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# Acoustic Features of Phonemes as Therapy Reference for Dysarthria Disorder: The Case of /r/ Alveolar Trill

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***Abstract*---**The increasing global competitiveness demands the development and improvement of self-quality, particularly the quality of self-performance. Dysarthria is one of the speech disorders that often provides significant obstacles to the sufferer's performance. For this reason, this study was intended as an initial study to investigate differences in the acoustic features of both contoid and vocoid phonemes produced by dysarthria and non-dysarthria as well as provide therapy suggestions to minimize the disorder. The scope of the study was limited to the case of /r/ alveolar trill dysarthria. This study was designed using a descriptive qualitative approach with field methods. In collecting data, the observation (*simak*) method was used to collect data in the form of contoid and vocoid phonemes produced by 4 dysarthria samples and 4 non-dysarthria samples. The collected data then went through the analysis with the extralingual and intralingual equivalent methods. The results showed that the inability to produce phoneme /r/ alveolar trill could be detected by observing the differences in the acoustic features of the alveolar and vocoid phonemes produced by both dysarthria and non-dysarthria samples. Further, the study also proposed some therapy suggestions to minimize the inflexibility of the tongue muscles to vibrate and to reach the alveolar ridge properly when producing sounds.

***Keywords*---**acoustic features, dysarthria, phonemes, therapy.


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**Introduction**

In increasing global competitiveness in terms of human resources, various types of self-development and self-improvement are needed. Nowadays, various efforts to develop self-quality are more intensively carried out, both in primary needs (nutrition, health, and body fitness), secondary needs (education and skills), as well as tertiary needs (appearance, performance, aesthetics, and technological support). However, efforts to develop self-quality should not be separated from efforts to improve self-quality. This is important, considering that development without improvement to minor matters will never be complete.

It must be admitted that self-performance is becoming an important aspect that gets attention in modern global life. This is evident from the widespread practice of plastic surgery to increase luck in occupation, as well as the increasing public demand for improvements in the shape and structure of teeth or jaws to improve appearance and pronunciation. Starting from these things, minor cases such as dysarthria began to receive public attention. Based on an initial interview with dysarthria sufferers, it was found that dysarthria disorders often provided obstacles that interfered with their performance while performing. Some of the obstacles faced were lack of self-confidence while speaking in public, the difficulty of the interlocutor in understanding the intent of the sufferer, and early fatigue of the tongue when speaking aloud for a long duration. Although these obstacles did not significantly reduce the sufferers' performance, dysarthria nonetheless caused sufferers to require more preparation before appearing in public compared to those without dysarthria. Some sufferers stated that it would be better if the disorder could be minimized or even completely disappeared. Based on the reasons, dysarthria which is considered a minor disorder by some people is a actually significant disorder for the sufferers. Therefore, effective remedies are important to investigate.

Dysarthria is actually an abnormal condition in the nervous system that can affect the performance of the articulators' muscles. Therefore, dysarthria causes speech disorders. In Indonesia particularly, the inability to produce phoneme /r/ alveolar trill is considered as one of the indicators of dysarthria. The /r/ alveolar trill dysarthria sufferers in Indonesia usually substituted the phoneme with the production of other phonemes such as /l/ or /rkh/ (Matondang, 2019; Andriyana, 2020; Sundoro et al., 2020). Actually, phonetic disturbances are not merely limited to the production of /r/alveolar trill, but also to the production of other phonemes such as /t/, /l/, /s/, /d/, etc. However, dysarthria cases in the production of phoneme /r/ alveolar trill are more common in the community. This is due to the fact that the phoneme /r/ in Indonesian is mere /r/ alveolar trill, in which the production of the phoneme requires the highest flexibility of the tongue to vibrate continuously for a long duration compared to other types of /r/ phonemes, such as /ɾ/ alveolar tap, /ɹ/ alveolar approximant, /ʀ/ uvular trill, and /ʋ/ labio-dental approximant. Therefore, people who have less flexible tongues often experience failure in the production of the /r/ alveolar trill.

Physiological factors such as tongue flexibility are not the only factors that cause dysarthria. In general, dysarthria can be caused by two factors, namely physiological and neurological factors (brain nerve disorders) (Sundoro et al., 2020). This far, therapy is carried out for dysarthria sufferers with problems in their speech organs. However, to overcome dysarthria with brain nerve problems, medication and surgery are needed. This study focuses on the case of dysarthria phoneme /r/ alveolar trill. Further, it is intended as an initial study to investigate differences in the acoustic features of both contoid and vocoid phonemes produced by dysarthria phoneme /r/ alveolar trill sufferers compared to those produced by people without dysarthria (Iverson et al., 2003). The differences in acoustic features are expected to provide indications related to which parts of the sufferers' articulators should be treated (Taguchi et al., 2018). In addition, this study is also intended to provide therapy suggestions that are more targeted to the parts of the sufferers' articulators which are found to be having problems (Horwitz et al., 2005). Although many types of therapy for dysarthria have been offered in the community, the existing therapies are still considered general exercises to flex and strengthen the tongue (Nezu, 2004). Basically, if someone is not able to produce a certain phoneme appropriately, then it is an indicator of a problem in some parts of the articulators. By finding the problem points in the articulators, the duration of recovery is expected to be shorter and more effective.

**Method**

This study was designed by using a descriptive qualitative approach with field method. The descriptive qualitative approach was used to provide maximum space for researchers to describe the correlation of each variable (Arikunto, 2006). The stages in this study include (1) the sampling process, (2) the data collection, and the data analysis. This study was conducted at the Language Laboratory of Warmadewa University by using the observation method (*simak* method) to collect data in the form of contoid and vocoid phonemes (Mitterer et al., 2013). The observation method is a method used by researchers to collect data by watching the discourse uttered by the informant or printed in the text (Sudaryanto, 2015). In this study, the observation method was conducted by watching and recording techniques to tap the utterances of 8 samples consecutively through a recorder. The samples were selected by purposive sampling with the following criteria:

- Four people who suffer from dysarthria phoneme /r/ alveolar trill and four people who are non-dysarthria. The dysarthria samples consist of two men and two women as well as the non-dysarthria samples.
- The eight samples are in the age range of 20-30 years. In this age range, the samples have passed the golden age of acquiring language (Miasari et al., 2015; Slamet et al., 2017), and is considered mature to be cooperative during the data collection process.
- The samples should have complete organs of speech and not suffer from influenza, asthma, and cough. These aim to maintain pronunciation clarity and avoid bias caused by lung capacity.
- The samples had to live in low altitude areas to avoid bias in the air pressure in the lungs, considering that the atmospheric air pressure where people live can affect the air pressure in their lungs (Putri, 2015). Lower altitude area causes higher air pressure in human lungs, while higher altitude area causes lower air pressure in human lungs (Putri, 2015).

The criteria are given by Ayatrohaedi (2002), with some modifications in the terms of the number of samples, age range, and concepts related to the influence of atmospheric air pressure on air pressure in human lungs. The modifications were intended to get the appropriate data.

The data source of this study was syllables obtained from the eight samples. The syllables then went through the segmentation stage to obtain the data in the form of contoid and vocoid phonemes. The segmentation process was carried out via electronic media before going through the analysis stage (Manrique, 2021).

In analyzing the differences in the acoustic features of contoid and vocoid phonemes produced by both dysarthria and non-dysarthria samples, the intralingual equivalent method was used which was assisted by the differential comparison technique (Sudaryanto, 2015). Through the method and technique, different linguistic symptoms could be well observed based on the phonemes' acoustic features, namely frequency, intensity, formants, and spectrum (Nanni et al., 2016; Jaramillo et al., 2001).

Frequency is an acoustic feature that indicates the loudness of sound. Higher frequency indicates a louder sound (Sugiyono, 2003). Meanwhile, intensity is an acoustic feature that indicates the strength of sound. Higher intensity indicates a stronger sound (Sugiyono, 2003). Other than those two features, there is a vocoid-related feature called formant. Formant is usually measured to estimate the position of the tongue during sound production (Mantra et al., 2016). In estimating the position of the tongue, the first and second formants of vocoid phoneme are needed (Ladefoged, 2011). The first formant indicates the height of the tongue, in which larger value of the first formant means a lower tongue position (Ladefoged, 2011). Meanwhile, the difference between the second and the first formants indicates the backness of the tongue, in which the larger difference value means more forward tongue position (Ladefoged, 2011).

Further, in analyzing the problematic parts of articulators in dysarthria sufferers, the extralingual equivalent method was used to compare language with aspects outside of language, namely physiological aspects (Sudaryanto, 2015). The implementation of this method was realized by using the comparison technique to equate some main points, considering that this study aimed to investigate the main similarities of the acoustic features of phonemes produced by dysarthria sufferers so that conclusions can be drawn regarding the problematic parts of the articulators in dysarthria sufferers (Pinto et al., 2004; Hawley et al., 2007).

To determine the effective therapy for dysarthria sufferers, the researchers used the extralingual and intralingual equivalent method with the comparison technique to equate the main points (Sudaryanto, 2015). The method and technique were chosen because they can bridge the relationships between linguistic components and non-linguistic components.

**Discussion**

The results are displayed into four subsections, namely (1) Frequency and Intensity, (2) Formant, (3) Spectrum, and (4) Therapy Suggestions. Each subsection shows data tabulation, interpretation, and explanation.

**Frequency and intensity**

This subsection presents the comparison of frequency and intensity features between contoid phonemes produced by dysarthria samples and non-dysarthria samples. The contoid phonemes displayed are merely five phonemes, namely /d/, /n/, /s/, /t/, and /z/. The five contoid phonemes were chosen because they showed the most relevant results and patterns that correlate to the acoustic features of phoneme /r/ alveolar trill. In other words, the five phonemes were discovered to sound strange too when they were produced by the samples with the /r/ alveolar trill dysarthria. In addition, the five phonemes were surprisingly found to be alveolar phonemes, which shared the same place of articulation with /r/ alveolar trill. The tabulations of the comparison of frequency and intensity features between contoid phonemes produced by dysarthria samples and non-dysarthria are displayed as follows.

Table 1
Frequency and intensity of phoneme /d/

| Phoneme /d/ | Frequency (Hz) | | Intensity (dB) | |
|---|---|---|---|---|
| | Dysarthria | Normal | Dysarthria | Normal |
| Sample 1 | 212,3 | 190,6 | 58,2 | 59,1 |
| Sample 2 | 127,7 | 116,6 | 67 | 62,5 |
| Sample 3 | 162 | 192,6 | 60,4 | 65,1 |
| Sample 4 | 135,3 | 137 | 50 | 66 |
| Average | 159,3 | 159,3 | 58,9 | 63,2 |

Based on Table 1, it could be observed that the frequency average of the phoneme /d/ produced by dysarthria samples was the same as the frequency average of the phoneme /d/ produced by non-dysarthria samples. It means that the two groups have the same level of sound loudness. On the other hand, the intensity average of the phoneme /d/ produced by dysarthria samples was lower than the intensity average of the phoneme /d/ produced by non-dysarthria samples. This shows that non-dysarthria samples could produce stronger sound.

Table 2
Frequency and intensity of phoneme /n/

| Phoneme /n/ | Frequency (Hz) | | Intensity (dB) | |
|---|---|---|---|---|
| | Dysarthria | Normal | Dysarthria | Normal |
| Sample 1 | 222,5 | 229,2 | 68,3 | 67 |
| Sample 2 | 127,3 | 129,1 | 63,5 | 71,6 |
| Sample 3 | 196,1 | 215,2 | 64 | 65,3 |
| Sample 4 | 143,9 | 150,7 | 64,4 | 70,9 |
| Average | 172,5 | 181,1 | 65,0 | 68,7 |

In Table 2, it could be seen that both the frequency and intensity averages of the phoneme /n/ produced by the dysarthria samples were lower than those produced by the non-dysarthria samples. It means that the non-dysarthria samples were able to produce the louder and stronger phoneme /n/ than the dysarthria samples.

Table 3
Frequency and intensity of phoneme /s/

| Phoneme /s/ | Frequency (Hz) | | Intensity (dB) | |
|---|---|---|---|---|
| | Dysarthria | Normal | Dysarthria | Normal |
| Sample 1 | 295,3 | 269,4 | 76,8 | 50 |
| Sample 2 | 75 | 75 | 58,7 | 64 |
| Sample 3 | 255,3 | 280,9 | 60,5 | 54 |
| Sample 4 | 146,6 | 185,2 | 58,4 | 58,6 |
| Average | 193,1 | 202,6 | 63,6 | 56,7 |

Based on Table 3, it could be seen that the frequency average of the phoneme /s/ produced by the dysarthria samples were lower than that produced by the non-dysarthria samples. It indicates that the non-dysarthria samples produced louder sound than the dysarthria samples. On the other hand, the intensity average of the phoneme /s/ produced by the dysarthria samples was found to be higher than the intensity average produced by non- dysarthria samples. This shows that the dysarthria samples produced stronger sound.

Table 4
Frequency and intensity of phoneme /t/

| Phoneme /t/ | Frequency (Hz) | | Intensity (dB) | |
|---|---|---|---|---|
| | Dysarthria | Normal | Dysarthria | Normal |
| Sample 1 | 254,2 | 244 | 50 | 50 |
| Sample 2 | 130,9 | 75 | 50 | 50 |
| Sample 3 | 75 | 243 | 50 | 50 |
| Sample 4 | 142,5 | 75 | 50 | 50 |
| Average | 150,7 | 159,3 | 50 | 50 |

In Table 4, it can be observed that the frequency average of the phoneme /t/ produced by the dysarthria samples was lower than that produced by the non-dysarthria samples. It indicates that the productions of the phoneme /t/ by the non-dysarthria samples were louder than the productions by the dysarthria samples. Further, the intensity average of the phoneme /t/ produced by dysarthria samples was the same as the intensity average of the phoneme /t/ produced by non-dysarthria samples. It shows that the two groups have the same level of sound strength.

Table 5
Frequency and Intensity of Phoneme /z/

| Phoneme /z/ | Frequency (Hz) | | Intensity (dB) | |
|---|---|---|---|---|
| | Dysarthria | Normal | Dysarthria | Normal |
| Sample 1 | 202 | 196,6 | 61,4 | 59 |
| Sample 2 | 126,3 | 132 | 61,5 | 61,7 |
| Sample 3 | 158,8 | 202,9 | 59,4 | 62,2 |
| Sample 4 | 129,7 | 141,7 | 59,3 | 66,8 |
| Average | 154,2 | 168,3 | 60,4 | 62,4 |

Based on Table 5, it can be seen that both the frequency and intensity averages of the phoneme /z/ produced by the dysarthria samples were lower than those produced by the non- dysarthria samples. This indicates that the productions of the phoneme /z/ by the non-dysarthria samples were louder and stronger than the productions of the phoneme /z/ by the dysarthria samples.

Based on the data above, it could be observed that the non-dysarthria samples had a tendency to produce louder and stronger sounds which were proven by higher frequency and intensity averages. This indicated that there were obstacles for dysarthria samples to produce sounds with sufficient quality, considering the productions of sounds were discovered to be mostly low and weak. This condition could be one of the factors that caused dysarthria sufferers to get tired more easily when talking for a long time since the production of sounds needed more energy to ensure the low and weak sounds could be received by the listener properly.

Considering the phonemes /d/, /n/, /s/, /t/, /z/, and /r/ alveolar trill are alveolar phonemes, the low and weak sounds produced by dysarthria sufferers might be caused by the inflexibility of the tongue muscles to reach or adhere to the alveolar ridge properly or such low air pressure in the lungs to support sounds' productions. However, the bias regarding air pressure in the lung has been minimized during the sampling process. Therefore, the most likely answer would be the inflexibility of the tongue. Nonetheless, drawing answers merely based on frequency and intensity would not give sufficient results. Therefore, other acoustic feature which is known as formant need to be measured. Formant can provide relevant evidence regarding the position of the tongue during sounds production. If the positions of the tongue of the dysarthria samples were found to be mostly lower and further back compared to that of the non-dysarthria samples, then it would be valid that the core of the problem lies in the tongue's inflexibility to reach or adhere to the alveolar ridge properly.

**Formant**

Sound waves, especially vowel sounds, consist of many components in the form of repeated sine waves (Sugiyono, 2003). The repeated sine waves are known as harmonies (Sugiyono, 2003). The first harmony is called the fundamental frequency, while the repeating ones are called formants. Therefore, formants are repeated tones of the fundamental frequency of speech sounds (Ladefoged, 2011; Sugiyono, 2003).

As mentioned above, formants are usually observed through vocoid phonemes. Therefore, in investigating the positions of the tongue during the production of phonemes /d/, /n/, /s/, /t/, and /z/, the sounds should no longer be measured as single phonemes like it was carried out in the measurement of frequency and intensity. Instead, the sounds should be measured as syllables such as /de/, /ne/, /se/, /te/, and /ze/. The phoneme /e/ was chosen as a pair to phonemes /d/, /n/, /s/, /t/, and /z/ because the phoneme /e/ is a front middle vocoid phoneme. It means the position of the tongue when producing the phoneme /e/ is located in the middle of the oral cavity in which the tip of the tongue is slightly forward. This position is considered ideal for comparing how high and forward the tongue when pronouncing the phonemes /d/, /n/, /s/, /t/, and /z/.

To investigate how high and forward the tongue position through formants, there are two formulas that should be understood. The formulas were given by Ladefoged (2011), that require the first formant (F1) of the phoneme /e/ to estimate how high the position of the tongue and the difference between the second formant and the first formant (F2-F1) of the phoneme /e/ to estimate how forward the position of the tongue. Further, the higher the F1 means the lower the position of the tongue when producing the syllables. Meanwhile, the higher the F2-F1 means the further forward the position of the tongue when producing the syllables.

By analyzing how high and forward the tongue when producing the syllables, the tongue's reach to the alveolar ridge could be estimated. The tabulations of the comparison of height and backness of the tongue between dysarthria and non-dysarthria samples are displayed as follows.

Table 6
Height and backness of tongue during the production of phoneme /e/ in syllable /de/

| Phoneme /e/ | Formant 1 (Hz) | | Formant 2- formant 1 (Hz) | |
|---|---|---|---|---|
| | Dysarthria | Normal | Dysarthria | Normal |
| Sample 1 | 482 | 461 | 1.584 | 2.110 |
| Sample 2 | 386 | 401 | 1.689 | 1.969 |
| Sample 3 | 468 | 465 | 2.115 | 1.713 |
| Sample 4 | 385 | 360 | 1.810 | 1.801 |
| Average | 430 | 422 | 1.800 | 1.898 |

Based on Table 6, it could be seen that the F1 average of the phoneme /e/ produced by dysarthria samples was found to be higher than that produced by non- dysarthria samples. It means that the tongue position of the dysarthria samples when producing the phoneme /e/ in the syllable /de/ was lower than the tongue position of the non-dysarthria samples. Then, based on the F2-F1 average, it can be seen that the position of the tongue of the non-dysarthria samples was further forward than that of the dysarthria samples since the F2-F1 average of the phoneme /e/ in the syllable /de/ by the non-dysarthria samples was found to be higher.

Table 7
Height and Backness of Tongue during the Production of Phoneme /e/ in Syllable /ne/

| Phoneme /e/ | Formant 1 (Hz) | | Formant 2- formant 1 (Hz) | |
|---|---|---|---|---|
| | Dysarthria | Normal | Dysarthria | Normal |
| Sample 1 | 498 | 443 | 1.971 | 2.315 |
| Sample 2 | 486 | 530 | 1.624 | 1.906 |
| Sample 3 | 453 | 653 | 1.121 | 1.527 |
| Sample 4 | 420 | 387 | 2.152 | 1.854 |
| Average | 464 | 503 | 1.717 | 1.901 |

Based on Table 7, it could be seen that the F1 average of the phoneme /e/ produced by dysarthria samples was found to be lower than that produced by non- dysarthria samples. It means that the tongue position of the dysarthria samples when producing the phoneme /e/ in the syllable /ne/ was higher than the tongue position of the non-dysarthria samples. Then, based on the F2-F1 average, it can be seen that the position of the tongue of the non-dysarthria samples was further forward than that of the dysarthria samples since the F2-F1 average of the phoneme /e/ in the syllable /ne/ by the non-dysarthria samples was found to be higher.

Table 8
Height and backness of tongue during the production of phoneme /e/ in Syllable /se/

| Phoneme/e/ | Formant 1 (Hz) | | Formant 2- formant 1 (Hz) | |
|---|---|---|---|---|
| | Dysarthria | Normal | Dysarthria | Normal |
| Sample 1 | 533 | 479 | 1.871 | 1.944 |
| Sample 2 | 434 | 448 | 1.560 | 1.904 |
| Sample 3 | 488 | 584 | 1.276 | 1.596 |
| Sample 4 | 397 | 374 | 1.922 | 1.679 |
| Average | 463 | 471 | 1.657 | 1.781 |

Based on Table 8, it could be seen that the F1 average of the phoneme /e/ produced by dysarthria samples was found to be lower than that produced by non- dysarthria samples. It means that the tongue position of the dysarthria samples when producing the phoneme /e/ in the syllable /se/ was higher than the tongue position of the non-dysarthria samples. Then, based on the F2-F1 average, it can be seen that the position of the tongue of the non-dysarthria samples was further forward than that of the dysarthria samples since the F2-F1 average of the phoneme /e/ in the syllable /se/ by the non-dysarthria samples was found to be higher.

Table 9
Height and backness of tongue during the production of phoneme /e/ in syllable /te/

| Phoneme/e/ | Formant 1 (Hz) | | Formant 2- formant 1 (Hz) | |
|---|---|---|---|---|
| | Dysarthria | Normal | Dysarthria | Normal |
| Sample 1 | 544 | 481 | 1.783 | 1.881 |
| Sample 2 | 433 | 435 | 1.567 | 1.913 |
| Sample 3 | 467 | 460 | 1.815 | 1.822 |
| Sample 4 | 407 | 377 | 1.974 | 1.772 |
| Average | 463 | 438 | 1.785 | 1.847 |

Based on Table 9, it could be seen that the F1 average of the phoneme /e/ produced by dysarthria samples was found to be higher than that produced by non- dysarthria samples. It means that the tongue position of the dysarthria samples when producing the phoneme /e/ in the syllable /te/ was lower than the tongue position of the non-dysarthria samples. Then, based on the F2-F1 average, it can be seen that the position of the tongue of the non-dysarthria samples was further forward than that of the dysarthria samples since the F2-F1 average of the phoneme /e/ in the syllable /te/ by the non-dysarthria samples was found to be higher.

Table 10
Height and backness of tongue during the production of phoneme /e/ in syllable /ze/

| Phoneme /z/ | Formant 1 (hz) | | Formant 2- formant 1 (hz) | |
|---|---|---|---|---|
| | Dysarthria | Normal | Dysarthria | Normal |
| Sample 1 | 432 | 425 | 1.729 | 1.805 |
| Sample 2 | 437 | 427 | 1.502 | 1.911 |
| Sample 3 | 442 | 453 | 2.034 | 1.543 |
| Sample 4 | 389 | 371 | 1.968 | 1.696 |
| Average | 425 | 419 | 1.808 | 1.739 |

Based on Table 10, it could be seen that the F1 average of the phoneme /e/ produced by dysarthria samples was found to be higher than that produced by non- dysarthria samples. It means that the tongue position of the dysarthria samples when producing the phoneme /e/ in the syllable /ze/ was lower than the tongue position of the non-dysarthria samples. Then, based on the F2-F1 average, it can be seen that the position of the tongue of the non-dysarthria samples was further back than that of the dysarthria samples since the F2-F1 average of the phoneme /e/ in the syllable /ze/ by the non-dysarthria samples was found to be lower.

After observing the comparison of formant data, it could be said that the dysarthria samples tended to have lower and further backward tongue positions when producing the five syllables. To ensure that the positions of the tongue when producing the five syllables could be used as a parameter to estimate the position of the tongue when producing the phoneme /e/ in the syllable /re/

alveolar trill, the researcher also measured the F1 and F2-F1 of the phoneme /e/ in syllable /re/ alveolar trill. The result is displayed as follows.

Table 11
Height and Backness of Tongue during the Production of Phoneme /e/ in Syllable /re/

| Phoneme /e/ | Formant 1 (Hz) | | Formant 2- formant 1 (Hz) | |
|---|---|---|---|---|
| | Dysarthria | Normal | Dysarthria | Normal |
| Sample 1 | 565 | 528 | 1.063 | 1.519 |
| Sample 2 | 421 | 440 | 1.681 | 1.812 |
| Sample 3 | 496 | 544 | 1.621 | 1.657 |
| Sample 4 | 450 | 406 | 1.806 | 1.614 |
| Average | 483 | 480 | 1.543 | 1.651 |

Based on Table 11, it could be seen that the F1 average of the phoneme /e/ produced by dysarthria samples was found to be higher than that produced by non- dysarthria samples. It means that the tongue position of the dysarthria samples when producing the phoneme /e/ in the syllable /re/ was lower than the tongue position of the non-dysarthria samples. Then, based on the F2-F1 average, it can be seen that the position of the tongue of the non-dysarthria samples was further forward than that of the dysarthria samples since the F2-F1 average of the phoneme /e/ in the syllable /re/ by the non-dysarthria samples was found to be higher.

Since the comparison of the tongue position when producing syllable /re/ between the dysarthria samples and the non-dysarthria samples was found to be similar to most of the comparisons of the tongue position when producing the five syllables, then the comparisons were valid to use as a parameter. In case most of the readers are confused regarding why the tongue position should be estimated from the measurement of the five syllables instead of merely measuring the syllable /re/ alveolar trill. The one and the only reason to avoid comparing the syllable /re/ or phoneme /r/ produced by dysarthria and non-dysarthria samples was that the dysarthria samples could not produce a so-called right phoneme /r/ alveolar trill. They mostly substituted phoneme /r/ alveolar trill into other phonemes such as /w/, /rkh/, or /l/. Therefore, the researcher should find another way to bring better results.

Regarding the tongue positions, in which the dysarthria samples tended to have lower and further backward tongue positions when producing the five syllables, it indicated that the tongue was not able to reach or adhere to the alveolar ridge properly. This condition might be caused by three things, namely the distance between the tip of the tongue to the alveolar ridge was not ideal, the tongue tie was too thick, or the inflexibility of the tongue muscles to move inside the oral cavity.

**Spectrum**

In addition to the frequency, intensity, and formant, the spectrum of the sound can also be an indicator to refer to the condition of the human speech organ.

Spectrum is the sound feature that is displayed in the form of a figure or spectrogram. Based on the observation on the spectrum of the phoneme /r/ alveolar trill, the tongue condition of the dysarthria samples and non-dysarthria samples could be estimated. The spectrum of the phoneme /r/ alveolar trill produced by one of the dysarthria samples and non-dysarthria samples can be seen as follows.

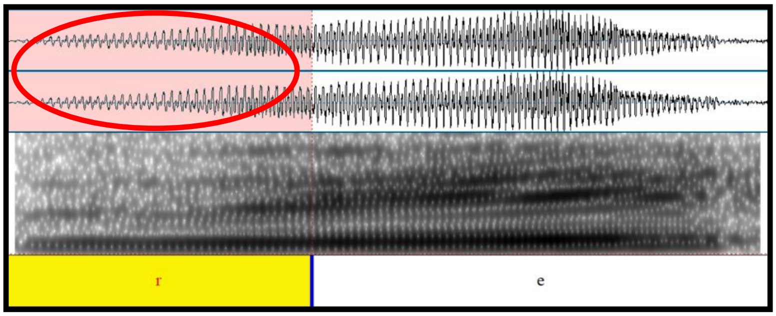


Figure 1. The spectrum of phoneme /r/ alveolar trill by dysarthria sample

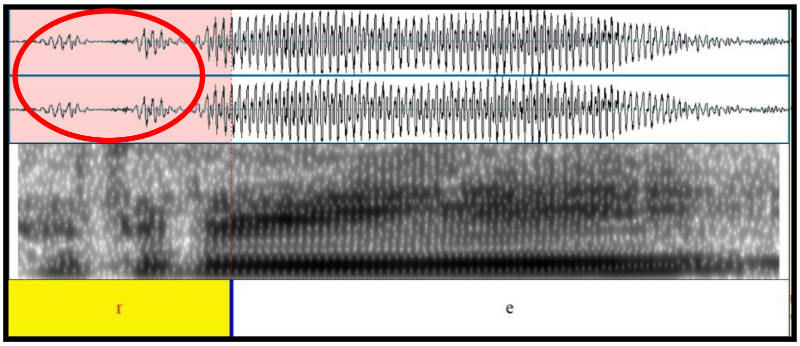


Figure 2. The spectrum of phoneme /r/ alveolar trill by non-dysarthria sample

Based on the two figures above, it could be observed that the spectrum of the phoneme /r/ alveolar trill produced by the dysarthria sample was completely different from that produced by the non-dysarthria sample. In Figure 1, the spectrum of the phoneme /r/ alveolar trill and the phoneme /e/ did not show a significant difference. This indicated that both sounds produced were not sounds with a truly different category. This happened because the dysarthria sample who produced the phonemes in Figure 1 substituted the phoneme /r/ alveolar trill into phoneme /w/. Therefore, the spectrum of phoneme /r/ alveolar trill in Figure 1 showed such spectrum that looked similar to the vocoid phoneme spectrum since the phoneme /w/ is one of the semi-vocoid phonemes.

It should be noted that the contoid phonemes' spectrums tend to be thin, short, and have an irregular pattern which is caused by the absence of tone or harmony. In contrast to the contoid phonemes' spectrums, the vocoid phonemes' spectrums have the characteristics of thick, long, and regular harmonies, just like the spectrums of both phonemes /e/ in the two figures.

The real spectrum of phoneme /r/ alveolar trill could be seen In Figure 2 since the phoneme was produced by a non-dysarthria sample. The jumping spectrum which was displayed there indicated vibrations that should have been involved during the production of phoneme /r/ alveolar trill. Based on the spectrum features, it seemed that one of the factors that prevent dysarthria sufferers to produce proper phoneme /r/ alveolar trill was the inflexibility of the tongue muscles to vibrate.

**Therapy suggestions**

Based on the three acoustic features analyses, it could be said that the two most prominent factors that caused the condition of phoneme /r/ alveolar trill dysarthria were the inflexibility of the tongue muscles to vibrate and the inability of the tongue to reach or adhere to the alveolar ridge properly when producing sounds. In case the inability of the tongue to reach or adhere to the alveolar ridge is caused by a too thick tongue tie, the sufferers are recommended to get a surgical procedure first before trying any therapy.

Considering the two obstacles, some suggestions for therapy are proposed to accelerate the improvement of dysarthria. First, the sufferers could practice flexing the muscles by routinely pronouncing the alveolar phonemes, namely /d/, /l/, /n/, /s/, /t/, and /z/, which are combined with vocoid phonemes, namely /a/, /i/, /u/, /e/, /o/, and /ə/. The combination could be /de/, /le/, /ne/, /se/, /te/, /ze/, or /du/, /lu/, /nu/, /su/, /tu/, /zu/. By pronouncing the alveolar phonemes that are combined with the vocoid phonemes, it could train and stretch the tongue to reach the alveolar ridge properly. Further, the combination of alveolar phonemes with vocoid phonemes could train the tongue muscles to move actively from the upper part to the bottom part of the oral cavity as well as to move forward and backward continuously. Second, the sufferers could also practice pronouncing the phoneme /r/ alveolar trill by combining the phoneme /r/ alveolar trill with phoneme /e/ particularly. For example by pronouncing /re/ or /ere/. The reason is that the pronunciation of the phoneme /e/ could make the jaws move backward while the tip of the tongue moves forward. The condition could shorten the distance between the tip of the tongue and the alveolar ridge. Third, the dysarthria sufferers were also suggested to drink more water, so that the articulators would always be hydrated and stay flexible. With those therapy suggestions, it was hoped that the tongue of the sufferers would become more flexible to vibrate and could reach the alveolar ridge properly.

**Conclusion**

Based on the analyses above, the researchers could draw some conclusions. First, the inability in producing certain sounds could be learned from the acoustic features of the phonemes produced by the sufferers. In this case, the inability to produce phoneme /r/ alveolar trill can be detected by observing the differences in the frequency, intensity, formant, and spectrum of the alveolar and vocoid phonemes produced by both dysarthria and non-dysarthria samples. Second, the sounds which were produced at the same place of articulation will have similar quality. If the place of articulation where the sounds were produced had problems, then the problems would affect all of the sounds produced in that place. However, the interplay gave guidance that therapy could be started from the easiest sound produced in the place of articulation. Therefore, in improving the quality of the phoneme /r/ alveolar trill, the therapy could be started by improving the quality of other alveolar phonemes such as /d/, /l/, /n/, /s/, /t/, and /z/. This allowed building such a gradual and regular therapy pattern. Third, the part of articulators that played an important role in the production of the phoneme /r/ alveolar trill was the tongue, particularly the flexibility of the tongue and the tongue tie. Fourth, therapy suggestions that could be proposed to accelerate the improvement of dysarthria were (1) the sufferers could practice flexing the muscles by routinely pronouncing the alveolar phonemes, namely /d/, /l/, /n/, /s/, /t/, and /z/, which are combined with vocoid phonemes, namely /a/, /i/, /u/, /e/, /o/, and /ə/ to stretch the tongue to reach the alveolar ridge properly and to train the tongue to move actively from the upper part to the bottom part of the oral cavity as well as to move forward and backward continuously, (2) the sufferers could also practice pronouncing the phoneme /r/ alveolar trill by combining the phoneme /r/ alveolar trill with phoneme /e/ such /re/ or /ere/ since the pronunciation of the phoneme /e/ could shorten the distance between the tip of the tongue and the alveolar ridge, (3) thE sufferers were also suggested to drink more water so that the articulators would always be hydrated and stay flexible.

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