sound [t] with the voiced sound /d/. The spectrogram shows the acoustic characteristics of the sound /titi/ ('bridge'), as presented in Figure 1.

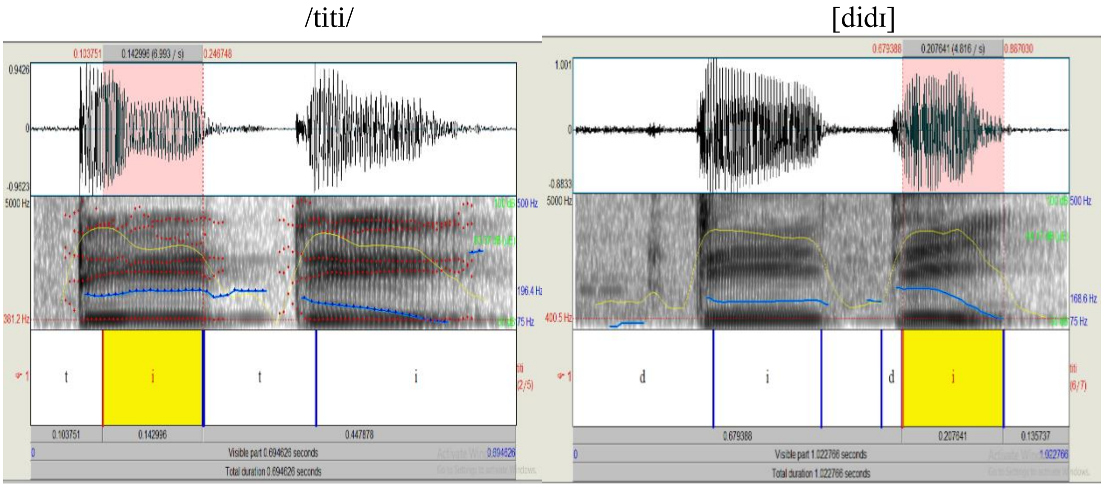

Figure 12. Waveform and Spectrogram Pattern for the Pronunciation of the Sound /i/

The visual waveform pattern of the sound [i] in the word *"titi"* shows significant differences. The sound [i] in the spectrogram on the left has an F1 value of around 381.2 Hz, an F2 reaching 2123 Hz, and an F3 at 2608 Hz. The duration of the /i/ sound is relatively short, at 0.142996 seconds. The differences in the characteristics of the aphasia patient's [i] sound in the spectrogram on the right can be seen in the F1 and F2 values, which range around 414.4 Hz and 2209 Hz, respectively. Both of these formant values are higher than the formant values for a normal [i] sound. The patient's lip stretching is wider, as indicated by the F3 value reaching 2741 Hz. There is an elongation in articulation time, reaching 0.188543 seconds, with a pitch of 161.8 Hz and a denser sound intensity of 85.82 dB. This proves that the aphasia patient can pronounce the [i] sound in specific environments, with an articulation time difference of

0.045547 seconds. Below is a summary of the formant values for the weakened vowel segments in aphasia.

Table 5. Formant Values for Vowel Segment Weakening in Aphasia

Informan	Bunyi	F1 (Hz)	F2 (Hz)	F3 (Hz)	Pitch (Hz)	Durasi md	Tekanan dB
Pasien KW	i	414.4	2209	2741	161.8	0.188	82.52
Normal	i	381.2	2123	2608	207.2	0.142	84.40
	df	33.2	86	133	45.4	0.046	1.88
Pasien KW	e	584.6	1877	2577	156.7	0.567	79.61
Normal	e	671.2	1998	2566	163.4	0.165	94.40
	df	86.6	121	11	6.7	0.402	14.79
Pasien KW	ə	535.9	1644	2375	156.8	0.415	80.16
Normal	ə	671.1	1245	2874	170.7	0.245	83.11
	df	135.2	399	499	13.9	0.17	2.95
Pasien KW	u	475.1	1176	2534	208.7	0.895	86.62
Normal	u	409.4	1023	2621	191.2	0.231	86.65
	df	65.7	153	87	17.5	0.664	0.03
Pasien KW	o	644.2	996	2377	177.1	0.172	80.48
Normal	o	514.7	979.5	2741	182.4	0.195	83.48
	df	129.5	16.5	364	4.5	0.023	3
Pasien KW	a	781	1176	2665	157.3	0.341	83.18
Normal	a	803.6	1198	2906	162.7	0.226	84.11
	df	22.6	22	241	5.4	0.115	0.93

This data shows that the vowel sounds investigated in this case tend to remain largely intact. The occurrence of substitutions is often due to the vowel's position within consonant environments where the articulation is complex, and the difficulty in anticipating the following sound. Meanwhile, consonant sound errors appear more complex and occur more frequently compared to vowel sounds, which generally remain intact. Below is a map showing the direction of consonant sound changes in a patient's speech with non-fluent aphasia.

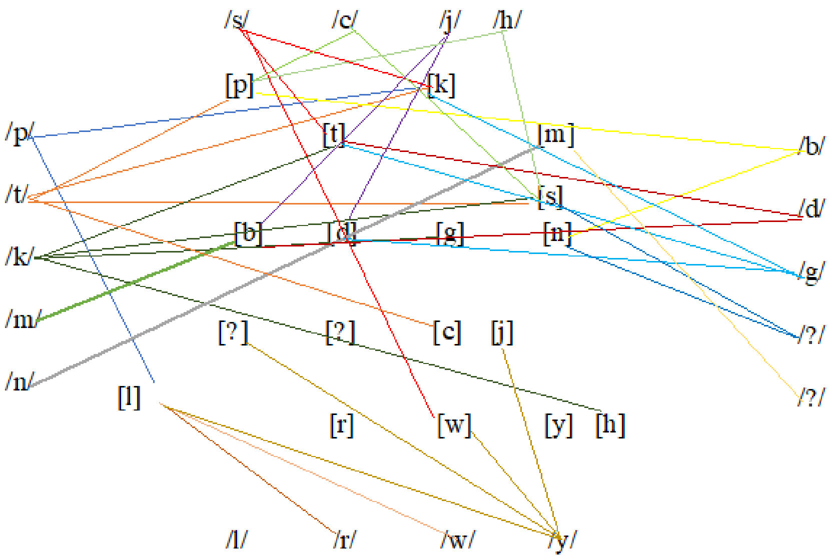

Figure 3. Consonant alteration produced by the patient

Based on the direction of the consonant sound changes mentioned above, it can be explained that the sound /p/ has two forms of sound substitution, [k] and [l]; the sound /t/ undergoes five types of weakening, becoming [p], [t], [k], [s], and [c]; the sound /k/ is replaced by five segments, [t], [g], [s], [h]; the sound /m/ becomes [b]; the sound /n/ becomes [m]; the sound /s/ has four substitutions, [t], [k], [l], and [w]; the sound /c/ becomes [p] and [s]. The sound /j/ is pronounced as [b], [l], and [d]; the sound /h/ is pronounced as [p] and [s]; and the sound /b/ is pronounced as [p] and [n]. The substitutions for /d/ are [t] and [b]. The sound /g/ has three substitutions, [k], [t], and [d]. The sound [ɲ] is pronounced as [n] and [s], the sound [ŋ] is pronounced as [m], and the sounds /r/ and [w] are pronounced as [l]. The sound /w/ is pronounced as [y], [w], [r], and [ɲ]. To ensure the accuracy of the /k/ sound, the waveform pattern and spectrogram for the pronunciation of this sound in the words *'katak'* and *'kasa'* by a motor aphasia patient can be seen in Figure 3.

Targeted sound /katak/ | Uttered sounds /sasəs/

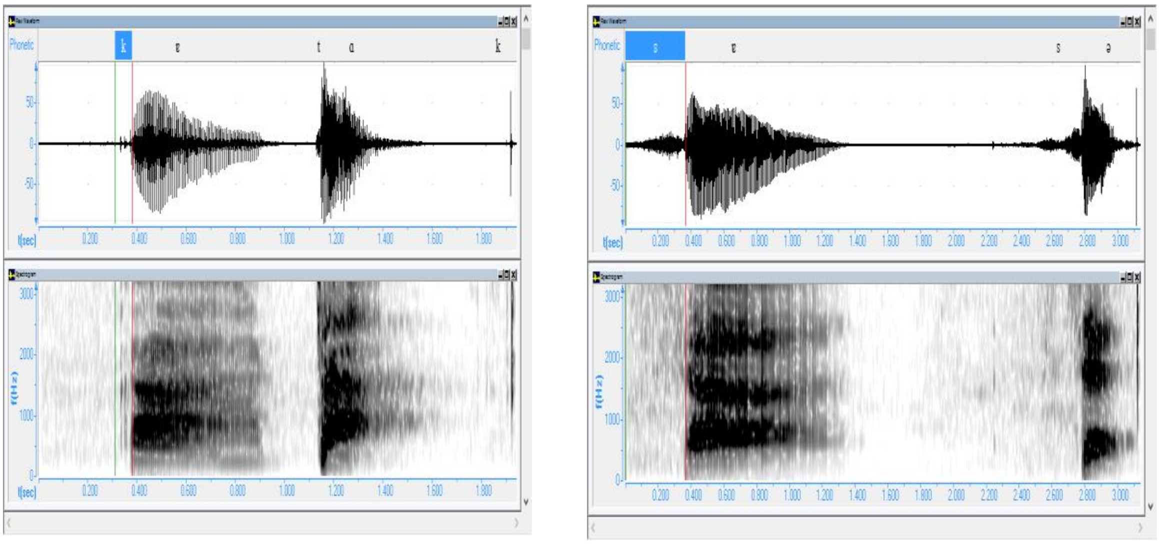

Figure 4. Waveform and Spectrogram Pattern of /k/ Pronunciation in an Aphasia Patient

The silent wave and burst wave at the beginning and end of the syllable *'katak'* in the spectrogram on the left demonstrate that the aphasia patient can pronounce the /k/ sound fairly well, although there is some inaccuracy in the silence. The silent wave indicates the place of articulation for the /k/ sound and the voicing. The thin vertical frequency line reaching around 2500 Hz - 3000 Hz shows that the larynx narrows due to closure in the back area, between the back of the tongue and the uvula. The thinness of the silent wave indicates that the vocal cords are open, resulting in a voiceless stop consonant.

There are several types of substitution processes, namely fronting, stopping, and nasalization. For example, a flap sound may become a lateral sound, a uvular fricative may become a lateral, a dorsovelar may become an alveolar fricative or an alveolar may become a bilabial. Fronting is a common phonological process in aphasic speech. Aphasia patients tend to replace back sounds, such as palatal and velar consonants, with alveolar and bilabial sounds, as in /c/-[s]; for example, /cicɪŋ/ becomes [seɪce].

Stopping is a phonological process that occurs when fricatives and other sounds are replaced by stop consonants, such as /c/-[p], as in /cedɔk/ becoming [peye]. Nasalization occurs when oral sounds are replaced with nasal sounds; for example, /məlaɪb/ becomes [lakɔŋ]. The lateralization process involves replacing the flap sound /r/ with the lateral sound /l/; for example, /rəramə/ becomes [ləlamə]. Assimilation is a process in which a sound changes to become similar to or the same as another sound nearby. For example, the word *entip* is pronounced [empit] by the aphasia patient, where the sound [t] is replaced by [p] and the /n/ is adjusted to [m] because they are both bilabial sounds.

Syllable structure processes involve the adjustment of other sounds through the elimination or deletion of sounds in all positions; for example, /bulu/ becomes [ulʊh]. Cluster reduction is the elimination of one of the consonants in a consonant cluster; for instance, /sambæl/ becomes [samæl].

CONCLUSION

The analysis of KW's phonological errors reveals significant challenges in articulating both vowel and consonant sounds, Notably, the patient struggled with articulating sounds at both the beginning and end of words, with voiceless stops often replaced by fricatives and velar sounds omitted. Vowel sounds, while less frequently altered, demonstrated a pattern of substitutions primarily influenced by their position within consonant environments, leading to vowel weakening and shifts from high to low vowel sounds. The detailed spectrogram analysis further confirms that while some vowel sounds remain largely intact, consonantal changes are more pronounced, reflecting the complexity of phonological processing in non-fluent aphasia. These findings highlight the intricate relationship between phonological errors and the underlying difficulties in sound articulation faced by patients with aphasia, contributing valuable insights into the phonological processes involved in their speech production.

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