Psychoacoustic Study: 
Mapping of Language Deviation in Down Syndrome Children

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Abstract— Down syndrome is an underdevelopment physical and mental condition in children caused by chromosomal development abnormalities. Signs that show from down syndrome may vary from the invisible, slightly visible to a typical sign of down syndrome. The most typical sign of children with Down syndrome is the children’s underdevelopment of physical and mental condition (Olds, London, & Ladewig, 1996). Down syndrome sufferers are very easily recognizable by the presence of a prominent physical appearance where the head is relatively smaller than normal head (microcephaly) with (anteroposterior) the head flattened. On the face usually can be seen from the flat and low bridge nose, the mouth is smaller and the tongue slightly larger and sometimes protrudes out (macroglossia). The eyes slant upwards and have an extra fold of skin on the upper eyelid (epicanthic folds). Down Syndrome children also have sensory difficulties, speaking barriers, and verbal development. This study aims to identify the speech impairment disorder in Down Syndrome children. The research method used is mix methods. The data source is conversation which produced by Down Syndrome children’s aged 8-10 years old. The results showed that DS children had an indication of disruption (1) voice production, i.e. noise production to communicate verbally, (2) disruption in speech sounds, i.e. disruption in phoneme production on certain vowels and consonants, and (3) fluency and prosody, i.e. pitch production, duration and formants.

Keywords— down syndrome; voice production; speech sounds; formants; prosody

I. INTRODUCTION

Language difficulties are common to Down Syndrome (DS) children. Their language skills are usually below other children’s mental abilities in general. Unclear speech and false errors are more common in DS children than others. The speaking barrier is getting worse if there is mental retardation, motor oral deficit, sensory deficit, or environmental deprivation. Often, language disorder in DS children is associated with the mental level of the children’s abilities so that their language development does not fit the context of ongoing communication.

DS children is also obstructed in academic ability. Specifically this academic barrier is the impact of the limitations of cognitive ability. Ashman (1983) suggests that children who are classified as having mild and moderate mental retardation have problems in processing information to integrate or generalize information. Early stimulation is believed to improve the intelligence of DS children. One of the medical seminars stated that children who experience DS have a low Intelligence Quotient (IQ). However, now, by giving regularly and intensively early detection and stimulation, the intelligence of children with DS can be improved sub normally between 70-90.

Down Syndrome (DS) is a genetic condition that causes a child’s inability to learn because of his physical characteristics. Children with Down syndrome are characterized by limited mobility due to their weak muscle tissue (hypo- tonia), protruding eyes, small mouths with tongue sticking out, and flat rear heads. These children also have limited cognition making it difficult to process information that related to routines. They also have limitations to adapt to the environment and tasks, and tend to rely on others (Lewis, 2000).

One of the disruption inherent in DS children is a language disorder associated with physical characteristics in the linguistic sound organ and disruption of the cognitive aspects. Therefore, language development in DS children shows significant differences with children who develop normally. Based on data sources in the field mentioned that the prevalence of DS children tends to increase, with the calculation between 700 births or 1 in 800-1000 births and estimated there are four million DS sufferers worldwide, and 300 thousand cases in Indonesia. Increased DS prevalence and surrounding disorders are increasing, but in-depth studies of language disorders, especially phonology and phonetics have not been done so these area are interesting to examine.

The Stoel-Gammon (2001) study of language disorders in DS children shows that these children have a phonological
disorder or language system, such as cluster reduction, final consonant removal, stop, prevocalic voice, gliding, vocalization, and final consonant devoicing. These speech disorders, detected from mild to severe levels. Rupela and Manjula (2007) examined the phonotactic pattern of Down Syndrome children and compared them with Specific Language Impairment (SLI) children and found that DS children were only able to use simple phonotactic patterns and often eliminate the attributes of vowel sounds or consonant sounds or characterized by atypical speech error. Some researchers consider that atypical error of speech tends to be caused by a delay in the development of phonological systems in children.

Based on these descriptions, there is a relationship between the phases of children’s developmental disorders, language development disorders, and academic disorder in DS children. The condition of Down Syndrome that is attached to a child will affect the level of maturity of its development that distinguishes it from the development of children in general. However, by having the knowledge to recognize the normal developmental stage that children go through in general, parents can get the disorder description in each child, especially the language disorder.

This study aims to provide an overview of the ability of sound language production and formant structure in children with Down Syndrome using acoustic phonetic analysis. Phonetics is the study of how the sound of the language is formed, the frequency of vibration, intensity, and its timbre, and how the sound of the language can be accepted by the ear. Based on the breadth of the scope of phonetic studies, phonetics are divided into three types, namely organic phonetics, acoustic phonetics and auditor phonetics (O’Grady and Archibald, 2000: 13). According to Yulianto and Tirtawijaya (1989: 25) acoustic phonetics is the most exact phonetic because it is based on the discovery of physics and mathematical discoveries. Acoustic phonetics investigates the sound waves that vibrate the air around which the ear hears as the language sounds. Malmberg, Bertil (1963: 20) says that what is learned in the field of acoustic phonetics is the sound of language in terms of sound as physical phenomena, such as studying the frequency of vibration, amplitude, intensity, and its timbre (fig. 1)

- articulatory phonetics
- acoustic phonetics
- auditory phonetics

Fig. 1. Phonetic domain

According to Marsono (1999: 3) this acoustic phonetic has much to do with physics in phonetic laboratories, this is also useful in producing telephone calls, recording records and so on. To measure the frequency of air vibrations in the form of waves as a used tool called oscillography. Similar tools then emerge, such as spectrograms, which allow us to know the acoustic quality of the said sounds to be analyzed (Yusuf, Suhendra, 1998: 35). Next comes a tool called Praat program. When a speech is recorded and then inserted into Praat program and from the sound wave, it can be recognized the characteristic of speech sound image.

One of the analysis that will be done is formant analysis. Formants are the resonant frequencies of the filter, the vocal tract (articulator) that continues and filters out the vowel, consonant, or word output. Cohn in Aronoff and Janie (2003), explains that the vowel sounds in general have characteristics in terms of the height of the tongue or jaw (high, medium, low) and the moving part of the tongue (front, center, back). In addition, the vowel sounds appear because the utterance is not too close so the airflow does not experience any obstacles (Ladefoged and Johnson, 2011). Ladefoged and Johnson (2011) explain that vowel sounds are better explained by explanation of acoustic structures than by explaining the effect of articular movements.

The production ability of speech sounds that emphasized in this research is the sound of language which is part of the phonological and phonetic processes. Therefore, the theoretical frames of this study are theories summarized in the synchronous study in acoustic, articulatory, and psychoacoustic phonetic studies.

II. RESEARCH METHOD

The research method used is experimental phonetic analysis. Source of data used is the speech production by children with down syndrome, age 8 years old. The research method used is acoustic study (van Zanten and van Heuven, 1983). The production process is done through recording of DS children. The recording process is done using a Sony recorder with an ideal recording distance and natural. Data were analyzed using Praat software (formant analysis), to generate F0 value, formant value, and duration value on each word produced. The research flowchart is described in Figure 3.
III. RESULT AND DISCUSSION

Based on the findings of data obtained from this study, it can be explained that the ability of DS children in expression is low because they can only say something at the level of words or syllables, not to the level of morphology, syntax or discourse. The following is the result of acoustic analysis on the word ‘bahu’ (shoulder).

Fig. 3. Flowchart Analysis

Fig. 5. Analysis of pitch movement on the word ‘bahu’ (shoulder)

Fig. 6. Formant analysis of the word ‘bahu’ (shoulder)

Fig. 7. Acoustic analysis of the word ‘mata’ (eyes)

Examples of words produced in this study are the words ‘mata’ (eye), ‘dada’ (chest), ‘lengan’ (arms), ‘tangan’ (hands), ‘kepala’ (head), and ‘kelapa’ (coconut). ‘mata’ (eyes), ‘dada’ (chest), ‘lengan’ (arms), ‘tangan’ (hands) have two syllables of CV-CV and CV-CV. The word ‘kepala’ (head) and ‘kelapa’ (coconut) have 3 syllables, namely CV-CV-CV.

The result of acoustic analysis on said data is described in figure 7.
The result of the acoustic analysis of each word is described in the following:

**Table 1. F0 value of the word ‘dada’ (chest), ‘mata’ (eye (s)), and ‘paha’ (thigh)***

<table>
<thead>
<tr>
<th>Words said</th>
<th>Mean F0 (Hz)</th>
<th>F0 minimum (Hz)</th>
<th>F0 maximum (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dada</td>
<td>273.536</td>
<td>192.898</td>
<td>321.777</td>
</tr>
<tr>
<td>Mata</td>
<td>249.811</td>
<td>152.318</td>
<td>281.903</td>
</tr>
<tr>
<td>Paha</td>
<td>260.839</td>
<td>237.283</td>
<td>280.414</td>
</tr>
</tbody>
</table>

F0 value analysis on the table above explains that the word ‘paha’ (thigh) has the highest F0 value compared to the word ‘dada’ (chest) and ‘mata’, but the difference is not significant. The lowest minimum F0 value is the word ‘mata’ (eye(s)), and the highest minimum F0 value is found in ‘paha’ (thigh). The lowest minimum F0 value is found in ‘paha’ (thigh), whereas the highest maximum value is found in the word ‘dada’ (chest).

**Table 2. F0 value of the word ‘kepala’ (head) and ‘kelapa’ (coconut)**

<table>
<thead>
<tr>
<th>Words said</th>
<th>Mean F0 (Hz)</th>
<th>F0 minimum (Hz)</th>
<th>F0 maximum (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kepala</td>
<td>856.979</td>
<td>1599.721</td>
<td>2975.511</td>
</tr>
<tr>
<td>Kelapa</td>
<td>863.898</td>
<td>1650.006</td>
<td>2768.213</td>
</tr>
</tbody>
</table>

Acoustic analysis on the word ‘kepala’ (head) is 856.979 Hz, while the word ‘kelapa’ (coconut) has a value of 863.898 Hz. The value of F2 on the word ‘kelapa’ (coconut) is higher than the word ‘kepala’ (head).

**Table 3. F0 value of the word ‘tangan’ (hands) and ‘lengan’ (arms)**

<table>
<thead>
<tr>
<th>Words said</th>
<th>Mean F0 (Hz)</th>
<th>F0 minimum (Hz)</th>
<th>F0 maximum (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tangan</td>
<td>148.856</td>
<td>94.622</td>
<td>205.070</td>
</tr>
<tr>
<td>Lengan</td>
<td>182.549</td>
<td>75.444</td>
<td>260.765</td>
</tr>
</tbody>
</table>

The F0 value analysis on the table above explains that the word ‘lengan’ (arms) has a higher F0 value than the word ‘tangan’ (hand), while the minimum F0 value of the word ‘tangan’ (hand) is lower than the word ‘lengan’ (arms). The value of F0 of the word ‘lengan’ (arms) is lower than the word ‘tangan’ (hand).

**Table 4. Formant analysis of the word ‘dada’ (chest), ‘mata’ (eye (s)), and ‘paha’ (thigh)**

<table>
<thead>
<tr>
<th>Words said</th>
<th>F1 (Hz)</th>
<th>F2 (Hz)</th>
<th>F3 (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dada</td>
<td>714.096</td>
<td>1680.952</td>
<td>3774.428</td>
</tr>
<tr>
<td>Mata</td>
<td>923.803</td>
<td>1766.375</td>
<td>2721.560</td>
</tr>
<tr>
<td>Paha</td>
<td>974.323</td>
<td>1841.008</td>
<td>2883.671</td>
</tr>
</tbody>
</table>

F1 value analysis on the word ‘dada’ (chest) is 714.096 Hz, ‘mata’ (eye (s)) is 923.803 Hz, and ‘paha’ (thigh) is 974.323 Hz. The value of F2 on the word ‘dada’ (chest) is 1680.952 Hz, the word ‘mata’ (eye (s)) is 1766.375 Hz, and the word ‘paha’ (thigh) is 1841.008 Hz.

**Table 5. Formant analysis of the word ‘kepala’ (head) and ‘kelapa’ (coconut)**

<table>
<thead>
<tr>
<th>Words said</th>
<th>F1 (Hz)</th>
<th>F2 (Hz)</th>
<th>F3 (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kepala</td>
<td>856.979</td>
<td>1599.721</td>
<td>2975.511</td>
</tr>
<tr>
<td>Kelapa</td>
<td>863.898</td>
<td>1650.006</td>
<td>2768.213</td>
</tr>
</tbody>
</table>

Acoustic analysis on the word ‘kepala’ (head) is 856.979 Hz, while the word ‘kelapa’ (coconut) has a value of 863.898 Hz. The value of F2 on the word ‘kelapa’ (coconut) is higher than the word ‘kepala’ (head).

**Table 6. Formant analysis of the word ‘tangan’ (hands) and ‘lengan’ (arms)**

<table>
<thead>
<tr>
<th>Words said</th>
<th>F1 (Hz)</th>
<th>F2 (Hz)</th>
<th>F3 (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tangan</td>
<td>716.411</td>
<td>1466.868</td>
<td>2368.426</td>
</tr>
<tr>
<td>Lengan</td>
<td>740.017</td>
<td>1617.333</td>
<td>2600.765</td>
</tr>
</tbody>
</table>

The acoustic analysis on ‘tangan’ (hand) is 716.411 Hz, while the word ‘tangan’ (arm) has a value of 740.017 Hz. The value of F2 in said ‘tangan’ (arm) is higher by 1617.333 compared to the word ‘tangan’ (hand) (1466868).
The low intelligence level of the study subjects had an effect on understanding and working mechanism of the brain perception rates and knowledge production of speech on the children. The DS children noted that the vowels of 

\[ \text{[a]}, \text{[i]}, \text{[u]}, \text{[e]}, \text{[o]} \] prove that the articulation abilities in normal children and DS children are significantly different. Knowing the weakness of motion articulator is important for speech therapy in children with Down syndrome. The weakness disposition of the articulator's motion is based on sounds that have difficulty involving the motion of speech devices, not the consonant sounds themselves. So, what is treated is sounds that involve the motion of a speech implements, for example the child has difficulty in sound dorso velar means that the things to be trained are all sounds involving the articulator motion of the tongue and soft palate.

<table>
<thead>
<tr>
<th>WORDS</th>
<th>DURATION (SC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DADA</td>
<td>0.592138 0.398701</td>
</tr>
<tr>
<td>TOTAL OF DURATION</td>
<td>0.990839</td>
</tr>
<tr>
<td>MATA</td>
<td>0.638582 0.323817</td>
</tr>
<tr>
<td>TOTAL OF DURATION</td>
<td>1.189751</td>
</tr>
<tr>
<td>PAHA</td>
<td>0.657018 0.427154</td>
</tr>
<tr>
<td>TOTAL OF DURATION</td>
<td>1.084172</td>
</tr>
</tbody>
</table>

The longest duration analysis is the word ‘mata’ (eye(s)) for 1.189751 sc, while the lowest duration is the word ‘dada’ (chest) for 0.990839 sc.

<table>
<thead>
<tr>
<th>WORDS</th>
<th>DURATION (SC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TANGAN</td>
<td>0.323817 0.489521</td>
</tr>
<tr>
<td>TOTAL OF DURATION</td>
<td>0.813424</td>
</tr>
<tr>
<td>LENGAN</td>
<td>0.482375 0.490783</td>
</tr>
<tr>
<td>TOTAL OF DURATION</td>
<td>0.197914</td>
</tr>
</tbody>
</table>

The duration for the word ‘tangan’ (hands) is longer (0.813424 ms) than the word ‘lengan’ (arms) (0.197914 ms). The duration of the syllable ‘–ngan’ (‘tangan’) that appears in the second syllable is 0.489521 sc, not significantly different in the ‘–ngan’ syllable (lengan), is 0.490783.

The results of the above acoustic analysis explain that the children of DS that observed are able to produce speech with good quality. There are some disruptions in producing consonants ((p and t), but the meaning is still well received.

Speech production disorders in the sound sequence produced by DS children indicate a close relationship between perception rates and knowledge production of speech on the child. The low intelligence level of the study subjects had an effect on understanding and working mechanism of the brain...
References


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