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Implications of Word-Initial Vowel Glottalization in Childhood Apraxia of Speech Treatment

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Abstract: *A vowel is a speech sound in which the airflow moves freely with minimal obstructions through the vocal tract and can appear in different places in the words structure. Word initial vowel glottalization is a phenomenon described in the literature while clinical implications were observed among children diagnosed with Apraxia of speech (CAS). This research examined the clinical consequences of the phenomenon on the analysis and treatment of CAS.*
256 CAS cases were examined using the VML (Verbal Motor Learning) method evaluation. Analysis of the consonant groups shows that 11% of the children had difficulty with producing the glottal consonant, in comparison to other consonants.
The implications of the findings influence the analysis process and are crucial for the treatment of 11% of the CAS population. Further theoretical discussions and findings are reported.

Keywords: *childhood apraxia of speech; autism; NSOME; oral motor; glottalization; phonetics.*

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Introduction

A Vowel is a speech sound in which the airflow moves freely with minimal obstructions through the vocal tract. The vocal cords vibrate through the vowel production and are considered to be the main element of vowel production. Different languages contain different vowels; however, there are five basic vowel groups: /a/, /o/, /u/, /i/, /e/. The vowels differ from one another by the minimal obstructions created by the tongue, lips, jaw and vocal cavities. Vowels also differ by the length of the sound and the tone (QC Vowel - Wikipedia, 2020). In the spoken language we can also find combinations of two or three vowels together (diphthongs and triphthongs) in which vowels are blended in overlapping transitions. The vowel's production physiology consists of a preliminary vocal tract air pressure, which creates a pressurized air flow from the lungs directed out through mouth and nose. The airflow is facing mild structural changes along the vocal tract which modify it to perform a phoneme. A speech sound created with higher degree of airflow obstruction (partial or full) is considered to be a consonant. Vowels can appear in various places in the word structure, among places is the head of an utterance.

The word "apple" is considered to be pronounced with a vowel at the head of the word. During my work with children diagnosed with Childhood Apraxia of Speech (CAS) I have started questioning this perception. CAS is defined as *"a neurological childhood (pediatric) speech sound disorder in which the precision and consistency of movements underlying speech are impaired in the absence of neuromuscular deficits (e.g. abnormal reflexes, abnormal tone)"* (American Speech-Language-Hearing Association, 2007; Lupu et al., 2016; Lupu, et al., 2016). The core problem in CAS is a deficit in the ability to plan speech sounds on a motor basis. A phenomenon I observed during my work as a clinician is a poor ability to imitate or spontaneously pronounce the sounds /a/, /o/, /u/, /i/ and /e/ (the 5 vowels in Hebrew and the basic 5 vowel group sounds) as a single sound, and later on at the beginning of a word. These sounds can be referred to as word initial vowels (WIV). Interestingly, some of the children who had this problem could pronounce the sounds /ba/, /bo/, /boo/, /bee/, /beh/ or other consonants with all the 5 vowels. If there is an ability to produce the consonant /b/ with all the vowels, one would expect that production of WIV would be intact. Why could these children pronounce the vowels with other consonants but not as WIV? Can we consider them as having the ability to pronounce the vowels? How does it influence the decision-making process in treatment? The purpose of this article is to try and answer these questions.

The sound /a/ (as in the word /apple/) appears in the vowels chart of the English phonetics as a short vowel. The science of phonetics defines 3 critical parameters for vowel existence: 1. The portion of the tongue that is involved, in the articulation. Example: front versus back vowels. 2. The tongue's position relative to the palate. Example: high versus low vowels. 3. The degree of lip rounding or non-rounding (Shriberg & Kent, 2003). This vowel exists in other languages such as French, German, Hebrew or Arabic, having similar basic phonetic characters. In English the sound /a/ is considered to be a vowel regardless of its location within the word. In Hebrew or Arabic languages, the sound /a/ is also considered to be a vowel when it is located at the head of the word (e.g. Vowel-consonant-Vowel structure like in the word /ani/). However, In Hebrew and Arabic writing, the sound /a/ at the beginning of a word is represented by two graphemes, one for the glottal consonant (/ʔ/) and the other for the vowel /a/ (consonant/vowel combination, CV), similar to CV combinations such as /ba/, /ta/ or /ka/. The sound /a/ in Hebrew physiologically consists of a glottal, plosive, voiceless consonant /ʔ/ and the vowel /a/.

Surprisingly, in Hebrew speech acquisition research the consonant /ʔ/ does not appear in the charts (Lavie, 1978). When the glottal consonant appears at the beginning of a word with a vowel (CV combination) it is still considered to be only a vowel in the speech acquisition tables. For example, the word "Ani" in Hebrew (which means "I" in English) is considered as VCV structure while the first sound of the word actually consists of the consonant /ʔ/ & the vowel /a/. The phrase /ani/ is physiologically pronounced as a consonant-vowel-consonant-vowel combination (CVCV structure). It is true for any vowel combined with the consonant /ʔ/ in Hebrew. Physiologically it is a CV combination; phonetically or in writing it is considered to be a vowel (Burlea et al., 2010; Lupu et al., 2015).

If the sound /a/ as in "apple" in English is physiologically pronounced identically to the sound /ah/ in Hebrew as in the word "Ani", and we consider the sound /a/ in Hebrew as a syllable (the consonant /ʔ/ + vowel /a/) then how should we treat the sound /a/ (as in /apple/) in English? As V or CV?

Word-initial vowel glottal stopping

Hebrew is different from English regarding the glottal consonant, since in Hebrew it is part of the spoken language while in English it is an irregularity. Many researchers investigated this phenomenon since the late 70's until very recently (Garellek, 2012; Umeda, 1978). The researcher's main objective is to understand the factors that contribute to the occurrence of this phenomenon. For this article it is only important to acknowledge the existence and prevalence of this phenomenon so we can apply this knowledge to the CAS treatment.

Dilley, Shattuck-Hufnagel and Ostendorf (1996) investigated factors that affect glottalization. They used 5 radio broadcasters and analyzed their utterances. They have found differences in rates of glottalization between the 5 subjects and between the locations of the vowel (non-phrase initial vs phrase initial). Glottalization was measured in one case at 70% in phrase initial condition, while the lower rates were in the range of 15-20%. Garellek looked for the factors which are most important in predicting where full glottal stops occur, and for whether incomplete glottal stops can be detected acoustically (Garellek, 2012). Garellek used the same method as Dilley et al. (1996) but included only 4 subjects in the study. 2010 word initial vowels were extracted. 53% of them were found to have irregularities (range 43-64%) and 15% to have a full glottalization (range 6-32%).

For the vast population with no speech problems, the glottalization is not such an important functional phenomenon. However, for the children diagnosed with CAS it might be. If the vowels appear with some consonants but not with the plosive glottal consonant, then the assumption of poor vowels pronunciation is questionable. It might lead us to avoid using these vowels with other consonants and focus only on practicing the vowels as WIV. That can cost months of treatment with no progress. In addition, if we consider the WIV as a syllable, then the approach to treatment might differ. We might try other techniques in order to establish a new consonant, the plosive glottal.

The hypothesis of this research was that a large percentage of children diagnosed with CAS will present low control over WIV while being able to better pronounce the vowels with other consonants. Another question we wanted to answer was whether the vowels are the first sounds to appear among children diagnosed with CAS as in Typical development.

Method

A retrospective study was conducted analyzing 256 entry evaluations of children diagnosed with CAS. The data was collected over the years 2006-2012 of children evaluated at a private clinic in Israel. A set of variables based on the VML method assessment was established for the retrospective data collection (Vashdi, 2013; Vashdi, 2014). Each evaluation was examined thoroughly, and the data was extracted according to a detailed index. Each variable had a ladder of 3-5 score with a specific definition of each stage for scoring. Reliability tests of the VML assessment tool show inter-rater agreement of 81% and correlation of 0.79.

Subjects

256 evaluations were examined. Sex distribution: 76.6% boys, 23.4% girls. The average age was 5 years old, and the age range was 1:7 – 19 years old. All subjects were diagnosed with speech delay and suspected CAS. 65% of them came with diagnosis of Autism as well.

The inclusion criteria were: 1. Speech delay or suspected CAS evaluation. 2. Extracting at least 80% of data needed. Data that was not clear enough to fit the variables criteria was not used. 3. The evaluations were only in the Hebrew language.

Measurements

In this study we used the scores of single sound production (SSP) (WIV, CV, coda form of consonants) in the Hebrew language. Every sound got a score of 0-3 (see Table 1).

Table 1 – sounds scoring index
Source: authors'own contribution

3	Consistent imitation or deliberate production of sound at least 80% of the time
2	Non-consistent production of sound, low accuracy of sound production, low intelligibility of sound.
1	Spontaneous production of sound. Inability to imitate the sound.
0	No ability to pronounce the sound

New variables were formed out of the raw data: 1) percentage of WIV, 2) percentage of each consonant group (ba +bo + boo+ bee+ beh+bb). We sorted the scores of each group of sounds from high to low (Table 2).

Table 2 – consonant and word initial vowel groups sum score
Source: authors'own contribution

Consonant &vowel group	score	percentage	significance
Word initial vowels	2111	54.97396	b and rest
B	1863	40.42969	m and rest
M	1619	35.13455	n and rest
P	1609	34.91753	n and rest
N	1429	31.01128	t and rest
T	1348	29.25347	ch and rest
D	1334	28.94965	g and rest
CH	1298	28.1684	g and rest
G	1253	27.19184	k and rest
K	1182	25.65104	l and rest
L	1163	25.23872	v and rest
V	960	20.83333	j and rest
SH	957	20.76823	j and rest
J	913	19.81337	f and rest
F	860	18.66319	ts and rest
S	858	18.61979	ts and rest
TS	768	16.66667	r
Z	768	16.66667	r
R	537	11.65365	

*Represents the vowels with the glottal consonant.

- The score column summarizes the total score for the group across all participants.
- The percentage column shows the percentage of score out of the possible maximum for each consonant or word-initial vowel group across all participants.
- The significance column describes significant paired t-test at level of <0.05 for the consonant mentioned, and all the other consonants that are beneath it.
- The following consonant pairs were not significantly different: d:t, d:ch, v:sh, f:s, ts:z.

We sorted the scores of each single sound from high to low. For each subject a qualitative examination for differences between vowels group score and single consonant groups score was performed. In this examination the score of the vowel group was compared to the score of each consonant group (e.g. /B/, /P/) while excluding the non-vowel consonant score. The purpose was to find differences in occurrence of vowels with consonants versus WIV. The null assumption was that the vowels group score will be higher in all cases, since the vowels are first to develop and the occurrence of CVs depends on the WIV development. We wanted to see if there are cases in which other CV combinations are stronger than WIV. Even minor gaps of 1-2 points between WIV and another consonant group were recorded, since for a child with minimal sound control every sound or degree of control over a sound might be significant.

Paired t test was used to obtain statistical significance for the single sound test between the sound /e/ and the sound /m/, since, if such difference will be found, then we can conclude that all the WIV are within the 8 strongest sounds (see Table 3) . Paired t test was used in addition for the comparison between the vowels group and the consonant /B/ group.

Results

The score of the sound /e/ was found significantly higher than the sound /m/ score (paired t test<0.05). The results show that the 5 WIV are with in the 8 strongest sounds. The other three were /ba/, /pa/ and /ma/ (see Table 3).

Table 3 – Top 15 sounds
Source: authors'own contribution

Sound	score
A (apple)	546
Ba (banana)	461
I (eat)	426
O (or)	422
Ma (mum)	391
U (uzi)	367
E (elephant)	350*
Pa (pancake)	348*
Mm (came)	321
Bo (ball)	311

Da (dance)	306
Na (nine)	304
Ta (task)	294
Bu (bully)	285
Bi (bee)	283

*no significant difference was found between /e/ and /pa/.

Significant differences at the level of <0.05 were found between every two adjacent sounds on the table.

In addition, the WIV group was found to significantly have the highest score in comparison to the other consonant groups, obtaining 54.76% of the maximum score, while the B consonant group which was ranked second, obtained only 38.62% (paired t test<0.01)

In 28 cases (11%) the WIV was not the strongest consonant group. Table 4 presents these cases and the specific differences between the groups. In these cases, the vowels were in better control under another consonant then as WIV.

Table 4 – Weak word-initial vowels cases
Source: authors'own contribution

Score Percentage													**Number of differences**
B	P	M	N	L	T	D	K	G	SH	F	Word initial Vowels	Highest differences	
100	46.7	93.3	80	73.3	0.0	66.7	40	80	0.0	0.0	53.3	46.6	6
53.3	66.7	13.3	26.7	40	40	26.7	0.0	26.7	13.3	0.0	26.7	40	2
93.3	73.3	60	93.3	0.0	0.0	0.0	80	26.7	0.0	13.3	60	33.3	4
0.0	0.0	0.0	60	26.7	0.0	40	0.0	0.0	13.3	20	26.7	33.3	2
80	80	80	93.3	0.0	80	53.3	80	66.7	0.0	13.3	66.7	26.6	7
20	0.0	33.3	13.3	13.3	13.3	13.3	0.0	0.0	0.0	0.0	6.7	26.6	6
40	0.0	0.0	0.0	0.0	0.0	6.7	40	26.7	0.0	0.0	13.3	26.6	2
40	40	20	0.0	86.7	26.7	0.0	20	0.0	40	20	60	26.6	1
40	40	13.3	0.0	0.0	33.3	33.3	0.0	0.0	0.0	0.0	20	20	4
26.7	0.0	6.7	0.0	0.0	0.0	0.0	6.7	0.0	0.0	0.0	6.7	20	2
60	60	40	0.0	40	40	100	80	0.0	0.0	0.0	80	20	1
86.7	86.7	86.7	100	100	100	100	100	100	100	86.7	86.7	13.3	7
13.3	13.3	0.0	0.0	0.0	13.3	13.3	0.0	0.0	0.0	0.0	0.0	13.3	4
6.7	0.0	0.0	0.0	0.0	0.0	13.3	0.0	13.3	0.0	0.0	0.0	13.3	3
13.3	20	13.3	0.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0	6.7	13.3	3

100	100	100	66.7	66.7	0.0	0.0	0.0	0.0	0.0	0.0	86.7	13.3	3
46.7	53.3	20	0.0	0.0	0.0	0.0	60	60	0.0	0.0	46.7	13.3	2
0.0	0.0	0.0	93.3	13.3	0.0	13.3	0.0	0.0	0.0	6.7	80	13.3	1
6.7	0.0	20	46.7	26.7	0.0	0.0	0.0	0.0	0.0	0.0	33.3	13.3	1
100	80	33.3	73.3	46.7	100	100	100	100	40	100	93.3	6.6	8
60	66.7	6.7	6.7	0.0	6.7	6.7	6.7	6.7	0.0	0.0	60	6.6	7
93.3	100	100	93.3	100	93.3	100	100	93.3	0.0	0.0	93.3	6.6	5
6.7	0.0	0.0	0.0	0.0	0.0	6.7	0.0	0.0	0.0	0.0	0.0	6.6	2
40	0.0	100	100	0.0	0.0	6.7	13.3	0.0	0.0	0.0	93.3	6.6	2
6.7	0.0	6.7	0.0	0.0	6.7	13.3	0.0	6.7	0.0	0.0	6.7	6.6	1
13.3	0.0	6.7	0.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0	6.7	6.6	1
93.3	93.3	93.3	93.3	93.3	93.3	93.3	0.0	0.0	93.3	100	93.3	6.6	1
13.3	0.0	13.3	20	0.0	20	33.3	0.0	0.0	0.0	0.0	26.7	6.6	1

The score percentage of all the relevant consonants and vowels in 28 cases in which the vowels score was lower than at least one consonant group. The difference in percentage is shown form the highest to the lowest. The number of differences for each case is summarized in the last column.

Table 5 – Inclusive Vowel-form groups and word initial vowel ladder
Source: authors'own contribution

Inclusive Vowel group	**Percentage**	**Word-initial vowel**	**Percentage**
Va	31.66*	a	71.09*
Vo	24.45	i	55.46
Vi	24.42	o	54.94
Ve	24.14	u	47.78***
Vu	21.49**	e	45.57***

*significantly higher than the rest of the results (<0.01)
**significantly lower than the rest of the results (<0.05)
***significantly lower than the first 3 results (<0.01) and higher than the last one (<0.05)

● No differences were found between Vo, Vi and Ve variables in the inclusive vowel group.

● No differences were found between I and o variables in the word-initial vowel group.

● The lower percentage score of the inclusive vowel group is attributed to the influence of the consonants control.

Discussion

This research dealt with the hypothesis that WIV should be addressed in speech as syllables constructed from the consonant /ʔ/ and a vowel, rather than a single vowel. The consonant /ʔ/ exists in some languages while represented with a letter (like the letter /א/ in Hebrew); however, it is not mentioned in the developmental consonants acquisition charts. The pronunciation of the WIV is probably the same in most languages, which is different to the graphemic representation. The English language does not have a representation for the glottal consonant since it does not formally exist in the language; however, it does exist in the spoken English language.

The vowels are known to be the first sounds a child will master, followed by the consonants. It is well demonstrated in research on typical development and the findings here support that (Irwin, 1983; Templin, 1957). However, in 11% of the cases observed here, which are non-regular developmental processes, the WIV group was not the strongest in comparison to other consonant groups. We consider vowels as sounds with minimal obstruction of air flow; however, with a word-initial vowel, it is not always the case. The occurrence of glottalization in WIV in English can reach up to 70% (Dilley et al., 1996).

The phenomenon of vowel glottalization in English, the existence of a glottal consonant in some languages and the finding of the struggle of children diagnosed with CAS can lead us to think differently about definitions. It is true that in most cases of CAS, the WIV will be the strongest sounds as was reflected in the retrospective study (89%), but the residual 11% is a significant group that requires a different intervention.

The reason that 11% of the children struggle with the WIV might be the plosive glottal consonant, since the vowels are being produced with other consonants. The ability to pronounce a vowel depends on achieving the control parameters which are crucial for the vowel's motor scheme. If one can produce a vowel in some combinations, there is probably some control over these parameters, hence the reason for poor pronunciation in other CV's relays on the consonant control rather than on the vowel control. In some cases, it might also be related to a specific consonant/vowel transition difficulty.

The implications on evaluation and treatment of CAS might be:

1) Consider WIV as a group of the glottal consonant /ʔ/ just as the /B/ or /K/ group. The analysis of these sounds will consider not only the vowels but also the glottal consonant.

2) When analyzing the ability to pronounce vowels, we should consider the occurrence of vowels along all the consonants and not just as WIV, since such consideration might result with wrong decision making. If the child can produce the vowels with the consonant /B/ for example, but cannot produce the WIV, we can assume that he has control over the vowels parameters and likely to have a problem with producing the glottal consonant. Hence, we should consider a plan in which he would be able to use these vowels with another consonant even before acquiring them as WIV. Table 5 shows the difference between WIV development ladder and inclusive vowel developmental ladder.

These two implications are crucial in treating the 11% group of the CAS population. Glottalization probably does not influence the rest of 89% of children with CAS, but we assume that this new way of analyzing vowel production can be beneficial for them as well.

Summary

Phonetically, the glottal consonant should be included in the consonant developmental charts. It is important for professionals to acknowledge its existence, even in English, since in cases like that it might come useful.

It seems that the plosive glottal consonant is being pronounced and used in many languages but at the same time it is being ignored phonetically. We are grateful to the children with CAS for throwing light on that spot.

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