BUKTI KORESPONDENSI

ARTIKEL JURNAL NASIONAL TERINDEKS SINTA 2

Judul Artikel	:	Spectral And Temporal Processing In Balinese Vowel Of Non-Fluent Aphasia
Jurnal	:	Aksara
Penulis	:	I Ketut Wardana

No	Perihal	Tanggal
1	Bukti konfirmasi submit artikel dan artikel yang disbumit	4 Mei 2020
2	Bukti konfirmasi review dan hasil review pertama	25 Juli 2020
3	Bukti konfirmasi submit revisi kedua	18 Januari 2022
4	Bukti approved article	5 April 2022
5	Bukti Publikasi	16 September

1
Bukti dan Artikel yang Disubmit
(4 Mei 2020)

ASPECTRAL AND TEMPORAL PROCESSING IN BALINESE VOWEL OF NON-FLUENT APHASIA

PEMROSESAN SPEKTRAL DAN TEMPORAL BUNYI VOKAL BAHASA BALI AFASIA NON-FASIH

NB-2

Article accepted: …….; revised: ……; approved: …….

Abstract

Acoustic investigation on Balinese vowel of non-fluent aphasia (NFA) has not been previously paid attention yet. Thus, this study examined the acoustic abnormalities of vowel articulation for patients with NFA. Therefore, spectral and temporal charateristic of their vowel sound are essentially searched by comparing the formant value and prosodic features with the normal vowel articulation. Speech output of two patients were observed and analyzed by using Praat and the data were described by implementing the theory of clinical phonetics and acoustics. The spectral analysis showed that the inaccurate constriction of the tongue in vowel articulation affected the range of oral tract (F2), pharynx space (F1), and shape of the lips (F3). Furthermore, the lesion in Broca's area affected the temporal features of the sounds, such as the lower pitch, lower intensity and longer timing especially voicing environment. The vowels preceded by voiced consonants were significantly longer than those preceded by voiceless ones. So, the highly complex vowels tend to be articulated inaccurately due to articulatory implementation deficit. This finding is consistent with previous results that the spectral and temporal distortion are primarily phonetics rather than phonological planning program.

Keywords: aphasia, disprosody, distortion, vowel

Abstraksi

Penyelidikan fitur akustik bunyi vokal pada ujaran bahasa Bali afasia nonfasih (ANF) belum bernah menjadi perhatian selama ini. Maka, penelitian ini menyelidiki abnormalitas akustik bunyi vokal pasien ANF. Untuk itu, karakteristik spektral dan temporal bunyi vokal mutllak diselidiki dengan membandingkan nilai forman dan fitur prosodi dengan artikulasi vokal normal. Luaran ujaran dua pasen ANF diamati dan dikaji dengan menggunakan spectroram Praat dan data dijabarkan dengan menerapkan teory akustik dan fonetik klinis. Analisis spektral bunyi vokal menunjukkan bahwa kontriksi lidah yang tidak tepat memengaruhi rentangan ruang rongga mulut (F2), ruang faring (F1) dan bentuk bibir (F3). Kerusakan jaringan di area Broca juga dapat melemahkan ciri temporal bumyi termasuk melodi, tekanan, dan rentang waktu pada lingkungan bunyi bersuara. Artinya, bunyi vokal yang didahului oleh konsonan bersuara memiliki rentang waktu yang lebih panjang dari pada bunyi vokal yang didahului oleh bunyi yang tak bersuara. Dalam penyelidiki akustik, bunyi vokal yang lebih kompleks cenderung dilafalkan tidak akurat karena defisit implementasi artikulasi. Temuan ini konsistent dengan penelitian sebelumnya bahwa ketidakakuratan artikulasi dan prosodi ada pada tataran gangguan fonetis bukan pelemahan pogram perencanaan fonologis.

Kata kunci: afasia, disprosodi, penyimpangan, vokal

INTRODUCTION

Patients with articulatory deficits can be clinically recognized from either in terms of primary lesion site or their speech outputs. Several studies have been carried out on articulatory deficits characterizing speakers with non-fluent aphasia (NFA) and find some correlation between the anterior lesion and typical sound abnormality (Collins, Rosenbek, & Wertz, 1983., Kent, & Rosenbek, 1982., Gandour, 1992., Hisham, 2014). The deficit occurs at a low-level impairment in the articulatory implementation of selected and planned speech segments (Luria, 1966., Gandour, 1998, Kurowski, Hazen, & Blumstein, 2003). This impairment manifests in sound distortion or even segmental alteration that results in unrecognizable words. Phonological errors produced by patients with NFA can be described as an articulation or conceptual phenomenon. Their speech is featured with the phonetic inaccuracy of both place and manner of articulation (Darley, Aronson & Brown, 1975). NFA is also characterized by a slow speaking rate with longer duration, abnormal prosody, and segmental alteration. This type of prolongation refers to the lengthening duration of segments as a symptom of self-correcting efforts. However, each individual with NFA might perform different segmental errors even though they suffer from identical phonological symptoms. The articulatory deficit manifests two parameters of phonological errors, namely vowels and consonants. Previous acoustic studies focus on certain impaired consonants, such as voicing in fricative (Shadle, Mair, Sheila, 1996, Kurowski, Hazen, & Blumstein, 2003, Hisham, 2014), stop consonants, and trill /r/ (Boyce, 2015). In fact, the acoustic studies on vowels and consonants produced by NFA are considered less in number than on consonants. Some of them are carried out by Perkins & Ryalls, (2012) and Ryalls (1986)

However, the study that focuses on acoustic features on impaired Balinese vowels has not been investigated yet though the findings can be very helpful conception for additional clinical diagnose. As a peak of syllable and the most sonorant features in the sonority scale, vowels play prominent roles in forming a sequence of words (Bastiaanse, Gilbers & Linde 1994). Though vowels are considered easy to produce in isolation, the patients perform typical changes of vowels in the context which can be deeply investigated by its acoustic features. For example, the Balinese word aluh 'easy' was realized as [oules]. Thus, the acoustic investigation can further find out the presence of lax high back vowel /u/. From the acoustic side of views, the weakening quality of vowel /a/ in the initial position of the word above can be viewed from statistic measurement as phonetic distortion. The impaired sound can be seen from the measurement of acoustic features, namely intensity, pitch, frequency and duration that displays the inaccuracy of individual sound production (Lieberman & Blumstein, 1988, Ladefoged, 2003). Recent research in aphasia has been encouraged to determine the nature of these deficits and it often focuses on the stages of processing that underlie speech production. The deficits displayed by Broca's aphasics could be the result of either higher-order impairments in the selection and planning of speech output or a low-level impairment in the articulatory implementation of selected and planned speech segments.

The major goal of the acoustic analysis on distorted, simplified and devoiced vowels in NFA is to acknowledge the natural correlation of acoustic features and the state of the abnormality. The abnormality of vowel production can not only be viewed from the point of substitution, insertion and omission errors, but it also can be necessarily seen from the acoustic inaccuracy, such as abnormality in standard frequency, pitch, duration, and intensity. Schane (1992) claims that the phonological process can be explained as an articulatory description and an accurate articulation mechanism is pictured in acoustic components as of how the listeners interpret the sounds as meaningful input of information. The acoustic components can release any conditions of speakers' speech production. The failure of phonetic implementation can result in phonemic and phonetic changes. The later can be seen from the mechanism of how the sounds are inappropriately produced.

The investigation on acoustic features of impaired sound might spread information on how the patients understand the words or pictures given to them, the existence they interpret the symbols into sounds, and how they realize sounds program into concrete articulation. The errors might not appear either from selecting the phonemes of the target words or planning the articulation, but failure in articulatory implementation. Acoustic features of vowel parameters are essentially determined by formant value, duration, and phonation. The different patterns of formants is a system of physical function of articulators in producing language sounds (Lieberman & Blumstein, 1988). The distortion of standard formant value indicates the three phonetic variations, namely accurate, almost accurate and inaccurate. The accuracy of vowel articulation can be obtained from the appropriate function, the position of constriction and timing. Formants of vowels are associated with the acoustic measurement of the resonance frequency (Ladefoged, 2003, p. 71).

This study tries to find out any evidence of acoustic features of vowels realization in speech errors of NFA through sound wave and spectrogram. The inaccuracy of articulation can be recognized from the different values of formants, a pattern of sounds wave, prolongation of timing rate, abnormal intensity, and pitch. The discussion focuses on terms of temporal analysis, spectral analysis, and trajectory measures. The temporal analysis included vowel duration solely, while spectral analysis included the following parameters: F1 and F2 values. Trajectory measures included F2 slope and trajectory length. F1 dan F2 of both standard Balinese vowels /i/, /e/, /ə/, /a/, /o/, u/ in initial, medial and final position. Therefore, it is required to find out (1) whether the value of acoustic measurement of vowel sounds is relatively higher or lower than the vowels produced by normal speakers; (2) whether the timing or duration of vowels production is longer or shorter in all distribution than it is produced by the normal speaker; and (3) whether the patients with NFA produce disprosody in vowels production as evidence of motor aphasic syndrome.

The previous studies suggest that anticipatory coarticulation effects are present in aphasic speech, but that these effects are delayed on the order of 20–30ms in subjects with nonfluent aphasia or apraxia of speech (Kent & Rosenbek, 1983., Marotta, Barbera & Bongioanni, 2008). However, a subsequent series of studies performed by Hisham, (2014). and others strongly argued that the time course of anticipatory coarticulation is relatively normal in nonfluent aphasics, though coarticulatory effects are impaired in other ways. There are suggestions in the literature that anterior aphasics will display impairments in the production of voicing in fricative consonants. Frequent devoicing of initial and medial voiced fricatives has been reported in anterior aphasic's speech production (Kent & Rosenbek, 1983), as has the premature onset of voicing in voiceless fricatives before the frication segment has ended (Kent & Rosenbek, 1983). These results suggest an inability to combine vocal cord vibration and supralaryngeal articulatory gestures. Additionally, Harmes et al. (1984) ascribed the presence of numerous 10–30ms silent gaps during alveolar fricative production ([s z]) in one aphasic speaker to "rapid glottal closure and/or pauses in respiratory drive" (p. 382).

Although studies above have explored a number of acoustic parameters associated with the implementation of consonants, this study explores the implementation of different acoustic attributes in the different patients. With respect to the role of the phonetic context, three broad assumptions are addressed. First, the value of the acoustic measurement of vowel sounds is relatively higher than the vowels produced by normal speakers. Second, the timing or duration of vowel production is longer in all distribution than it is produced by the normal speaker. The third, the patients with NFA produce disprosody including lower intensity and pitch in vowels production as evidence of motor aphasic syndrome.

METHOD

There were two patients with NFA whose speech was observed for the present study. The first participant, KW, is a 70-year-old, a right-handed male with a BA degree in teaching and was employed as an elementary school teacher prior to t cerebral vascular attack in 2017 in the onset of his left middle cerebral artery. The second participant, NS is a 52-year-old, a right-handed male, and a woodcarver. He suffered from NFA and right hemiplegia immediately following the non-hemorrhagic stroke (NHS) in 2018. Both participants had the same syndrome of non-fluent aphasia, such as difficulties in repeating words, phonological anomia, naming, reading, and writing.

The participants' speech output was stimulated by different eliciting phonological tasks, e.g, and word-picture matching stimulation. They were given phonological tasks consisting of 260 simple and complex target words. These words or pictures mainly represented consonants and vowels in different distributions, including consonant clusters. The speech was digitally recorded using a SONY MP3 player. The observation of the recorded speech was conducted by classifying types of phonological errors including phonemes substitution, distortion, insertion, omission, and metathesis. The segmental errors were counted and transcribed phonemically and phonetically in accordance with I.P.A. The data were copied and measured for Character of Balinese Vowels by Praat (Boersma & Weenink, 2008) to ensure the acoustic features of a single sound and its coarticulations. The acoustic measurement may provide any phenomenon of either segmental or suprasegmental errors.

A phonological analysis of segmental errors, including substitution, distortion, omission, and insertion was carried out and treated as inputs of intervention. All errors that occurred across all tasks were analyzed. This analysis refers to the distinctive features in a model proposed by Schane (1992) and the segments matrix for the Balinese language was used. The features contained in this matrix include: syllabic, high, low, back, rounded and voiced. The phonological process such as assimilation, syllable structure, and simplification meant observed in order to understand the reason for errors, e.g., the influence of neighboring phonemes. All changes or outputs were analyzed to understand the articulatory process by applying the theory of clinical phonetics and acoustics.

RESULT AND DISCUSSION

Referring to recorded speech taken from words and pictures naming, patients under study tended to make vowel alteration in medial position because they found difficulties in blending or configuring the sounds in coarticulation with other neighboring sounds. There was three acoustic variations found in the study; normal, close to normal, and far from normal articulation. The vowels that were being observed were /i/ in the word of titi 'bridge', /u/ in the word alu 'water monitor', /e/ in the word keket 'thorn', /ə/ in the word emas 'gold, /o/ in the word oleg 'a dance'', and matah 'raw'. The patients were able to articulate the vowels individually. However, they could not configurate the movement of the articulators if the vowels were in the context of other segments. Besides, they have produced dysprosodic sounds, such as inappropriate timing, melody or pitch, and intensity. Phonetical errors in NFA occur because the brain lesion is in the anterior left hemisphere of the brain that has a specific function of the articulatory planning program. So the word ipah which was pronounced as [aleh] was not the consideration of neuromuscular failure.

From the acoustic side of view, articulatory deficit suffered by the patients can set the different acoustic features, such as formant value, intensity, pitch, and duration or timing. Formant is the acoustic term that refers to a classification of features of the vowels in the configuration of blending in other sounds. The formant value of vowels is a statistical measurement that provides information about the frequency of resonance which is associated with measurement two cavities in the separated oral cavity. Measurement, in this case, is the measurement of space formed by the tongue movement in articulation. F1 is associated with measurement of pharynx space, F2 is related with oral cavity space, and F3 shows lips shape, such as close, open, rounded and unrounded position (Ladefoged, 2003: 71). If the constriction occurs in the front position of the oral cavity, there will be less space but it has a higher frequency and the space of the pharynx is wider but it has a lower frequency. The segmental and suprasegmental analysis through acoustic investigation on vowels of two pairs of vowels production by the normal speaker and patients with NFA can be presented below.

Spectral and temporal analysis of sound /i/

The different character of sound /i/ in medial and final position can be seen from the way the articulators configurate all the system, however, the prosodic side of view as Lancker Sidtis, et.al. (2009) found in term of initial, medial, and final shortening or lengthening vowels errors. Phonetically, vowel /i/ involves high complex articulation, therefore it can not be articulated in initial of the word ipah 'sister /brother in law' which was pronounced [aleh]. However /i/ can be articulated in medial and in final of the word titi even though it is not as accurate as the normal speakers can produce. Figure 1 shows the acoustic wave and the spectrogram of articulation /i/.

/titi/ [dɪdɪ]

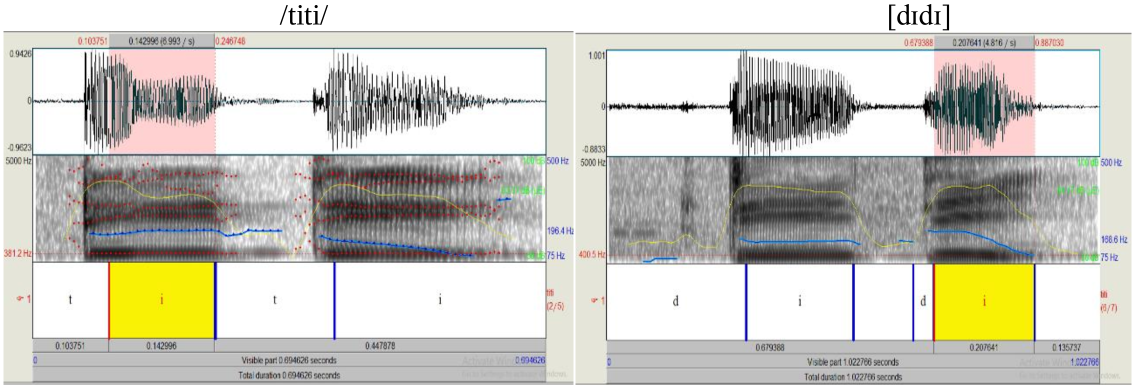

Figure 1. Sound Wave and Spectrogram of Articulation /i/

From the two spectrograms above, a significant difference between the normal sound (on the left) and the inaccurate sound produced by patients with NFA (on the right) can be evidence of phonetic variation in this study. Forman value of F1 of the sound [i] pictured in the left spectrogram was 381.2 Hz. It means that the space of pharynx was wider so the frequency is low because the constriction occurs in the initial part of the oral cavity and it left a smaller space of oral cavity but it has a high frequency as it can be seen by formant value of F2 which was 2123 Hz. The formant value of F3 reached 2608 Hz which means that the shape of the lips is not rounded. The timing range which is required for this vowel is relatively short; 0.142996 ms. However, the difference of vowel [i] produced by patients with NFA in the right spectrogram can be seen from the formant value of F1 which 414.4 Hz, meaning the space of pharynx is 33.2 less wide than the normal and the inaccuracy of the tongue movement can be seen from the higher formant value of 2209 Hz. The shape of the spreading lips was wider as formant value of the F3 reached to 2741 Hz. This formant value led to the lax vowel /ɪ/. The timing was one of the dysprosodic found in the study. The difference of final vowel lengthening was 0.045547 ms, meaning patients produced longer duration in producing vowel /i/. The pitch was 161.8 Hz and intensity was 85.82 dB. As Kurowski, et.al (2002) found that one of the clinical manifestations of aphasia is the presence of deficits in speech production, this finding declares that deficit in articulatory planning program suffered by patients with NFA can set not just inaccuracy of articulation of /i/ but also distortion in the dysprosodic features.

Spectral and temporal analysis of sound /u/
Phonological distinctive features are derived from the phonetic concept of sound production. The articulation of vowel /u/ is one of the complex sounds that involves the back and high constriction of the tongue. The variation of articulation /i/ by the patients with NFA are [o], /uled/ 'caterpillar' → [oles], [o] /l əgu/ 'mosquito' → [ləgo]. Sound /u/ can be nearly articulated as [u] if it is preceded by lateral sound, like in the word alu water monitor' or /guru / 'teacher' → [kulu].. Distortion of segmental and suprasegmental of sound /u/ by patients with NFA can be presented in figure 2.

/alu/ /alu/

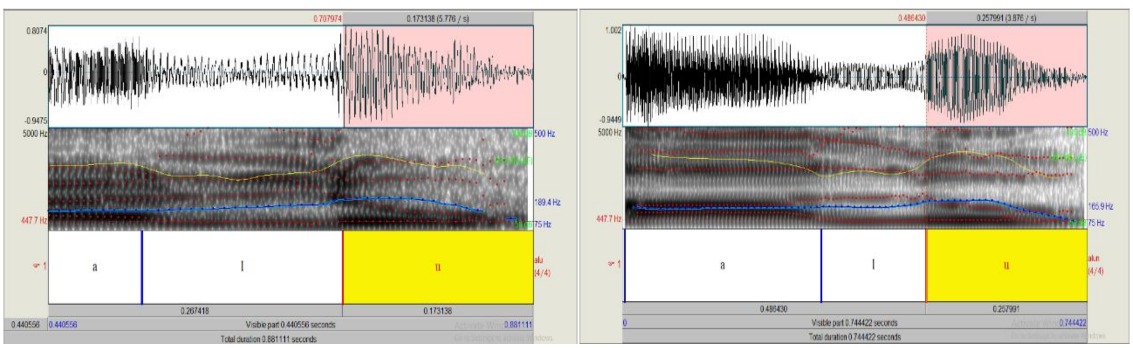

Figure 2. Sound Wave and Spectrogram of Articulation /u/

Even though/u/ can be articulated at the back after the lateral sound, the characteristic of segmental and suprasegmental distinction can be described from the acoustic value. The value of F1, F2, and F3 of normal /u/ was 489.4 Hz, 1223 Hz, and 2621 Hz, meanwhile the value of F1, F2, and F3 of vowel /u. produced by patients with NFA was 475.1 Hz, 1176 Hz, and 2534 Hz. So the difference was 33.2Hz, 86Hz, and 133dB. It means the tense vowel of /u/ was not accurately articulated. The pitch, duration, and intensity of vowel /u/ produced by the normal speaker was 191.2 Hz, 0.231 ms, 86.65 dB, and the patients reached up to 208.7 Hz, 0.895 ms, and 86.62 dB. Normal speech timing and rhythmic relations have been consistently associated with a left hemispheric function (Zatorre and Belin, 2001). This finding emphasizes that patients with NFA had inaccurate articulation and final lengthening of vowel /u/ because the impaired melody of speech is associated with LH damage (Goodglass and Kaplan, 1972).

Spectral and temporal analysis of sound /e/
The articulation of sound [e] involves the constriction that occurs at the front oral track, namely the blade of the tongue moves upwards to the palate so the space of pharynx is wider

and acoustic frequency tends to be low, meanwhile the space in oral track seems to be narrower but the frequency is high. Variation of articulation /e/ by the patients with NFA are [i], /gatep/ 'fruit' → [gatit], [o] /toke/ 'gecko' →[topɔ]. Distortion of segmental and suprasegmental of sound /e/ by patients with NFA can be presented in figure 3.

/toke/ [toʊke]

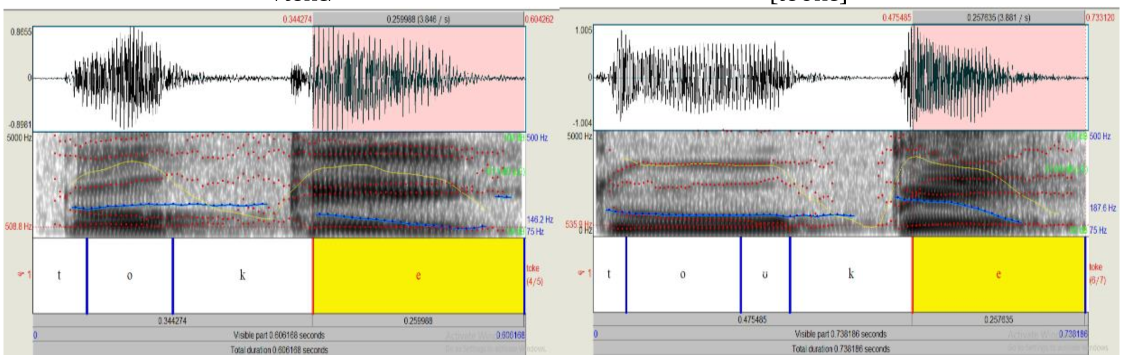

Figure 3. Sound Wave and Spectrogram of Articulation /e/

Vowel /e/ can be articulated at the back after voiceless stopped velar sound /k/, the characteristic of segmental and suprasegmental distinction can be described from the acoustic value. The value of F1, F2, and F3 of normal /e/ was 580.6 Hz, 2143 Hz, and 2475 Hz, meanwhile the value of F1, F2, and F3 of vowel /u. produced by patients with NFA was 535.9 Hz, 2025 Hz, and 2729 Hz. It means the vowel of /u/ was nearly accurate. The pitch, duration, and intensity of vowel /u/ produced by the normal speaker was 146.2 Hz, 0.259988 ms, 81.10 dB, and the patients reached up to 149.1 Hz, 0.257635 ms, and 81.27 dB. So, the patients with NFA tend to have suprasegmental deficit due to lesion Broca's area.

Spectral and temporal analysis of sound /ə/. Sound /ə/ is produced by neutralizing tongue and lips position. It means that the part of the tongue is not moved to the front, backward, upwards, or downwards and the lips are not rounded or unrounded. The variation of articulation /e/ by the patients with NFA are [i], /ə/ → [i] əntip/ 'rice → [nitıp], ə/ → [o] as /dədarə/ 'dove → [tolalə], and [ə] → [o] / - # as /batə / 'brick' → [batɔh]. Distortion of segmental and suprasegmental of sound / Distortion of segmental and suprasegmental of sound /ə/ by patients with NFA can be presented in figure 4.

/əmɑs/ [əmɑs]

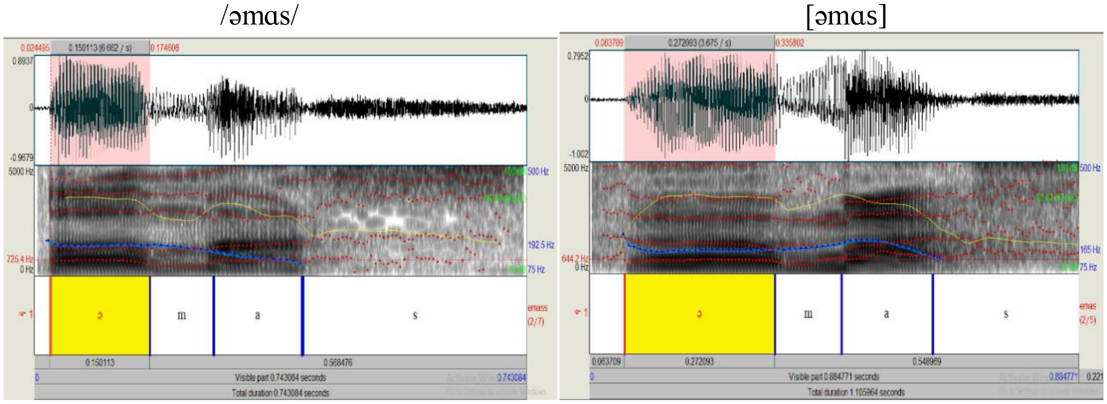

Figure 4. Sound Wave and Spectrogram of Articulation /ə/

The spectrogram which is presented in yellow slot shows some acoustic distinctions of the sound [ə] produced by the normal speaker and the patients. The difference of the sound produced by the patients can be seen from the configuration of the tongue, the shape of the lips, the lengthening duration, impaired melodic and intensity of the sound. Vowel / ə / can be articulated in the initial position, The characteristic of segmental and suprasegmental distinction can be described from the acoustic value. The value of F1, F2, and F3 of normal was 671.1 Hz, 1245 Hz, and 2874 Hz, meanwhile the value of F1, F2, and F3 of vowel /ə/ produced by patients with NFA was 535.9 Hz, 1644 Hz, and 2375 Hz. It means the vowel of /ə/ was nearly accurate. The pitch, duration, and intensity of vowel /ə/ produced by the normal speaker was 170.7 Hz, 0.245 ms, 83.11 dB, and the patients reached up to 156.8Hz, 0.415 ms, and 80.16 dB. So it was found that patients with NFA had inaccurate articulation, the impaired melody of speech, and final lengthening of vowel /ə/.

Spectral and temporal analysis of sound /o/

The sound error of /o/ which is produced by patients with NFA is known as heightening. The tongue tends to move upwards. So the sound /o/ is mainly substituted by a tense or lax high back vowel; [u] or [ʊ]. The variation of articulation /e/ by the patients with NFA are / o / → [u]/ C - C as / toke/ 'gecko' → [tuke], / ɔ / → [ʊ]/ C – C as /katos/ 'hard' →[astʊh]. However,/o/ can be articulated in initial as in the word of oleg 'dance'. Distortion of segmental and suprasegmental of sound /o/ by patients with NFA can be presented in figure 5.

/olɛg/ [olɛʔ]

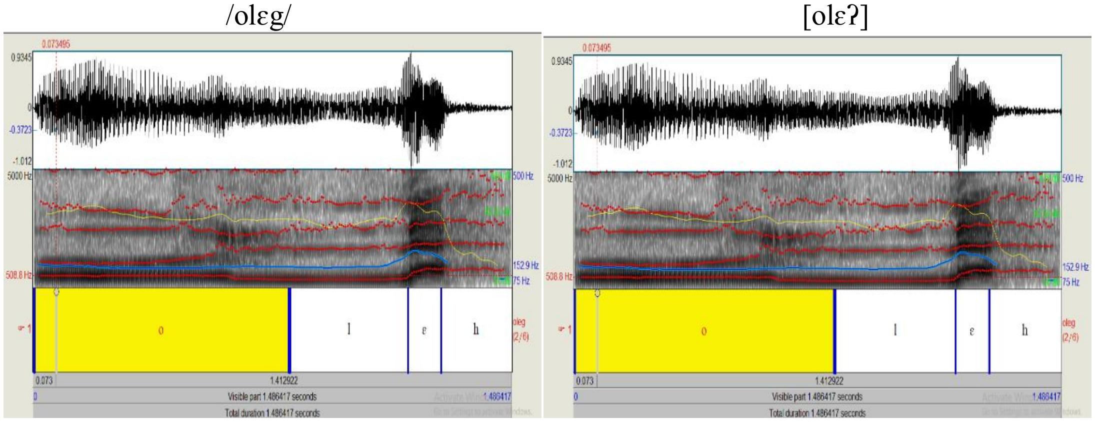

Figure 5. Sound Wave and Spectrogram of Articulation [o]

Both yellow slots above show the acoustic distinctions of sound [o] in initial position produced by normal speaker and the patients. The configuration of the tongue, shape of the lips, the initial lengthening duration, impaired melodic and intensity of the vowel /o/ are presented in acoustic measurement of the articulation, resonanse, and duration that can be described from the acoustic value. Specific observation on sound wave and the pectrogram of articulation /o/ produced by the patients on the right showed that the narrow pharinx space with high frequency of 540.8Hz and oral tract was wide with low frequency of 803.6 Hz. Standard rounded lips is presented in F3 that was 2621Hz. However, timing duration 0.209 ms and the normal speaker needs only 0.195 ms. It means that there is 0.023 ms longer. The normal pitch for this vowel is 182.4Hz however the patients decreased the pitch into 160.2 Hz and the fifference was 4.5 Hz. For intensity, the normal speaker has 83.4 dB and the patient had 84.54, so the patient had 1.06 dB more intensity on vowel /o/ in initial position. So it was found that patients with NFA had inaccurate articulation, impaired melody of speech, and final lengthening of vowel /o/.

Spectral and temporal analysis of sound /a/

Vowel sound /a/ is produced by lowering the tongue from the palate and the jaws are opening so the airstream goes through the oral tract. This vowel is the easiest articulation the patients can produce because it has low complexity. So the sound /a/ can be substituted by /ə/ or /i/ in media position. The variation of articulation /a/ by the patients with NFA are /a/→ [æ] / V- C as /sampi/ 'cow' → [səmpi] and /a/→ [ɛ] /C-C as /ipɑh/ 'brother or sister in law' → [alɛh]. However /a/ can be articulated in a medial position in a complex word.

From both spectrograms below, it seems that the patients with NFA do not find any difficulties articulating the sound [a]. However, the level of accuracy either segmental or suprasegmental features can only be distinguished by searching the acoustic features. The sound wave and the spectrogram of articulation /a/ produced by the patients on the right slot showed that the narrow pharynx space with a high frequency of 781 Hz and the oral tract was in the middle with the medium frequency of 1176 Hz. Unrounded lips were presented in F3 that was 2665 Hz. However, the timing duration was 0.341 ms. It means the patients articulated the sound 0.115md longer than the normal speaker which is 0.226 ms. The normal pitch for this vowel is 162.7Hz however the patients decreased the pitch into 157.3 Hz and the difference was 5.4 Hz. For intensity, the normal speaker has 84.11dB and the patient had 83.18dB so the patient had 0.93 dB less intensity on vowel /a/ in the first syllables. So it was found that patients with NFA had inaccurate articulation, the impaired melody of speech, and final lengthening of vowel /o/. Broca's aphasic speech is characterized by slow and effortful speech, resulting in increased vowel durations which suggest motor planning and temporal control deficits (Baum, 2002). Distortion of segmental and suprasegmental of sound /o/ by patients with NFA can be presented in figure 6.

/matɑh/ [matɑh]

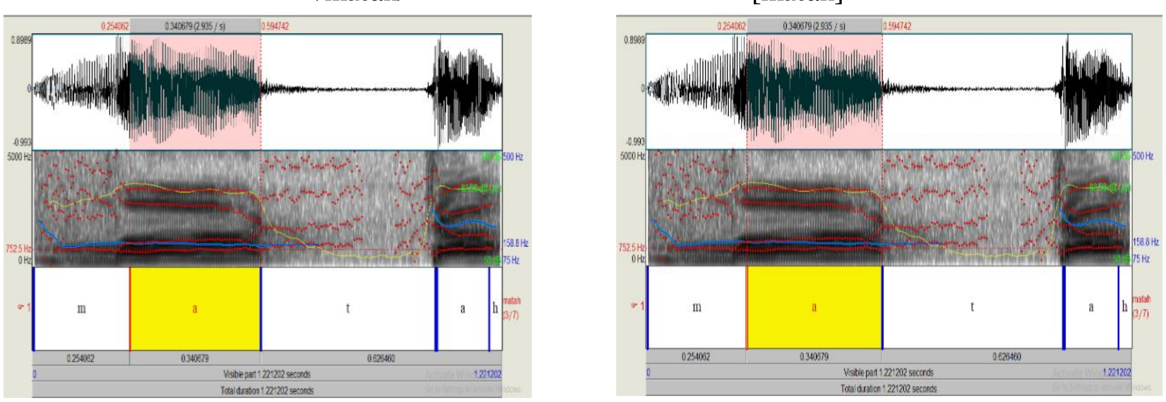

Figure 6. Sound Wave and Spectrogram of Articulation /a/.

Based on the spectral analysis on vowels by using Praat, the characteristic of vowels is mainly dominated by the distortion of segmental and suprasegmental. The distortion occurs on the level of phonetic, intensity, prolongation, and pitch. There are some significant finding concerning the spectral analysis on vowels distortions in this study; (1) vowels with high complex articulation indicate weakening phonation, pharynx space lengthening, and the inappropriate constriction of articulators which is recognized from unstable formant value; (2) vowel alteration mainly occurs in medial position; (3) intensity of vowels produced by patients with NFA is lower than the same sound produced by normal speakers; (4) there has been vowel lengthening in all position if is preceded by voiced consonants; and (5) melodic features, such as pitch and intensity are mainly lower than normal vowels. So, damage in inferior frontal gyrus in the left hemisphere of the brain following a stroke can impair the function of articulatory planning program and can effect inaccuracy of sound production and segmental simplification. The distribution of acoustic features on vowels produced by KW and a normal speaker can be seen in table 1.

Tabel 1. Distribution of Acoustic Features on Vowels Produced by KW and a Normal Speaker

Penutur		Sound	F1 (Hz)	F2 (Hz)	F3 (Hz)	Pitch (Hz)	Duration ms	Intensity dB
Petient KW	Tense	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
	lax	ɪ	431.3	2161	2884	194.6	0.106	85.87
		ɪ	409.4	2030	2534	157.7	0.055	87.59
			21.9	131	350	36.9	0.051	28.28
Patient KW	tense	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
	lax	ɛ	650.3	1855	2621	181.3	0.105	83.85
		ɛ	668.4	2138	2634	188.6	0.053	82.65
		df	18.1	283	13	7.3	0.052	1.2
Patient KW	tense	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
	lax	æ	737.9	1482	2293	173.1	0.160	84.37
		æ	628.4	1461	2840	198.2	0.082	86.08
		df	109.5	21	547	25.1	0.08	1.71
Patient KW	tense	u	475.1	1176	2534	208.7	0.895	86.62
Normal		u	489.4	1223	2621	191.2	0.231	86.65
		df	65.7	153	87	17.5	0.664	0.03
	lax	ʊ	540.8	825.5	2293	189.9	0.156	81.79
		ʊ	562.7	1242	2687	193.7	0.074	80.20
Patient KW	tense	o	540.8	803.6	2621	160.2	0.209	84.54
Normal		o	574.7	979.5	2741	182.4	0.195	83.48
		df	129.5	16.5	364	4.5	0.023	1.06
	lax	ɔ	644.2	996	2377	177.1	0.172	80.48
		ɔ	672.2	1110	2840	180.5	0.097	75.50
		df	28	114	463	3.4	0.075	4.98
Patient KW	tense	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
	lax	ɑ	869.3	1439	2380	192.2	0.309	83.71
		ɑ	875.5	1498	2556	176	0.076	84.39
		df	6.2	59	176	16.2	0.23	0.68

From the data above, the range of pharynx space and the oral tract when the tense and the lax vowels are articulated can be recognized from the value of F1. The lax vowels have a higher frequency than the tense vowels. It means that the constriction is a little bit backward so the pharynx has narrow space than the production of the tense vowels. It means that this condition leaves smaller space in the oral tract so the frequency of tense vowels is higher than the lax ones. For disprodic syndrome in lengthening or shortening duration of vowels, there is prosodic evidence of tense and lax vowels for both patients with NFA and normal speakers. The tense vowels require a longer time than the lax vowels because of the maximum movement of the constriction by stretching the articulators. The inaccuracy of vowel production in speech sound produce by patients with NFA is associated with the impaired language function in the third convolution of the left hemisphere.

So, the characteristic of vowel sound produced by patients with NFA that was found in this study can be evidence for neurolinguistics description of impaired language. NS showed quite similar acoustic features, including inaccurate articulation, such as phenomenon of lengthening or shortening duration of vowels. NS also had dysprosodic evidence resulting from brain damage in the third convolution of the left hemisphere of the brain. Table 2.

Table 2. Distribution of Acoustic Features on Vowels Produced by NS and Normal a Speaker

Penutur		Sound	F1 (Hz)	F2 (Hz)	F3 (Hz)	Pitch (Hz)	Duration ms	Intensity dB
Patient NS	Teg	i	343.4	2446	2840	148.9	0.345	83.20
Normal		i	381.2	2123	2608	207.2	0.142	84.40
		df	37.8	323	232	58.3	0.203	1.2
	Ken	ɪ	451.3	2261	2984	194.6	0.096	80.87
		ɪ	409.4	2030	2534	157.7	0.055	57.59
		df	41.9	231	450	36.9	0.041	23.28
Patient NS	Teg	e	497	2271	2665	203.3	0.254	85.62
Normal		e	671.2	1998	2566	163.4	0.165	94.40
		df	174.1	273	99	39.9	0.089	8.78
	Ken	ɛ	540.3	1855	2621	191.3	0.120	80.82
		ɛ	628.4	2138	2534	188.6	0.053	82.65
		df	88.1	283	87	27	0.067	1.83
Patient NS	Teg	ə	453	1701	2753	151.6	0.354	82.62
Normal		ə	671.1	1245	2874	170.7	0.245	83.11
		df	218.1	456	121	19.1	0.109	0.49
	Ken	æ	437.9	1482	2293	163.1	0.160	75.52
		æ	628.4	1461	2840	198.2	0.082	86.08
		df	190.5	21	547	35.1	0.082	10.56
Patient NS	Teg	u	540	935	2818	187.7	0.341	81.60
Normal		u	409.4	1023	2621	191.2	0.231	86.65
		df	130.6	88	197	3.5	0.11	5.05
	Ken	ʊ	520.8	850.5	2593	179.9	0.256	80.79
		ʊ	562.7	1242	2687	193.7	0.074	80.20
		df	41.9	391.5	94	13.8	0.182	0.59
Patient NS	Teg	o	628	1088	3015	119.4	0.262	80.50
Normal		o	514.7	979.5	2741	182.4	0.195	83.48
		df	113.3	108.5	274	63	0.067	2.98
	Ken	ɔ	550.2	956	2477	157.1	0.152	87.48
		ɔ	672.2	1110	2840	180.5	0.097	75.50
		df	1.220	154	363	23.4	0.055	11.98
Patient NS	Teg	a	825	1701	2928	126.1	0.352	80.34
Normal		a	803.6	1198	2906	162.7	0.226	84.11
		df	21.4	503	22	36.6	0.126	3.77
	Ken	ɑ	769.3	1139	2480	182.2	0.209	80.70
		ɑ	825.5	1198	2556	176	0.076	84.39
		df	56.2	59	76	6.2	0.133	3.69

From the temporal analysis on vowel duration and spectral analysis on the formant value of the two patients, the results show a wide variability among the aphasic subjects and greater vowel durations compared to the normal speakers. This study suggests that mechanisms of temporal abnormalities among the sounds produced by patients with NFA are primarily phonetic rather than phonological planning impairments as what has been found by Luria (1966), Gandour, (1998), Buckingham & Chrisman (2008), and Shinn & Blumstein (1983). This phenomenon occurs due to phonetic implementation, temporal coordination, and timing deficits of articulatory movements as Sidtis, & Van Lancker-Sidtis (2003) have claimed. However, this study suggests that the deficits affect speech production mechanisms which is characterized by inaccurate articuation, a slow rate of vowels, and other prosodic disorders. So, the inaccuracy of segmental and suprasegmental features of vowels is caused by insufficient tactile feedback during the production. Thus, it is emphasized that the longer vowel durations and inaccurate articulatory mechanisms can be partially contributed to impairments in accessing and retrieving information concerning the articulatory target, as the word madu 'honey' is realized as [madoh].

CONCLUSION

The objective of the present study was to examine the spectral and temporal characteristic of vowel articulation for patients with NFA compared to normal speakers. The acoustic features showed that the vowel alteration which were produced by patients with NFA mainly occurs in medial position and the inaccurate constriction of the tongue could affect the range of oral tract and pharynx space, shape of lips, and temporal distortion in voicing environment. The vowels preceded by voiced consonant were significantly longer than those preceded by voiceless ones. Melodic features, such as pitch and intensity are mainly lower than normal vowels. Concerning acoustic analysis, high complex vowels tend to be articulated inaccurately due to articulatory implementation deficit in Broca's area. This finding is consistent with previous results that the segmental and suprasegmental inaccuracy are primarily phonetic rather than impaired phonological planning program. The study suggests the observation of two patients with NFA may give a primary description of impaired vowel sounds from acoustic analysis, however, the generalization of vowel distortion requires bigger samples and wider scope of analysis. Further research should include more subjects and investigate Balinese consonants in Broca’s aphasia, including phonological process and syllable structure, Nevertheless, this study was an attempt to provide new insights on vowel production in cross neurolinguistic research in Balinese languages.

REFERENCES

Adam, H. (2014). Dysprosody in aphasia: An acoustic analysis evidence from Palestinian Arabic. *Journal of Language and Linguistic Studies*, 10 (1), 153- 162.

Baum, S. (2002). Consonant and vowel discrimination by brain damaged individuals: Effects of phonological segmentation. *Journal of Neurolinguistics*, 15, 447-461.

Bastianse, R., Gilbers, B.B., & Linde, K. (1994). Sonority substitutions in Broca’s and conduction aphasia. *Journal of Neurolinguistics*, 8 (4), 247–255. DOI: 10.1016/0911-6044(94)90011-6.

Boersma, P & Weenink, D. (2008). *Doing phonetics by computer*. http://www.Praat (Boersma, & Weenink, 2008).org/, accessed June 7, 2012.

Boyce, S.E. (2015). Articulatory Phonetics for Residual Speech Sound Disorders: A Focus on /r/. *Semin Speech Lang*. 36(4), 257–270.

Buckingham, H.W., & Chrisman, S. S. (2008). “Disorders of Phonetics and Phonology”. Dalam Stemmer, B & Whitaker, H.A. *Handbook of Neuroscience of Language*. London: Elsevier Ltd, hlm. 127 – 136.

Collins, M., Rosenbek, J.C.,and Wertz,R.T. (1983).Spectrographican alysis of vowel and word duration in apraxia of speech. *Journal of Speech and Hearing Research*, 26, 217–224.

Darley, F. L., Aronson, A. E., & Brown, J. R. (1975). *Motor speech disorders*. Philadelphia: Saunders.

Gandour, J.T. (1998). Phonetics and Phonology in: Stemmer, B. & Whitaker, H.A. *Handbook of Neurolinguistics.*, (pp. 207 – 218). Indiana: Academic Press.

Goodglass, H., & Kaplan, E. (1972). The assessment of aphasia and related disorders. Philadelphia: Lea and Febiger.

Hisham, A. (2014). An acoustical study of the fricative /s/ in the speech of palestinian-speaking Broca's aphasics – Preliminary findings. *Linguistik online* 53, 3-12.

Kent, R.D.,& Rosenbek, J.C.(1983). Acoustic patterns of apraxia of speech.Journal of Speech and Hearing Research, 26, 231–249.

Kurowski, K., Hazen, E., & Blumstein, S. (2003). The nature of speech production impairments in anterior aphasics: An acoustic analysis of voicing in fricative consonants. *Brain and Language,* 84, 353–371.

Ladefoged, P. (2001). *Vowels and consonants: Introduction to the sounds of language*". Oxford: Blackwell Publishing Ltd.

Ladefoged, P. (2003). *Phonetic Data Analysis*. Oxford: Blackwell Publishing Ltd.

Lieberman, P., & Blumstein, S.E. (1988). *Speech Physiology, Speech Perception, and Accoustic Phonetics*. New York: Cambridge University Press.

Luria, A. (1966). *Higher Cortical Functions in Man*. New York: Basic Books.

Marotta, G., Barbera, M., & Bongioanni, P. 2008. "Prosody and Broca's aphasia: An Accoustic analysis". *On line Journal of Studi Linguistici e Filologici,* 6, Hlm. 79-98.

Ryalls, J. (1986) An acoustic study of vowel production in aphasia. *Brain and Language.* 29, 48-67.

Schane, S. B. (1992). *Generative Phonology*. San Diego: Prentice Hall Inc.

Shadle, Christine H./Mair, Sheila (1996). Quantifying spectral characteristics of fricatives. The International Conference on Spoken Language Processing (ICSLP 96), Philadelphia, USA: 1517–1520.

Shinn, P., & Blumstein, S. (1983). Phonetic disintegration in aphasia: Acoustic analysis of spectral characteristics for place of articulation. *Brain and Language*. 20, 90–114.

Sidtis, J. J., & Van Lancker-Sidtis, D. (2003). A neurobehavioral approach to dysprosody. Seminars in Speech and Language, 24, 93–105.

Zatorre, R. J., & Belin, P. (2001). Spectral and temporal processing in human auditory cortex. *Cerebral Cortex,* 11, 946–953.

2

Bukti review dan revisi

(25 Juli 2020)

(Placeholder1)**SPECTRAL AND TEMPORAL PROCESSING IN BALINESE VOWEL OF NON-FLUENT APHASIA**

PEMROSESAN SPEKTRAL DAN TEMPORAL BUNYI VOKAL BAHASA BALI AFASIA NON-FASIH

INTRODUCTION

Non-fluent aphasia (NFA) is an acquired language disorder in adults resulting from a lesion of the third frontal convolution of the left hemisphere (Akhutina, 2016). The lesion may affect the patient's speech modalities. Stroke survivors have difficulty speaking, repeating words and sentences, naming thins, reading, and writing spontaneously (Sastra, 2011). The speech output of patients with NFA generally consists of two- or three-word utterances, mostly basic words (Bastiaanse, Glibers, & Linde, 1994) Most of the time they have problems initiating utterances in the speech efforts, groping sound movements, multiple failed attempts, and self-correction (Herbert, 2004).

Patients with NFA can be recognized clinically either at the primary lesion site or by their speech output. Several studies have been conducte on articulation deficits that characterize speakers with NFA and some correlation between the anterior lesion and the typical tonal disorder (Galluzzi, Bureca, Guariglia, & Romani, 2015). The deficit occurs with a slight impairment in the articulatory implementation of selected and planned speech segments (Gandour, 1998). This impairment manifests itself in sound distortions or even segmental changes resulting in unrecognizable words (Meier, E. L., , Lo, & Kiran, 2016). Phonological errors produced by patients with NFA can be described as an articulation or conceptual phenomenon. Their language is characterized by phonetic imprecision of both location and mode of articulation (Darley, Aronson, & Brown, 1975). NFA is also characterized by a slow speech rate with longer duration, abnormal prosody, and segmental change (Kent & Rosenbek, 1983). This type of lengthening refers to lengthening the duration of segments as a symptom of self-corrective efforts. However, each person with NFA may perform different segment errors despite suffering from identical phonological symptoms. The articulatory deficit manifests two parameters of phonological errors, namely vowels and consonants.

Previous acoustic studies have focused on certain impaired consonants, such as voicing of fricatives (Adam, 2014) Kurowski et al., 2003; Shadle & Mair, 1996), stop consonants, and trills /r/ (Boyce, 2015) In fact, the acoustic studies on vowels produced by NFA are considered to be fewer in number than on consonants. Some of them are performed by (Galluzzi, Bureca, Guariglia, & Romani, 2015) and (Shinn & Blumstein, 1983).

However, the study, which focuses on acoustic features in disturbed Balinese vowels, has not yet been investigated, so the results may be a very useful conceptual design for additional clinical diagnoses. As the nucleus of a syllable and the most sonorous feature in the sound scale, vowels play a prominent role in word order formation (Bastiaanse, Glibers, & Linde, 1994). Although vowels are considered easy to produce in isolation, patients perform typical vowel changes in context, which can be deeply explored through its acoustic properties. For example, the Balinese word *aluh* ‘easy’ was realized as [oules]. Thus, the acoustic examination can further detect the presence of the lax high back vowel /u/. From an acoustic point of view, the weakening of the vowel /a/ in the initial position of the above word can, from statistical measurement, be considered phonetic distortion. Sound impairment can be measured from acoustic characteristics, namely intensity, pitch, frequency and duration, which reveal the inaccuracy of individual sound production (Lieberman & Blumstein, 1988). Recent research on aphasia has been encouraged to determine the nature of these deficits, and it often focuses on the processing stages underlying language production. The deficits displayed by Brocas' aphasics could either be the result of higher-order impairments in the selection and planning of speech output, or a low-level impairment in the articulatory implementation of selected and planned segments of speech (Buckingham & Christman, 2008).

The main goal of acoustic analysis of distorted, simplified, and unvoiced vowels in NFA is to acknowledge the natural correlation of acoustic features and the state of the abnormality The abnormality of the vowel production can be considered not only from the point of view of errors of substitution, insertion and omission, but can also necessarily arise from the acoustic inaccuracy, such as e.g. an abnormality in standard frequency, pitch, duration and intensity. (Schane, 1992) asserts that the phonological process can be explained as an articulatory description and a precise articulatory mechanism is mapped into acoustic components of how listeners interpret the sounds as meaningful input of information.

The acoustic components can release any conditions of speakers' speech production. The failure of phonetic implementation can result in phonemic and phonetic changes. The later can be seen from the mechanism of how the sounds are inappropriately produced.

Studying the acoustic characteristics of impaired sounds could provide information on how patients understand the words or images given to them, how they interpret the symbols in sounds, and how they translate sound programs into concrete articulations. The errors may not occur in the selection of the phonemes of the target words or in the articulation planning, but in the articulatory implementation. Acoustic properties of vowel parameters are essentially determined by formant value, duration and phonation. The different forms of formants are a system of the physical function of articulators in the production of speech sounds (Lieberman & Blumstein, 1988). The distortion of the standard formant value indicates the three phonetic variations, namely exact, almost exact and inaccurate. The accuracy of the vowel articulation can be obtained from the corresponding function, the position of the constriction, and the timing. Vowel formants are associated with the acoustic measurement of resonant frequency (Ladefoged, 2003). This study attempts to find evidence of acoustic features of vowel realization in speech errors from NFA by sound waves and spectrograms. The inaccuracy of the articulation can be recognized by the different values of formants, a pattern of sound waves, a prolongation of the articulation rate, an abnormal intensity, and pitch. The discussion focuses on notions of time analysis, spectral analysis, and trajectory measures. Temporal analysis included vowel duration only, while spectral analysis included the following parameters: F1 and F2 values. Formant measurements included F2 pitch and formant length. F1 dan F2 of the two standard Balinese vowels /i/, /e/, //, /a/, /o/, u/ in initial, middle and final position. Therefore, it is necessary to find out (1) whether the value of the acoustic measurement of vowels is relatively higher or lower than the vowels produced by normal speakers; (2) whether the timing or duration of vowel production in all distributions is longer or shorter than that produced by the normal speaker; and (3) whether the patients with NFA produce a disprosody in vowel production as evidence of motor aphasic syndrome.

Previous studies on aphasia have focused on speech disorders in the form of sound distortion and simplification, the differences between non-fluent and fluent aphasia, and the relationship between phonological disorder and brain damage, whether anterior or posterior syndrome. Regarding distortion, (Darley, Aronson, & Brown, 1975) found that the distortion in aphasia represents a weakening of the voice's quality of articulation, such that the acoustic character becomes imprecise. For example, the effect of delayed anticipatory co-articulation in aphasic speech 20-30 ms in subjects with non-fluent aphasia (Kent & Rosenbek, 1983).

However, Adam, (2014: 154) strongly argues that the time course of anticipatory co-articulation is relatively normal in nonfluent aphasics, although the co-articulatory effects are otherwise impaired. Adam, (2014: 154) also asserts that utterances in non-fluent aphasia do not reflect distortion or inaccuracy in sound quality, sound prolongation, vocalization, and phonation. However, (Darley, Aronson, & Brown, 1975) assert that phonetic error bias refers to imprecise and unrecognizable phoneme production. Meanwhile, (Cera & Ortiz, 2010) hold that distortion is not a type of simplification by substituting one sound for another. Distorted sound is more common with the symptom of dysarthria. The sound attenuation is not phonetic or phonemic, but inherent in the weak character of the voice.

Meanwhile, non-fluent aphasia is more likely to show symptoms of simplification of sound through sound alteration. The phonological alteration can take the form of substitution, deletion, insertion, addition and metathesis of sound segments. The results of previous studies have shown that the most commonly found type of alternation is substitution (Novick dkk., 2010; Cera & Ortiz, 2010: 60). However, aphasic patients simplify sounds with complex levels of articulation through phonological changes in their language Alternating phonemes in non-fluent aphasia arise not from a weakening of the function of the phoneme-mapping program but from a deficit in the implementation of phonetic planning Aphasia patients simplify substitute phonemes with other phonemes.

There are suggestions in the literature that anterior aphasics display impairments in the production of voicing fricative consonants. Frequent devoicing of initial and medial voiced fricatives has been reported in anterior aphasic's speech production (Kent & Rosenbek, 1983) as has the premature onset of voicing in voiceless fricatives before the frication segment has ended (Kent & Rosenbek, 1983) These results suggest an inability to combine vocal cord vibration and supralaryngeal articulatory gestures. Additionally, Harmes et al. (1984) ascribed the presence of numerous 10–30ms silent gaps during alveolar fricative production ([s z]) in one aphasic speaker to "rapid glottal closure and/or pauses in respiratory drive" (p. 382).

From the above empirical point of view, it can be stated that sound distortion in aphasia is more directed to the quality of sound characteristic accuracy, while sound simplification relates to the inability of patients with non-fluent aphasia to translate phonemic messages into phonetic implementation. This study therefore attempts to examine these two symptoms as evidence of the spectral and temporal aspects of sound. From exposure to sound parameters, research on consonant sounds in aphasia (Kent & Rosenbek, 1983) and Adam, (2014: 154) found that patients with non-fluent aphasia did not have much difficulty articulating vowels However, this study assumes that patients with non-fluent aphasia also have difficulty pronouncing vowels, particularly of sounds that have complex articulation. The results of the study therefore may suggest that acoustic spectrograms of vowels can prove that non-fluent aphasia can lead to vowel distortion and simplification.

METHOD

There were two patients with NFA whose speech was observed for the present study. The first participant, KW, is a 70-year-old, right-handed male with a BA in teaching and was an elementary school teacher prior to suffering a cerebrovascular accident in 2017 when his left middle cerebral artery started. The second participant, NS, is a 52-year-old right-handed woodcarver. Immediately following the non-hemorrhagic stroke (NHS) in 2018, he suffered from NFA and right hemiplegia. Both participants had the same syndrome of non-fluent aphasia, such as difficulty repeating words, phonological anomie, naming, reading and writing.

Participants' speech output was stimulated by various eliciting phonological tasks and word-image matching stimulation. They were given phonological tasks consisting of 260 simple and complex target words. These words or images mainly represented consonants and vowels in various distributions, including consonant clusters. The speech was digitally recorded with a SONY MP3 player. Observation of recorded speech was performed by classifying types of phonological errors including phoneme substitution, distortion, insertion, omission and metathesis. The segment errors were counted and phonemic and phonetic according to I.P.A. Data were copied for Characters of Balinese vowels from Praat (Boersma & Weenink, 2008) and measured to ensure the acoustic properties of a single tone and its co-articulations. The acoustic measurement can provide any phenomenon of either segmental or suprasegmental errors.

A phonological analysis of segmental errors, including substitution, distortion, omission, and insertion was carried out and treated as inputs of intervention. All errors that occurred across all tasks were analyzed. This analysis refers to the distinctive features and the segments matrix for the Balinese language was used. The features contained in this matrix include syllabic, high, low, back, rounded and voiced. The phonological process such as assimilation, syllable structure, and simplification meant observed in order to understand the reason for errors, e.g., the influence of neighboring phonemes (Schane, 1992). All changes or outputs were analyzed to understand the articulatory process by applying the theory of clinical phonetics and acoustics.

RESULT AND DISCUSSION

Regarding recorded speech extracted from words and picture names, the patients tended to make vowel changes in medial position because they found difficulties in mixing or configuring the sounds in the co-articulation with other neighboring sounds. Three acoustic variations were found in the study; normal, near normal, and far from normal articulation. The vowels observed were /i/ in the word 'bridge', /u/ in the word *alu* 'water monitor', /e/ in the word *keket* 'thorn', // in the word *emas* 'gold', /o/ in the word *oleg* 'a dance', and *matah* 'raw'. The patients were able to articulate the vowels individually. In addition, they have produced dysprosodic sounds, such as inappropriate timing, melody or pitch and intensity. Phonetic errors in NFA occur because the brain lesion is located in the anterior left hemisphere of the brain, which has a specific function of the articulatory planning program. So the word *ipah, 'in law'* pronounced as [aleh], was not associated with neuromuscular failure.

From an acoustic point of view, the patient's articulation deficit can determine the various acoustic characteristics such as formant value, intensity, pitch and duration or timing. Formant is the acoustic term that refers to a classification of features of the vowels in the configuration of mingling with other sounds. The formant value of vowels is a statistical measure that provides information about the resonant frequency associated with measuring two cavities in the separate oral cavity. The measurement in this case is the measurement of the space formed by tongue movement in articulation. F1 is related to measurement of pharyngeal space, F2 is related to oral cavity space and F3 shows lip shape, such as closed, open, rounded and unrounded position (Ladefoged, 2003). If the narrowing occurs in the front position of the oral cavity, there will be less space, but it will have a higher frequency, and the space of the pharynx will be wider, but it will have a lower frequency. Therefore, the following sections contain acoustic analysis on characteristic and alteration of vowels /i/, /u/, /e/, /ə/, /o/, and /a/ produced by patients with NFA

Characteristic and alteration of vowel /i/

Spectral and temporal analysis of sound /i/ in medial and final position can be seen from the way the articulators configure all the system, however, the prosodic side of the view as (Sidtis & Sidtis, 2003) found in terms of initial, medial, and final shortening or lengthening vowels errors. Phonetically, vowel /i/ involves high complex articulation, therefore it can not be articulated in initial of the word ipah 'sister /brother in law' which was pronounced [aleh]. However /i/ can be articulated in medial and in final of the word titi even though it is not as accurate as the normal speakers can produce. Figure 1 shows the acoustic wave and the spectrogram of articulation /i/.

/titi/ [dɪdɪ]

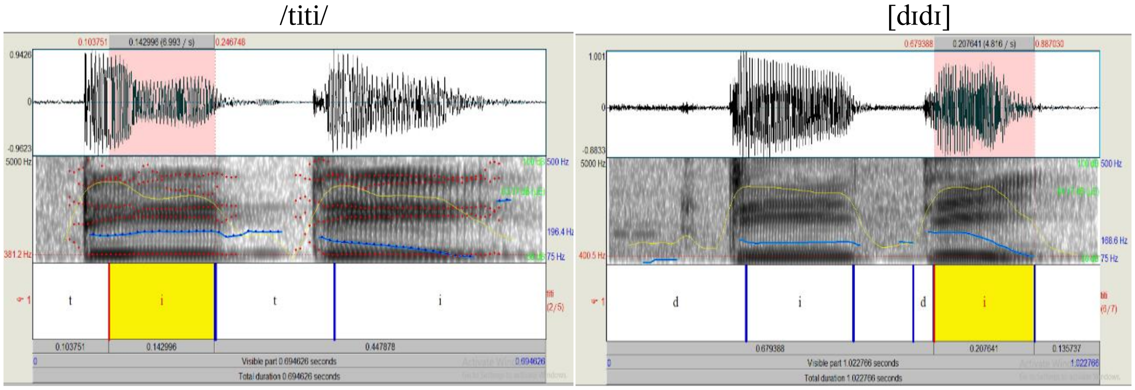

Figure 1. Sound Wave and Spectrogram of Articulation /i/

From the two spectrograms above, a significant difference between the normal sound (on the left) and the inaccurate sound produced by patients with NFA (on the right) can be evidence of phonetic variation in this study. Forman value of F1 of the sound [i] pictured in the left spectrogram was 381.2 Hz. It means that the space of pharynx was wider so the frequency is low because the constriction occurs in the initial part of the oral cavity and it left a smaller space of oral cavity but it has a high frequency The timing range which is required for this vowel is relatively short; 0.142996 ms. However, the difference of vowel [i] produced by patients with NFA in the right spectrogram can be seen from the formant value of F1 which 414.4 Hz, meaning the space of pharynx is 33.2 less wide than the normal and the inaccuracy of the tongue movement can be seen from the higher formant value of 2209 Hz. The shape of the spreading lips was wider as formant value of the F3 reached to 2741 Hz. This formant value led to the lax vowel /ɪ/. The timing was one of the dysprosodic found in the study. The difference of final vowel lengthening was 0.045547 ms, meaning patients produced longer duration in producing vowel /i/. As (Novick, Trueswell, & Thompson, 2010) found that one of the clinical manifestations of aphasia is the presence of deficits in speech production. This finding declares that deficit in articulatory planning program suffered by patients with NFA can set not just inaccuracy of articulation of /i/ but also distortion in the dysprosodic features.

Characteristic and alteration of vowel /u/

Phonological distinctive features are derived from the phonetic concept of sound production. The articulation of vowel /u/ is one of the complex sounds that involve the back and high constriction of the tongue. The variation of articulation /i/ by the patients with NFA are [o], /uled/ 'caterpillar' → [oles], [o] /l əgu/ 'mosquito' → [ləgo]. Sound /u/ can be nearly articulated as [u] if it is preceded by lateral sound, like in the word alu water monitor' or /guru / 'teacher' → [kulu].. Distortion of segmental and suprasegmental of sound /u/ by patients with NFA can be presented in figure 2.

/alu/ /alu/

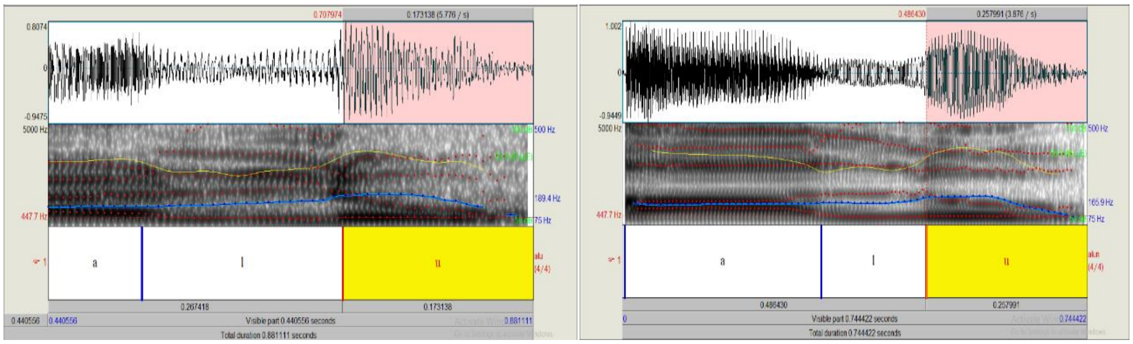

Figure 2. Sound Wave and Spectrogram of Articulation /u/

Even though /u/ can be articulated at the back after the lateral sound, the characteristic of segmental and suprasegmental distinction can be described from the acoustic value. The value of F1, F2, and F3 of normal /u/ was 489.4 Hz, 1223 Hz, and 2621 Hz, meanwhile the value of F1, F2, and F3 of vowel /u. produced by patients with NFA was 475.1 Hz, 1176 Hz, and 2534 Hz. So the difference was 33.2Hz, 86Hz, and 133dB. It means the tense vowel of /u/ was not accurately articulated. The pitch, duration, and intensity of vowel /u/ produced by the normal speaker was 191.2 Hz, 0.231 ms, 86.65 dB, and the patients reached up to 208.7 Hz, 0.895 ms, and 86.62 dB. This finding emphasizes that patients with NFA had inaccurate articulation and final lengthening of vowel /u/ because the impaired melody of speech is associated with anterior zone (Wagenaar, Snow, & Prins, 1975).

Characteristic and alteration of vowel /e/

The articulation of sound [e] involves the constriction that occurs at the front oral track, namely the blade of the tongue moves upwards to the palate so the space of pharynx is wider and acoustic frequency tends to be low, meanwhile the space in oral track seems to be narrower but the frequency is high. Variation of articulation /e/ by the patients with NFA are [i], /gatep/ 'fruit' → [gatit], [o] /toke/ 'gecko' →[topɔ]. Distortion of segmental and suprasegmental of sound /e/ by patients with NFA can be presented in figure 3.

/toke/ [toʊke]

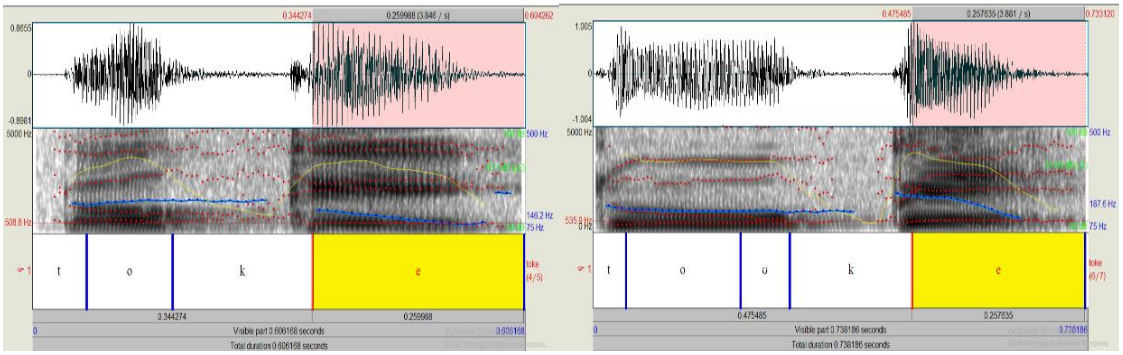

Figure 3. Sound Wave and Spectrogram of Articulation /e/

Vowel /e/ can be articulated at the back after voiceless stopped velar sound /k/, the characteristic of segmental and suprasegmental distinction can be described from the acoustic value. The value of F1, F2, and F3 of normal /e/ was 580.6 Hz, 2143 Hz, and 2475 Hz, meanwhile the value of F1, F2, and F3 of vowel /u. produced by patients with NFA was 535.9 Hz, 2025 Hz, and 2729 Hz. It means the vowel of /u/ was nearly accurate. The pitch, duration, and intensity of vowel /u/ produced by the normal speaker was 146.2 Hz, 0.259988 ms, 81.10 dB, and the patients reached up to 149.1 Hz, 0.257635 ms, and 81.27 dB. So, the patients with NFA tend to have suprasegmental deficit due to lesion Broca's area.

Characteristic and alteration of vowel /ə/.

Sound /ə/ is produced by neutralizing tongue and lips position. It means that the part of the tongue is not moved to the front, backward, upwards, or downwards and the lips are not rounded or unrounded. The variation of articulation /e/ by the patients with NFA are [i], /ə/ → [i] əntip/ 'rice' → [nitɪp], ə/ → [o] as /dədarə/ 'dove → [tolalə], and [ə] → [o] / - # as /batə / 'brick' → [batɔh]. Distortion of segmental and suprasegmental of sound / Distortion of segmental and suprasegmental of sound /ə/ by patients with NFA can be presented in figure 4.

/əmɑs/ [əmɑs]

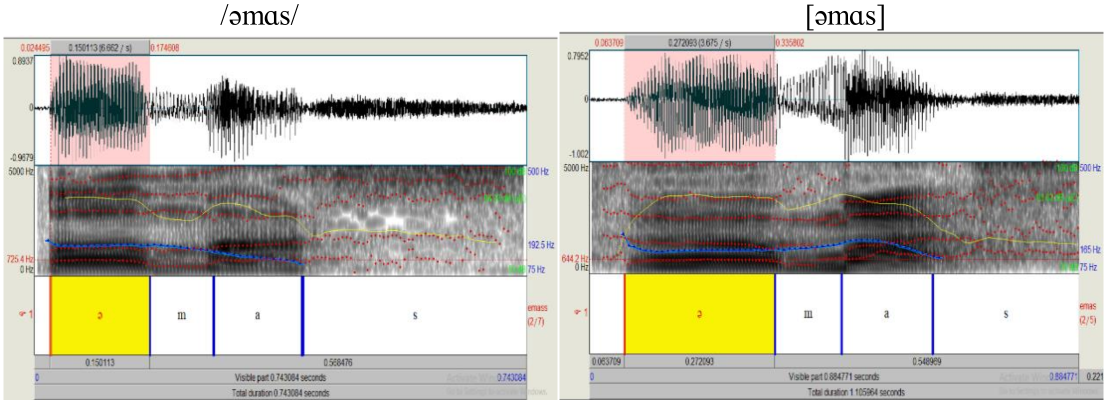

Figure 4. Sound Wave and Spectrogram of Articulation /ə/

The spectrogram which is presented in yellow slot shows some acoustic distinctions of the sound [ə] produced by the normal speaker and the patients. The difference of the sound produced by the patients can be seen from the configuration of the tongue, the shape of the lips, the lengthening duration, impaired melodic and intensity of the sound. Vowel / ə / can be articulated in the initial position, The characteristic of segmental and suprasegmental distinction can be described from the acoustic value. The value of F1, F2, and F3 of normal was 671.1 Hz, 1245 Hz, and 2874 Hz, meanwhile the value of F1, F2, and F3 of vowel /ə/ produced by patients with NFA was 535.9 Hz, 1644 Hz, and 2375 Hz. It means the vowel of /ə/ was nearly accurate. The pitch, duration, and intensity of vowel /ə/ produced by the normal speaker was 170.7 Hz, 0.245 ms, 83.11 dB, and the patients reached up to 156.8Hz, 0.415 ms, and 80.16 dB. So it was found that patients with NFA had inaccurate articulation, the impaired melody of speech, and final lengthening of vowel /ə/.

Characteristic and alteration of vowel /o/

The sound error of /o/ which is produced by patients with NFA is known as heightening. The tongue tends to move upwards. So the sound /o/ is mainly substituted by a tense or lax high back vowel; [u] or [ʊ]. The variation of articulation /e/ by the patients with NFA are / o / → [u]/ C - C as / toke/ 'gecko' → [tuke], / ɔ / → [ʊ]/ C – C as /katos/ 'hard' →[astʊh]. However,/o/ can be articulated in initial as in the word of oleg 'dance'. Distortion of segmental and suprasegmental of sound /o/ by patients with NFA can be presented in figure 5.

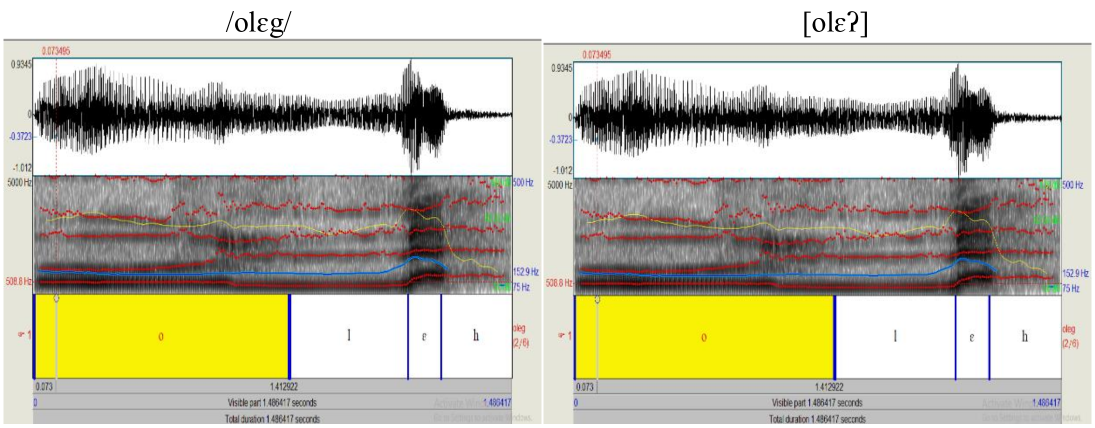

Figure 5. Sound Wave and Spectrogram of Articulation [o]

Both yellow slots above show the acoustic distinctions of sound [o] in initial position produced by normal speaker and the patients. The configuration of the tongue, shape of the lips, the initial lengthening duration, impaired melodic and intensity of the vowel /o/ are presented in acoustic measurement of the articulation, resonanse, and duration that can be described from the acoustic value. Specific observation on sound wave and the pectrogram of articulation /o/ produced by the patients on the right showed that the narrow pharinx space with high frequency of 540.8Hz and oral tract was wide with low frequency of 803.6 Hz. Standard rounded lips is presented in F3 that was 2621Hz. However, timing duration 0.209 ms and the normal speaker needs only 0.195 ms. It means that there is 0.023 ms longer. The normal pitch for this vowel is 182.4Hz however the patients decreased the pitch into 160.2 Hz and the fifference was 4.5 Hz. For intensity, the normal speaker has 83.4 dB and the patient had 84.54, so the patient had 1.06 dB more intensity on vowel /o/ in initial position. So it was found that patients with NFA had inaccurate articulation, impaired melody of speech, and final lengthening of vowel /o/.

Characteristic and alteration of vowel /a/

Vowel sound /a/ is produced by lowering the tongue from the palate and the jaws are opening so the airstream goes through the oral tract. This vowel is the easiest articulation the patients can produce because it has low complexity. So the sound /a/ can be substituted by /ə/ or /i/ in media position. The variation of articulation /a/ by the patients with NFA are /a/→ [æ] / V- C as /sampi/ 'cow' → [səmpi] and

/a/→ [ɛ] /C-C as /ipɑh/ 'brother or sister in law' → [alɛh]. However /a/ can be articulated in a medial position in a complex word.

From both spectrograms below, it seems that the patients with NFA do not find any difficulties articulating the sound [a]. However, the level of accuracy either segmental or suprasegmental features can only be distinguished by searching the acoustic features. The sound wave and the spectrogram of articulation /a/ produced by the patients on the right slot showed that the narrow pharynx space with a high frequency of 781 Hz and the oral tract was in the middle with the medium frequency of 1176 Hz. Unrounded lips were presented in F3 that was 2665 Hz. However, the timing duration was 0.341 ms. It means the patients articulated the sound 0.115md longer than the normal speaker which is 0.226 ms. The normal pitch for this vowel is 162.7Hz however the patients decreased the pitch into 157.3 Hz and the difference was 5.4 Hz. For intensity, the normal speaker has 84.11dB and the patient had 83.18dB so the patient had 0.93 dB less intensity on vowel /a/ in the first syllables. So it was found that patients with NFA had inaccurate articulation, the impaired melody of speech, and final lengthening of vowel /o/. Broca's aphasic speech is characterized by slow and effortful speech, resulting in increased vowel durations which suggest motor planning and temporal control deficits (Boyce, 2015). Distortion of segmental and suprasegmental of sound /o/ by patients with NFA can be presented in figure 6.

/matɑh/ [matɑh]

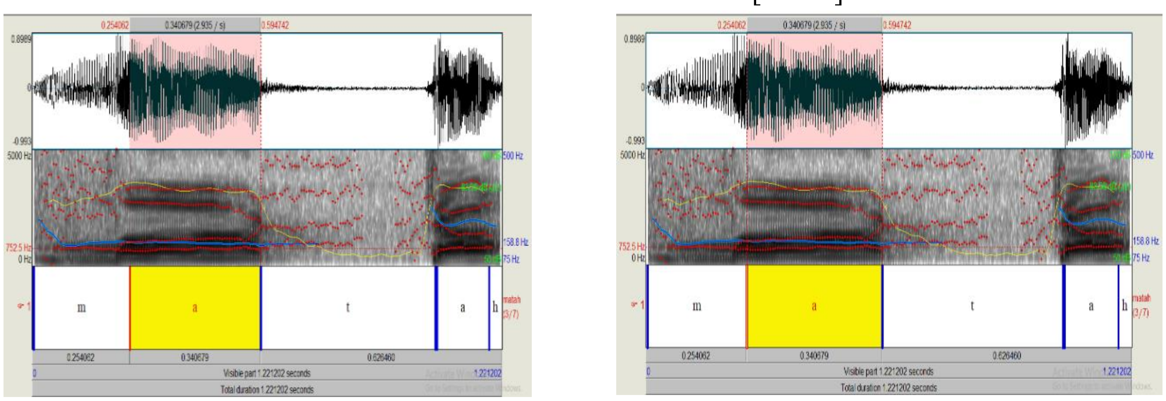

Figure 6. Sound Wave and Spectrogram of Articulation /a/.

Based on the spectral analysis of vowels using Praat, the characteristic of vowels is mainly dominated by the distortion of segmental and suprasegmental. The distortion occurs at the level of phonetics, intensity, lengthening, and pitch. There are some significant results regarding the spectral analysis of vocal distortions in this study; (1) vowels with highly complex articulation indicate a weakening of phonation, lengthening of the pharyngeal space and the inappropriate narrowing of articulators, which is recognized by an unstable formant value; (2) vowel changes occur mainly in medial position; (3) the intensity of the vowels produced by patients with NFA is lower than the same tone produced by normal speakers; (4) there was vowel lengthening in all positions when preceded by voiced consonants; and (5) melodic features such as pitch and intensity are primarily lower than normal vowels. Therefore, damage to the inferior frontal gyrus in the left cerebral hemisphere after stroke can impair the function of the articulatory planning program, causing inaccuracy in sound production and segmental simplification. The distribution of acoustic features on vowels produced by KW and a normal speaker can be seen in Table 1.

Tabel 1. Distribution of Acoustic Features on Vowels Produced by KW and a Normal Speaker

Penutur		Sound	F1 (Hz)	F2 (Hz)	F3 (Hz)	Pitch (Hz)	Duration Ms	Intensity dB
Petient KW	Tense	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
	lax	ɪ	431.3	2161	2884	194.6	0.106	85.87
		ɪ	409.4	2030	2534	157.7	0.055	87.59
			21.9	131	350	36.9	0.051	28.28
Patient KW	tense	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
	lax	ɛ	650.3	1855	2621	181.3	0.105	83.85
		ɛ	668.4	2138	2634	188.6	0.053	82.65
		df	18.1	283	13	7.3	0.052	1.2
Patient KW	tense	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
	lax	æ	737.9	1482	2293	173.1	0.160	84.37
		æ	628.4	1461	2840	198.2	0.082	86.08
		df	109.5	21	547	25.1	0.08	1.71
Patient KW	tense	u	475.1	1176	2534	208.7	0.895	86.62
Normal		u	489.4	1223	2621	191.2	0.231	86.65
		df	65.7	153	87	17.5	0.664	0.03
	lax	ʊ	540.8	825.5	2293	189.9	0.156	81.79
		ʊ	562.7	1242	2687	193.7	0.074	80.20
Patient KW	tense	o	540.8	803.6	2621	160.2	0.209	84.54
Normal		o	574.7	979.5	2741	182.4	0.195	83.48
		df	129.5	16.5	364	4.5	0.023	1.06
	lax	ɔ	644.2	996	2377	177.1	0.172	80.48
		ɔ	672.2	1110	2840	180.5	0.097	75.50
		df	28	114	463	3.4	0.075	4.98
Patient KW	tense	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
	lax	ɑ	869.3	1439	2380	192.2	0.309	83.71
		ɑ	875.5	1498	2556	176	0.076	84.39
		df	6.2	59	176	16.2	0.23	0.68

From the above data, the area of the pharyngeal space and the oral tract when the tense and the lax vowels are articulated can be recognized from the value of F1. The lax vowels have a higher frequency than the tense vowels. This means that the constriction is set back a little, giving the pharynx narrower space than the production of the tense vowels. This means that this condition leaves less room in the oral tract, so the frequency of tense vowels is higher than lax ones. For the dysprodic syndrome of lengthening or shortening of vowel duration, there is prosodic evidence of tense and lax vowels in patients with NFA as well as in normal speakers. The tense vowels take a longer time than the lax vowels due to the maximum movement of the constriction by stretching the articulators. The inaccuracy of vowel production in the speech sound of patients with NFA is associated with impaired speech function in the third convolution of the left hemisphere. Thus, the property of the vowel sound produced by patients with NFA found in this study may provide evidence for the neurolinguistic description of impaired speech. NS showed fairly similar acoustic features, including imprecise articulation, such as B. the phenomenon of lengthening or shortening of the duration of vowels. NS also had dysprosodic signs resulting from brain damage in the third convolution of the left cerebral hemisphere, shown in Table 2.

Table 2. Distribution of Acoustic Features on Vowels Produced by NS and Normal a Speaker

Penutur		Sound	F1 (Hz)	F2 (Hz)	F3 (Hz)	Pitch (Hz)	Duration Ms	Intensity dB
Patient NS	Teg	i	343.4	2446	2840	148.9	0.345	83.20
Normal		i	381.2	2123	2608	207.2	0.142	84.40
		df	37.8	323	232	58.3	0.203	1.2
	Ken	ɪ	451.3	2261	2984	194.6	0.096	80.87
		ɪ	409.4	2030	2534	157.7	0.055	57.59
		df	41.9	231	450	36.9	0.041	23.28
Patient NS	Teg	e	497	2271	2665	203.3	0.254	85.62
Normal		e	671.2	1998	2566	163.4	0.165	94.40
		df	174.1	273	99	39.9	0.089	8.78
	Ken	ɛ	540.3	1855	2621	191.3	0.120	80.82
		ɛ	628.4	2138	2534	188.6	0.053	82.65
		df	88.1	283	87	27	0.067	1.83
Patient NS	Teg	ə	453	1701	2753	151.6	0.354	82.62
Normal		ə	671.1	1245	2874	170.7	0.245	83.11
		df	218.1	456	121	19.1	0.109	0.49
	Ken	æ	437.9	1482	2293	163.1	0.160	75.52
		æ	628.4	1461	2840	198.2	0.082	86.08
		df	190.5	21	547	35.1	0.082	10.56
Patient NS	Teg	u	540	935	2818	187.7	0.341	81.60
Normal		u	409.4	1023	2621	191.2	0.231	86.65
		df	130.6	88	197	3.5	0.11	5.05
	Ken	ʊ	520.8	850.5	2593	179.9	0.256	80.79
		ʊ	562.7	1242	2687	193.7	0.074	80.20
		df	41.9	391.5	94	13.8	0.182	0.59
Patient NS	Teg	o	628	1088	3015	119.4	0.262	80.50
Normal		o	514.7	979.5	2741	182.4	0.195	83.48
		df	113.3	108.5	274	63	0.067	2.98
	Ken	ɔ	550.2	956	2477	157.1	0.152	87.48
		ɔ	672.2	1110	2840	180.5	0.097	75.50
		df	1.220	154	363	23.4	0.055	11.98
Patient NS	Teg	a	825	1701	2928	126.1	0.352	80.34
Normal		a	803.6	1198	2906	162.7	0.226	84.11
		df	21.4	503	22	36.6	0.126	3.77
	Ken	ɑ	769.3	1139	2480	182.2	0.209	80.70
		ɑ	825.5	1198	2556	176	0.076	84.39
		df	56.2	59	76	6.2	0.133	3.69

From the temporal and the spectral analysis of the formant value of the two patients, the results show a large variability among the aphasic subjects and longer vowel durations compared to the normal speakers. This study suggests that vowel mechanisms of temporal errors produced by patients with NFA are phonetic rather than phonological planning disorders, as noted by (Akhutina, 2016) as phonemic implementation (Buckingham & Christman, 2008) and (Shinn & Blumstein, 1983).

This phenomenon occurs due to phonetic implementation, temporal coordination, and timing deficits of articulatory movements, as (Sidtis & Sidtis, 2003) have claimed. However, this study suggests that the deficits affect speech production mechanisms characterized by imprecise articulation, a slow vowel rate, and other prosodic disturbances. So, the inaccuracy of segmental and suprasegmental features of vowels is caused by insufficient tactile feedback during production. Therefore, it is emphasized that the more complex the articulation of the vowels, the more possibilities there will be for sound change and the longer the duration will be. For example, the word *madu* 'honey' is realized as [madɔh]. The imprecise articulation mechanisms can contribute in part to impairments in accessing and retrieving information about the articulation target.

CONCLUSION

This study shows two main results regarding spectral and temporal features of vowels. Spectral errors included longer duration, lower intensity, and weaker pitch, while segmental alteration in NFA included vowel substitution, addition, insertion, and metathesis. The first finding revealed that vowels with highly complex articulation resulted in weakening of phonation, pharyngeal expansion, and inappropriate constriction presented with unstable formant values. In addition, the intensity of the vowels produced by patients with NFA is lower than the same tone produced by normal speakers in all positions when preceded by voiced consonants. In terms of melodic characteristics, the pitch and intensity of NFA are primarily lower than ordinary speakers.

Of the temporal features, the high front and back vowels tended to be modified by less complex low vowels. For example, /u/ in /uled/ 'caterpillar' was substituted by [o] in [oles]. In addition, front vowels are replaced with middle and back vowels. For example, /e/ is realized as [o] by patients with NFA; /toke/ becomes [topo], /ə/ in /dədari/ 'dove' is realized as [tolali], or /batə / 'brick' becomes [batɔh]. It can be specified that a segmental substitution is followed by another segmental substitution in the same syllables. Furthermore, longer duration or stronger pitch of vowels can result in the vowel alteration. The longer the duration of vowel may take the more possible the segments in the syllable will be substituted. The vowel substitution take place due to (1) complexity level of articulation, (2) position of the vowels in syllables, (3) the neighboring segment, and (4) weakening prosodic features. So, this study can be used as guidance for language rehabilitation and empirical study for clinical phonology.

REFERENCES

(n.d.).

Adam, H. (2014). Dysprosody in aphasia: An acoustic analysis evidence from Palestinian Arabic. *Journal of language and Linguistic Studies, 10*(1), 153-162.

Akhutina, T. (2016). Luria's Classification of aphasias and its theoretical basis. *Aphasiology, 30*(8), 878-897. doi:https://doi.org/10.1080/02687038.2015.1070950

Bastiaanse, R., Glibers, D., & Linde, K. D. (1994). Sonority substitution in Broca's and conduction aphasia. *Journal of Neurolinguistik, 8*(4), 247-255. doi:https://doi.org/10.1016/09116044(94)90011-6

Bastiaanse, Roelien, Gilbers, Dicky, Linde, KlarienVan Der. (1994). Sonority substitutions in Broca's and conduction aphasia. *Journal of Neurolinguistics*, 247.

Boersma, P., & Weenink, D. (2008). Praat, a system for doing phonetics by computer (Version 5.0. 34). *[Computer software].*

Boyce, S. E. (2015). Articulatory Phonetics for Residual Speech Sound Disorders: A Focus on /r/. *Semin Speech Lang, 36*(4), 257–270. doi:https://dx.doi.org/10.1055%2Fs-0035-1562909

Buckingham, H. W., & Christman, S. S. (2008). *Disorders of Phonetics and Phonology.* London: Academic Press.

Cera, M. L., & Ortiz, K. Z. (2010). Phonological analysis of substitution errors of patients with apraxia of speech. *Dement Neuropsychol, 4*(1), 58–62. doi:https://doi:10.1590/S1980-57642010DN40100010

Darley, F. L., Aronson, A. E., & Brown, J. R. (1975). *Motor speech disorders.* Philadelphia: WB Saunders Company.

Galluzzi, C., Bureca, I., Guariglia, C., & Romani, C. (2015). Phonological Simplifications, Apraxia of Speech and the Interaction between Phonological and Phonetic Processing. *Neuropsychologia, 71*, 64–83.

Gandour, J. T. (1998). Phonetics and Phonology. In B. Stemmer, & H. A. Whitaker, *Handbook of Neurolinguistics* (pp. 207-218). Indiana: Academic Press.

Herbert, R. E. (2004). *Therapy for word finding in aphasia: Effects on picture naming and conversation.* University College London. ProQuest LLC. Retrieved from https://discovery.ucl.ac.uk/id/eprint/1446711

Kent , & Rosenbek. (1983). Acoustic patterns of apraxia of speech. *Journal of Speech, Language, and Hearing Research,, 26*(2), 231-249.

Ladefoged, P. (2003). *Phonetic Data Analysis.* Oxford: Blackwell Publishing Ltd.

Lieberman, P., & Blumstein, S. E. (1988). *Speech physiology, speech perception, and acoustic phonetics.* Cambridge: Cambridge University Prose.

Meier, E. L., , E. L., Lo, M., & Kiran, S. (2016). Understanding semantic and phonological processing deficits in adults with aphasia: Effects of category and typicality. *Aphasiology,, 30*(6), 719–749. doi:https://doi:I10.1080/02687038.2015.1081137

Novick, J., Trueswell, J. C., & Thompson, S. (2010). Broca's Area and Language Processing: Evidence for the Cognitive Control Connectione. *Language and Linguistics Compass, 4*(10), 906–924. doi:doi: 10.1111/j.1749-818X.2010.00244.x

Romani, C., & Calabrese, A. (1998). Syllabic Constraints in the Phonological Errors of an Aphasic Patient. *Brain Lang, 64*(1), 83–121.

Romani, C., & Calabrese, A. (1998). Syllabic Constraints in the Phonological Errors of an Aphasic Patient. *Brain Lang, 64*(1), 83–121. doi:https://doi:10.1006/br1n.1998.1958

Sastra, G. (2011). *Neurolinguistik suatu Pengantar.* Bandung: Alfabeta.

Schane, S. B. (1992). *Generative Phonology.* San Diego: Prentice Hall Inc.

Shinn, P., & Blumstein, S. E. (1983). Phonetic disintegration in aphasia: Acoustic analysis of spectral characteristics for place of articulation. *Brain and Language, 20*(1), 90-114.

Sidtis, J. J., & Sidtis, D. V. (2003). A neurobehavioral approach to dysprosody.

Speech and Language. 4, pp. 093-106. New york: Thieme Medical Publishers.

Wagenaar, E., Snow, C., & Prins, R. (1975). Spontaneous speech of aphasic patients: A psycholinguistic analysis. *Brain and language, 2*, 281-303.

(Adam, 2014)

Baum, S. (2002). Consonant and vowel discrimination by brain damaged individuals: Effects of phonological segmentation. *Journal of Neurolinguistics*, 15, 447-461.

Bastianse, R., Gilbers, B.B., & Linde, K. (1994). Sonority substitutions in Broca's and conduction aphasia. *Journal of Neurolinguistics*, 8 (4), 247–255. DOI: 10.1016/0911-6044(94)90011-6.

Boersma, P & Weenink, D. (2008). *Doing phonetics by computer*. http://www.Praat (Boersma, & Weenink, 2008).org/, accessed June 7, 2012.

Boyce, S.E. (2015). Articulatory Phonetics for Residual Speech Sound Disorders: A Focus on /r/. *Semin Speech Lang*. 36(4), 257–270.

Buckingham, H.W., & Chrisman, S. S. (2008). "Disorders of Phonetics and Phonology". Dalam Stemmer, B & Whitaker, H.A. *Handbook of Neuroscience of Language*. London: Elsevier Ltd, hlm. 127 – 136.

Collins, M., Rosenbek, J.C.,and Wertz,R.T. (1983).Spectrographican alysis of vowel and word duration in apraxia of speech. *Journal of Speech and Hearing Research*, 26, 217–224.

Darley, F. L., Aronson, A. E., & Brown, J. R. (1975). *Motor speech disorders*. (Darley, Aronson, & Brown, 1975) (Darley, Aronson, & Brown, 1975): Saunders.

Gandour, J.T. (1998). Phonetics and Phonology in: Stemmer, B. & Whitaker, H.A. *Handbook of Neurolinguistics.*, (pp. 207 – 218). Indiana: Academic Press.

Goodglass, H., & Kaplan, E. (1972). The assessment of aphasia and related disorders. Philadelphia: Lea and Febiger.

Kent, R.D.,& Rosenbek, J.C.(1983). Acoustic patterns of apraxia of speech.Journal of Speech and Hearing Research, 26, 231–249.

Kurowski, K., Hazen, E., & Blumstein, S. (2003). The nature of speech production impairments in anterior aphasics: An acoustic analysis of voicing in fricative consonants. *Brain and Language,* 84, 353–371.

Ladefoged, P. (2001). *Vowels and consonants: Introduction to the sounds of language*". Oxford: Blackwell Publishing Ltd.
(Ladefoged, 2003)
Ladefoged, P. (2003). *Phonetic Data Analysis*. Oxford: Blackwell Publishing Ltd.

Lieberman, P., & Blumstein, S.E. (1988). *Speech Physiology, Speech Perception, and Accoustic Phonetics*. New York: Cambridge University Press.

Luria, A. (1966). *Higher Cortical Functions in Man*. New York: Basic Books.

Marotta, G., Barbera, M., & Bongioanni, P.

2008. “Prosody and Broca’s aphasia: An Accoustic analysis”. *On line Journal of Studi Linguistici e Filologici*, 6, Hlm. 79-98.

Ryalls, J. (1986) An acoustic study of vowel production in aphasia. *Brain and Language*. 29, 48-67.

Schane, S. B. (1992). *Generative Phonology*. San Diego: Prentice Hall Inc (Schane, 1992)

Schane, S. B. (1992). *Generative Phonology*. San Diego: Prentice Hall Inc.

Schane, S. B. B. 1992. Generative Phonology.

Shadle, Christine H./Mair, Sheila (1996). Quantifying spectral characteristics of fricatives. The International Conference on Spoken Language Processing (ICSLP 96), Philadelphia, USA: 1517–1520.

Shinn, P., & Blumstein, S. (1983). Phonetic disintegration in aphasia: Acoustic analysis of spectral characteristics for place of articulation. *Brain and Language*. 20, 90–114.

Sidtis, J. J., & Van Lancker-Sidtis, D. (2003). A neurobehavioral approach to dysprosody. Seminars in Speech and Language, 24, 93–105.

Zatorre, R. J., & Belin, P. (2001). Spectral and temporal processing in human auditory cortex. *Cerebral Cortex*, 11, 946–953.

3

Bukti konfirmasi submit revisi kedua

18 Januari 2022

I Ketut Wardana
Fakultas Keguruan dan Ilmu Pendidikan, Universitas Mahasaraswati Denpasar, Bali, Indonesia
Jalan Kamboja 11A, Denpasar, Bali. Telephone (0361) 240985, Faximile (0361) 240985,
E-mail: wardanak3tut@yahoo.co.id

Article accepted: …….; revised: ……; approved: …….

Abstract

Non-fluent aphasia (NFA) is a speech disorder produced by stroke survivors either because of bleeding or blood clots in Broca's area. The damage resulted in weakening language modalities such as stuttering, naming, reading, and writing, but the comprehension ability is still intact. There are two types of phonological disorders in NFA; Phonetic-level distortion and phonemic-level simplification. However, the vowel simplification produced by Balinese patients with NFA has not been a priority for clinical phonological studies so far. Thus, this study examined the spectral and temporal properties of vowel sounds produced by patients with NFA. Speech output was observed and analyzed using Praat. The data were compared with normal speech and described by implementing the theory of acoustic phonetics. Spectral analysis showed that imprecise narrowing of the tongue in vowels articulation affected the area of the oral tract (F2), pharynx (F1), and the shape of the lips (F3). In addition, the lesion in Brocas' area affected the temporal characteristics of the sounds, such as the lower pitch, lower intensity, and longer timing, especially the segmental environment. It means that the vowels preceded by voiced consonants were significantly longer than those preceded by unvoiced ones. Therefore, the highly complex vowels tend to be imprecisely articulated due to an articulatory conversion deficit. This finding is consistent with previous findings that the spectral and temporal distortion are primarily phonetic rather than inaccurate phonological planning programs.

Keywords: aphasia, disprosody, distortion, vowel, Neurolinguistics

Abstraksi

Afasia nonfasih (ANF) merupakan pelemahan bahasa yang pernah dikuasai oleh pasien stroke, baik akibat pendarahan ataupun pembekuan darah di area konvolusi ketiga belahan otak sisi kiri. Kerusakan tersebut mengakibatkan pelemahan modalitas bahasa, seperti ujaran terbata-bata, penamaan, membaca, menulis, namun keupayaan pemahaman masih utuh. Terdapat dua jenis gangguan fonologis dalam ANF; distorsi pada tataran fonetis dan penyederhanaan bunyi pada tataran fonemis. Penyelidikan fitur fonetik akustik bunyi vokal pada ujaran bahasa Bali afasia nonfasih (ANF) belum menjadi proritas penyelidikan fonologi klinis selama ini. Sehingga, penelitian ini bertujuan untuk menyelidiki karakteristik spektral dan temporal bunyi vokal pasien ANF dengan artikulasi vokal penutur normal. Luaran ujaran dua pasien ANF diamati dan dikaji dengan menggunakan spectrogram Praat dan data dijabarkan dengan menerapkan teori akustik dan fonetik klinis. Analisis spektral bunyi vokal menunjukkan bahwa kontriksi lidah yang tidak tepat memengaruhi rentangan ruang rongga mulut (F2), ruang faring (F1) dan bentuk bibir (F3). Kerusakan jaringan di area Broca juga dapat melemahkan ciri temporal bumyi termasuk melodi, tekanan, dan rentang waktu pada lingkungan bunyi bersuara. Artinya, bunyi vokal yang didahului oleh konsonan bersuara memiliki rentang waktu yang lebih panjang dari pada bunyi vokal yang didahului oleh bunyi yang tak bersuara. Dalam penyelidiki akustik, bunyi vokal yang lebih kompleks cenderung dilafalkan tidak akurat karena defisit implementasi artikulasi. Temuan ini selaras dengan *penelitian sebelumnya bahwa ketidakakuratan artikulasi dan prosodi ada pada tataran gangguan fonetis bukan pelemahan pogram perencanaan fonologis.*

Kata kunci: afasia, disprosodi, penyimpangan, vokal, neurolinguistic

4

Bukti approved

(5 April 2022)

SPECTRAL AND TEMPORAL PROCESSING IN BALINESE VOWEL OF NON-FLUENT APHASIA

PEMROSESAN SPEKTRAL DAN TEMPORAL BUNYI VOKAL BAHASA BALI AFASIA NON-FASIH

I Ketut Wardana
Fakultas Keguruan dan Ilmu Pendidikan, Universitas Mahasaraswati Denpasar, Bali, Indonesia
Jalan Kamboja 11A, Denpasar, Bali. Telephone (0361) 240985, Faximile (0361) 240985,
E-mail: wardanak3tut@yahoo.co.id

Article accepted: …….; revised: ……; approved: …….

Abstract

Non-fluent aphasia (NFA) is a speech disorder produced by stroke survivors either because of bleeding or blood clots in Broca's area. The damage resulted in weakening language modalities such as stuttering, naming, reading, and writing, but the comprehension ability is still intact. There are two types of phonological disorders in NFA; Phonetic-level distortion and phonemic-level simplification. However, the vowel simAplification produced by Balinese patients with NFA has not been a priority for clinical phonological studies so far. Thus, this study examined the spectral and temporal properties of vowel sounds produced by patients with NFA. Speech output was observed and analyzed using Praat. The data were compared with normal speech and described by implementing the theory of acoustic phonetics. Spectral analysis showed that imprecise narrowing of the tongue in vowels articulation affected the area of the oral tract (F2), pharynx (F1), and the shape of the lips (F3). In addition, the lesion in Brocas' area affected the temporal characteristics of the sounds, such as the lower pitch, lower intensity, and longer timing, especially the segmental environment. It means that the vowels preceded by voiced consonants were significantly longer than those preceded by unvoiced ones. Therefore, the highly complex vowels tend to be imprecisely articulated due to an articulatory conversion deficit. This finding is consistent with previous findings that the spectral and temporal distortion are primarily phonetic rather than inaccurate phonological planning programs.

Keywords: aphasia, disprosody, distortion, vowel, Neurolinguistics

Abstraksi

Afasia nonfasih (ANF) merupakan pelemahan bahasa yang pernah dikuasai oleh pasien stroke, baik akibat pendarahan ataupun pembekuan darah di area konvolusi ketiga belahan otak sisi kiri. Kerusakan tersebut mengakibatkan pelemahan modalitas bahasa, seperti ujaran terbata-bata, penamaan, membaca, menulis, namun keupayaan pemahaman masih utuh. Terdapat dua jenis gangguan fonologis dalam ANF; distorsi pada tataran fonetis dan penyederhanaan bunyi pada tataran fonemis. Penyelidikan fitur fonetik akustik bunyi vokal pada ujaran bahasa Bali afasia nonfasih (ANF) belum menjadi proritas penyelidikan fonologi klinis selama ini. Sehingga, penelitian ini bertujuan untuk menyelidiki karakteristik spektral dan temporal bunyi vokal pasien ANF dengan artikulasi vokal penutur normal. Luaran ujaran dua pasien ANF diamati dan dikaji dengan menggunakan spectrogram Praat dan data dijabarkan dengan menerapkan teori akustik dan fonetik klinis. Analisis spektral bunyi vokal menunjukkan bahwa kontriksi lidah yang tidak tepat memengaruhi rentangan ruang rongga mulut (F2), ruang faring (F1) dan bentuk bibir (F3). Kerusakan jaringan di area Broca juga dapat melemahkan ciri temporal bumyi termasuk melodi, tekanan, dan rentang waktu pada *lingkungan bunyi bersuara. Artinya, bunyi vokal yang didahului oleh konsonan bersuara memiliki rentang waktu yang lebih panjang dari pada bunyi vokal yang didahului oleh bunyi yang tak bersuara. Dalam penyelidiki akustik, bunyi vokal yang lebih kompleks cenderung dilafalkan tidak akurat karena defisit implementasi artikulasi. Temuan ini selaras dengan penelitian sebelumnya bahwa ketidakakuratan artikulasi dan prosodi ada pada tataran gangguan fonetis bukan pelemahan pogram perencanaan fonologis.*

Kata kunci: afasia, disprosodi, penyimpangan, vokal, neurolinguistik

INTRODUCTION

Non-fluent aphasia (NFA) is an acquired language disorder in adults resulting from a lesion of the third frontal convolution of the left hemisphere (Akhutina, 2016). The lesion may affect the patient's speech modalities. Stroke survivors have difficulty speaking, repeating words and sentences, naming thins, reading, and writing spontaneously (Sastra, 2011). The speech output of patients with NFA generally consists of two- or three-word utterances, mostly basic words (Bastiaanse, Glibers, & Linde, 1994) Most of the time they have problems initiating utterances in the speech efforts, groping sound movements, multiple failed attempts, and self-correction (Herbert, 2004).

Patients with NFA can be recognized clinically either at the primary lesion site or by their speech output. Several studies have been conducte on articulation deficits that characterize speakers with NFA and some correlation between the anterior lesion and the typical tonal disorder (Galluzzi, Bureca, Guariglia, & Romani, 2015). The deficit occurs with a slight impairment in the articulatory implementation of selected and planned speech segments (Gandour, 1998). This impairment manifests itself in sound distortions or even segmental changes resulting in unrecognizable words (Meier, Lo, & Kiran, 2016). Phonological errors produced by patients with NFA can be described as an articulation or conceptual phenomenon. Their language is characterized by phonetic imprecision of both location and mode of articulation (Darley, Aronson, & Brown, 1975). NFA is also characterized by a slow speech rate with longer duration, abnormal prosody, and segmental change (Kent & Rosenbek, 1983). This type of lengthening refers to lengthening the duration of segments as a symptom of self-corrective efforts. However, each person with NFA may perform different segment errors despite suffering from identical phonological symptoms. The articulatory deficit manifests two parameters of phonological errors, namely vowels and consonants.

Previous acoustic studies have focused on certain impaired consonants, such as voicing of fricatives (Meier, Lo, & Kiran, 2016) stop consonants, and trills /r/ (Boyce, 2015) In fact, the acoustic studies on vowels produced by NFA are considered to be fewer in number than on consonants. Some of them are performed by (Galluzzi, Bureca, Guariglia, & Romani, 2015) and (Shinn & Blumstein, 1983).

However, the study, which focuses on acoustic features in disturbed Balinese vowels, has not yet been investigated, so the results may be a very useful conceptual design for additional clinical diagnoses. As the nucleus of a syllable and the most sonorous feature in the sound scale, vowels play a prominent role in word order formation (Bastiaanse, Glibers, & Linde, 1994). Although vowels are considered easy to produce in isolation, patients perform typical vowel changes in context, which can be deeply explored through its acoustic properties. For example, the Balinese word *aluh* ‘easy’ was realized as [oules]. Thus, the acoustic examination can further detect the presence of the lax high back vowel /u/. From an acoustic point of view, the weakening of the vowel /a/ in the initial position of the above word can, from statistical measurement, be considered phonetic distortion. Sound impairment can be measured from acoustic characteristics, namely intensity, pitch, frequency and duration, which reveal the inaccuracy of individual sound production (Lieberman & Blumstein, 1988). Recent research on aphasia has been encouraged to determine the nature of these deficits, and it often focuses on the processing stages underlying language production. The deficits displayed by Brocas' aphasics could either be the result of higher-order impairments in the selection and planning of speech output, or a low-level impairment in the articulatory implementation of selected and planned segments of speech (Buckingham & Christman, 2008).

The main goal of acoustic analysis of distorted, simplified, and unvoiced vowels in NFA is to acknowledge the natural correlation of acoustic features and the state of the abnormality The abnormality of the vowel production can be considered not only from the point of view of errors of substitution, insertion and omission, but can also necessarily arise from the acoustic inaccuracy, such as e.g. an abnormality in standard frequency, pitch, duration and intensity. (Schane, 1992) asserts that the phonological process can be explained as an articulatory description and a precise articulatory mechanism is mapped into acoustic components of how listeners interpret the sounds as meaningful input of information.

The acoustic components can release any conditions of speakers' speech production. The failure of phonetic implementation can result in phonemic and phonetic changes. The later can be seen from the mechanism of how the sounds are inappropriately produced.

Studying the acoustic characteristics of impaired sounds could provide information on how patients understand the words or images given to them, how they interpret the symbols in sounds, and how they translate sound programs into concrete articulations. The errors may not occur in the selection of the phonemes of the target words or in the articulation planning, but in the articulatory implementation. Acoustic properties of vowel parameters are essentially determined by formant value, duration and phonation. The different forms of formants are a system of the physical function of articulators in the production of speech sounds (Lieberman & Blumstein, 1988).

The distortion of the standard formant value indicates the three phonetic variations, namely exact, almost exact and inaccurate. The accuracy of the vowel articulation can be obtained from the corresponding function, the position of the constriction, and the timing. Vowel formants are associated with the acoustic measurement of resonant frequency (Ladefoged, 2003). This study attempts to find evidence of acoustic features of vowel realization in speech errors from NFA by sound waves and spectrograms. The inaccuracy of the articulation can be recognized by the different values of formants, a pattern of sound waves, a prolongation of the articulation rate, an abnormal intensity, and pitch.

The discussion focuses on notions of time analysis, spectral analysis, and trajectory measures. Temporal analysis included vowel duration only, while spectral analysis included the following parameters: F1 and F2 values. Formant measurements included F2 pitch and formant length. F1 dan F2 of the two standard Balinese vowels /i/, /e/, //, /a/, /o/, u/ in initial, middle and final position. Therefore, it is necessary to find out (1) whether the value of the acoustic measurement of vowels is relatively higher or lower than the vowels produced by normal speakers; (2) whether the timing or duration of vowel production in all distributions is longer or shorter than that produced by the normal speaker; and (3) whether the patients with NFA produce a disprosody in vowel production as evidence of motor aphasic syndrome.

Previous studies on aphasia have focused on speech disorders in the form of sound distortion and simplification, the differences between non-fluent and fluent aphasia, and the relationship between phonological disorder and brain damage, whether anterior or posterior syndrome. Regarding distortion, (Darley, Aronson, & Brown, 1975) found that the distortion in aphasia represents a weakening of the voice's quality of articulation, such that the acoustic character becomes imprecise. For example, the effect of delayed anticipatory co-articulation in aphasic speech 20-30 ms in subjects with non-fluent aphasia (Kent & Rosenbek, 1983).

However, Adam, (2014: 154) strongly argues that the time course of anticipatory co-articulation is relatively normal in nonfluent aphasics, although the co-articulatory effects are otherwise impaired. Adam, (2014: 154) also asserts that utterances in non-fluent aphasia do not reflect distortion or inaccuracy in sound quality, sound prolongation, vocalization, and phonation. However, (Darley, Aronson, & Brown, 1975) assert that phonetic error bias refers to imprecise and unrecognizable phoneme production. Meanwhile, (Cera & Ortiz, 2010) hold that distortion is not a type of simplification by substituting one sound for another. Distorted sound is more common with the symptom of dysarthria. The sound attenuation is not phonetic or phonemic, but inherent in the weak character of the voice.

Meanwhile, non-fluent aphasia is more likely to show symptoms of simplification of sound through sound alteration. The phonological alteration can take the form of substitution, deletion, insertion, addition and metathesis of sound segments. The results of previous studies have shown that the most commonly found type of alternation is substitution (Novick dkk., 2010; Cera & Ortiz, 2010: 60). However, aphasic patients simplify sounds with complex levels of articulation through phonological changes in their language Alternating phonemes in non-fluent aphasia arise not from a weakening of the function of the phoneme-mapping program but from a deficit in the implementation of phonetic planning Aphasia patients simplify substitute phonemes with other phonemes.

There are suggestions in the literature that anterior aphasics display impairments in the production of voicing fricative consonants. Frequent devoicing of initial and medial voiced fricatives has been reported in anterior aphasic's speech production (Kent & Rosenbek, 1983) as has the premature onset of voicing in voiceless fricatives before the frication segment has ended (Kent & Rosenbek, 1983) These results suggest an inability to combine vocal cord vibration and supralaryngeal articulatory gestures. Additionally, the presence of numerous 10–30ms silent gaps during alveolar fricative production ([s z]) in one aphasic speaker to 'rapid glottal closure and/or pauses in respiratory drive.

From the above empirical point of view, it can be stated that sound distortion in aphasia is more directed to the quality of sound characteristic accuracy, while sound simplification relates to the inability of patients with non-fluent aphasia to translate phonemic messages into phonetic implementation. This study therefore attempts to examine these two symptoms as evidence of the spectral and temporal aspects of sound. From exposure to sound parameters, research on consonant sounds in aphasia (Kent & Rosenbek, 1983) and Adam, (2014: 154) found that patients with non-fluent aphasia did not have much difficulty articulating vowels However, this study assumes that patients with non-fluent aphasia also have difficulty pronouncing vowels, particularly of sounds that have complex articulation. The results of the study therefore may suggest that acoustic spectrograms of vowels can prove that non-fluent aphasia can lead to vowel distortion and simplification.

METHOD

There were two patients with NFA whose speech was observed for the present study. The first participant, KW, is a 70-year-old, right-handed male with a BA in teaching and was an elementary school teacher prior to suffering a cerebrovascular accident in 2017 when his left middle cerebral artery started. The second participant, NS, is a 52-year-old right-handed woodcarver. Immediately following the non-hemorrhagic stroke (NHS) in 2018, he suffered from NFA and right hemiplegia. Both participants had the same syndrome of non-fluent aphasia, such as difficulty repeating words, phonological anomie, naming, reading and writing.

Participants' speech output was stimulated by various eliciting phonological tasks and word-image matching stimulation. They were given phonological tasks consisting of 260 simple and complex target words. These words or images mainly represented consonants and vowels in various distributions, including consonant clusters. The speech was digitally recorded with a SONY MP3 player. Observation of recorded speech was performed by classifying types of phonological errors including phoneme substitution, distortion, insertion, omission and metathesis. The segment errors were counted and phonemic and phonetic according to I.P.A. Data were copied for Characters of Balinese vowels from Praat (Boersma & Weenink, 2008) and measured to ensure the acoustic properties of a single tone and its co-articulations. The acoustic measurement can provide any phenomenon of either segmental or suprasegmental errors.

A phonological analysis of segmental errors, including substitution, distortion, omission, and insertion was carried out and treated as inputs of intervention. All errors that occurred across all tasks were analyzed. This analysis refers to the distinctive features and the segments matrix for the Balinese language was used. The features contained in this matrix include syllabic, high, low, back, rounded and voiced. The phonological process such as assimilation, syllable structure, and simplification meant observed in order to understand the reason for errors, e.g., the influence of neighboring phonemes (Schane, 1992). All changes or outputs were analyzed to understand the articulatory process by applying the theory of clinical phonetics and acoustics.

RESULT AND DISCUSSION

Regarding recorded speech extracted from words and picture names, the patients tended to make vowel changes in medial position because they found difficulties in mixing or configuring the sounds in the co-articulation with other neighboring sounds. Three acoustic variations were found in the study; normal, near normal, and far from normal articulation. The vowels observed were /i/ in the word ‘bridge’, /u/ in the word *alu* ‘water monitor’, /e/ in the word *keket* ‘thorn’, // in the word *emas* ‘gold’, /o/ in the word *oleg* ‘a dance’, and *matah* ‘raw’. The patients were able to articulate the vowels individually. In addition, they have produced dysprosodic sounds, such as inappropriate timing, melody or pitch and intensity. Phonetic errors in NFA occur because the brain lesion is located in the anterior left hemisphere of the brain, which has a specific function of the articulatory planning program. So the word *ipah, ‘in law’* pronounced as [aleh], was not associated with neuromuscular failure.

From an acoustic point of view, the patient's articulation deficit can determine the various acoustic characteristics such as formant value, intensity, pitch and duration or timing. Formant is the acoustic term that refers to a classification of features of the vowels in the configuration of mingling with other sounds. The formant value of vowels is a statistical measure that provides information about the resonant frequency associated with measuring two cavities in the separate oral cavity. The measurement in this case is the measurement of the space formed by tongue movement in articulation. F1 is related to measurement of pharyngeal space, F2 is related to oral cavity space and F3 shows lip shape, such as closed, open, rounded and unrounded position (Ladefoged, 2003). If the narrowing occurs in the front position of the oral cavity, there will be less space, but it will have a higher frequency, and the space of the pharynx will be wider, but it will have a lower frequency. Therefore, the following sections contain acoustic analysis on characteristic and alteration of vowels /i/, /u/, /e/, /ə/, /o/, and /a/ produced by patients with NFA

Characteristic and alteration of vowel /i/

Spectral and temporal analysis of sound /i/ in medial and final position can be seen from the way the articulators configure all the system, however, the prosodic side of the view as (Sidtis & Sidtis, 2003) found in terms of initial, medial, and final shortening or lengthening vowels errors. Phonetically, vowel /i/ involves high complex articulation, therefore it can not be articulated in initial of the word ipah 'sister /brother in law' which was pronounced [aleh]. However /i/ can be articulated in medial and in final of the word titi even though it is not as accurate as the normal speakers can produce. Figure 1 shows the acoustic wave and the spectrogram of articulation /i/.

/titi/ [dɪdɪ]

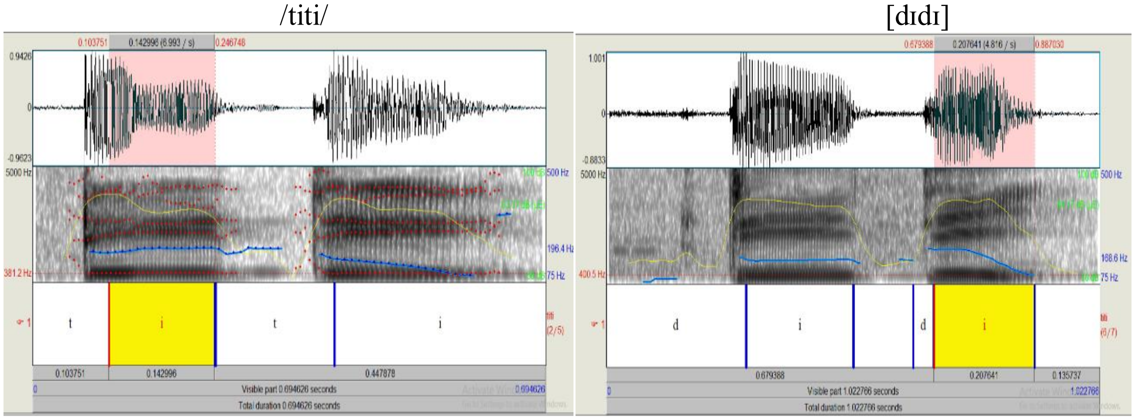

Figure 1. Sound Wave and Spectrogram of Articulation /i/

From the two spectrograms above, a significant difference between the normal sound (on the left) and the inaccurate sound produced by patients with NFA (on the right) can be evidence of phonetic variation in this study. Forman value of F1 of the sound [i] pictured in the left spectrogram was 381.2 Hz. It means that the space of pharynx was wider so the frequency is low because the constriction occurs in the initial part of the oral cavity and it left a smaller space of oral cavity but it has a high frequency The timing range which is required for this vowel is relatively short; 0.142996 ms. However, the difference of vowel [i] produced by patients with NFA in the right spectrogram can be seen from the formant value of F1 which 414.4 Hz, meaning the space of pharynx is 33.2 less wide than the normal and the inaccuracy of the tongue movement can be seen from the higher formant value of 2209 Hz. The shape of the spreading lips was wider as formant value of the F3 reached to 2741 Hz.

This formant value led to the lax vowel /ɪ/. The timing was one of the dysprosodic found in the study. The difference of final vowel lengthening was 0.045547 ms, meaning patients produced longer duration in producing vowel /i/. As (Novick, Trueswell, & Thompson, 2010) found that one of the clinical manifestations of aphasia is the presence of deficits in speech production. This finding declares that deficit in articulatory planning program suffered by patients with NFA can set not just inaccuracy of articulation of /i/ but also distortion in the dysprosodic features.

Characteristic and alteration of vowel /u/

Phonological distinctive features are derived from the phonetic concept of sound production. The articulation of vowel /u/ is one of the complex sounds that involve the back and high constriction of the tongue. The variation of articulation /i/ by the patients with NFA are [o], /uled/ 'caterpillar' → [oles], [o] /l əgu/ 'mosquito' → [ləgo]. Sound /u/ can be nearly articulated as [u] if it is preceded by lateral sound, like in the word alu water monitor' or /guru / 'teacher' → [kulu].. Distortion of segmental and suprasegmental of sound /u/ by patients with NFA can be presented in figure 2.

/alu/ /alu/

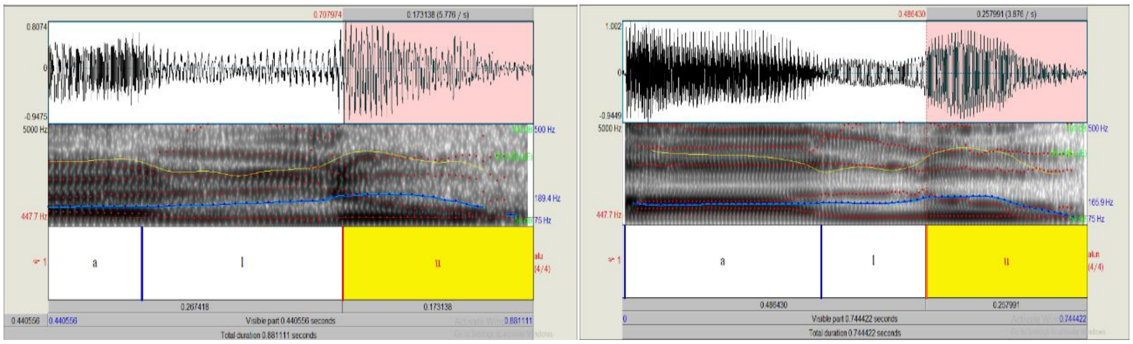

Figure 2. Sound Wave and Spectrogram of Articulation /u/

Even though /u/ can be articulated at the back after the lateral sound, the characteristic of segmental and suprasegmental distinction can be described from the acoustic value. The value of F1, F2, and F3 of normal /u/ was 489.4 Hz, 1223 Hz, and 2621 Hz, meanwhile the value of F1, F2, and F3 of vowel /u. produced by patients with NFA was 475.1 Hz, 1176 Hz, and 2534 Hz. So the difference was 33.2Hz, 86Hz, and 133dB. It means the tense vowel of /u/ was not accurately articulated. The pitch, duration, and intensity of vowel /u/ produced by the normal speaker was 191.2 Hz, 0.231 ms, 86.65 dB, and the patients reached up to 208.7 Hz, 0.895 ms, and 86.62 dB. This finding emphasizes that patients with NFA had inaccurate articulation and final lengthening of vowel /u/ because the impaired melody of speech is associated with anterior zone (Wagenaar, Snow, & Prins, 1975).

Characteristic and alteration of vowel /e/

The articulation of sound [e] involves the constriction that occurs at the front oral track, namely the blade of the tongue moves upwards to the palate so the space of pharynx is wider and acoustic frequency tends to be low, meanwhile the space in oral track seems to be narrower but the frequency is high. Variation of articulation /e/ by the patients with NFA are [i], /gatep/ 'fruit' → [gatit], [o] /toke/ 'gecko' →[topɔ]. Distortion of segmental and suprasegmental of sound /e/ by patients with NFA can be presented in figure 3.

/toke/ [toʊke]

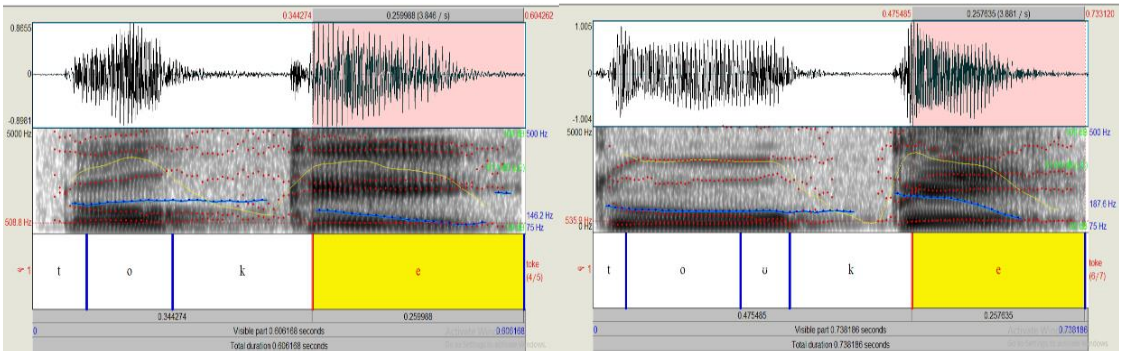

Figure 3. Sound Wave and Spectrogram of Articulation /e/

Vowel /e/ can be articulated at the back after voiceless stopped velar sound /k/, the characteristic of segmental and suprasegmental distinction can be described from the acoustic value. The value of F1, F2, and F3 of normal /e/ was 580.6 Hz, 2143 Hz, and 2475 Hz, meanwhile the value of F1, F2, and F3 of vowel /u. produced by patients with NFA was 535.9 Hz, 2025 Hz, and 2729 Hz. It means the vowel of /u/ was nearly accurate. The pitch, duration, and intensity of vowel /u/ produced by the normal speaker was 146.2 Hz, 0.259988 ms, 81.10 dB, and the patients reached up to 149.1 Hz, 0.257635 ms, and 81.27 dB. So, the patients with NFA tend to have suprasegmental deficit due to lesion Broca's area.

Characteristic and alteration of vowel /ə/.

Sound /ə/ is produced by neutralizing tongue and lips position. It means that the part of the tongue is not moved to the front, backward, upwards, or downwards and the lips are not rounded or unrounded. The variation of articulation /e/ by the patients with NFA are [i], /ə/ → [i] əntip/ 'rice' → [nitɪp], ə/ → [o] as /dədarə/ 'dove → [tolalə], and [ə] → [o] / - # as /batə / 'brick' → [batɔh]. Distortion of segmental and suprasegmental of sound / Distortion of segmental and suprasegmental of sound /ə/ by patients with NFA can be presented in figure 4.

/əmɑs/ [əmɑs]

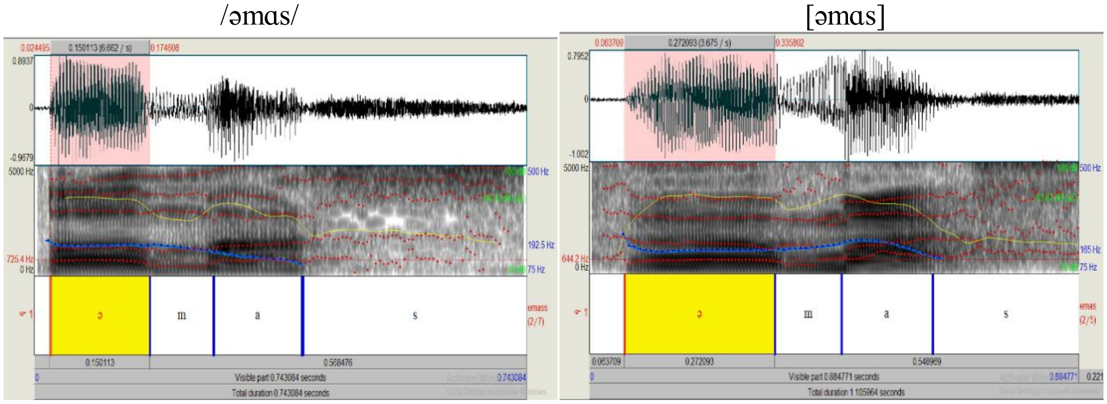

Figure 4. Sound Wave and Spectrogram of Articulation /ə/

The spectrogram which is presented in yellow slot shows some acoustic distinctions of the sound [ə] produced by the normal speaker and the patients. The difference of the sound produced by the patients can be seen from the configuration of the tongue, the shape of the lips, the lengthening duration, impaired melodic and intensity of the sound. Vowel / ə / can be articulated in the initial position, The characteristic of segmental and suprasegmental distinction can be described from the acoustic value. The value of F1, F2, and F3 of normal was 671.1 Hz, 1245 Hz, and 2874 Hz, meanwhile the value of F1, F2, and F3 of vowel /ə/ produced by patients with NFA was 535.9 Hz, 1644 Hz, and 2375 Hz. It means the vowel of /ə/ was nearly accurate. The pitch, duration, and intensity of vowel /ə/ produced by the normal speaker was 170.7 Hz, 0.245 ms, 83.11 dB, and the patients reached up to 156.8Hz, 0.415 ms, and 80.16 dB. So it was found that patients with NFA had inaccurate articulation, the impaired melody of speech, and final lengthening of vowel /ə/.

Characteristic and alteration of vowel /o/

The sound error of /o/ which is produced by patients with NFA is known as heightening. The tongue tends to move upwards. So the sound /o/ is mainly substituted by a tense or lax high back vowel; [u] or [ʊ]. The variation of articulation /e/ by the patients with NFA are / o / → [u]/ C - C as / toke/ 'gecko' → [tuke], / ɔ / → [ʊ]/ C – C as /katos/ 'hard' →[astʊh]. However,/o/ can be articulated in initial as in the word of oleg 'dance'. Distortion of segmental and suprasegmental of sound /o/ by patients with NFA can be presented in figure 5.

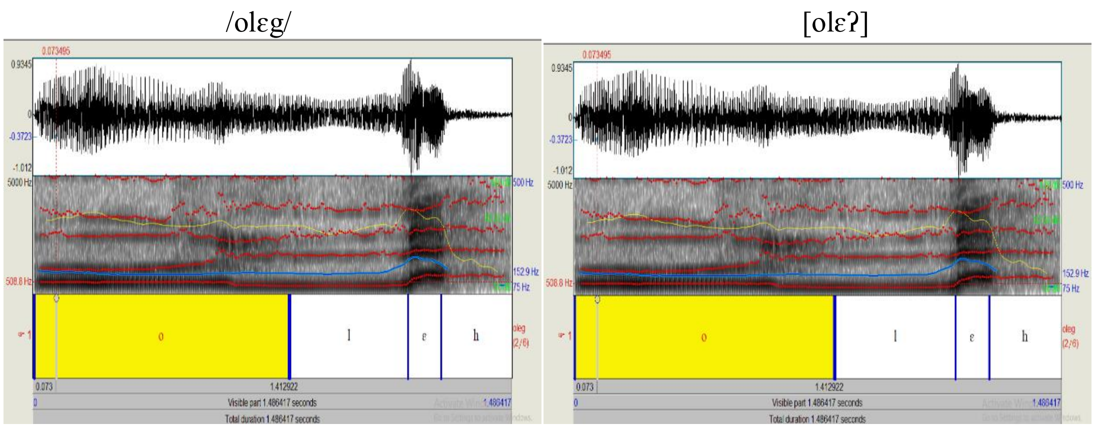

Figure 5. Sound Wave and Spectrogram of Articulation [o]

Both yellow slots above show the acoustic distinctions of sound [o] in initial position produced by normal speaker and the patients. The configuration of the tongue, shape of the lips, the initial lengthening duration, impaired melodic and intensity of the vowel /o/ are presented in acoustic measurement of the articulation, resonanse, and duration that can be described from the acoustic value. Specific observation on sound wave and the pectrogram of articulation /o/ produced by the patients on the right showed that the narrow pharinx space with high frequency of 540.8Hz and oral tract was wide with low frequency of 803.6 Hz. Standard rounded lips is presented in F3 that was 2621Hz. However, timing duration 0.209 ms and the normal speaker needs only 0.195 ms. It means that there is 0.023 ms longer. The normal pitch for this vowel is 182.4Hz however the patients decreased the pitch into 160.2 Hz and the fifference was 4.5 Hz. For intensity, the normal speaker has 83.4 dB and the patient had 84.54, so the patient had 1.06 dB more intensity on vowel /o/ in initial position. So it was found that patients with NFA had inaccurate articulation, impaired melody of speech, and final lengthening of vowel /o/.

Characteristic and alteration of vowel /a/

Vowel sound /a/ is produced by lowering the tongue from the palate and the jaws are opening so the airstream goes through the oral tract. This vowel is the easiest articulation the patients can produce because it has low complexity. So the sound /a/ can be substituted by /ə/ or /i/ in media position. The variation of articulation /a/ by the patients with NFA are /a/→ [æ] / V- C as /sampi/ 'cow' → [səmpi] and

/a/→ [ɛ] /C-C as /ipɑh/ 'brother or sister in law' → [alɛh]. However /a/ can be articulated in a medial position in a complex word.

From both spectrograms below, it seems that the patients with NFA do not find any difficulties articulating the sound [a]. However, the level of accuracy either segmental or suprasegmental features can only be distinguished by searching the acoustic features. The sound wave and the spectrogram of articulation /a/ produced by the patients on the right slot showed that the narrow pharynx space with a high frequency of 781 Hz and the oral tract was in the middle with the medium frequency of 1176 Hz. Unrounded lips were presented in F3 that was 2665 Hz. However, the timing duration was 0.341 ms. It means the patients articulated the sound 0.115md longer than the normal speaker which is 0.226 ms. The normal pitch for this vowel is 162.7Hz however the patients decreased the pitch into 157.3 Hz and the difference was 5.4 Hz. For intensity, the normal speaker has 84.11dB and the patient had 83.18dB so the patient had 0.93 dB less intensity on vowel /a/ in the first syllables. So it was found that patients with NFA had inaccurate articulation, the impaired melody of speech, and final lengthening of vowel /o/. Broca's aphasic speech is characterized by slow and effortful speech, resulting in increased vowel durations which suggest motor planning and temporal control deficits (Boyce, 2015). Distortion of segmental and suprasegmental of sound /o/ by patients with NFA can be presented in figure 6.

/matɑh/ [matɑh]

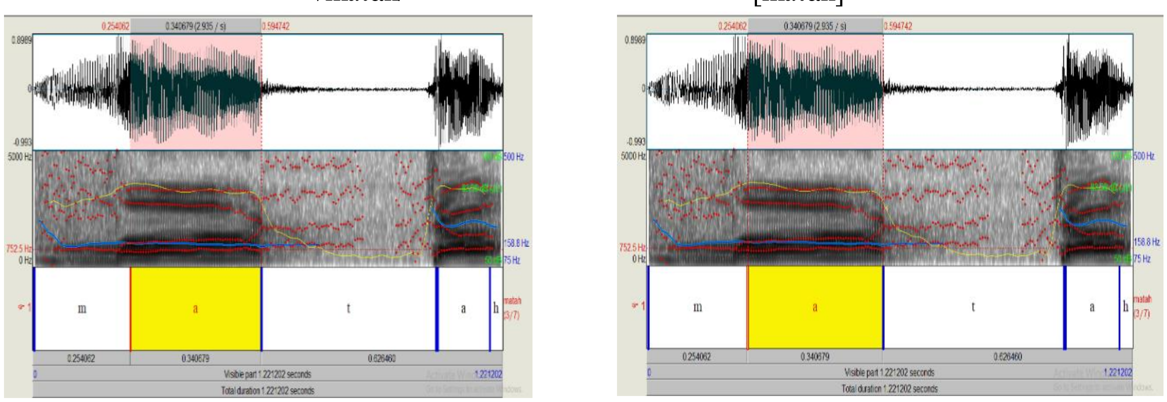

Figure 6. Sound Wave and Spectrogram of Articulation /a/.

Based on the spectral analysis of vowels using Praat, the characteristic of vowels is mainly dominated by the distortion of segmental and suprasegmental. The distortion occurs at the level of phonetics, intensity, lengthening, and pitch. There are some significant results regarding the spectral analysis of vocal distortions in this study; (1) vowels with highly complex articulation indicate a weakening of phonation, lengthening of the pharyngeal space and the inappropriate narrowing of articulators, which is recognized by an unstable formant value; (2) vowel changes occur mainly in medial position; (3) the intensity of the vowels produced by patients with NFA is lower than the same tone produced by normal speakers; (4) there was vowel lengthening in all positions when preceded by voiced consonants; and (5) melodic features such as pitch and intensity are primarily lower than normal vowels. Therefore, damage to the inferior frontal gyrus in the left cerebral hemisphere after stroke can impair the function of the articulatory planning program, causing inaccuracy in sound production and segmental simplification. The distribution of acoustic features on vowels produced by KW and a normal speaker can be seen in Table 1.

Tabel 1. Distribution of Acoustic Features on Vowels Produced by KW and a Normal Speaker

Penutur		Sound	F1 (Hz)	F2 (Hz)	F3 (Hz)	Pitch (Hz)	Duration Ms	Intensity dB
Petient KW	Tense	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
	lax	ɪ	431.3	2161	2884	194.6	0.106	85.87
		ɪ	409.4	2030	2534	157.7	0.055	87.59
			21.9	131	350	36.9	0.051	28.28
Patient KW	tense	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
	lax	ɛ	650.3	1855	2621	181.3	0.105	83.85
		ɛ	668.4	2138	2634	188.6	0.053	82.65
		df	18.1	283	13	7.3	0.052	1.2
Patient KW	tense	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
	lax	æ	737.9	1482	2293	173.1	0.160	84.37
		æ	628.4	1461	2840	198.2	0.082	86.08
		df	109.5	21	547	25.1	0.08	1.71
Patient KW	tense	u	475.1	1176	2534	208.7	0.895	86.62
Normal		u	489.4	1223	2621	191.2	0.231	86.65
		df	65.7	153	87	17.5	0.664	0.03
	lax	ʊ	540.8	825.5	2293	189.9	0.156	81.79
		ʊ	562.7	1242	2687	193.7	0.074	80.20
Patient KW	tense	o	540.8	803.6	2621	160.2	0.209	84.54
Normal		o	574.7	979.5	2741	182.4	0.195	83.48
		df	129.5	16.5	364	4.5	0.023	1.06
	lax	ɔ	644.2	996	2377	177.1	0.172	80.48
		ɔ	672.2	1110	2840	180.5	0.097	75.50
		df	28	114	463	3.4	0.075	4.98
Patient KW	tense	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
	lax	ɑ	869.3	1439	2380	192.2	0.309	83.71
		ɑ	875.5	1498	2556	176	0.076	84.39
		df	6.2	59	176	16.2	0.23	0.68

From the above data, the area of the pharyngeal space and the oral tract when the tense and the lax vowels are articulated can be recognized from the value of F1. The lax vowels have a higher frequency than the tense vowels. This means that the constriction is set back a little, giving the pharynx narrower space than the production of the tense vowels. This means that this condition leaves less room in the oral tract, so the frequency of tense vowels is higher than lax ones. For the dysprodic syndrome of lengthening or shortening of vowel duration, there is prosodic evidence of tense and lax vowels in patients with NFA as well as in normal speakers. The tense vowels take a longer time than the lax vowels due to the maximum movement of the constriction by stretching the articulators. The inaccuracy of vowel production in the speech sound of patients with NFA is associated with impaired speech function in the third convolution of the left hemisphere. Thus, the property of the vowel sound produced by patients with NFA found in this study may provide evidence for the neurolinguistic description of impaired speech. NS showed fairly similar acoustic features, including imprecise articulation, such as B. the phenomenon of lengthening or shortening of the duration of vowels. NS also had dysprosodic signs resulting from brain damage in the third convolution of the left cerebral hemisphere, shown in Table 2.

Table 2. Distribution of Acoustic Features on Vowels Produced by NS and Normal a Speaker

Penutur		Sound	F1 (Hz)	F2 (Hz)	F3 (Hz)	Pitch (Hz)	Duration Ms	Intensity dB
Patient NS	Teg	i	343.4	2446	2840	148.9	0.345	83.20
Normal		i	381.2	2123	2608	207.2	0.142	84.40
		df	37.8	323	232	58.3	0.203	1.2
	Ken	ɪ	451.3	2261	2984	194.6	0.096	80.87
		ɪ	409.4	2030	2534	157.7	0.055	57.59
		df	41.9	231	450	36.9	0.041	23.28
Patient NS	Teg	e	497	2271	2665	203.3	0.254	85.62
Normal		e	671.2	1998	2566	163.4	0.165	94.40
		df	174.1	273	99	39.9	0.089	8.78
	Ken	ɛ	540.3	1855	2621	191.3	0.120	80.82
		ɛ	628.4	2138	2534	188.6	0.053	82.65
		df	88.1	283	87	27	0.067	1.83
Patient NS	Teg	ə	453	1701	2753	151.6	0.354	82.62
Normal		ə	671.1	1245	2874	170.7	0.245	83.11
		df	218.1	456	121	19.1	0.109	0.49
	Ken	æ	437.9	1482	2293	163.1	0.160	75.52
		æ	628.4	1461	2840	198.2	0.082	86.08
		df	190.5	21	547	35.1	0.082	10.56
Patient NS	Teg	u	540	935	2818	187.7	0.341	81.60
Normal		u	409.4	1023	2621	191.2	0.231	86.65
		df	130.6	88	197	3.5	0.11	5.05
	Ken	ʊ	520.8	850.5	2593	179.9	0.256	80.79
		ʊ	562.7	1242	2687	193.7	0.074	80.20
		df	41.9	391.5	94	13.8	0.182	0.59
Patient NS	Teg	o	628	1088	3015	119.4	0.262	80.50
Normal		o	514.7	979.5	2741	182.4	0.195	83.48
		df	113.3	108.5	274	63	0.067	2.98
	Ken	ɔ	550.2	956	2477	157.1	0.152	87.48
		ɔ	672.2	1110	2840	180.5	0.097	75.50
		df	1.220	154	363	23.4	0.055	11.98
Patient NS	Teg	a	825	1701	2928	126.1	0.352	80.34
Normal		a	803.6	1198	2906	162.7	0.226	84.11
		df	21.4	503	22	36.6	0.126	3.77
	Ken	ɑ	769.3	1139	2480	182.2	0.209	80.70
		ɑ	825.5	1198	2556	176	0.076	84.39
		df	56.2	59	76	6.2	0.133	3.69

From the temporal and the spectral analysis of the formant value of the two patients, the results show a large variability among the aphasic subjects and longer vowel durations compared to the normal speakers. This study suggests that vowel mechanisms of temporal errors produced by patients with NFA are phonetic rather than phonological planning disorders, as noted by (Akhutina, 2016) as phonemic implementation (Buckingham & Christman, 2008) and (Shinn & Blumstein, 1983).

This phenomenon occurs due to phonetic implementation, temporal coordination, and timing deficits of articulatory movements, as (Sidtis & Sidtis, 2003) have claimed. However, this study suggests that the deficits affect speech production mechanisms characterized by imprecise articulation, a slow vowel rate, and other prosodic disturbances. So, the inaccuracy of segmental and suprasegmental features of vowels is caused by insufficient tactile feedback during production. Therefore, it is emphasized that the more complex the articulation of the vowels, the more possibilities there will be for sound change and the longer the duration will be. For example, the word *madu* ‘honey’ is realized as [madɔh]. The imprecise articulation mechanisms can contribute in part to impairments in accessing and retrieving information about the articulation target.

CONCLUSION

This study shows two main results regarding spectral and temporal features of vowels. Spectral errors included longer duration, lower intensity, and weaker pitch, while segmental alteration in NFA included vowel substitution, addition, insertion, and metathesis. The first finding revealed that vowels with highly complex articulation resulted in weakening of phonation, pharyngeal expansion, and inappropriate constriction presented with unstable formant values. In addition, the intensity of the vowels produced by patients with NFA is lower than the same tone produced by normal speakers in all positions when preceded by voiced consonants. In terms of melodic characteristics, the pitch and intensity of NFA are primarily lower than ordinary speakers.

Of the temporal features, the high front and back vowels tended to be modified by less complex low vowels. For example, /u/ in /uled/ 'caterpillar' was substituted by [o] in [oles]. In addition, front vowels are replaced with middle and back vowels. For example, /e/ is realized as [o] by patients with NFA; /toke/ becomes [topo], /ə/ in /dədari/ ‘dove’ is realized as [tolali], or /batə / ‘brick’ becomes [batɔh]. It can be specified that a segmental substitution is followed by another segmental substitution in the same syllables. Furthermore, longer duration or stronger pitch of vowels can result in the vowel alteration. The longer the duration of vowel may take the more possible the segments in the syllable will be substituted. The vowel substitution take place due to (1) complexity level of articulation, (2) position of the vowels in syllables, (3) the neighboring segment, and (4) weakening prosodic features. So, this study can be used as guidance for language rehabilitation and empirical study for clinical phonology.

REFERENCES

Adam, H. (2014). Dysprosody in aphasia: An acoustic analysis evidence from Palestinian Arabic. *Journal of language and Linguistic Studies, 10*(1), 153-162.

Akhutina, T. (2016). Luria's Classification of aphasias and its theoretical basis. *Aphasiology, 30*(8), 878-897. doi:https://doi.org/10.1080/02687038.2015.1070950

Bastiaanse, R., Glibers, D., & Linde, K. D. (1994). Sonority substitution in Broca's and conduction aphasia. *Journal of Neurolinguistik, 8*(4), 247-255. doi:https://doi.org/10.1016/09116044(94)90011-6

Bastiaanse, Roelien, Gilbers, Dicky, Linde, KlarienVan Der. (1994). Sonority substitutions in Broca's and conduction aphasia. *Journal of Neurolinguistics*, 247.

Boersma, P., & Weenink, D. (2008). Praat, a system for doing phonetics by computer (Version 5.0. 34). *[Computer software].*

Boyce, S. E. (2015). Articulatory Phonetics for Residual Speech Sound Disorders: A Focus on /r/. *Semin Speech Lang, 36*(4), 257–270. doi:https://dx.doi.org/10.1055%2Fs-0035-1562909

Buckingham, H. W., & Christman, S. S. (2008). *Disorders of Phonetics and Phonology*. London: Academic Press.

Cera, M. L., & Ortiz, K. Z. (2010). Phonological analysis of substitution errors of patients with apraxia of speech. *Dement Neuropsychol*, *4*(1), 58–62. doi:https://doi:10.1590/S1980-57642010DN40100010

Darley, F. L., Aronson, A. E., & Brown, J. R. (1975). *Motor speech disorders.* Philadelphia: WB Saunders Company.

Galluzzi, C., Bureca, I., Guariglia, C., & Romani, C. (2015). Phonological Simplifications, Apraxia of Speech and the Interaction between Phonological and Phonetic Processing. *Neuropsychologia*, *71*, 64–83.

Gandour, J. T. (1998). Phonetics and Phonology. In B. Stemmer, & H. A. Whitaker, *Handbook of Neurolinguistics* (pp. 207-218). Indiana: Academic Press.

Herbert, R. E. (2004). *Therapy for word finding in aphasia: Effects on picture naming and conversation.* University College London. ProQuest LLC. Retrieved from https://discovery.ucl.ac.uk/id/eprint/1446711

Kent , & Rosenbek. (1983). Acoustic patterns of apraxia of speech. *Journal of Speech, Lan-guage, and Hearing Research,*, *26*(2), 231-249.

Ladefoged, P. (2003). *Phonetic Data Analysis.* Oxford: Blackwell Publishing Ltd.

Lieberman, P., & Blumstein, S. E. (1988). *Speech physiology, speech perception, and acoustic phonetics.* Cambridge: Cambridge University Prose.

Meier, E. L., , E. L., Lo, M., & Kiran, S. (2016). Understanding semantic and phonological processing deficits in adults with aphasia: Effects of category and typicality. *Aphasiology,*, *30*(6), 719–749. doi:https://doi:I10.1080/02687038.2015.1081137

Novick, J., Trueswell, J. C., & Thompson, S. (2010). Broca’s Area and Language Processing: Evidence for the Cognitive Control Connectione. *Language and Linguistics Compass*, *4*(10), 906–924. doi:doi: 10.1111/j.1749-818X.2010.00244.x

Romani, C., & Calabrese, A. (1998). Syllabic Constraints in the Phonological Errors of an Aphasic Patient. *Brain Lang*, *64*(1), 83–121.

Romani, C., & Calabrese, A. (1998). Syllabic Constraints in the Phonological Errors of an Aphasic Patient. *Brain Lang*, *64*(1), 83–121. doi:https://doi:10.1006/br1n.1998.1958

Sastra, G. (2011). *Neurolinguistik suatu Pengantar*. Bandung: Alfabeta.

Schane, S. B. (1992). *Generative Phonology*. San Diego: Prentice Hall Inc.

Shinn, P., & Blumstein, S. E. (1983). Phonetic disintegration in aphasia: Acoustic analysis of spectral characteristics for place of articulation. *Brain and Language*, *20*(1), 90-114.

Sidtis, J. J., & Sidtis, D. V. (2003). A neurobehavioral approach to dysprosody. *Speech and Language. 4*, pp. 093-106. New york: Thieme Medical Publishers.

Wagenaar, E., Snow, C., & Prins, R. (1975). Spontaneous speech of aphasic patients: A psycholinguistic analysis. *Brain and language*, *2*, 281-303.

5
Bukti Publikasi
(16 September 2022)

Home > Archives > ***Vol 34, No 1 (2022)***

VOL 34, NO 1 (2022)

AKSARA, EDISI JUNI 2022

TABLE OF CONTENTS

ARTICLES