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VOWEL AND CONSONANT SIMPLIFICATION IN SPEECH DISORDER: AN ANALYSIS OF SEGMENTAL PHONOLOGY

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ABSTRACT

The objective of the study is to investigate the sound simplification of speech output in Broca's aphasics and describe the effect of the alteration within phonological features from the perspective of Sonority Sequencing Principle (SSP). The speech output of two patients was exposed using phonological tasks and recorded with a Sonny voice recorder. The effect of features in substitution sonority was measured with the Wilcoxon's test and acoustic features were analyzed with Praat. The results of the study revealed that the consonant substitution and omission errors in Broca's aphasia occur in the initial position due to the lesion in the anterior part of the left brain and that the less marked features that are statistically substituted by marked features are not significantly affected by marked features that are substituted by less marked features. The substitution was dominantly influenced by neighboring segments and the sonority violance occured againts the sonority scale.

Keywords: Phonology; Sonority; Sound Simplification; Aphasia; Neurolinguistics

I. Introduction

Phonological disorder in Broca's aphasia is an acquired impairment of language sounds in adults, resulting from a lesion to the third frontal convolution of the left hemisphere. The lesion can affect the patients' language modalities, which are described as spontaneous speech, repetition, naming, reading and writing (Blumstein, 1973; Romani and Calabrese, 1998). The speech output of patients with Broca's aphasia generally consists of two or three word utterances, mainly basic words (Bastiaanse, Gilbers, and Linde, 1994). Mostly, they have problems in initiating an utterance, groping sound movements, multiple false attempts, self-correction.

However, aphasia conduction tends to produce phonemic errors, including phoneme substitution, Broca's aphasia may produce these types of errors too (Cera and Ortiz, 2010). On the other hand, Broca's aphasia tends to make phonetic errors or impairment in articulatory processing, known as distortion in the manifestation of prolongation, voicing, or devoicing. Cera and Ortiz (2010) argue that distortion is not a domain of phonetics but phonemic analysis

because a segment is substituted by another. However, Darley (1975) claims that distortion in phonetic errors refers to inaccurate and unrecognizable phoneme production.

Studies focusing on phonemic and phonetic errors in aphasia have been widely conducted across languages, such as Blumstein (1973), Cera and
Ortiz (2010), Ferreres (1990), Gandour (1998), Goldman et al., (2001), and Romani et al., (2002). However, an investigation of the sonority substitution errors in the Balinese speech output of Broca's aphasia has not been conducted yet. Despite the fact, patients with aphasia are getting double in number and indeed the sound errors can be significantly patterned for further sound therapy. Specifically, patients with Broca's aphasia do not only modify the segmental features contained in each neighboring sound but also reconstruct the patterns of syllables. Thus, segmental omission, insertion, and metathesis possibly change the internal syllable structure. For example, three patients with Broca's aphasia have three different realizations of the Balinese word *kipas* fan, which were realized as [ipas], [hipat], [pah], so the syllable patterns vary (Wardana et al., 2018).

The way in which Balinese patients with Broca's aphasia simplify the complex sound is an interesting and prominent investigation to acknowledge. Therefore, the questions of why and how the sound simplification occurs, what the most dominant types of phonological errors may arise, how the segments are altered, and of course in line with the brain damage area for the language function, in what position the segments alteration may take place dominantly require further deep investigation and a lot of answers. These curious questions lead the natural way of human beings to configure the easier articulation of segments in syllables. Syllables can accommodate any segments that describe the blending physical property of sounds through articulatory processing to get the best syllable (Romani and Calabrese, 1998).

In Balinese language, a syllable mostly begins with an onset, consisting of a single consonant or a cluster. An onset is followed by a rhyme that contains a core, a nucleus, and a coda Furthermore, a one-syllable word may have a complex onset (CCVC), like in the word *pragat* 'finish' that is realized by the patients as [plagat] but Balinese does not recognize any complex coda (CVCC). Patients tend to repeat the first or last syllable or remove the second syllable to the beggining of words. For example, Balinese word *batu* 'stone' was realized as [tuh..Batuh], so CV.CV was substituted by CVC. CV.CVC. A syllable structure does not only present the mechanism of sequencing segments, but it also provides a space for appropriate features that fulfill a degree of sonority (Zivanovic, 2019).

The presentation of the sonority hierarchy in this study is the modification of the sonority scale model proposed by Bastiaanse et al., (1994). The substitution of a segment in this study is described as a change in feature value as phonetic property (Cera and Ortiz, 2010; Le and Boonmoh 2020; Zivanovic, 2019). The Balinese words *guru* teacher, which is realized as [kulu] by the patients, can be described as the realization of an intended voiced segment into an

unvoiced segment and it has identic phonologically based characters {[- continuant, -anterior, -coronal and + high]}. Articulation correlates with feature [voiced] that describes the difference between /g/ and /k/ as the physical laryngeal configuration. It is considered a phonetically based feature because it has a clear-cut relationship in the articulatory phenomenon. Phoneme substitution will never change the structure of the target syllable; however, it only changes the degree and feature value of sonority. Clement (1990) claims that [any feature theory] should use the non-abstract feature, which is a feature that has a core of acoustic variant and articulatory property. Based on this fact, patients with Broca's aphasia reconstruct target sounds by substituting this single impaired segment with another segment, inserting or omitting a segment in any position ordered in the sonority hierarchy. Therefore, this study has two research questions; (i) whether the less marked features that are statistically substituted by marked features are affected by marked features that are substituted by less marked features; and (ii) how the SSP plays the rules of controlling the direction of sound alteration. From the findings, the phonological description of the phenomenon can be a feedback for considering types of errors, phonological processes, syllabic constraints, and the rules of the sonority sequencing principle (SSP).

The present study aims (i) to provide evidence concerning phoneme alteration of the target words spoken by patients with Broca's aphasia. In this case, any possible new notion of feature assimilation can be implemented or there might be a violation of the SSP, especially features alteration or reconstruction of the syllable in insertion, deletion, and metathesis, (ii) to describe the role of SSP in controlling the phoneme alteration based on the phoneme distribution, articulatory base, and neighboring sounds. The high-complexity features will not always be substituted with low-complexity features or vice versa.

As consideration, This study reviews the previous findings concerning the dominant type of phonological process and the rules of SSP influence the direction of segment alteration. Amongst the phonological errors, it is known that the percentage of phoneme substitution made by patients with Broca's aphasia is the biggest category of errors and then omission. Blumstein (1973) found that 48.7 % phoneme substitution in Broca's aphasia and 35.2 % in Wernicke's aphasia. Ferreres (1990) showed that patients made 59% phoneme substitution errors. Caramazza and Chialant (2000) showed that a predominance of substitution errors, with an average of 61.5% of the total errors made. Goldman et al., (2001) reported that 83% substitution errors and Romani et al. (2002) found that non-fluent aphasics made 59% errors in substitutions. Wardana et al., (2018) observed three patients with Broca's aphasia and confirmed that KW made 65%, NS made 68%, and MD made almost 71% phonemes substitution errors. The substitution errors the patients mostly made were considered as phoneme simplification. The direction of segment simplification follows or violates the sonority sequencing principle or SSP.

Theoretically, Belvins (1995) defines SSP as the range between any member of syllable and syllable peak, and a sonority rise must occur. Meanwhile, Alqahtani (2017) states that SSP is the way in which sonority increases from the syllable margins towards the syllable peak and decreases from the syllable peak towards the syllable margins. This method controls any features for the initial and final syllable constraints (Romani and Calabrese (1998). For instance, in Balinese syllabic rules, the feature [nasal] may not occur before or after any features in onset (mpa, pma, nti, tni) as well as a feature [trill]. This phenomenon strengthens the argument that features do not only indicate the distinctive feature of a word, but they perform identical behavior in the phonological process. Bastiaanse, Gilbers, and Linde (1994) argue that features sonority is not determined by certain articulatory, but it is presented to indicate that a group of segments becomes the domain of phonological process, either phonologically based or phonetically based features (Bastiaanse, Gilbers, and Linde, 1994; Gandour, 1998; Gordon and Ledoux, 2008; Lieberman and Blumstein, 1988).

Even though investigations of SSP on phonological errors of aphasia have presented the mechanism of phonologically based and phonetically based features in the sonority hierarchy, however, the features selected for substitution based on sonority hierarchy and how a segment has the role to influencing other segments remain unexplained. Violation of substitution features and syllabic rules in sonority might occur and may result in unrecognizable words in that language; however, this phenomenon can be a kind of description of the thinking process of patients. Therefore, it is hypothesized that phoneme substitution, insertion, and omission errors concerning the degree of sonority and sonority violation in SSP are likely to occur in Broca's aphasics. To test this hypothesis, we compared the frequency of segment substitutions in which the degree of sonority changes (for example, /y/ → [w], as in *uyah* 'salt' realized as [uwas].

II. Methods

Two Balinese patients with Broca’s aphasia participated in this exploratory study. KW is a 70-year-old man with a right-handed and he is a retired elementary school teacher. Meanwhile, NS is a 52-year-old man with right-handed, too, and he is a woodcarver. The type of stroke that they suffered was NHS (non-hemorrhagic stroke), followed by right hemiplegia and language impairment. They performed four phonological tasks, namely naming words, naming pictures, answering questions and oral reading. Each task had 65 words or pictures that mainly represented consonants and vowels in different distributions. The speech output of the patients was recorded by Sonny's voice recording. The data were copied and analyzed using Praat to know the acoustic features of the patients' speech sounds. The recorded data were then phonetically and phonemically described and classified to determine the types of errors. All total correct and incorrect sounds were calculated to find out the percentage of errors. Each segment involved in the phonological errors was counted and calculated to know the number of marked

features was substituted by less marked features and less marked features were substituted with marked features. The data were analyzed using a simple descriptive statistic. The difference in mean for continuous data was tested using the Wilcoxon signed ranks test.

The sound errors were classified into four types of phonetic errors called distortion and phonological errors as substitution, insertion, addition, metathesis and omission. All alterations were analyzed to know the phonological process by applying the theory of generative phonology. The direction of substitution errors concerning SSP was classified, tabulated and investigated if there was any violation on the sonority scale. A descriptive statistical analysis was carried out on the data gathered. Differences among means for continuous data were measured using the Wilcoxon's test. A probability (p) value of less than 0.05 was considered statistically significant and all tests were two-tailed. Ninety-five percent confidence intervals (CI) were calculated for differences between means.

III. Findings and Discussion

In this study, all communication is gained with a type of severe non-fluent speech. Speech opponents require greater attention to conclude, wonder and predict the patients' speech outputs, and the information range is limited. Specifically, they simplified the vowels and consonant segments because the right sequence of phonemes cannot be accessed and information decays in a phonological output buffer, as it can be described in the following section.

Phonemes Alteration Errors

The speech output of the two patients in all phonological tasks showed one, two, and three words utterances. Sound simplification may occur for both vowels and consonants. Because the vowels are considered to be the easiest articulation that patients can produce, so there are not a lot of cases in vowel alteration errors. In other words, consonants have a high complexity of articulation, so the patients made more errors in producing speech sounds. From the findings, some patterns of both vowel and consonant alterations can be predicted to occur in certain sound environments due to the failure of the articulatory planning program.

Vowels

The pattern of vowel alteration made by patients with Broca’s aphasia under the study mostly I in middle distribution. The patterns can be formulated as 1) high front tense vowel /i/ was mostly substituted by [ɪ], [e], [o], and [a]; 2) high front lax vowel /ɪ/ was altered by [e], [ɔ], [a], [ɑ]; 3) high tense back vowel /u/ had four realizations: [i], [ʊ], [e], [ɔ]; 4) high back lax vowel /ʊ/ was substituted by [ɔ] and [ɑ]. Meanwhile, the middle front vowel /e/ was altered by four vowels: [i], [ʊ], [o], and [ɛ]; 5) the middle front lax vowel /ɛ/ was simplified by [e]; 6) middle vowel /ə/ became [æ], [ɔ], [a]; 7) middle lax vowel /æ/ was substituted by [ɛ]; 8) middle

rounded back tense vowel /o/ was simplified by [e],[ɔ], [ə], [ɑ]; 9) middle rounded back lax vowel /ɔ/ was substituted by a high rounded lax backvowel [ʊ]; 10) phoneme /a/ was substituted by [i], [u], [ə], [o], and [ɛ]; and 11) phoneme /ɑ/ was realized as [ɛ], [æ], and [ɔ]. The eleven patterns of vowel substitution above occur due to the influence of the neighboring sound environment. Therefore, the direction of segment alteration may vary from the high to low vowels, from tense to lax vowels, from front to back vowels or on the contrary, the substitution can be from back vowels to front vowels, or from low to high vowels. In short, patients can say individual vowels with ease.

Consonants

Consonants substitution errors can be elaborated as the change of one phonetic feature of a consonants into another ([+voiced]→[-voiced]). The data provide information on the consonant substitution errors that can be listed as follows: 1) /p/ has three phonetic realizations: [k], [t] and [l]; 2) /t/ has eight phonetic realization: [s], [p], [n], [c], [h], [b], [l], and [k]; 3) /k/ is substituted by [t], [g], [s], [h], [ʔ]; 4) /b/ is substituted by [p], [t], and [ŋ]; 5) /d/ was realized as [t], [b], [s], [h], and [l]; 6) /g/ is substituted by [k],[p],[b], [t], [d], [h], [n], [l]; 7) /ʔ/ is substituted by [k], [h]; 8) /s/ had five phonetic realizations: [t], [k]. [l], [n], [h]; 9) /h/ is substituted by [p], [s]; 10) /c/ is substituted by [t], [s], [k]; 11) /j/ is articulated as [t], [l], [d]; 12) /m/ was substituted by [l], [p], [b], [s]; 13) /n/ is substituted by [m]; 14) /ɲ/ is articulated [n], [s]; 15) /ŋ/ is substituted by [m], [g], [n]; 16) /l/ had four substitutions: [t], [n], [p], [g]; 17) /r/ is substituted by [l], [p], [t]; 18) /w/ is articulated as [l], [k], and finally 19) /y/ is substituted by [j], [w], [l], [d], and [ɲ].

Accoustic Features of Sound Distortion

From the data above, there are four mechanisms of SSP; (i) substitution sonority {[O → N], [N→L], [L→G], [G →V], (ii) multiple forwarding sonority {[O→L], [N→G], [L→V], [O→G]}, (iii) substitution reverse order {[G→L], [L→N], [N→O]}, and (iv) substitution within the feature group {O→O], [N→N], [L→L], [G→G]}. From the brief view, it can be seen that the substitution errors produced by the patients dominated by substitution within the feature group in all distributions. The insertion and omission sonority occurred more in onset than in coda due to phonological anomia or difficulty starting an utterance. The substitution errors are considered phonemically based as long as the segment is substituted by another segment, which is in this case regulated by the mechanism of the sonority hierarchy. The word tabuan wasp, which was realized as [na naŋkuan], resulted in an interesting phenomenon. The substitution of a segment to another does not only change its features but also change the degree of sonority. In this case, the substitution sonority of /t/ → /n/ in onset was not only the change of stop to nasal as a phonemically based mechanism but also involved the devoicing process, from voiced to unvoiced.

After observing the raw acoustic data by Praat, there was some specific character of sound distortion produced by patients with Broca's aphasia in comparison with the characteristic of normal sound. The pattern wave of the spectrogram of vowel and consonant articulated by normal and patients with Broca's aphasia is presented in Figure 1.

/katɔs/ → [astʊh]

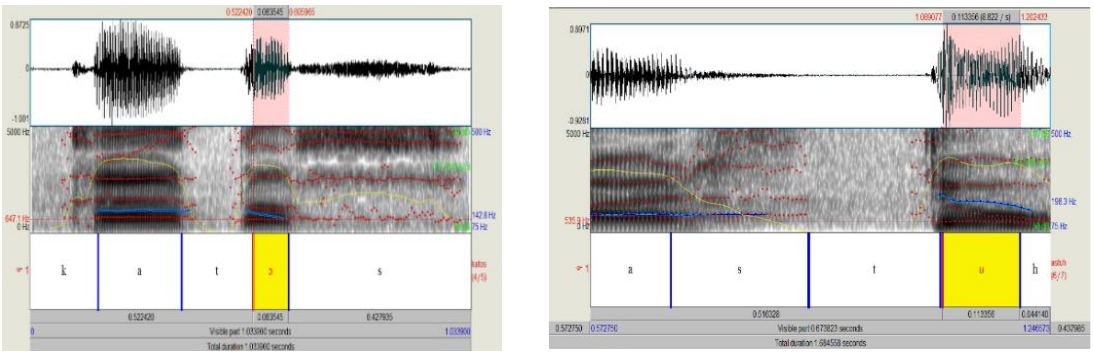

Figure 1. The spectrogram of normal speech sound (left) and sound distortion (right)

There are some specific findings regarding the characteristic of sound distortion: (i) the intensity of vowel sounds produced by patients is lower than it is produced by normal speakers; (ii) patients tend to prolong that timing duration of vowels in all positions that results in diphthongal; (iii) the vowels articulation is considered inaccurate since the value of F1, F2 and F3 is higher than normal speakers; (iv) the pitch of sounds produced by the patients is relatively lower than the of normal; and (v) the phonation might be affected in motor aphasia, so for sound voicing and sound devoicing occur because the larynx has less or more control on the vocal cord due to the implementation of articulation deficits resulting from lesions in Broca's area.

Analysis of Phonological Features

The types of sound simplification that are produced by patients with motor aphasia in this study are (as the claim of Romani & Calabrese, 1998) phoneme substitution errors, insertion, addition, transposition, and omission. However, substitution is dominant in phonological disorders. The substitution process consists of a fronted sound (+back → +front), stopped (- stop → + stop), and nasalized sound. Sound assimilation can be seen in vowels and consonants harmony). For the process of the structural syllable, there were some initial and middle consonant omissions (haplology). Patients tend to show phonological alterations which are different from those other researchers have found, such as (i) pattern of repeating first syllable /tabuan/ 'wasp' →[na naŋkuan], (ii) morpheme addition in the beginning of a word (especially [la]) i.e /jam/ 'clock' →[la le ma mi e nase] and /nasi/ 'rice' →[la eh nasi], (iii) pattern of

repeating final syllable, i.e /guak/ 'crow' → [kuak ku] and /kasə/ 'clothe'→ [sasə sə], (iv) syllable transposition to the front, i.e /batu/ 'stone' →/ [tuh batuh], and (5) third segment transposition to the front, i.e /ipah/ 'in law → [aleh].

Analysis of Sonority Sequencing Principle

The substitution of a segment with another segment is generally concerned with the natural way of articulatory configuration, which starts from the least sonorant features; obstruent [stops, affricative, fricative) increases gradually to the peak of the most sonorant vowels and then drops. SSP aims to describe the segment ordering in syllables by locating the syntagmatic connections of neighboring phonemes. The appropriate exponent in the principle of obstruent takes the position of onset and coda and, of course, this results in a great difference in sonority. The analysis of SSP on Balinese utterances constructed by patients with Broca's aphasia is presented in this study.

Substitution

Bastiaanse, Gilbers and Linde (1994) propose that the substitution sonority is a term that refers to the substitution of one segment in the sonority group with another segment, which is only one level more sonorant on the sonority scale, leading to syllable peak. Sonority indicates the structure of the syllables. From the data listed above, substitution errors occur due to the high phonetic complexity. Therefore, the strategy applied by the patients is by simplifying it with a more sonorant segment. The target word *sumping*, which was realized as [numpın], is one example of substitution sonority. The segment /s/, which has a high phonetic complexity, belongs to obstruent feature groups, so it was substituted by [nasal] due to the influence of the nasal environment /m/. The phonological process occurs due to the incapability of the patient to articulate /s/ in the initial position (onset); therefore, they alter the segment with a more sonorant once. A more complex process of alteration errors in sonority substitution in this study occurred in more than one segment of two-syllable words, as in the word *warung* (shop), which was pronounced as [luwung]. The sonority pattern of the target word in the sonority scale, which was ordered in [G-V- L- V- N] was substituted as [L-V-G-V-N]. The substitution of a segment in the syllable pattern may influence the change of other segments. If one segment is changed, so other segments may change too (Clements, 1990). In SSP analysis, the target phoneme /wa.ruŋ/ which was realized as [lu.wuŋ] can be explored as the mechanism of underlying form which is represented into deriving form and ordered in features group of sonority scale.

Concerning the mechanism of substitution sonority above, the intended sound of *warung* is ordered in the mechanism of the sonority scale [G-V-L-V-N]. The segment /w/ belongs to the glide feature group and it is only one level less sonorant then vowel /a/ commonly known as a semivowel. The sonority degree drops to liquid /r/, which is less sonorant than /w/ and increases

to the peak /u/ and drops again to a deeper slope to the nasal /ŋ/. This nasal is less sonorant than glide /w/ and liquid /l/. However, due to the damage in the Broca area, in the word selection level, /waruŋ/ was realized as [luwuŋ], which is ordered in the red line of the sonority scale [L-V-G-V-N]. The impaired sound /w/ was realized as [l] and /r/ were realized as [w]. Therefore, in the phoneme selection level, it was phonemically transcribed as /lu.wuŋ/. The substitution of /w/ with /l/ was considered a violation of the SSP due to the reverse order. This is in contrast with what Bastiaanse, Gilbers & Linde, (1994) state that is a sonority substitution error occurs when one segment is replaced by another segment that differs only one step more sonorant on the sonority scale. From the generative phonology side of view, the phonological process is a phenomenon of articulation, so metathesis rule in this study occurred when the segment /r/ in second syllable onset [wa.rung] was mutated to the first syllable and /w/ as the onset of the first syllable switched that position as /rawung/. Due to the difficulty of realization, /r/ was then substituted by a segment that belongs to the same feature group /l/ and the target word was realized as [larung]. Finally, a high rounded back vowel /u/ in the second syllable assimilated regresively the low unrounded back vowel /a/ in the first syllable peak by modifying the features, then the target word /warung/ was phonetically represented as [luwung]. Therefore, SSP is concerned with the role of sonority in ordering the errors (Clements, 1990). Meanwhile, generative phonology describes the phonological representation or underlying form of sound is represented as the phonetic realization or deriving form (Schane, 1992).

Insertion

Instead of substitution errors, it was also found insertion sonority as the loss of a phoneme in any distribution of a word. Insertion errors made by patients with Broca's aphasia involved in this study were the smallest category of errors. Insertion errors mostly take place in consonant clusters or they can set new consonant clusters. This condition supported previous studies (see Blumstein, 1973; Romani and Calabrese, 1998; Beland and Favreau (1991). Phoneme impairment usually triggers the insertion and is usually associated with feature groups on the sonority scale. It has been found that insertion sonority occurred between consonants and vowels, or between vowels and consonants in onset or coda by adding a new segment associated with features groups. The most category of insertion occurred was articulatory based-insertion. For example, insertion of liquid /l/ after alveolar nasal /n/ in the target word of *manas* 'pineapple' resulted in a new construction of syllable, [man.les]. In other cases, the word siap 'chicken' was inserted by a glide /y/, so it turned into [se.yap]. Romani and Calabrese (1998) found that liquids and glides were most commonly inserted. This insertion sets a phoneme substitution of other segments that proceeds and follows. After /l/ was inserted, the low back vowel /a/ was substituted by the middle front vowel /e/.

Insertion sets a new internal structure of syllable, as the figure above that /n/ is the onset of the second syllable /ma. nas/; however, after the insertion of /l/, it becomes a coda in a new realization of the target word, that was [man.les]. There was a consonant cluster after the insertion, called insertion sonority; a segment is inserted just one level more sonority than the previous segment {[nasal] ↔ [liquid] and there are articulatory based features [+anterior, + coronal, + sonorant]. The distinctive feature of these segments have that /n/ has features [+nasal, -lateral], while /l/ has features [–nasal, + lateral]. In short, there was an insertion of level 3 after level 4 in the feature sonority group due to the neighboring concept of articulation. In this study, glottal fricative /h/ is added after the vowel as coda. Therefore, /dui/ 'thorn' was realized as [tuwih]) and addition of /s/ in onset, as /aə 'yes' was spoken as [sae].

Omission

Omission, as can be seen in the vocabulary list, is a deletion of phonemes. It should be reminded that omission can be considered a phonemic error due to the incapability of coding the sound and processing it into the articulatory section. It was found that omission was mainly made by patients with Broca's aphasia in onset; for example, /kipas/ 'fan' was realized as [ipas]. Considering the sonority hierarchy, phoneme omission can be associated with natural patterns of articulators in sequencing the sounds by anticipating the following segments and of course neighboring segments may cause the change instead of the initial, medial and final positions. However, the deleted segment refers to a logical concept of the mechanism of the internal structure of the syllable. For example, an /s/ in initial word *sampi* 'cow' is deleted because the degree of feature sonority is four levels less sonorant, leading to the most sonorant segment /a/, therefore, it is very difficult for the patient to substitute or insert other segments.

The omission of /s/ in the figure above changed the internal structure of the syllable. The omission of segments in the onset is common in Broca's aphasia as a typical syndrome of phonological anomia; the difficulty of starting the utterance. The high complexity of fricative onset can be one reason for deletion; however, /s/ can be articulated very well in the coda. In the speech of patients with Broca's aphasia, consonants are deleted to eliminate hiatuses, while previous studies claim that Wernicke's aphasia has phoneme deletion in the coda. The study reported that omission took place in the middle distribution due to the disability of configurating or blending the semivowels or lateral that resulted in the alteration of vowels.

The impaired sound uttered by the patients above provides empirical pieces of evidence concerning inaccurate sound configuration. The phonological approach underlines that mental segments of /y/ and /l/ cannot be realized well by the patients if the segments are between a low back vowel /a/ or a high back vowel /u/.

Metathesis

One of the phonological errors found in this study was the reconstruction of the target word by mutating the segments in a different direction of distribution, known as metathesis. Therefore, it reveals a new form and internal construction of syllables. As mentioned above, it is very difficult for patients to produce /s/at the onset, so changing the position can be a way to cover this problem. As the word *siap* 'chicken' was realized as [ipas]. In the sonority scale, the metathesis occurred from features [O5 – V – V – O7] mutated to [V – O7 – V - O5]. The syllable pattern of the target word *siap* was changed from one to two syllables. The /s/ in onset was mutated and replaced the position of /p/ in the coda after forwarding it to be a core in the onset of the second syllable, so the new word started with metathesis sonority with the rules of SSP.

The figure above shows how patients reconstruct the sequence of phonemes (s-i-a-p) by transposing the less marked segment /s/ to the final position before the most marked segment /p/, which is transposed between the vowels /i/ and /a/. Based on the sonority hierarchy of the feature group of obstruent, the segments are ordered from stop to affricate [p, t, k, ʔ, d, b, g, s, h, c, j]. Therefore, the segment /s/ must not be in initial, so it is mutated to the back based on the sonority scale and then /p/ is mutated to the front. In this study, it was found that the sonority scale has an important role in transposing the less marked feature group (fricative) before the most marked feature group (stop). This means that it is easier to close the syllable with open air (s) than the blocked air (p).

Violation

Hierarchy sonority in syllable pattern orders the strings of consonant sounds in onset or coda, which ranges from the least sonorant gradually to the most sonorant. In many languages, the sequences of /pr/, /sn/ or /sw/ are acceptable in the sequence of the sonority hierarchy as [OL], [ON] and [OG]; however, the reverse order /rp/, /ns/ or /ws/ or sequencing sonority as [LO], NO] and [GO] are SSP violations. The feature [nasal], which was sequenced with another consonant in onset, is not accepted before and after any group of features on the sonority scale, for example [mdɑk], [semnpi], [mkon.. ndi]. So /m/, /n/, / ŋ/ which occurs before or after any consonant in onset or coda is considered abnormal in Balinese. Harris (1983) proposed that each language needs minimal distance in sonority among the consonant cluster in onset.

Instead of consonant cluster violation, some shreds of evidence of a violation in substitution sonority were also found in this study. Normally, one segment is replaced by another that differs only one step on the sonority scale. For example, the initial distribution of /s/ that belongs to feature [obstruent] in the word *sumping* 'Balinese cake' was substituted by /n/ a segment that belongs to just one level more sonorant than /s/ because the neigboring segment of /m/ in regressive assimilation so that the error was realized as [numpɪŋ]. The general rule of

sonority hierarchy implies the range from the right margin to the left or from the least sonorant level to the most sonorant one.

Patients with Broca's aphasia simplify the complex segments by substituting a high complex segment with a low one. The more sonorant the features, the easier the sound is articulated. SSP violation in substitution errors involved reverse ordering, from the left to the right or from the most sonorant to the least sonorant. The violation may occur when a more sonorant segment is replaced by another that differs one step less sonorant in the sonority hierarchy. The segment /l/ in the word *lindʊng* 'eel' was supposed to be replaced by a segment that differs just one level more sonorant than /l/. It must be a glide /w/ (windʊng) or /y/ (yinduŋ). However /l/ was substituted by /n/, so it was realized as [nindʊŋ]. This violation occurred because the substitution error of /l/ was associated with the nasal environment or neighboring phoneme /n/ after the vowel. This was in line with the ideas of phonological neighboring density by Munson and Solomon (2004). The phonological rule of this substitution error can be stated as /l/→ [n] / # - V.C [+nasal]. The sonority pattern is also changed from {[G – V – N – O – N]} to {[N – V – N – O – N]}. The omission of /t/ in word tomat tomato, was one of other evidence that patients with Broca aphasia tend to make omission in onset and leave the word as [omɑt].

The substitution /m/ in the word *tomat* with /p/ as in [opɑt] was due to the homorganic feature (bilabial) and the unvoiced stop alveolar sound. The third type of SSP violation found in this study was the alteration of a segment with another, which was called the reverse order within the feature sonority group. This could be the closest step to substitution errors that the patients have made. This kind of substitution may involve the segments in the initial, medial and final positions.

The substitution errors within the feature group on the sonority scale are considered not only as phonemically based but also as phonetically based features. For example, /k/ in the onset of kase was substituted by /s/ since it is in the environment of /s/. SSP violation in phoneme substitution occurs when a segment alters the target segment that comes from the same group, e.g [obstruent]. The sonority scale regulates the substitution of a segment with high articulation complexity with a segment with less high complexity. Schane (1992) states that the phonological process can be explained as an articulatory phenomenon. Phonetically, when /k/ in word *kase* was being articulated, the articulators anticipated oncoming /a/ and /s/ and the later assimilated /k/ in onset. In brief, voicing can affect substitution errors too. The substitution errors within the feature group on the sonority scale are considered not only as phonemically based but also as phonetically based features. For example, /k/ in the onset of kase was substituted by /s/ since it is in the environment of /s/. SSP violation in phoneme substitution occurs when a segment alters the target segment that comes from the same group, e.g [obstruent].

The sonority scale regulates the substitution of a segment with high articulation complexity with a segment with less high complexity. Schane (1992) states that the phonological

process can be explained as an articulatory phenomenon. Phonetically, when /k/ in word *kase* was being articulated, the articulators anticipated oncoming /a/ and /s/ and the later assimilated /k/ in onset. In brief, voicing can affect substitution errors too. The speech output of patients of Broca's aphasia in this study manifested two or three words just in single utterance and function words were mainly absent. The sequences of phonemes were too complex for the patients to produce so they simplified the phonemes by deleting, inserting, substituting, or transposing them. The consonants were distributed in different positions of the initial, middle, and final syllables to represent any existing differences in the sound characteristics or indicators of the location of lesions in the brain function for language expression.

The evidence shows that phoneme substitution and omission errors mainly occur in the initial distribution because lesion or brain damage occurs in the anterior part of the left hemisphere of the brain, which has a specific function for the articulatory implementing program. In other words, the posterior has a specific function for the phonemic planning program, while the anterior part is for phonetic implementation.

IV. Conclusion

The study concludes that (i) Broca's aphasia has a degree of phonemic errors due to a disorder in phonetic processing, namely, planning and executing the articulatory programs. The acoustic analysis shows that phonetically, patients made inaccurate articulation, voicing, prolongation, and disprosody; (ii) the less marked features that are statistically substituted by marked features are not significantly affected by marked features that are substituted by less marked features because the change of feature values was dominantly influenced and assimilated in such a way by neighboring segments; and (iii) the SSP violation in substitution errors involved the reverse ordering, from the most sonorant to the least sonorant and substitution within a feature sonority group. The feature [nasal], which was sequenced before and after any consonants of feature group in the sonority scale in onset, is not normal in the Balinese syllable. Therefore, evidence of [mdak], [semnpi], [mkon, ndi] produced by patients with Broca's aphasia was a type of SSP violation. A segment alteration that occurs in the assimilation of a similar segment in place of articulation but different in a manner of articulation is most common due to the inability to blend the sound movements. The impaired segments in any type of phonological error found in this study can be used for both linguistic analysis and neuronal base consideration for sound rehabilitation.

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