INFLUENCE OF TRANSITION DURATION ON SPEECH COMPREHENSION DEFICIT IN ACUTE APHASIA

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ABSTRACT

The perception of place of articulation in stop consonants was investigated in left hemisphere lesioned acute aphasics, right hemisphere lesioned nonaphasics and normal controls. Experiment 1 tested the discrimination of synthetic consonant vowel (CV) syllable pairs (/ba, da, ga/) with 40 ms formant transition duration. The results showed significant differences between the groups. While aphasics had difficulties in perceiving place of articulation in stop consonants, discrimination performances in right hemisphere lesioned patients and normal controls were nearly unimpaired. A significant correlation was observed between the ability of aphasics to discriminate synthetic syllable pairs and their auditory speech comprehension (Token Test). Experiment 2 measured the effects in aphasic patients of lengthening formant transitions of CV syllables (80 ms, 120 ms). The results showed a tendency towards improved perceptual performances with increasing transition duration.

1. INTRODUCTION

The place of articulation in stop consonants is signalled in part by an approximate 50 ms movement of formant transitions. Consequently, its perception requires the integration of rapidly changing acoustic cues in the speech signal [6]. The perceptual relevance of the fast frequency changes between consonant and vowel in CV syllables led to the assumption of the transition being the perceptual center of the syllable [3]. It was demonstrated that the ability to perceive synthetic syllables with rapid frequency changes was impaired in subjects with chronic left hemisphere damage and aphasia but not in subjects with chronic right hemisphere lesions [9]. This perceptive disability was highly correlated with the degree of speech comprehension impairment. To account for the underlying deficit two controverse hypotheses have been proposed: (i) A general auditory deficit in temporal processing in the aphasics is assumed by [9]. (ii) The perceptual disabilities are interpreted in terms of an underlying speech specific phonological disorder [8]. Tallal and Newcombe were able to demonstrate that some of their chronic aphasic patients obtained higher identification rates in syllables with synthetically lengthened formant transitions [9]. However, other authors were not able to replicate these results [1,7]. The patients investigated by [9] suffered from chronic aphasia for more than 20 years while the experimental group of [7] comprised patients with 3.2 years mean length of time post onset. However, there are no reports in the literature on the perceptual performances of patients with acute aphasia. In Germany, there is a clear tendency towards early neurological rehabilitation. Consequently, demands for diagnostic and therapeutic approaches in the management of acute aphasia gain growing interest.

In the present study the following questions were investigated: (1) Do patients with acute aphasia show a deficit in the perception of CV syllables with fast formant transition in contrast to right hemisphere lesioned nonaphasics? (2) Is the perceptual performance status of aphasics related to their speech comprehension abilities? (3) Do acute aphasics with a perceptual defecit benefit from lengthening of formant transitions?

2. METHODS

2.1. Subjects

The two clinical groups consisted of 27 consecutive patients of the neurological department of the Edith-Stein-Rehabilitation Clinic Bad Bergzabern, Germany, and were limited to unilateral left cerebral lesioned patients with aphasia (LH) and unilateral right cerebral lesioned patients without aphasia (RH), confirmed by neuroradiological diagnosis. 15 patients, 8 male, 7 female with mean age 58,3 (range 36 to 79 years) from the orthopedic department of the clinic served as normal controls (NC1). In addition, 13 staff members of the same institution, 5 male, 8 female with mean age 33,3 years (range 22 to 58 years) were selected as normal controls (NC2). All subjects were right-handed and native speakers of German (with palatinate accent). They had no history of pre-existing neurological, demential or psychiatric disorder or alcoholism. Subjects were screened for absence of subjective auditory disability, and additional tests for normal peripheral hearing in both ears were performed by means of pure tone audiometry through the speech frequencies. As a basic neuropsychological parameter of attention niveau in RH and LH tonic alertness was assessed by the standardized test battery *"Testbatterie fur Aufmerksamkeitspruefung"* (TAP) [11].

Linguistic testing of LH was carried out by certified speech-language pathologists and comprised diagnosis as well as classification of aphasia into different syndromes and severity based upon the standardized *Aachen Aphasia Test* battery (AAT) [4]. In case of insufficient feasibility of the AAT, diagnosis and classification were based upon clinical aphasia examination. Examination of auditory language comprehension comprised, beside aphasics performances on sentence level (Token Test [2]), a word comprehension test (WC). WC consisted of 34 picture pairs and required phonemic discrimination of /b/, /d/, /g/ in word initial and medial word context (Neurolinguistic status of LH is shown in Table 1.). In order to exclude aphasia in RH, subjects were submitted to the Token Test. Moderately impaired alertness was found in 4 of 5 right hemisphere lesioned nonaphasics and in 3 left hemisphere lesioned aphasics, indicating the general condition to which acute neurological patients are unspecifically affected. Patients who did not cope with the task demands because of either severe auditory

comprehension deficits or significantly reduced alertness were excluded from the study (n=10). Finally, the LH group consisted of 12 patients and the RH group comprised 5 patients (Clinical status of RH and LH patients is shown in Table 2.).

Subject	Fluency	Severity	Aphasic Sydrome[1]	TT[2] (%)	WC[3] (%)	DT[4] (%)
B.S.	fluent	mild	Wernicke	28	5,9	12,5
E.B.	fluent	moderate	Amnestic	32	0	6.3
H.B.	fluent	severe	Wernicke*	32	n.d.	4,2
H.H.	nonfluent	severe	Broca	94	5,9	50
K.E.	fluent	severe	n.c.	68	2,9	47,9
P.L.	fluent	mild	Broca*	4,0	8,8	8,3
S.I.	nonfluent	severe	global*	90	17	50
T.D.	fluent	mild	Amnestic*	44	2,9	50
T.H.	fluent	moderate	Wernicke	84	38,2	45,8
W.S.	fluent	mild	Amnestic	20	8,8	27,1
K.K.	fluent	mild	Amnestic	30	2,9	29,2
H.N.	fluent	mild	Amnestic	22	32,4	6,3

Table 1. Neurolinguistic Status of Aphasic Subjects (LH)

[1]aphasia classification based upon AAT or clinical aphasia examination (*) [2]Token Test [3]Word Comprehension Test [4]Discrimination Task (40 ms) n.c.=not classifiable TT/WC/DT: results are given as error percentage

2.2. Test materials

Prototypes of synthetic syllables [ba/da/ga] with a duration of 250 ms were generated by means of the Delta System/Syllable Tool SYLLT Version 0.2 [10] with different formant transition lengths (40-80-120 ms) on a cascade/parallel Klatt 88 [5] formant synthesizer (sampling rate 16 kHz, 16 bit accuracy).

Experiment 1

The first discrimination task consisted of 48 syllable pairs presented at random with 40 ms transition duration of all three formant frequencies, separated by 1000 ms of silence (Figure 1). Same-syllable pairs /ba-ba/, /da-da/, /ga-ga/ occurred eight times each, different-syllable pairs (/ba-da/, /da-ba/, /da-ga/, /ga-da/) occurred six times each. 16 practice trials preceded the test.

Experiment 2

The second discrimination task consisted of 72 syllable pairs (36 same, 36 different) presented at random. In contrast to experiment 1, formant transition of the syllable pairs varied between 40, 80 and 120 ms duration (24 pairs each) in the higher formants. Extension of transition duration was limited to F2 and F3, since they seem to be main cues to place of articulation, whereas F1 seems to be main cue to manner of articulation [6]. 18 training trials preceded the test. Figure 2 shows the synthesized syllable /da/ with three different transition durations.

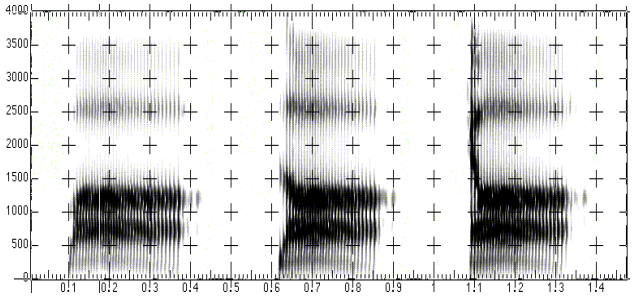

Figure 1. Spectrograms of the synthesized stimuli /ba/, /da/, /ga/ with 40 ms formant transition duration.

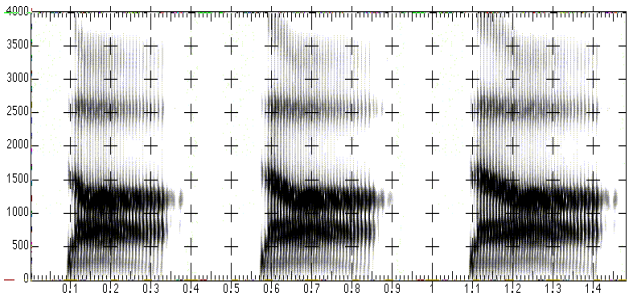

Figure 2. Spectrograms of the synthesized stimuli /da/ with 40 ms, 80 ms and 120 ms formant transition durations.

2.3. Procedure

Each subject was tested individually in a sound-treated room. Discrimination tasks were presented binaurally on a Computerized Speech Lab CSL (Model 4300B, Kay Elemetrics, USA) via headphone (AKG K 100, Austria) at comfortable listening level. Subjects were instructed to decide whether the presented syllable pairs were the same or different by responding orally, pointing to appropriate symbols or head movement.

3. RESULTS

3.1. Experiment 1

Figure 3 shows the results of mean error percentage of the discrimination task for CV syllable pairs with 40 ms formant transitions for all groups. A significant difference (**) in the discrimination performance (*Mann-Whitney U-Test*) was observed between aphasics (LH) and nonaphasic subjects (RH: $p= 0.001$, NC1: $p= 0.001$, NC2: $p= 0,000$). Young staff controls (NC2) showed a completely unimpaired discrimination function and even the age matched control groups NC1 and RH demonstrated highly satisfactory discrimination scores. Some individuals made a few false discrimination judgements in different-syllable pairs. In contrast, aphasic patients failed to discriminate the place of articulation in stop consonants in same- and different-syllable pairs. Furthermore, the data give evidence for a significant correlation ($r=0,81106$, $p<0.001$, *multiple regression analysis*) between phonetic discrimination disability (DT) and reduced general auditive comprehension deficit (Token Test) in aphasics. No direct relationship was indicated bet-

ween phonetic discrimination and word comprehension (WC: *r=0,23086, p< 0,494, multiple regression analysis*). Those patients with increased error rate in the syllable discrimination task took part in Experiment 2 (n=6).

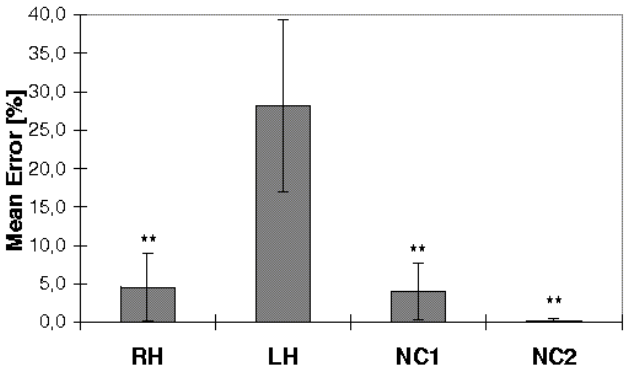

Figure 3. Discrimination Task (40 ms): RH, LH, NC1, NC2
** = high significant (p< 0.001) compared to LH
bars indicte mean error [%] +/- 95 % confidence interval

3.2. Experiment 2

Figure 4 presents the results of mean error rates in syllable discrimination with 40 ms, 80 ms and 120 ms transition duration in LH. Aphasics showed decreased error rates in CV syllables with lengthened formant transitions. Even though this pattern showed a clear tendency, it did not reach statistical significance (p>0.05).

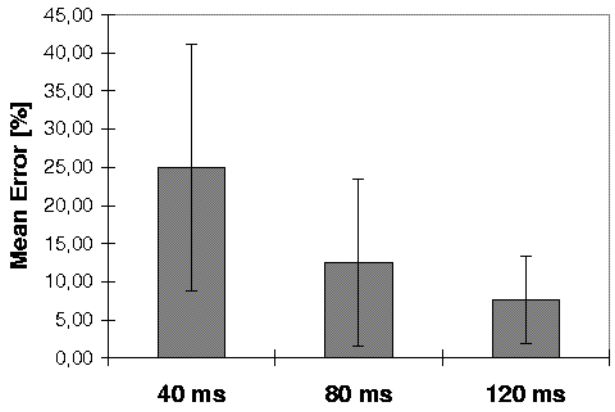

Figure 4. Discrimination Task (40, 80, 120 ms) in LH
bars indicate mean error [%] +/- 95 % confidence interval

4. SUMMARY AND DISCUSSION

Two experiments were designed to assess the ability of patients with acute aphasia (LH) to perceive the place of articulation of synthesized CV syllables. The results indicate that LH patients show a deficit in the perception of the phonetic contrast of stimulus pairs that are characterized by rapid frequency changes, while RH patients show a nearly unimpaired perception performance. In addition, it was demonstrated that this disability correlates with a more general speech comprehension deficit. Furthermore, lengthening of formant transitions enhanced the perception of place of articulation in stop consonants. The results of the present study are consistent with findings for chronic aphasics [9]. This observation in acute aphasics on the one hand and the positive correlation between perception (DT) and language comprehension (TT) on the other hand support the assumption that the described perceptual deficit may be a crucial factor in the underlying comprehension deficit in these patients. Unexpectedly, no significant correlation was found between the perception of CV syllables (DT) and the perception on the word level (WC). Possibly uncontrolled effects of the test items (word frequency, concreteness) account for this. Different results for perceptual error rates in LH and RH provides evidence for the left hemisphere specialization in the computation of fast frequency changes. To confirm this claim, more right hemisphere lesioned patients will have to be tested in further studies. However, the present data cannot provide a conclusive answer to the question whether the underlying perceptual deficit in aphasics is a general auditory deficit or a speech-specific phonological disorder. In accordance with [8], comparisons of perceptual performances on speech and nonspeech materials are required. Furthermore, perceptual tests with left hemisphere lesioned nonaphasics might indicate whether the computation of fast formant transitions represents a "general" function of the left hemisphere or a "specific" function of speech language areas.

The results of the present study might be relevant not only for a deeper understanding of the speech comprehension deficit in acute aphasic patients but also for aphasia therapy. Since some aphasics benefit from transition lengthening further therapeutic speech materials will have to be developed that involved temporal modifications of the speech signal. Specifically, it is our aim to investigate perceptual performances in acute aphasia therapy by means of temporal and spectral modifications of the speech signal as well.

Subject	Gender	Age	Type of Lesion[1]	Site of Lesion[2]	TPO[3]	Sensory Motor Status
RH						
F.G.	f	69	CVA	Right P	1	mild paresis
H.M.	f	48	CVA	Right P, BG	23	moderate paresis
H.E.	f	64	CVA	BG	14	moderate
K.L.	f	63	CVA	Right P	1	mild paresis
S.K.	m	52	tumor	Right P	3	no paresis
LH						
B.S.	f	47	CVA	Left BG	1,5	severe plegia
E.B.	f	35	CVA	Left FTP	1,5	severe paresis
H.B.	f	76	CVA	Left TP	2	no paresis
H.H.	m	58	CVA	Left FTP	2	severe plegia
K.E.	f	72	CVA	Left P	1	mild paresis
P.L.	f	74	CVA	Left TP	2	mild paresis
S.I.	f	69	CVA	Left TP	1	no paresis
T.D.	f	38	CVA	Left BG	1	severe plegia
T.H.	m	63	men. enc.	Left TOP	1	no paresis
W.S.	m	66	CVA	Left FTP	22	moderate paresis
K.K.	m	68	CVA	tumor	1	moderate paresis
H.N.	f	84	tumor	Left P	1	mild paresis

Table 2. Clinical Status of Experimental Subjects

[1]CVA=cerebral vascular apoplexy; men.enc.= meningo encephalitis [2]F=frontal, T=temporal, P=parietal, O=occipital, BG=basal ganglia [3] time post onset

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