PERCEPTUAL AND ACOUSTIC ANALYSIS OF VOWEL PRODUCTIONS IN WORDS AND PSEUDO WORDS IN CHILDREN WITH SUSPECTED CHILDHOOD APRAXIA OF SPEECH

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ABSTRACT

Purpose: Childhood Apraxia of Speech (CAS) is a developmental disorder affecting speech motor programming and planning. This study aims to investigate deviant vowel and diphthong articulations of German children with suspected CAS. **Methods and Data:** A corpus of 115 isolated stimulus words and 33 pseudo words were elicited by picture naming or by repetition respectively from three three German children with suspected CAS aged 5;9 to 6;3 years as well as for 21 age and gender matched controls. Perceptual and acoustic analyses were performed in order to judge the monophthong and diphthong realizations of suspected CAS-children versus control speakers.**Results:** The perceptual evaluation shows monophthong and diphthong errors in the suspected CAS-children in contrast to the controls. The deviant productions concern monophthongs and diphthongs in mono- as well as in multisyllabic words. The stimuli with incorrect monophthong and diphthong productions were examined more closely by acoustic means.**Discussion:** This study shows that incorrect monophthong and diphthong productions can be detected in children with suspected CAS by perceptual and acoustic evaluation. Incorrect monophthong and diphthong productions seem to be an appropriate diagnostic criterion, which can be also observed in the German population and described by perceptual and acoustic evaluation. Further Investigations are planned to dissociate children with Phonological Disorders (PD) from suspected CAS and to examine wether monophthong and diphthong errors can be used as an diagnostic marker.

Keywords: Childhood Apraxia of Speech, vowel errors, perceptive analysis, acoustic analysis

1. INTRODUCTION

The incidence of children with suspected CAS is around one or two children per thousand [5]. Children with CAS "display difficulties with planning, automating and programming speech" [6]. To date there is no agreement regarding the etiology, symptomatology and diagnostic criteria of the disorder. The need for a diagnostic marker, which differentiates this disorder from other symptomatologies like Phonologial Disorders (PD) still persists. A number of research studies have focused on describing the problems of speech production in English speaking children with CAS ([5][6][2]), however, the disorder has received less attention in Germany [1]. No standardized diagnostic instrument currently exists for this language that can be used in the differential diagnosis of CAS and other speech or phonological problems. This study presents a preliminary investigation to develop such an instrument. Materials were developed for German with the aim of capturing the vowel errors observed previously in English and Dutch native speakers ([5][6][2]) which belong to the international diagnostic criteria and symptoms of CAS. This study investigates the monophthong and diphthong productions in monolingual German children with suspected CAS in order to generalize the international criterion of the symptom cluster and to explore vowel errors by perceptual and acoustic analysis. Perceptual and acoustic analysis of monophthong and diphthong productions are performed in real words and in pseudo words in children with suspected CAS and their controls.

2. METHODS AND MATERIAL

2.1. Subjects

Three monolingual German children with suspected CAS between 5;9 and 6;3 years and 21 age and gender matched control speakers (7 control speakers per CAS case) participated (Tab. 1). The diagnosis of suspected CAS was based on the evaluation of a cluster of typical symptoms associated with CAS [2]. The control participants were also monolingual

Table 1: Child A,B,C= Child with suspected CAS; C= Control

Controls	Child A, w., 6;3	Child B, m., 5;9	Child C, m., 6;0
C 1	w., 6;1	m., 5;7	m., 6;2
C 2	w., 6;2	m., 5;8	m., 5;11
C 3	w., 6;3	m., 5;11	m., 6;3
C 4	w., 6;3	m., 5;8	m., 6;3
C 5	w., 6;0	m., 5;8	m., 5;9
C 6	w., 6;5	m., 5;6	m., 5;10
C 7	w., 6;6	m., 5;10	m., 5;9

German speakers with no known disorder of speech.

2.2. Stimuli

The stimulus words consisted of 115 items with one- to three-syllables, containing monophthongs and diphthongs including vocalic /r/- realizations [3]. The majority of stimulus words were nouns from the vocabulary of four year old children and were elicited by picture naming. 33 pseudo words with legal German phonotactic structure and a maximum length of two syllables were repeated from the children after aural presentation (Tab. 2). Not all items (only pseudo words vs. real words) were matched for phonotactic structure, as the intention was to study the vowels in natural context without imitation. Of the 148, 135 items were used for final analysis, as some of the remaining words could not be produced by all children. All word realizations were recorded using the digital recorder Sony Mk2 with 44,1 Hz, mono 16 Bit and the microphone Sony-DR.

Table 2: List of used words and pseudo words in classes

Classes	Words	Pseudo words
$\sum$	102	32
Monophthongs	84	26
Diphthongs	18	6
Monosyllabic	58	18
Multisyllabic	44	14

2.3. Perceptual evaluation

All vowel productions were rated perceptually by total 21 listeners. Each group of subjects (one suspected CAS-child with its matched controls) was evaluated by seven different listeners who had to decide whether the vowel realization in the 135 test items was correct or not. Those items where the vowel production of the CAS participant was judged as being different to the control speakers were analysed further acoustically.

2.4. Selection of items for acoustic analysis

For child A and B, a vowel production was classified as erroneous, when at least three of seven listeners judged the production as incorrect. For child C this would have resulted in no perceived vowel errors and the criterion was therefore lowered to two of seven listeners having to perceive an error. This resulted in an analysis set of five real words and three pseudo words from child A, nine different real words and three pseudo words from child B and three real words and one pseudo word from child C (Tab. 4).

2.5. Acoustic analysis

The vowels and their time course of F1, F2 and F3 have been extracted with "Praat" (version 4.3.19, [4]). An example of the time course for vowels of three words is given in Fig. 1 (a, b, c) for CAS-childs (dots) and for the corresponding controls (lines, dashed lines, and dashed-dotted lines). Horizontal position, slope and parabolic curvature of the first and second formant were estimated using a fitting algorithm programmed in Matlab by the second author. A number of differences were apparent between the CAS-children and their control speakers. Fig. 1a shows that the horizontal position of F1 for /kɔl/ is lower for the CAS-child than the control speakers. In Fig. 1b the slope of F2 for /kʀɔ͡yt͡s/ is positive for the CAS-child while it is around zero for the controls participants. In addition the parabolic curvature of F1 shows a hhigher (negative) value for the CAS-child in the word /kʀɔ͡yt͡s/. The parabolic curvature of F2 is also different in the word /hɔ͡y/ for the CAS-child in comparison to the control speakers who additionally show a straight line at the beginning of the vowel (Fig. 1c). These acoustic data for F1 and F2 of the children with suspected CAS were statistically compared to those of the control speakers (t-test).

2.6. RESULTS

Perceptual analysis: As can be seen in the descriptive data (Tab. 3), child A and B had the highest number of monophthong and diphthong errors, whereas child C produced less deviations. For the perceptual analysis the rater congruity and rater reliability were checked first. This results show, that both the congruity and the reliability for child A and C is not acceptable (Congruity child A: k=0,26 for real words; k=0,29; child C: k=0,13 for real words; k=0, 25 for pseudo words). Anyway all erroneous items (from perceptive evaluation) were analysed further to confirm the perceptive evaluation by an objective measurement. The perceptual evaluation of the listener could be influenced by the occuring

consonantal errors due to the symptoms of the disorder. The ratings of the vowel productions of child B however demonstrate a good rater congruity and reliability.
Child A and B (producing the most errors in total) show significant differences to the control speakers in vowel productions for all subgroups (monophthongs, diphthongs in words, pseudo words). Child C shows significant differences only for subgroups monophthongs in words and diphthongs in pseudo words. A comparison of the production of monophthongs and diphthongs shows, that the children with suspected CAS do not show any differences in error rate between these categories. The control speakers however showed more variation in the production of the monophthongs in real words as well as in pseudo words than in diphthongs.
The investigation of the monophthong and diphthong productions in words with an increasing number of syllables, shows again that child A and B produce more vowel errors in the subgroups monosyllabic and multisyllabic than the controls. From our data, it can be seen that child C made more monophthong and diphthong errors in the subgroups multisyllabic real and pseudo words than the control speakers (Tab. 3).

Table 3: Percentage of mean vowel/diphthong articulations judged as incorrect; A,B,C=Child with suspected CAS; C A, C B, C C= Controls of child A,B,C

Classes	**A**	C A	**B**	C B	**C**	C C
Words						
Monophthongs	27	9	41	4	15	7
Diphthongs	22	7	20	4	8	5
Monosyllabic	24	8	33	4	11	6
Multisyllabic	28	10	41	4	16	6
Pseudo Words						
Monophthongs	35	11	49	6	14	9
Diphthongs	34	9	43	2	11	3
Monosyllabic	35	10	41	6	4	8
Multisyllabic	34	12	54	5	23	8

The comparison of error frequency of monophthong and diphthong productions between one and multisyllabic words shows, that the children with suspected CAS do not produce more vowel errors in longer words neither for real nor for pseudo words.
Acoustic analysis: The criterion for "acoustically deviant" is, that at least one of the six acoustic parameters have to be significant different in comparison to the control speakers. Within the small corpus for the acoustic analysis, the extracted acoustic parameters confirm the deviant production of all monophthongs and diphthongs of child A and B except one pseudo word of child B. These monophthong and diphthong productions are significantly deviant compared to their control speakers. Only child C shows two of three selected items as not different in contrast to the control speakers (see Table 4).

Table 4: A,B,C= Child with suspected CAS; W=selected Word, PW=selected Pseudo Word; M1/M2=Mean value of F1/F2; S1/S2=slope of F/F2; C1/C2=Curvature of F1/F2; x=significant, o=significant after Bonferroni-correction

Child	Items	Transcription	M1	M2	S1	S2	C1	C2
A	W 1	/gryn/	-	-	x	x	-	-
	W 2	/jɛːgɐ/	x	-	x	-	-	x
	W 3	/meːɐ/	x	-	-	-	-	-
	W 4	/oːɐ/	-	-	-	x	x	-
	W 5	/zɛːgə/	-	-	-	x	-	-
	PW 1	/k ɔl/	x o	-	-	-	-	-
	PW 2	/lɔyɐ/	x	-	-	x	-	-
	PW 3	/tɛk/	-	x	-	-	-	-
B	W 1	/feː/	-	-	-	-	-	x
	W 2	/hɔy/	-	-	-	x	-	x
	W 3	/kʀɔyts/	x	-	-	x o	x	x
	W 4	/meːɐ/	x	-	x	x	x	-
	W 5	/ʃɔɐnʃtain/	-	x	-	-	-	-
	W 6	/vɛːg/	x	x	x	-	-	-
	W 7	/vɪpə/	-	x	-	-	-	-
	W 8	/tseːbr ə/	x	-	-	-	-	-
	W 9	/tseːn/	x	-	-	-	-	-
	PW 1	/bʏkəl/	-	-	-	-	-	-
	PW 2	/fɪrçə/	x o	x	-	-	-	-
	PW 3	/mɔytə/	x	-	-	x	-	-
C	W 1	/kloː/	-	-	-	-	-	-
	W 2	/kɔɐp/	-	x	-	-	-	-
	W 3	/zɛːgə/	-	-	-	-	-	-
	PW 1	/ʃøːlə/	-	-	-	-	-	-

Further examination of monophthongs and dipthongs in real words in contrast to pseudo words indicates no differences concerning horizontal position, slope and parabolic curvature in the vowel productions of the children with suspected CAS, but the control speakers demonstrate a difference in the horizontal position of the first formant.

2.7. DISCUSSION

The results show that the children with suspected CAS produce deviant vowels in contrast to the control speakers monophthongs and diphthongs in real words as well as in pseudo words with different syllable structures. Mainly the acoustic and perceptual analysis highlight the same differences in these children. Due to these analyses and results, the children with suspected CAS varied in the extent of vowel errors. They seem to represent various grades, but this was not further studied. Milder cases (less vowel errors) of the

suspected CAS-children resulted in less listener agreement. Mild vowel errors seem to be difficult to detect and to be judged by the perceptual analysis.

2.8. CONCLUSIONS

This study has demonstrated, that German children with suspected CAS make vowel errors. These vowel errors could be detected both by acoustic and perceptual means. Children with suspected CAS have to be differentiated from other disorders with similiar symptomatology. Further investigations should consider the dissociation between children with suspected CAS and children with Phonological Disorders. Therefore vowels should be closely examined as a potential diagnostic marker. Now it is veritable shown, that vowel errors are made by German children with suspected CAS. By means of the German language vowel and diphthong errors are proved of existence using methods of acoustic and perceptual analysis. Children with suspected CAS have to be divided from other disorders with similar symptomatology. Further investigations should consider the dissociation between children with suspected CAS and children with SD, especially with Phonological Disorders. Therefore vowels should be closely examined as a potential diagnostic marker of the disorder.

3. REFERENCES

[1] F. Dannenbauer. Auf der Suche nach der verbalen Entwicklungsdyspraxie. *Die Sprachheilarbeit*, (3):136–150, 1999.

[2] B. Davis, K. Jakielski, and T. Marquardt. Developmental apraxia of speech: determiners of differential diagnosis. *Clinical Linguistics and Phonetics*, 12(1):25–45, 1998.

[3] E. Franz. Akustische und perzeptive Analysen von Vokalen bei verbaler Entwicklungsdyspraxie: Eine Einzelfallstudie. Master's thesis, RWTH Aachen, 2006.

[4] W. D. P., Boersma. Praat. http://www.praat.org, 1995.

[5] L. Shriberg, D. Aram, and J. Kwiatkowsky. Developmental Apraxia of Speech: I. Descriptive and Theoretical Perspectives. *Journal of Speech, Language, and Hearing Research*, pages 273–285, 1997.

[6] R. van den Berg, L. Nijland, and B. Maassen. Kinematic measurements of diadochokinetic performances on children with das or pd. In *Stem-, Spraak- en Taalpathologie*, 2006.

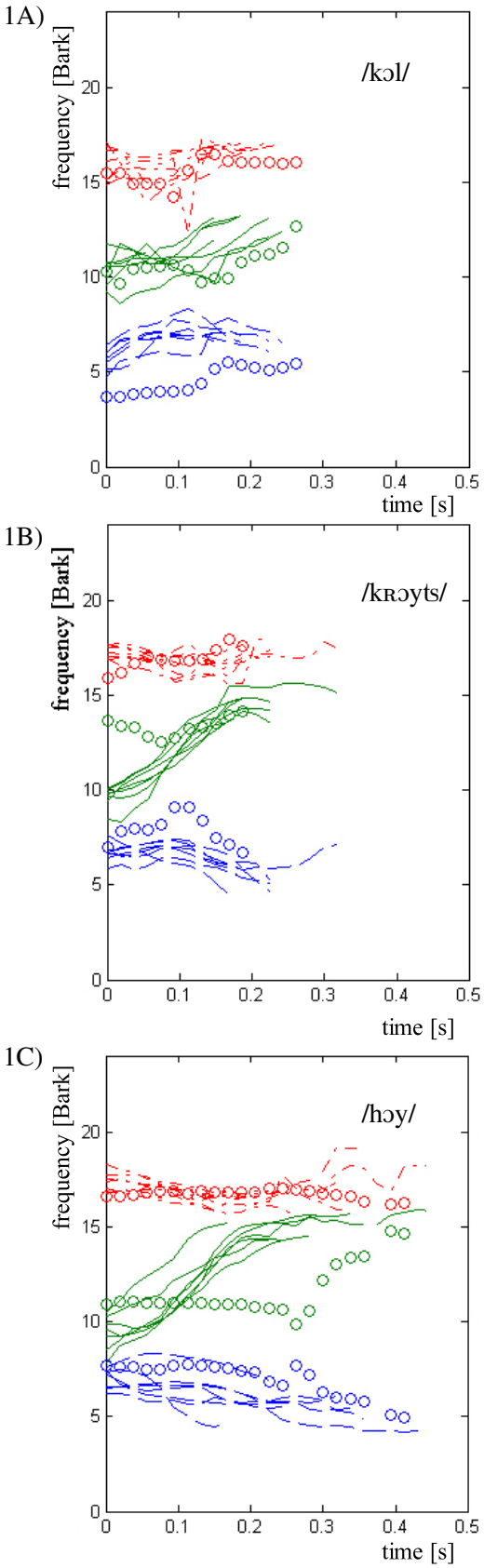

Figure 1: Illustration of the determination of horizontal position, slope and parabolic curvature of F1, F2 and F3 from one pseudo word produced by child A and two standard German words produced by child B; 000= CAS-children, —= controls