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Effect of gap detection threshold on consistency of speech in children with speech sound disorder

Fateme Sayyahi, Zahra Soleymani, Mohammad Akbari, Mahmood Bijankhan, Behrooz Dolatshahi

Tehran University of Medical Sciences
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Abstract

Background and Aims: The nature of the suggested relationship between gap detection threshold and speech sound disorder, stated in the previous studies, has not been explored. The present study was identified to examine the specific effect of gap detection threshold on the consistency of speech errors, as one clinical marker of children with speech sound disorder.

Methods and Procedures: The participants were five to six years of age with and without speech sound disorder. They were categorized into three groups of typical, consistent, and inconsistent. phonetic gap detection threshold test was used for this study, which is a valid test comprised six syllables with inter-stimulus intervals between 20 to 300 ms. The participants were asked to listen to the recorded stimuli and determine whether they heard one or two sounds.

Outcomes and Results: The results showed that there was a highly significant difference between inconsistent group and the two other groups (p= 0.00), but no significant difference was found between typical and consistent groups (p= 0.55).

Conclusions and Implications: The relationship between gap detection threshold and speech sound disorder is specifically related to the consistency of speech errors. It is suggested that a high gap detection threshold would result in inconsistency in speech.
What this paper adds? The effect of auditory processing on the speech sound disorder has been studied extensively, but the results are with contradictions. The nature of the relationship between auditory processing and speech errors is not clear. Clarification the details of the effect of the auditory processing on the speech errors needs specification in examining the children with speech sound disorder, but most studies examined the children with speech sound disorder as one heterogeneous group. To the knowledge of the authors of the current study, this is the first study to examine the effect of gap detection threshold on speech errors in categorized groups of children with speech sound disorder based on the consistency of speech errors. The results of the present study suggest that there is a significant relationship between gap detection threshold and consistency in speech. It is suggested that one underlying deficit of the inconsistency in speech of children with speech sound disorder is the high gap detection threshold.

Keywords: speech sound disorder; consistency of speech; gap detection threshold
1. Introduction

Speech sound disorder (SSD) is a common developmental disorder in children that prohibits the child producing accurate speech. Guenther (1995) suggests that the achievement of accurate speech is related to construct adequate perceptual knowledge of speech sounds by mapping between the perception of acoustic patterns of speech sounds and productive gestures of speech. The acoustic patterns of perceived speech sounds allow the child to discover articulatory patterns in phonetic contexts and would lead to perceptual knowledge of speech sounds as the reference for accurate speech performance.

Considering the effect of auditory perception on the accurate speech performance, the relationship between auditory processing and SSD has been studied extensively, which has been with contradictions in the results. Schissel (1980) and Supple (1983) suggested that there is no significant relationship between auditory discrimination and speech errors of children with SSD. In contrast, Jamieson & Ravchew (1992) examined the effect of auditory training on accurate production of speech errors of a small group of children who had production errors in /ʃ/. Only one of the participants did not show improvement and the rest of the participants could achieve the correct production under the auditory training. In another study (Thyer & Dodd, 1996), children were asked to listen to competing sentences contralaterally or ipsilaterally, and show the
perceived message with the pictures. The responses of the children with SSD were not significantly different with typically-developing children and Thyer & Dodd (1996) suggested that the auditory perception is not effective in SSD, but Edwards, Fox & Rogers (2002) found that performance of children with SSD in auditory discrimination tasks was poorer than typically-developing children. The same results were achieved by Muniz, Roazzi, Schochat, Teixeria, & de Lucena (2007) who studied the relationship between auditory temporal processing and SSD. Participants with SSD showed higher thresholds in detecting the temporal gaps between pure tones compared to children without SSD. Recent studies confirmed the effect of auditory temporal processing, especially the gap detection threshold on the speech performance of children with SSD (Liu and Whitesell, 2008; Muluk, Yalcınkaya & Keith, 2011; Vilela, Barrozo, Pagan-Neves, Sanches, Wertzner & Carvallo, 2012).

One explanation for the observed contradiction in the results of the studies listed above has stated by Edwards et al., (2002) who indicated that although there is a relationship between auditory discrimination and SSD, the relationship is complex and it is not dependent on the speech errors of children with SSD. The relationship between auditory processing and SSD has not been found consistently in specific speech errors (Schissel, 1980; Supple, 1983; Jamieson and Ravchew, 1992; Thyer & Dodd, 1996; Edwards et al., 2002), but the effect of auditory perception on SSD has been observed in discriminating temporal gaps between the speech sounds (Muniz et al., 2007; Liu and Whitesell, 2008; Muluk et al.,...
2011; Vilela et al., 2012). Thus, clarification the details of the effect of the auditory processing on speech sound disorder needs specification in examining the children with speech sound disorder. The difficulty of auditory discrimination of children with SSD is not significantly related to specific speech errors, but as it has been studied in recent studies, the deficit could be in detecting the correct boundaries between adjacent speech sounds through speech stream.

The nature of speech between and within speakers is highly variable and transient (Munson, Edwards & Beckman, 2005). On the other hand, auditory temporal processing of the speech signal is limited to less than 250 ms (Sable, Gratton & Fabiani, 2003). The child has a narrow temporal window to detect each phonetic segment in articulatory transitions and perceives the speech sounds in variable phonetic contexts (Goldinger & Azumar, 2004). If the gap detection threshold is high for the narrow temporal window of the auditory processing, it would prohibit the child to detect correctly the boundaries between speech sounds in variable phonetic contexts (Ben-Artzi, Fostick & Babkoff, 2005). Thus, according to Guenther (1995) constructing the perceptual map for the temporal parameter of perceived speech sounds would be with difficulties because of temporal delay in detecting the gaps between speech sounds.

The previous studies indicated the relationship between the gap detection threshold and SSD, but one constraint of the previous studies is that the participants with SSD were examined as one heterogeneous group. Thyer
Dodd (1996) stated that to prevent contradiction in the responses of children with SSD, participants should be categorized based on the consistency in speech into two groups: children with consistent speech errors and children with inconsistent speech errors. Consistency in speech is one of the most influential factors on speech errors of children with SSD (Forrest, Elbert & Dinssen, 2000), but in the previous studies that examined the effect of gap detection threshold on SSD, the relationship between detection the boundaries between speech sounds in children with SSD and the consistency of the speech errors has not been clarified.

Muluk et al. (2011) and Vilela et al. (2016) reported variability in the results within participants with SSD. In the study of Muluk et al. (2011), some participants with SSD showed variability in thresholds of detection the gaps between sounds. The speech of those children with variable gap detection threshold was also inconsistent including clear words and intelligible phonetic segments. The participants had not been categorized based on the consistency in speech, but the results suggested that the gap detection threshold is apparently related to the consistency of speech errors of children with SSD.

Considering the results of the previous studies, this study was motivated by this fact that the specific effect of gap detection threshold on the categorized groups of children with SSD has not well been elucidated. Thus, the aim of this study was to compare gap detection threshold of children with SSD that were categorized based on the consistency in
speech. The authors had no prior assumption about the effect of gap detection threshold on the consistency of speech errors in children with SSD.

2. Method

1. Participants

Participants were monolingual Persian-speaking five to six years of age children. Forty-three children with typical development and 52 children with SSD entered in the present study. Children with typical development were recruited from kindergartens using the simple sampling method. Children with SSD were clients of speech-language pathology clinics of Tehran University of Medical Sciences selected based on the percentage of consonants correct which was between 50 and 65. According to the metric values of Shriberg, Aram & Kwaitkowski (1997), the severity of speech errors in all participants with SSD in this study was moderate to severe.

Oral motor difficulties, language disorder and hearing impairment were the exclusion criteria of this study. All participants passed hearing screenings for pure tones at 0.5, 1.0, 2.0, 4.0, and 8.0 kHz presented at 20 dB HL separately to each ear. Language development of participants was diagnosed by calculating the mean length of utterance. The achieved scores were compared to the standard scores of Persian-speaking children (Zanjani, Ghorbani & Keykha, 2006). A total of 12 of the participants (three
typical and nine with SSD) were excluded from the study because they were diagnosed with oral-motor difficulty and language impairments.

Categorization of children with SSD into consistent and inconsistent groups was employed by the inconsistency index of Persian phonology test (Zarifian, Modarresi, Tehrani, Kazemi, & Salavati, 2013). This index is a diagnostic test for children aged three to six years comprised 27 pictures with different syllabic structures. The child is asked to name the pictures three times. The percent of the inconsistency is calculated for produced names for the pictures. Children with higher inconsistency percents than 33.3 are diagnosed with inconsistent speech errors.

The final participant pool comprised 85 children; 40 typical (27 boys and 13 girls), 17 inconsistent (11 boys and six girls), and 28 consistent (16 boys and 12 girls) participated in the present study. The research was approved by the ethics committee of Tehran University of Medical Sciences in Iran. The children attended to the study that their parents signed the consent forms.

2. Materials

Phonetic gap detection threshold test (P-GDT) comprises six syllables ([zi], [çi], [mi], [li], [ji], [bi]) and five single speech sounds ([z], [i], [l], [j], [m]) recorded by an adult native Persian-speaker female in a sound-proof room using the SM10A model of Shure microphone. The consonants were selected based on the age of acquisition of speech sounds (Keshavarz, 2002; Tyler, Williams & Lewis, 2006), as representatives of the
categories of consonants: [z] form fricatives, [ç] from affricates, [m] from nasals, [l] from liquids, [j] from glides and [b] from stops. The purpose of inserting the single speech sounds were prevention of considering all stimuli as two sounds.

The stimuli were designed in five steps of inter-stimulus intervals (ISI) including 20, 50, 100, 200 and 300 ms selected based on detecting steps for speech stimuli (Gordon & Poeppel, 2001). There were five ISIs for each syllable created by Praat 5.0.08 (Boersma & Weenink, 2008). The syllables were designed to present three times with each of the ISIs. Thirty syllables (five ISIs for each of six syllables) as well as five single speech sounds were prepared in a random order to present the participants.

P-GDT has high concurrent validity (0.89, p < 0.001) for three to six years of age children, compared to the results of randomized gap detection threshold of pure tones at 0.5 to 4 kHz.

3. Procedure

The stimuli were presented to the participants using a SoundBlaster card and TDH-39 headphones. The examiner asked participants to listen to the recorded stimuli and determine if they heard one or two sounds. The children listened to each stimulus once and responded using logos. The examiner registered the responses on the answer sheet.
The participants should detect each of six syllables as two sounds for three times in a specific ISI as the gap detection threshold for the syllable. For example, the child should discriminate [b] and [i] in the syllable [bi] with 100 ms ISI for three times to register 100 ms as the gap detection threshold for [bi]. The mean of detection threshold for each syllable and each group of the study (typical, consistent, and inconsistent) was calculated. One-way ANOVA and post-hoc Tukey test were employed to detect the difference between participants in three groups.

3. **Results**

Table 1 presents P-GDT results for each syllable in all groups. The range of gap detection threshold for the typical group was 47.22-115.28 ms (M: 89.04; SD: 11.94), for the consistent group was 54.92 - 198.57 ms (M: 141.06; SD: 34.9) and it was 216.66 - 287.56 ms (M: 258.82; SD: 16.36) for the inconsistent group.

<table>
<thead>
<tr>
<th></th>
<th>[zi]</th>
<th>[çi]</th>
<th>[mi]</th>
<th>[li]</th>
<th>[ji]</th>
<th>[bi]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical</td>
<td>32.59 ± 21.58 ms</td>
<td>32.22 ± 21.29 ms</td>
<td>55.55 ± 11.43 ms</td>
<td>140.74 ± 43.61 ms</td>
<td>209.25 ± 25.06 ms</td>
<td>63.88 ± 18.3 ms</td>
</tr>
<tr>
<td>Consistent</td>
<td>60.71 ± 14.23 ms</td>
<td>85.71 ± 12.72 ms</td>
<td>105.71 ± 22.13 ms</td>
<td>242.85 ± 54.96 ms</td>
<td>214.28 ± 35.76 ms</td>
<td>157.14 ± 44.06 ms</td>
</tr>
<tr>
<td>Inconsistent</td>
<td>229.41 ± 34.96 ms</td>
<td>241.17 ± 42.87 ms</td>
<td>288.23 ± 29.48 ms</td>
<td>-a</td>
<td>-b</td>
<td>276.47 ± 24.22 ms</td>
</tr>
</tbody>
</table>

a. None of the children in the inconsistent group could discriminate [l] and [i] from each other in the syllable [li].
b. only two children in the inconsistent group could discriminate [j] and [i] from each other in the syllable [ji].

The minimum detected gap in the inconsistent group was in the syllable [zi] with 216.66 ms. The maximum detected gap was not specified for the inconsistent group because none of the children of this group, even in 300 ms ISI, could discriminate [l] and [i] as two sounds in the syllable [li] and only two of the participants could discriminate the syllable [ji] at 300 ms ISI between [j] and [i].

The distribution of gap detection thresholds within three groups of participants was normal (M: 142.69; SD: 67.99). The results of ANOVA showed that there was a significant difference in P-GDT results of the three groups (F\(_{\text{(2,82)}}\) = 122.6; p< 0.001). Table 2 presents the results of the post hoc Tukey test.

### Table 2. Post hoc Tukey test of P-GDT results for three groups of participants

<table>
<thead>
<tr>
<th>(I) Group</th>
<th>(J) Group</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical</td>
<td>Consistent</td>
<td>-3.37302</td>
<td>3.22680</td>
<td>.552</td>
<td>-11.1277 to 4.3817</td>
</tr>
<tr>
<td>Typical</td>
<td>Inconsistent</td>
<td>-152.14869*</td>
<td>3.61228</td>
<td>.000</td>
<td>-160.8298 to -143.4676</td>
</tr>
<tr>
<td>Consistent</td>
<td>Inconsistent</td>
<td>148.77568*</td>
<td>3.28406</td>
<td>.000</td>
<td>140.8834 to 156.6680</td>
</tr>
</tbody>
</table>

* The mean difference is significant at the 0.05 level.

As it is observed in Table 2, there was no significant difference between groups of typical and consistent, but the performance difference
was significant between groups of typical and inconsistent. The performance difference between groups of inconsistent and consistent was also significant that the inconsistent group discriminated the speech sounds with a higher threshold than typical and consistent groups.

4. Discussion

In the previous studies, it has been reported that children with SSD detect boundaries between sounds with higher thresholds compared to typically-developing children (Muniz et al. 2007; Liu and Whitesell, 2008; Muluk et al., 2011; Vilela et al., 2012), which examined participants as one heterogeneous. In the present study, children with SSD were categorized based on the consistency in speech. The aim of this study was to detect specific effect of gap detection threshold on the consistency of speech errors, as one of the most influential factors in SSD. Thus, children with consistent and inconsistent speech errors were compared to typically-developing children.

The results showed that gap detection thresholds of participants with SSD who had consistency in speech errors were not different from participants with typical development of speech. This group of children with SSD detected boundaries between speech sounds similar to children without SSD; whereas participants with SSD who had inconsistency in speech errors showed a significantly higher gap detection threshold compared to the two other groups of children including participants with consistent speech errors and participants with typical development of
speech. Thus, the gap detection threshold has an influence on the consistency of speech errors and it is not effective in all children with SSD.

The temporal window of auditory processing of a phonetic segment is less than 250 ms and the first 200 ms are critical to discriminate the speech sounds (Ben-Artzi et al., 2005; Sable et al., 2003). Children with consistent speech errors could detect speech sounds in a mean of 141.06 ms in this study and their gap detection threshold was adequate for the time-limitation of the auditory processing. Children with inconsistent speech errors discriminated the speech sounds in a mean of 258 ms. It means children with SSD that have inconsistent speech errors, loose the time for detecting the boundaries between the speech sounds correctly in the stream of speech. It indicates that as Edwards, Fourakis, Beckman, & Fox (1999) stated, fine temporal control in auditory processing would lead to consistency in the perceptual knowledge of temporal parameters of speech sounds that performs as a reference for productive gestures of speech.

The observed high gap detection threshold for children with inconsistent speech errors is in agreement with findings of Muluk et al. (2011). It was reported in the study of Muluk et al. (2011) that children who had a different gap detection threshold were the participants with inconsistent speech errors. Thyer & Dodd (1996) also categorized children with SSD based on the consistency in speech, but they did not observe a
significant difference in auditory processing of children with consistent and inconsistent speech errors. Both groups of children with SSD showed similar performance to typically-developing children. In the study of Thyer & Dodd (1996), central processing of perception of auditory messages was examined semantically and the children were not asked to discriminate distinctive boundaries between two sounds. Gravel & Wallace (1992) stated that phonetic context is influential on the inconsistency of perception and production of speech. The results of the current study showed that even children with SSD who have consistency in speech errors can discriminate boundaries between speech sounds in the time-limited auditory processing. Thus, it is suggested that the influence of auditory perception on the consistency of speech might be examined without the effect of phonetic contexts.

To the knowledge of the authors of the current study, this is the first study to examine the effect of gap detection threshold on the consistency of speech errors. The results of the present study suggest that one underlying deficit of the inconsistency in speech of children with SSD is high gap detection threshold. Children with inconsistent speech errors need more time to discriminate precisely the boundaries between speech sounds and it is in contrast to the time limitation of the auditory processing of the phonetic segments.

One constraint of this study was that it only identified the auditory temporal processing of the children with inconsistent errors. The
comparison between auditory perception and production performance did not employ in this study. It is recommended that future studies compare gap detection threshold with the inconsistency of the produced words.

5. Conclusion

Children with inconsistency in speech showed a higher gap detection threshold compared to the participants with consistency in speech. The relationship between gap detection threshold and speech sound disorder is specifically related to the consistency of speech errors. It is suggested that a high gap detection threshold would result in inconsistency in speech. Children with inconsistent speech errors cannot discriminate the speech sounds during the time-limited auditory processing and it could be suggested that the inconsistency in speech is a representation of the inconsistency in the auditory perception because of high gap detection threshold.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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