Segmental Speech Characteristics in Individuals with Auditory Neuropathy Spectrum Disorder

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Abstract

Speech primarily is learnt through auditory mode. Disruption in the auditory feedback, as in instances of cochlear hearing loss, is reported to have deleterious influence on speech production. Individuals with ANSD are reported to have severe speech perception deficits especially in spectral and temporal processing. In light of these findings, the present study hypothesized that long standing ANSD could affect speech production characteristics similar to that of cochlear hearing loss and thus aimed to investigate the segmental speech characteristics in individuals with ANSD. Twenty individuals each with ANSD and normal auditory abilities were recruited as participants. Word lists consisting of target vowels and consonants in initial and medial positions were prepared and speech samples of all participants were recorded. The samples were acoustically analyzed in terms of spectral and temporal parameters of speech. Results revealed significant differences between the two groups of participants for several acoustic measures, especially in case of plosives. The temporal measures such as voice onset time, burst duration and transition duration were among the variables which differed significantly between the two groups. The findings are discussed in light of the existing literature on speech perception and support the closed loop models of speech production. The study was a preliminary investigation on speech production in ANSD and highlights the importance of auditory feedback in speech production.

Keywords: *Auditory Neuropathy Spectrum Disorder (ANSD), Segmental, Vowels, Stops, Fricatives*

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Background

The disorder of auditory neuropathy spectrum disorder (ANSD) is characterized by absence of auditory brainstem responses in the presence of normal otoacoustic emissions and/or cochlear microphonics (Starr, Picton, Sininger, Hood, & Berlin, 1996; Sininger & Oba, 2001). Speech identification abilities of individuals with ANSD are reported to be disproportionate to the degree of their hearing loss (Zeng & Liu, 2006; Starr, Picton, Sininger, Hood, & Berlin, 1996) and are the cardinal characteristic of persons with ANSD. Speech perception abilities in this population appears to depend on the extent of distortion of temporal cues at suprathreshold levels rather than access to speech spectrum (related to audibility), unlike in patients with cochlear hearing loss (Zeng, Oba, Garde, Sininger, & Starr, 1999; Zeng, Kong, Michalewski, & Starr, 2005).

Davis and Hirsh (1979) reported that 1 out of 200 children with hearing impairment exhibit an audiological profile that is consistent with the contemporary diagnosis of ANSD. In an Indian study, Ajith and Jayaram (2006) estimated a prevalence of 1 in 183 (0.54%) among individuals with sensorineural hearing loss. The psychoacoustical, neurophysiological and perceptual aspects of individuals with ANSD have been well established in the literature (Sininger & Oba, 2001; Sininger, Hood, Starr, Berlin, & Picton, 1995; Kumar & Jayaram, 2006).

Disruptions in the perception of temporal cues are reported both in children and adults with ANSD (Kraus et al., 2000; Michalewski, Starr, Nguyen, Kong, & Zeng, 2005; Rance, McKay, & Grayden, 2004; Starr, Picton, Sininger, Hood, & Berlin, 1996; Zeng, Kong,

Michalewski, & Starr, 2005). In addition to the distortion of the spectral information seen in individuals with cochlear hearing loss (Moore, 1995; Rance, McKay, & Grayden, 2004), individuals with ANSD have relatively greater distortion in temporal information (Rance, McKay, & Grayden, 2004; Zeng, Kong, Michalewski, & Starr, 2005; Kraus et al., 2000). Hence, the input signal in the auditory system is expected to be lot more distorted in individuals with ANSD compared to those with cochlear hearing loss. This is supported by the findings of earlier studies that have reported speech perception in individuals with ANSD (Kumar & Jayaram, 2006; Rance, McKay, & Grayden, 2004; Starr, Picton, Sininger, Hood, & Berlin, 1996; Starr, Sininger, & Pratt, 2000; Zeng, Oba & Starr, 2001; Zeng & Liu, 2006).

Speech characteristics of adults with ANSD have not been systematically explored in any of the earlier western studies. However, Pooja and Sandeep (2009) found that speech of ANSD is perceptually abnormal, more so in its prosody. They also reported a significant high correlation between deficits in speech production and speech perception scores. However, it was only a preliminary attempt and did not include detailed evaluation of segmental or supra-segmental speech characteristics.

The present study aimed to investigate the influence of long-term disruption in the temporal characteristics of the input auditory signal, if any, on speech production in ANSD. Findings of the present study would help in verifying the Direction into velocities of articulators (DIVA) of speech production and will validate the findings of Pooja and Sandeep (2009). It is speculated that if the segmental characteristics of speech are found to be deviant, it will stress on the need for early identification and rehabilitation of ANSD. The specific deviant characteristics would further guide in understanding the relationship between the auditory cues and speech production. Further these might also aid in developing better management strategies, thus

improving the quality of life of individuals with ANSD. Thus, the present study was set forth to characterize the segmental speech production of individuals with ANSD. Specifically, the acoustic characteristics of vowel and consonant production were compared between the ANSD and control group.

Materials and Methods

Participants: Two groups of participants were included in the study; a clinical group (N= 20; Mean age = 25;6 years) comprising of individuals with a confirmed diagnosis of Auditory Neuropathy Spectrum Disorder (ANSD) and a control group (N= 20; Mean age = 24;4 years) consisting of individuals with normal hearing sensitivity. All the participants were native speakers of Kannada and knew to read as well as write Kannada.

Stimuli: Three short vowels /a/, /I/ and /U/ were considered and a wordlist of nine meaningful words with these vowels was prepared. In the consonats, eight plosives (four voiced & four unvoiced): /k/, /g/, /ʈ/, /ɖ/, /t̪/, /d̪/, /p/, /b/ and three fricatives /s/, /ʃ/ and /f/ were considered. A total of 16 meaningful words having plosives and 6 having fricatives, with each of the consonants in word initial and word medial position were prepared.

Procedure: Participants were instructed to read each of the target words embedded in a common carrier phrase. The speech samples were recorded using a Sony digital voice recorder (Model: IC recorder ICD-UX81) and analyzed using Praat software.

Analyses: The acoustic characteristics analyzed included F_0, F_1, F_2, bandwidth of two formants (F_1BW & F_2BW) and vowel duration (VD); burst duration (BD), closure duration (CD), voice onset time (VOT), transition duration (TD), extent of transition (EoT) and speed of transition (SoT) for stop consonants; and frication duration (FD), transition duration (TD), extent of

transition (EoT) and speed of transition (SoT) for fricatives. The group data was statistically analyzed using parametric test in SPSS (version 20.0) platform.

Results

The present study aimed to investigate the segmental characteristics of speech of individuals with ANSD, in particular the acoustic characteristics of vowels and consonants. The mean and standard deviation for each of the vowels and consonants is summarized in the tables below.

Table 1.1

Mean and standard deviation (SD) for acoustic parameters of the vowels /a/, /i/, and /u/

Vowel	Parameter	AN		Control	
		Mean	SD	Mean	SD
/a/	F_0	196.60	51.00	173.46	40.82
	F_1	666.78	123.26	688.24	53.55
	F_1BW	212.35	106.63	202.89	150.87
	F_2	1501.16	188.20	1555.93	128.34
	F_2BW	267.78	242.52	286.08	239.75
	VD	71.31	16.42	68.45	11.39
/i/	F_0	208.05	51.98	185.72	46.25
	F_1	457.14	252.93	672.65	510.42
	F_1BW	178.19	130.16	211.15	184.14
	F_2	2302.19	223.48	2458.90	155.91
	F_2BW	528.96	780.14	299.93	150.29
	VD	67.86	26.69	63.13	16.74
/u/	F_0	204.47	47.00	181.21	47.77
	F_1	499.03	133.40	554.53	184.89
	F_1BW	231.88	180.19	262.17	173.94
	F_2	1434.39	233.72	1624.39	351.24
	F_2BW	343.54	263.27	475.39	263.38
	VD	54.85	22.68	56.38	11.30

Table 1.2

Mean and standard deviation (SD) for acoustic parameters of plosives

Consonant	Parameter	AN		Control	
		Mean	SD	Mean	SD
/p/	BD	10.75	4.04	8.20	3.29
	CD	97.55	28.59	102.20	30.36
	VoT	15.82	9.96	12.57	11.28
	TD	17.77	6.36	18.77	6.09
	EoT	198.90	77.66	140.06	68.08
	SoT	13.01	7.25	8.61	5.28
/b/	BD	9.70	3.26	8.62	3.13
	CD	61.10	26.56	70.50	15.19
	VoT	64.97	14.16	80.87	18.17
	TD	19.57	5.59	18.02	5.98
	EoT	205.64	82.89	137.99	65.03
	SoT	11.06	4.00	8.15	3.94
/t̲/	BD	10.67	4.11	8.80	2.81
	CD	83.30	22.10	86.00	17.97
	VoT	14.92	6.39	10.90	6.65
	TD	18.55	5.60	19.42	8.36
	EoT	224.23	125.51	160.50	79.63
	SoT	13.59	8.13	8.95	3.94
/d̲/	BD	10.10	4.44	8.42	3.18
	CD	56.90	28.00	57.05	17.22
	VoT	66.17	15.96	75.92	11.89
	TD	18.32	5.26	17.90	9.59
	EoT	190.58	68.20	155.97	81.76
	SoT	11.61	5.72	9.95	6.23
/ṭ/	BD	7.32	1.62	6.40	1.47
	CD	68.60	20.27	80.50	18.16
	VoT	10.85	4.23	6.87	1.93
	TD	17.72	7.11	18.37	6.42
	EoT	206.68	110.08	172.57	85.50
	SoT	12.87	8.53	10.02	4.67
/ḍ/	BD	8.20	3.21	6.32	2.14
	CD	35.60	29.23	36.00	19.83
	VoT	49.80	16.43	62.87	14.17
	TD	14.85	5.21	15.32	5.12
	EoT	147.72	78.41	144.08	69.32
	SoT	11.34	8.14	9.84	4.73
/k/	BD	19.25	6.65	19.47	5.00
	CD	92.15	29.73	92.85	25.29
	VoT	18.02	6.51	15.90	7.03
	TD	17.10	4.71	17.90	6.99
	EoT	128.50	50.63	135.40	83.60
	SoT	8.02	2.74	8.11	5.35

/g/	BD	14.47	5.55	15.65	4.02
	CD	46.90	14.25	52.15	11.00
	VoT	61.10	12.70	74.97	15.02
	TD	17.82	4.83	17.65	5.08
	EoT	75.24	47.58	60.70	29.68
	SoT	7.41	3.04	6.23	2.96

Table 1.3

Mean and standard deviation (SD) for acoustic parameters of fricatives

Consonant	Parameter	AN		Control	
		Mean	SD	Mean	SD
/s/	FD	111.13	23.26	113.23	17.04
	TD	22.55	6.03	19.21	4.79
	EoT	201.41	136.94	164.56	86.98
	SoT	9.05	4.75	9.06	5.21
/ʃ/	FD	122.39	21.19	114.44	18.35
	TD	20.81	5.73	18.94	6.24
	EoT	212.76	102.88	201.85	104.45
	SoT	10.56	5.04	11.20	5.54
/f/	FD	94.05	30.94	109.73	23.07
	TD	23.57	7.20	23.84	9.56
	EoT	246.26	139.15	236.80	145.35
	SoT	10.80	4.09	10.13	4.57

Descriptive statistics was followed by a normality check done using Shapiro Wilk's test of normality which revealed a normal distribution. Further parametric tests were used to investigate any significant differences between the two groups.

Individuals with ANSD were found to have higher mean F_0, lower mean F_1 and F_2, and similar mean VD when compared to the control group. The F_1BW was higher for vowel /i/ and /u/ and lower for vowel /a/ in individuals with ANSD than controls. Further, the F_2BW was higher for vowel /a/ and /i/, and lower for vowel /u/ in ANSD group than controls (see Table 1.1). To compare between the two groups, an independent t-test was done and significant difference was observed only in F_2 for vowel /i/ [$t(38)= -2.572$, $p <0.05$].

Among the stop consonants, individuals with ANSD had higher mean VOT for all voiceless stops and lower mean VOT for voiced stops when compared to controls. The CD had lower mean values for all stops in ANSD group than controls. The mean BD and SoT were found to have higher mean values in ANSD group for all stops except velar stops (see Table 1.2). On independent t-test following measures were observed to be significantly different between the two groups: VOT for /g/ [$t(38) = -3.154$, $p<0.05$], /t̪/ [$t(38) = 3.818$, $p<0.01$], /d̪/ [$t(38) = -2.694$, $p<0.05$], /d̲/ [$t(38) = -2.190$, $p<0.05$], and /b/ [$t(38) = -3.086$, $p<0.01$]; BD for /d̪/ [$t(38) = 2.168$, $p<0.05$] and /p/ [$t(38) = 2.186$, $p<0.05$]; EoT for /p/ [$t(38) = 2.548$, $p<0.05$] and /b/ [$t(38) = 2.872$, $p<0.01$]; and SoT for /t̲/ [$t(38) = 2.294$, $p<0.05$], /p/ [$t(38) = 2.190$, $p<0.05$] and /b/ [$t(38) = 2.312$, $p<0.05$].

In fricatives, individuals with ANSD had higher mean EoT compared to the control group (see Table 1.3). On independent t-test a significant difference was observed only for the TD for the phoneme /s/ [$t(38)=2.088$, $p<0.05$].

Discussion

The major objective of the present study was to investigate the segmental speech characteristics in individuals with ANSD. The study hypothesized that long-standing speech perception deficits could result in speech production deficits as in case of cochlear hearing loss (Culbertson & Kricos, 2001; Dunn & Newton, 1986; Hudgins & Numbers, 1942; Smith, 1982).

Findings of the present study revealed that the speech production characteristics of ANSD are deviant compared to controls, particularly in consonants. In case of plosives individuals with ANSD significantly differed from normal hearing individuals on temporal measures like VOT and BD. Though there is limited literature reporting deviant acoustic

characteristics in the speech of individuals with ANSD, there exists a vast body of literature reporting significant deficits in their perception. To reiterate, individuals with ANSD are reported to have relatively greater deficits in temporal processing when compared to spectral processing. A study by Ajith & Jayaram (2006) revealed increased just noticeable differences in VOT, BD and TD. Based on these findings it is speculated that long standing temporal processing deficits could be reflected as a distortion or disruption of the temporal measures like VOT and BD. Further, greater mean values or longer duration was observed for both VOT and BD in individuals with ANSD. These findings are in consensus with the findings of Pooja and Sandeep (2009) reporting lengthened temporal cues in the speech of individuals with ANSD and suggested this to be a compensatory strategy used for a better perception.

A greater TD was also found for the fricative /s/ in individuals with ANSD. Thus, a longer TD implies slower articulatory movement. Pooja and Sandeep (2009) also reported perceptually abnormal rate of speech in individuals with ANSD.

On comparison of the three classes of speech sounds considered in the present study, it was found that plosives were affected more when compared to vowels and fricatives. This could be due to their transient nature. As discussed earlier individuals with ANSD are known to have significant temporal processing deficits. In such instances, perception of plosives is more prone to disruption when compared to vowels and fricatives which are temporally longer in duration.

Considering that the consonants are more dynamic in nature, one can assume that the distorted auditory perception found in ANSD has greater negative influence on the dynamic phonemes than the static phonemes. Perceptually, ANSD show more deviance in consonants. Greater deviation in the production of consonants hints at the direct relation between the

perception and production. Further the findings of the present study supports the closed loop models of speech production highlighting the importance of auditory feedback and its role in speech production.

Conclusion

The present study shows definite objective evidence for differences in the acoustic characteristics of speech production of ANSD. The consonant production is more deviant than that of vowels. The spectral and temporal distortion in the auditory processing is attributed to be the reason for the deviation in their production. The findings warrant assessment of speech production in individuals with ANSD and if found to be deviant, it needs to be addressed through appropriate management strategy. This shall ensure better quality of life for individuals with ANSD.

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