Sonority in aphasic language production: Effects of the sonority dispersion principle on error patterns in demisyllables of varying phonological complexity

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Abstract

Repetition data were collected from aphasic patients with differing symptoms: All of the test items were monosyllabic and controlled for their phonological markedness calculated by the sonority ranks of demisyllables. Two types of results were significant: only a small number of errors occurred overall and only errors in three member demisyllables exhibited reduced markedness. We explain this last result by a combination of the mechanism of associating segments to the timing tier of syllables and due to buffer problems by the default operation of a random generator.

Keywords: Phonological markedness; Syllabification; Buffer; Random Generator

1 Introduction

Aphasic speech often displays phonological errors, ranging from phonological paraphasias to abstruse neologisms. In order to analyse the exact phonological nature of these aberrations, we based our investigation on the phonological markedness theory of Clements (1990).

1.1 Sonority and phonological markedness

In this theory, the complexity of a syllable can be defined in terms of sonority. Sonority is not phonetically measurable, but connected to major-class features as defined in the SPE-model (Chomsky & Halle 1968) supplemented with the feature ‘approximant (Clements 1990: 284).

The four major classes (obstruents, nasals, liquids, and glides/vowels) are defined by the three major class features [+-vocoid], [+-approximant] and [+-sonorant].

The feature [+-syllabic] is motivated by the associations of segments with C-roots and V-roots of the CV-skeleton, therefore it is related to the prosodic distinction between V and C elements of the timing tier. Segments which are dominated by a V-node are vowels or syllabic consonants with the feature [+syllabic], segments dominated by a C-node are glides or syllabic consonants with the feature [-syllabic]. Therefore, only the feature [syllabic] cross-classifies all other major class features. That is because this feature defines the probability of a class to represent a syllable peak in terms of the major classes. A greater sonority increases the probability of associating a segment with a V-root and assigning to it the feature [+syllabic]:

O	<	N	<	L	<	V	
+		+		+		+	syllabic
-		-		-		+	vocoid
-		-		+		+	approximant
-		+		+		+	sonorant
1		2		3		4	rank

Figure 1: Sonority ranking for V-slots (O: obstruent, N: nasal, L: liquid, V: vowel, G: glide)

O	<	N	<	L	<	G	
-		-		-		-	“syllabic”
-		-		-		+	vocoid
-		-		+		+	approximant
-		+		+		+	sonorant
0		1		2		3	rank

Figure 2: Sonority ranking for C-slots (O: obstruent, N: nasal, L: liquid, V: vowel, G: glide)

The linearization of segments constitutes a sonority cycle according to the above mentioned ranking. A relevant attribute of the sonority cycle is that it displays a quasiperiodic rise and fall in sonority. Proceeding from left to right of a syllable, the preferred sonority profile rises maximally towards the peak and falls minimally towards the end, which is equivalent to the optimal syllable.

The distance from a given structure to the preferred syllable can be calculated and contributes to its phonological complexity. This distance to the optimal syllable is termed D and is calculated on the basis of demisyllables. The syllable splits into two overlapping parts, the demisyllables, each containing a syllable peak.

Syllables as e.g. [klun] consist of the demisyllables [klu,un], [pa] of [pa,a] and [ap] of [a,ap]. The sonority profile of the first demisyllable is independent of the sonority profile of the second demisyllable, therefore phonological complexity of the demisyllables can differ from each other.

Phonological complexity is measured by "Dipersion" which is calculated as follows:

$$D= \sum_{i=1}^{m} 1/ di^2$$

> “Here, d is the distance in sonority rank between each i-th pair of segments in the demisyllable (including all nonadjacent pairs), and m is the number of pairs in the demisyllable, equal to n(n-1)/2, where n is the number of segments. It states that D, the dispersion in sonority within a demisyllable, varies according to the sum of the inverse of the squared values of the sonority distances between the members of each pair of segments within it.” (Clements 1990: 304)

Given the calculated value for possible initial and final demisyllables, the dispersion principle can be derived:

Dispersion Principle

a. The preferred initial demisyllables minimizes D

b. *The preferred final demisyllables maximizes D.*

	D	C (degree of complexity)
a.Two member demisyllables		
i. initial:		
OV	0.06	1
NV	0.11	2
LV	0.25	3
GV	1.00	4
ii. final		
VO	0.06	4
VN	0.11	3
VL	0.25	2
VG	1.00	1
b.Three-member demisyllables		
i. initial:		
OLV	0.56	1
ONV, OGV	1.17	2
NLV, NGV	1.36	3
LGV	2.25	4
ii. final		
VLO	0.56	4
VGO, VNO	1.17	3
VLN, VGN	1.36	2
VGL	2.25	1

Table 1: Dispersion in sonority (D) and phonological complexity (C)

One of the basic observations motivating markedness theories is that language which contains e.g. a nasal onset also contains obstruent in the onset but not vice versa. In Clements' theory, this implicational relation is defined by core syllabification rules in such a way that they do not create complex types unless they create the simpler syllable types.

1.2 Aphasic speech and phonological markedness

As we have already seen, phonological complexity can be understood in terms of major class features, syllable structure and position of a segment. Thus, in Clement's theory sonority is a principle that associates segmental information with suprasegmental structure. Interestingly, this function of sonority seems to be preserved even in cases of severe brain damage (cf. Christman 1992a, 1992b; Code & Ball 1994). Productions of jargon aphasics provide the main evidence for the assumption of hard-wired sonority constraints. Patients with jargon aphasia tend to produce neologisms for all lexical categories, i.e. nouns, adjectives and verbs. If no phonological relation to an existing word can be established, the term abstruse neologism is used. The first question to be asked in this connection is where these forms come from and the second one whether sonority restricts not only the production of target-related words but also the realisation of abstruse neologisms. Suppose one could observe neologisms not restricted by sonority the following conclusions should hold (cf. Christman 1992b: 225-226):

(1) sonority is not well-distributed in the brain and can therefore be impaired;

(2) *in contrast to legitimate words, neologisms are not governed by sonority constraints*

To answer the first question, Buckingham (1990: 215) assumes a mental component which he calls random generator as part of the phonological knowledge of all speakers and therefore not created by a neurological lesion but rather a normal albeit underused capacity. This cognitive component is operative in the speech of severely anomic Wernicke aphasics.

In an enriched model of Garrett (1982), the random generator resides at the level of the buffer which normally stores target words. In case of blocked lexical access, the random generator kicks in and substitutional forms are inserted at the positional level.

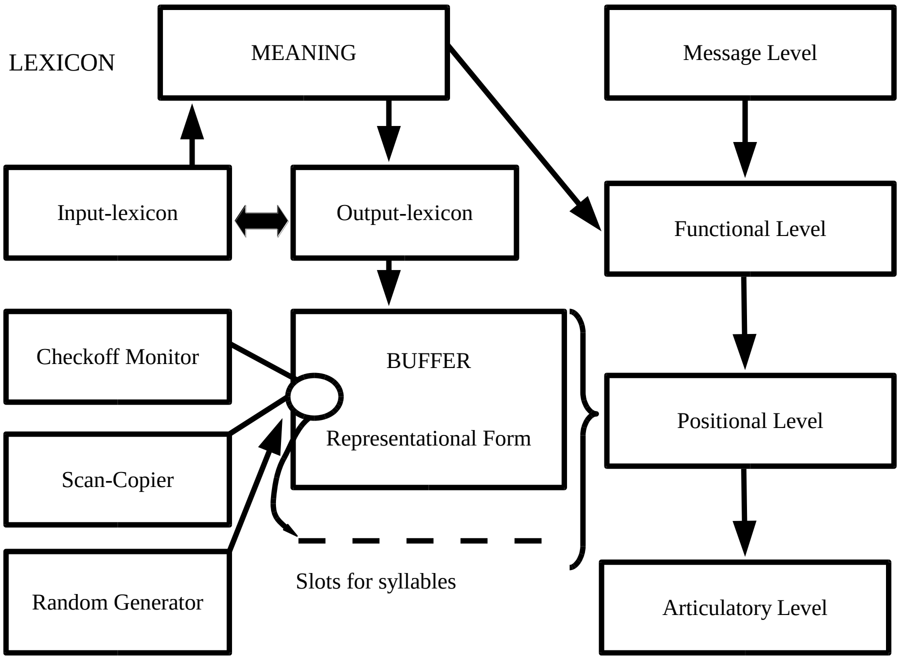

Figure 4: Model of language production (Dümig & Leuninger 2013: 56)

Christman (1992b) found that these substitutes are constrained by sonority. Spontaneous as well as elicited speech of jargon aphasics revealed that their neologisms consisted primarily of initial CV- and final V-demisyllables. The syllable positions were mostly associated initially with obstruents and finally with vowels. Altogether, optimal CV-syllables seem to be preferred. According to Christman, these results support the notion of sonority as (1) well-distributed component of the language system, since it was not significantly impaired in otherwise seriously impaired phonological systems; and (2) governs the phonological construction in all word forms, legitimate words, paraphasias, and neologisms (Christman 1992b: 234)[1].

Stenneken et al. (2005) analysed the spontaneous speech of a German speaking jargon aphasic, KP, with respect to demisyllable frequency. A type-token analysis revealed that the aphasic neologisms tended to be of the preferred German syllable type. The most frequent demisyllable types were of maximal sonority (OV- in syllable initial position and –V in syllable final position (Stenneken et al.: 289).

Summing up, the results of the above-mentioned studies provide evidence for the psychological reality of the dispersion principle. Sonority constraints are operative even or especially in the production of abstruse neologisms. The latter are considered to be

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[1] Reduction of phonological complexity was also attested by Romani & Calabrese (1998) in their analysis of the speech of an Italian Broca-aphasic, DB. His language behaviour was in accordance with the predictions of the dispersion principle: less sonorant sound classes were inserted into the onset position. They mention that complex codas are not licensed in Italian, besides vowels only liquids and nasals are allowed in this position. Consequently, significant markedness reductions in final demisyllables cannot be measured.

constructions of a random generator, a normally underused component of the speech production system.

2 Method

2.1 Hypothesis

As the random generator is not operative in phonological paraphasias, our first hypothesis is derived as follows:

H1: There is no overall significant markedness reduction in phonological paraphasias.

2.2 Subjects

12 aphasic patients (7 male, 5 female; mean age 68,6, range 54-79) were included in the study. All of them were either scored for aphasia via the AAT (Huber et al., 1983) or the AST (Kroker, 2002). All patients developed their aphasia due to neurological damage of various etiologies (mostly due to stroke, bleeding or tumour). Although subjects varied in severity of disorder, there was no reason to believe that these factors influenced the error-pattern when trying to repeat our target items. Apart from RC, who was bilingual Italian/German, all of our participants were native speakers of German.

2.3 Material

Based upon the above discussed concept of sonority, we constructed a set of test items (see Appendix) comprising 104 monosyllabic, monomorphemic words. Since these syllables are analysed as consisting of demisyllables there are 79 initial two-member demisyllables and 25 initial three-member demisyllables as well as 49 final two-member and 55 final three-member demisyllables at hand. Not all of these demisyllables were taken into account. Three-member demisyllables which form a plateau as [ʃva] in [ʃva:n] (“swan”) or [ɪçt] in [lɪçt] (“light”) were excluded form the analysis. This finally resulted in 98 initial (79 two-member and 19 three-member) demisyllables and 86 final (49 two-member and 37 three-member) demisyllables.

Demisyllables are ranked according to their complexity. Some demisyllable types remain empty for the chosen items, because it is not certain if there are appropriate words in Standard German. This refers to the demisyllable types VG, NLV, LGV and VGL.

The complexity rankings for the analysed demisyllable types are listed in the tables below (Tab. 2 a-d).

a

Complexity ranking	Type of demisyllable	Demisyllable	Complete syllable
1	OV	[ba]	[bal] (“ball”)
2	NV	[nu]	[nus] (“nut”)
3	LV	[ro:]	[ro:t] “(red)”
4	GV	[ja:]	[ja:gt] (“hunt”)

b

Complexity ranking	Type of demisyllable	Initial demisyllable	Complete syllable
1	VG	-	-
2	VL	[a:l]	[a:l] (“scarf”)
3	VN	[iŋ]	[riŋ] (“ring”)
4	VO	[o:t]	[bo:t] (“boat”)

c

Complexity ranking	Type of demisyllable	Demisyllable	Complete syllable
1	OLV	[ʃra]	[ʃraŋk] (“wardrobe”)
2	ONV	[kne]	[kneçt] (“servant”)
3	NLV	-	-
4	LGV	-	-

d

Complexity ranking	Type of demisyllable	Initial demisyllable	Complete syllable
1	VGL	-	-
2	VLN	[alm]	[psalm] (“psalm”)
3	VNO	[emt]	[hemt] (“shirt”)
4	VLO	[olf]	[volf]] (“wolve”)

Tab 2: Complexity ranking initial and final demisyllables (a-d)

2.4 Procedure

Data acquisition

Patients were required to repeat items which were presented verbally. All verbal responses of the aphasics were noted and transcribed into phonetic script according to the IPA by five raters. Interrater reliability was 93%.

Data aggregation

The initial and the final demisyllable of each utterance by the aphasic patient were compared with its intended target. The utterances were classified (relative to their target item) as right or wrong (%) with identical or different sonority rank. We further differentiated between errors made within two- and within three-member-demisyllables, with special interest in changes of the relative sonority rank (higher vs. lower). All together we investigated 2208 (1176 initial, 1032 final) demisyllables. No errors came into account, when there were exchanges between categories (i.e. when a two- member demisyllable became a three-member demisyllables by an insertion or vice versa by an omission). These errors were excluded, for it is not yet clear from the sonority rank concept of Clements (1990), if these changes are comparable to each other.

All inferential statistics were calculated with SPSS (Statistical Package for the Social Sciences, Version 11.5.1), using the χ^2–test when looking for significant differences.

3 Results

Within the 2208 demisyllables under investigation only 79 (3,57%) errors occurred. In 53 (67,08%) of these errors there was no change in the sonority rank, as for example in the first demisyllable OV is retained as in [gans] to[dans], and in the second demisyllable VO is retained as in [Rok] to [Rot]. In 26 (32,91%) cases there was a change in sonority. As mentioned above, there was no equal distribution across two- and three-member demisyllables in our data. Out of the 184 demisyllables in the items list that came into account there were 79 + 49 = 128 two-member (69,57%) and only 19 + 37 = 56 three-member (30,43%) demisyllables. Hence, the expected distribution of two- and three-member demisyllables within the 26 changes of the sonority rank was not 50%-50% (13-13) but rather 69,57%-30,43% (18-8). After differentiation into two- and three-member demisyllables the following significant error pattern emerged. 12 (18 expected) changes of sonority ranks occurred within two-member- and 14 (8 expected) changes occurred within three-member demisyllables (χ^2 = 6,500, df = 1, p = 0,011). Within the two-member demisyllables some kind of chance performance emerged. Of the 12 errors in this category 7 resulted in a higher and 5 in lower sonority rank (χ^2 = 0, 333, df = 1, p = 0,564), namely in the second demisyllable VN is realized as VO as in [ʃva:n] to [[ʃve:t], increasing the rank from three to four. Within the three-member demisyllables there was a significant difference. There were only three changes resulting in a higher, e.g. VLN to VLO as in [halm] to [halp], increasing the complexity rank from two to four but 11 changes resulting in a lower sonority rank (χ^2 = 4,571, df = 1, p = 0,033), namely in the second demisyllable VLO to VLN as in [kalp] to [kal]. In combination there were 10 changes resulting in a lower and 16 changes resulting in a higher sonority rank, which did not show a significant difference (χ^2 = 1,385, df = 1, p = 0,239).

4 Discussion

Three main findings of this study require an in-depth analysis. First, it is surprising how few errors occurred overall. Thus, the repetition task based on complexity controlled items reveals only a weak disruption of the sublexical routes and components, namely form lexicon access, scan copier and check-off monitor.

Secondly, we did not find a significant reduction of phonological complexity in two-member demisyllables, confirming our hypothesis, whereas this reduction was observed in three-member demisyllables. This result can hardly be explained by the theory of Clements (1990), since according to his assumptions there is no difference in the degree of complexity between two- and three-member demisyllables, hence the same amount of errors in both categories should occur.

Thirdly, the majority of errors in three-member demisyllables did not result in the deletion of C-positions, e.g. cluster reduction. This result contradicts expectations that follow from previous studies (cf. Ardila et al. 1989; Béland et al. 1990; Buckingham 1992; Den Ouden 2002; Kohn & Smith 1994).

In the following, we give an explanation why complexity is reduced whereas the C-slots of the three-member demisyllables were not affected.

Measured in mere length of the items, a buffer problem apparently cannot account for this observation, since there is no problem in processing the coarse length of a target word and sonority apparently plays no role within a buffer.

We assume to the contrary a special sort of deficit, derived from the interaction of buffering, syllable structure, and sonority.

Our explanation is based on Wiese’s (1996) theory of syllabification understood as a rule-governed assignment of syllable structure to a string of segments in a word. First, a timing unit X is assigned to each root node of a segment. Then the default rule *Syllable head assignment* applies (Wiese 1996: 52):

a. Assign [+ syllabic] to an X unless another X immediately precedes.
$$\begin{array}{cc} | & | \\ \text{[- consonantal]} & \text{[- consonantal]} \end{array}$$
b. Join all X dominating [-consonantal] into a nucleus N.

Rules for syllable onset and coda apply afterwards. In light of this syllabification process, late assignment of the feature [-syllabic] to every X is not possible because the segments at the syllable edges could not be held in the buffer that long. The position of the segment is already assigned to an X, but the segmental content is not available anymore. At this point of processing, the random generator kicks in as a default device and a random segment with less sonority is assigned to the open X-position. Therefore, no cluster reduction takes place and absolute length remains.

In other words, a ‘special’ buffer deficit is a dissociation between the timing tier and the segmental content.

To sum up, the following conclusions can be drawn from the present study.

1. To detect fine-grained buffer deficits, it is necessary to construct diagnostic items in terms of phonological complexity and not absolute length.
2. The small number of errors and their patterns indicate what Christman (1992b) has already stated: Sonority is a well-distributed component of the language system and governs the phonological construction in all word forms, legitimate words, paraphasias, and neologisms. [2]

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[2] Syllables are assembled on-line from segmental and subsegmental units. If there would be only a syllabary (cf. Levelt et al. 1999), the different patterns of two member and three member demisyllables could not be explained. At least one must assume both routes of phonetic encoding (cf. Mayer et al. 2003), namely a retrieval from the syllabary and an incremental syllabification.

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Appendix

Test items sorted by structure and segment class

structure/place	segment class	stimulus	translation
no cluster	plosive vs. liquid	Ball	„ball“
	plosive vs. nasal	Baum	„tree“
		Bein	„leg“
		Kamm	„comb“
	plosive vs. fricative	Haus	„house“
		Bus	„bus“
		Tisch	„table“
		Buch	„book“
		Eis	„ice“
	plosive vs. plosive	Bett	„bed“
		Boot	„boat“
	fricative vs. liquid	Wal	„whale“
		Schal	„scarf“
	fricative vs. nasal	Fön	„hair dryer“
	fricative vs. Fricative	Schaf	„sheep“
		Schiff	„ship“
		Fisch	„fish“
		Fass	„barrel“
		Fuß	„foot“
	fricative vs. plosive	Sieb	„sieve“
		Sack	„sack“
	nasal vs. nasal	Mohn	„poppy“
	nasal vs. fricative	Nuss	„nut“
		Maus	„mouse“
	liquid vs. nasal	Ring	„ring“
	liquid vs. fricative	Reis	„rice“
		Rauch	„smoke“
	liquid vs. plosive	Rot	„red“
		Rad	„wheel“
		Rock	„skirt“
		Lok	„loc(omotive“)
Cluster initial	plosive + liquid	Clown	„clown“
		Gras	„grass“

		Fleisch	„meat“
		Brot	„bread“
		Kran	„crane“
		Blatt	„leaf“
	fricative + liquid	Frosch	„frog“
		Floß	„raft“
		Schrank	„cupboard“
		Schloss	„castle“
	plosive + nasal	Knie	„knee“
		Knecht	„servant“
	fricative + nasal	Schmuck	„jewelry“
		Schmied	„blacksmith“
		Schnell	„quick“
		Schmal	„narrow“
		Schnee	„snow“
	plosive + fricative	Psalm	„psalm“
		Qualm	„fume“
	fricative + fricative	Schwan	„swan“
		Schwein	„pig“
Cluster final	liquid + plosive	Alt	„old“
		Bild	„picture“
		Wald	„forest“
		Geld	„money“
		Gold	„gold“
		Kalt	„cold“
		Kalb	„calf“
		Gelb	„yellow“
	liquid + fricative	Alf	Alf
		Wolf	„wolf“
		Golf	„golf“
		Hals	„neck“
		Schiff	„ship“
		Pils	„pils“
		Elch	„elk“
		Milch	„milk“
		Dolch	„dagger“

		Kelch	„cup“
	liquid + nasal	Halm	„halm“
		Helm	„helmet“
		Qualm	„fume“
		Alm	„alp“
		Psalm	„psalm“
	nasal + plosive	Hund	„dog“
		Schrank	„cupboard“
		Bank	„bank“
		Tank	„tank“
		Hemd	„shirt“
		Sand	„sand“
		Samt	„velvet“
	nasal + fricative	Sims	„cornice“
		Hanf	„hemp“
		Senf	„mustard“
		Hans	„Jack“
		Gans	„goose“
	fricative + plosive	Saft	„juice“
		Knecht	„servant“
		Gift	„poison“
		Hecht	„pike“
		Licht	„light“
		Nacht	„night“
		Docht	„wick“
		Schicht	„layer“
		Schacht	„chamber“
		Wicht	„dwarf“
		Yacht	„yacht“
	plosive + plosive	Abt	„abbot“
		Nackt	„nude“
		Takt	„beat“
		Akt	„act“
		Jagd	„chase“
		Magd	„maidservant“