Sonority substitutions in language disorders

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1. Introduction

In this paper we consider a widely attested process: *sonority substitutions* whereby sounds of a certain sonority class change into sounds of another sonority class[1]. These sonority substitutions concern, for example, liquids (/l,r/) changing into glides (/j,w/). The target word *groen* 'green' may be realized by an aphasic speaker as [xjun] or [xwun]. We will discuss these sonority substitutions in phonological disorders in children and in aphasic patients.

We claim that these phenomena cannot adequately be accounted for in current phonological theories. In the first part of this paper (section 2) we will give a short sketch of the way in which the naturalness of phonological processes can be represented in relation to the complexity of their description and the reason why an alternative account is required. In the second part (section 3) we will introduce data from language disorders and discuss the consequences thereof for phonological theories. Finally (section 4 and 5) we will propose a phonological model that is capable of describing sonority substitutions adequately.

2. Commonness and complexity of phonological processes

Sonority substitutions occur very generally in many language data. The above-mentioned liquid-glide substitutions occur not only in phonological disorders but also in normal language acquisition and non-pathological speech errors. For example, the target word *drinken* 'drink' may be pronounced as [dwɪŋkə] by children of about two years old (Van Zonneveld 1988). Van Rheenen (1986) described liquid-glide substitutions in language change. Since we find these phenomena in many language data, this process must be considered a common process.

McCarthy (1988) states that common, natural processes should be far more easy to describe than uncommon ones. The naturalness of a certain process follows from a theory if it can be described as a single operation on a single element of the representation. A process such as *final devoicing*, for example, involves only the change of value of one feature. A rare process such as

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metathesis, however, involves a whole series of changing feature values. Therefore metathesis has to be considered a *marked* process. The traditional SPE-account (Chomsky & Halle 1968) of phonological processes as rules cannot reflect the commonness and naturalness of certain processes. Therefore nowadays many phonologists prefer a hierarchical organization of features. An example of such a hierarchical organization is the *feature geometry* (henceforth: FG) (Clements 1985, McCarthy 1988). In general the FG-account of phonological processes appears to reflect the markedness of phonological processes better than the SPE-account[2].

How do these types of theories explain sonority substitutions? Let us look at liquid-glide substitutions. A phonological model should describe this process as a simple rule or operation on the representation, as it is such a common process. However, looking at the SPE-analysis of liquid-glide substitutions in (1), we see that this process involves the changing in value of a number of features.

(1) SPE-like rules of liquid-glide substitutions:

/l/ -> [w]		/l/ -> [j]		/r/ -> [w]		/r/ -> [j]	
+ son →		+ son →		+ son →		+ son →	
+ cons	- cons	+ cons	- cons	+ cons	- cons	+ cons	- cons
+ cont		+ cont		+ cont		+ cont	
+ lat	- lat	+ lat	- lat	- lat		- lat	
- lab	+ lab	- lab		- lab	+ lab	- lab	
+ ant	- ant	+ ant	- ant	+ ant	- ant	+ ant	- ant
+ cor	- cor	+ cor		+ cor	- cor	+ cor	
- high	+ high	- high	+ high	- high	+ high	- high	+ high
- back	+ back	- back		- back	+ back	- back	
- round	+ round	- round		- round	+ round	- round	

SPE cannot account for these substitutions as a single operation on just one element of the representation. The value of at least three features has to be changed for a liquid to become a glide. Hence the SPE-account is unable to represent the commonness of the process.

A spreading operation in FG, however, is also unable to describe these substitutions as a simple operation on one element of the representation. Most versions of FG use the same features as SPE; they only differ in the way the features are organized (and in the restrictions on possible rules). If, for example, an /l/ is substituted by a [w], the values of eight features (occupying different positions in the hierarchy) have to be changed. Therefore, even in FG a number of association lines must be spread and delinked to describe the liquid-glide substitution. Moreover, in all the above-mentioned cases a liquid changes into a glide, but FG is not able to reflect the similarity of these processes. There is no general explanation of this process of liquid-glide substitutions in FG.

2 McCarthy (1988) supports this claim by comparing the traditional SPE-account of the process of place assimilation of nasals with the FG-account.

3. Phonological disorders

The data in (2) show substitutions produced by aphasic patients and children with phonological disorders. We observe many kinds of substitutions (for example glides changing into liquids, liquids into nasals and nasals into liquids).

(2) Sonority substitutions:

a phonemic paraphasias[3] (own data)

target word			realization
grasmaaien	'mow'	/xrasmAj@n/	[xrasmAl@n]
slijpen	'sharpen'	/sleIp@n/	[sneIp@n]
knippen	'cut'	/knip@n/	[krip@n]
knippen	'cut'	/knip@n/	[klip@n]
neus	'nose'	/n0s/	[l0s]
lam	'lamb'	/lam/	[nam]
stoel	'chair'	/stUl/	[stUn]

b. phonological disorders in children (Koch 1989)
(age: 4;0 to 5;7)

target word			realization
drinken	'drink'	/driNk@n/	[dwiNk@]
clown	'clown'	/klaUn/	[kjaUn]
slee	'sledge'	/slE/	[snE]
knie	'knee'	/knI/	[klI]
knie	'knee'	/knI/	[krI]

In these data, segments of one sonority class are substituted by segments of another. As we saw in section 2, such data are hard to describe by SPE- and Feature Geometry approaches.

What is the reason for the problems encountered by both theories when they have to describe substitutions of the kind mentioned above? The reason is that in neither theory a distinction is made between degrees of sonority in a structural

[3] *Phonemic paraphasias* are unintended substitutions, transpositions, deletions or additions of sounds. In the case of a phonemic paraphasia it is suggested that the phonological system of the patient is fundamentally disturbed (Buckingham 1989).

way. These theories only incorporate a feature [sonorant], with the value 'plus' or 'minus'. This distinction is inadequate for describing, for example, liquid-glide substitutions. Both liquids and glides are [+sonorant] sounds, but the degree of sonority of glides is higher than the degree of sonority of liquids. The degree of sonority of different sounds can be represented in the so-called *sonority hierarchy*, as shown below.

(3) Sonority hierarchy (increasing sonority from left to right):

class of segments:	obstruents -	nasals -	liquids -	glides -	vowels
exemplary segments:	/p,t,k.../	/n,m.../	/l,r.../	/j,w.../	/a,i,u.../
level of sonority:	5	4	3	2	1

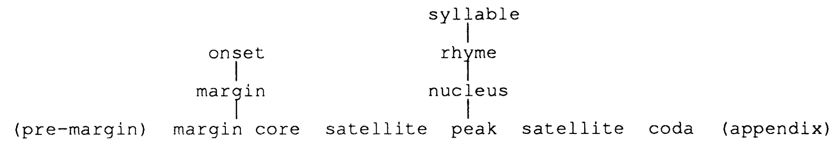
We claim that to describe the sonority substitutions mentioned above, we have to incorporate this sonority hierarchy in a phonological model. Some attempts have been made in FG to derive sonority from the atomic features. Clements (1990), for example, proposes simple feature counting, that is, deriving the sonority scale by taking the number of 'plus' specifications for a certain set of features. Dogil and Luschützky (1989) propose identifying the sonority of a segment by the degree of branchedness of its feature structure. These proposals, however, are not able to represent in which way the change of degree of sonority can be connected with the change of value of other atomic features. As we saw above, changing a liquid into a glide involves at least the change of value of a manner feature and two place features. Therefore, a number of association lines has to be spread and delinked.

To summarize, the problem is that in both SPE and Feature Geometry, sonority substitutions must (unjustly) be considered to be extremely marked, since they cannot be accounted for as a single operation on a single element of the representation. The process cannot be described as a *minimal change* in these theories.

4. *The model*

For an adequate description of the examples mentioned above, we need a model that is able to represent the connection between the degree of sonority and the value of the atomic features. Degree of sonority plays an important role in syllable structure. The distribution of segments within the syllable follows a certain pattern: sonority increases from the pre-margin towards the peak and decreases from the peak towards the appendix (*sonority slope* or *sonority sequencing principle*). The syllable structure in (4) is a constituent model based on Cairns and Feinstein (1982).

(4) Syllable structure (based on Cairns and Feinstein 1982):



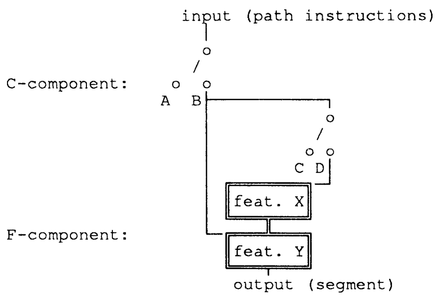
This model represents a hierarchical organization of the segment distribution within a syllable. Vertical lines represent the head of the constituent, whereas the slanting lines represent the dependent parts. These dependent parts are the optional parts of a dominating constituent. The vertical line from *syllable* to *peak* shows that the peak position is the most important segment position of the syllable. The other positions are dependent on this peak. All positions are phonotactically constrained. In Dutch, for example, the peak position can only be filled by a vowel. The margin-core position, on the other hand, can be filled by all segments except vowels. In the syllable structure of Cairns and Feinstein, however, we do not find these constraints. These have to be stipulated separately. The representation in (4) does not show, for example, that a satellite position cannot be filled by an obstruent. The representation only represents the dependency relations between segment positions.

We claim that the differences in sonority of segments and their place in the syllable model play an important role in the description of processes of sonority substitutions. Furthermore, we think that only a model that establishes a connection between both the degree of sonority of a segment and the value of its atomic features is able to account for the process as a single operation on a single element of the representation.

In order to give such an adequate account, we will transform the syllable model in (4) into a phonological network representation (Gilbers 1992). First we will give a short introduction to the framework of *Phonological Networks*.

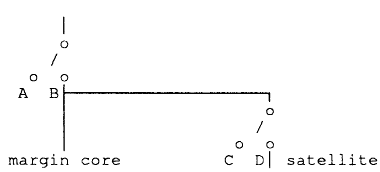
Phonological Networks is a model of segment representation, consisting of two components, a feature-component and a control-component, the so-called *F-component* and *C-component*. The *F-component* represents the organization of phonetically-defined features. All the F-component features explicitly indicate instructions to the articulators. Therefore, there are no *major class features*, such as sonorant or syllabic, in this F-component. These major class features only indicate classes of segments; they are not defined as articulator instructions. The determination of classes of segments is taken care of in the *C-component* of the model. This C-component is a complex network of connections -a sort of electricity circuit- that constrains the possible combinations of features within a segment. This network functions in such a way that the resulting model can generate only all those feature combinations that represent all contrastive segments of a language. So, it is a highly restrictive model. Furthermore, the network is extended to higher phonological domains. It also constrains the possible sequences of segments within a syllable, and sequences of syllables within feet, and so on. A simplified representation of the input and output of the network model is presented in (5).

(5) Simplified representation of Phonological Networks:



In (5), an instruction to the articulators is activated if the input of the model is connected to the feature by the correct switch position. So here, position B activates feature Y. We can also see that the activation of feature X -which requires switch position D in the network- is dependent on the activation of feature Y. Only if feature Y is activated can the CD switch be reached. In this way, dependency relations between features are incorporated in the model. In the same way, dependency relations on a higher level -between segments in a syllable- can be represented as shown in (6). Just as the satellite in syllable model (4) depends on the margin core, a network satellite can only be activated if its head constituent is activated. In (6) we see how the dependency relations between segment positions in the syllable can be represented by the C-component.

(6) Dependency relation between Margin core and Satellite:

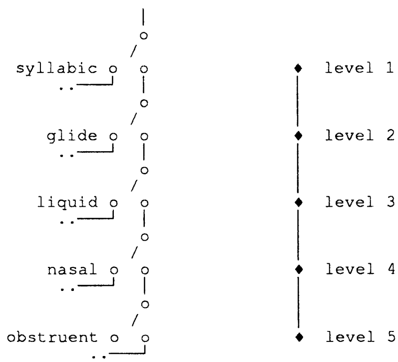


In the C-component a satellite can only be activated when its head constituent is activated. This is represented by means of an optional implication line in the C-component: if a syllable exhibits a branching margin core (switch option B), this margin core can optionally be extended with a satellite (option D).

The representation in (6) does not show, however, that the distribution of segments within a syllable follows a certain pattern, the aforementioned *sonority slope*. In order to represent the sonority slope of the syllable, the options for each segment position in the C-component must be restricted. In (7) the non-restricted version of the C-component sonority path is shown.

(7) Sonority levels:

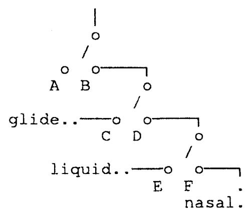
a. circuit b. levels



As the path in the C-component becomes more embedded, the derived segment becomes less sonorant. Every branch of this sonority path adds different restrictions to the possible feature combinations by means of implication lines within the C-component. All levels have their own restrictions on possible feature combinations. For example, the atomic feature [nasal] cannot be activated if the path *liquids* (level 3) has been chosen, but it cannot be deactivated if the path *nasals* (level 4) has been chosen.

Every segment position in the syllable exhibits a path of embedded switches, but no position allows for all the possible sonority levels in (7). For example, in (8) we see how the sonority path of the satellite only allows for segments of sonority levels 2, 3 or 4. The C-component is constructed in such a way that levels 1 and 5 are not available in this segment position.

(8) Satellite (part of the C-component):



This part of the C-component offers the possibility to generate sonorant consonants (option B). The output is restricted to glides (option BC), liquids (option BDE) and nasals (option BDF). For example, consider the Dutch word *groen*. In this word the liquid /r/ occupies the satellite position. If we choose the path to liquids, the possible feature combinations are restricted in such a way that only /l/ or /r/ can be the output segment. In a similar way, the chosen path glides will result in either /j/ or /w/. Given this option, there are no alternatives and there is no way back. In other words, a small change on the sonority path causes major changes in the ultimate feature combination output.

Consider now the implementation of all the segment options in the hierarchically organized Dutch syllable model. In (9), we can clearly see the sonority slope of the segments. For practical reasons, we have represented the switches in (9) as diamonds '♦'.

(9) Dutch Syllable Sonority Slope:

	syllable						
	onset			rhyme			
	pre-margin	margin		nucleus		coda	appendix
		margin core	satellite	peak	satellite		
level							
♦ 1				♦ syl			
♦ 2		♦ glide	♦ glide		♦ glide	♦ glide	
♦ 3		♦ liq	♦ liq		♦ liq	♦ liq	
♦ 4		♦ nas	♦ nas		♦ nas	♦ nas	
♦ 5	♦ obstr	♦ obstr				♦ obstr	♦(♦(♦))

The model shows that no segment position in the syllable allows for all sonority levels. Levels 2 to 5 are excluded from peak position, whereas level 1 is excluded from all positions but the peak. The syllable edges can only be filled by segments of level 5. This Dutch C-component restricts the possible feature combinations in such a way that, for example, the only possible obstruent in the pre-margin is an /s/.

By incorporating the Phonological Networks-model in Cairns and Feinstein's syllable structure, it is possible to represent structurally both the dependency relations within the syllable and the restrictions on the possible segments in syllable positions.

5. *Applications of the model*

As mentioned before, in language acquisition data we observe changes from liquids to glides, that is children ending up one switch too high on the sonority hierarchy. These examples are observed in Dutch and English, and also in Czech (Rūke-Draviņa 1990). In Czech the adult form of 'box of matches' is *krabička*. One child pronounces this word at 1;11 as *abiška*. The next stages are *kabička* 2;0 → *kjabička* 2;4 → *klabička* 2;6 and finally *krabička* at 4;1. How can these changes be explained?

Grunwell (1987) states that normal acquisition of liquids involves much individual variation. She assumes that in general the /w/ will be used correctly at 2;0-2;6, but this /w/ will also be used for other segments. The /j/ will be correctly produced at about 3;0 and /l/ at 3;0-3;6. The pronunciation of /r/ as [w] may be used until 4;0-5;0 or even later. In many studies of child language these processes are reported, but an explanation for these data is never given. What makes liquids hard to acquire?

In the theory of Phonological Networks this is explained as follows: at a certain stage in language acquisition children have not yet acquired all sonority levels in every position within the syllable. Especially in the more embedded positions, such as the satellite positions, a child has problems in reaching the correct switch. This does not explain, however, why it is difficult for a two-year old child to produce the segments in a satellite position. Since Jakobson (1939, 1962) it has been assumed that a child acquires its language in terms of phonemic opposition, starting with the contrast between obstruents and open vowels. These are levels 1 and 5 in the network model in (9). When we look at the difficult satellite positions, we can see that in these positions the level 1 and 5 segments are excluded. This means that the child has to produce a segment of a sonority class it is not as familiar with. Furthermore, this segment is in a position of the syllable that is more embedded and therefore more marked. Hence, it is not surprising that a child slips on the sonority scale and ends up one switch too high. Gilbers (1992) assumes this is the reason why liquids (level 3) are late-acquired segments, since these are exactly in between the easiest levels. The substitutions in normal children can be described as a minimal change upwards along the sonority scale. Although the child is able to distinguish the five sonority levels, he or she is unable to distinguish between these sonority levels when the segment is in a marked position, such as the satellite position. We expect a child who is seeking maximum contrast to aim too high on the sonority scale of the satellite if he tries to realize a margin core - satellite combination. And then, this will result in a sort of 'domino effect' of fixed switches and implication lines. So, a small deviation on the sonority path inevitably results in a big change of atomic feature values. However, the initial change is a minimal change, indicating that we are dealing with a common process, according to the claim by McCarthy (1988).

When we look at the data from phonological disorders in (2), we see that both in the data from children and in the data from aphasic patients, not only liquid-glide substitutions, but also nasal-liquid substitutions occur. Furthermore, these changes are not unidirectional. A nasal may change into a liquid, but a liquid may as easily change into a nasal. Blumstein (1991:157) mentions that in general:

> ...phoneme substitutions should occur more commonly among sounds sharing a number of feature dimensions, for example, /p/-/b/ versus /t/-/w/. Moreover, sound substitutions should be characterized more commonly by single feature changes than by several feature changes.

In our data from aphasic patients this pattern is indeed found. The total number of simple phonemic consonant substitutions in our corpus is 102. Of these paraphasias, 66 (64.7%) are substitutions within one sonority class, for example *fles* /fles/ 'bottle' realized as [fres]. The number of substitutions between neighboring sonority classes is 17 (16.7%). At first sight, a few substitutions (8.8%) seem to exemplify changes crossing an intervening sonority class, but closer examination reveals that these examples may generally be interpreted as examples of segment perseveration or deletion. In data from aphasic patients of Braam-Voeten and Blaauw-Baerends (1979), we find a similar distribution. Of the most frequent consonant substitution errors, 55.6% are substitutions within a sonority class, 22.8% are substitutions between neighboring classes, whilst substitutions crossing an intervening class are negligible (2.7%).

The fact that most substitution errors occur within one sonority class, is exactly what is expected from the point of view of phonological representations. McCarthy (1988), as noted above, claims that in an ideal phonological representation, common substitutions should be analyzed as minimal changes. The percentage of substitutions between neighboring sonority classes, however, is around 20%. Hence, these substitutions should also be considered as common in language disorders. What happens in aphasic language in terms of Phonological Networks? In comparison with child language, we can say that adults, naturally, do exhibit all permitted sonority classes in all positions of the syllable. When their phonological abilities deteriorate, as happens in aphasia, the patient can slip to both sides on the sonority scale. Therefore, an aphasic speaker can as easily substitute a nasal for a liquid as a liquid for a glide (or vice versa).

In data from children with phonological disorders we observe the same kind of substitutions. Not only do liquid-glide substitutions occur, but also substitutions of nasals and liquids. Just as in aphasic patients, these children (varying in age from 4;0 to 5;7) may have acquired all segments in all positions, but are not able to aim at the right switch, and therefore make the same mistakes that aphasic patients do. The Phonological Networks template representation allows us to describe these changes as minimal changes on the sonority scale. Changing one switch in a certain position in the circuit will change the intended feature combination into a totally different output combination. This operation involves one minimal change in the representation. In almost all errors it is the satellite of the margin core that is most vulnerable to change. Apparently, the most embedded positions in a syllable, and hence the most marked, are the positions that may easily be changed.

6. *Conclusion*

We have shown that a common process like sonority substitution causes many problems for those phonological theories that do not make a distinction between degrees of sonority in relation to the value of atomic features. Incorrectly, these theories consider sonority substitutions as extremely marked. The process cannot be described as a simple operation on one single element of the representation, since the target segment and the produced segment differ in a large number of feature dimensions.

We showed that within the framework of Phonological Networks the relation between major class features and atomic features can be represented in the C-component. This component not only restricts the possible feature combinations within a segment, but also restricts the possible segment combinations within a syllable. Each segment position within the syllable has its own path of embedded switches that represents the sonority scale: the further this path is embedded in the C-component, the less sonorant the output segment will be. Each branch of the sonority path has different restrictions on possible output feature combinations by means of implication lines within the C-component. This network representation allows us to show that a minor deviation on the sonority path causes major changes in the ultimate output feature combination. The process of sonority substitutions can be considered an unmarked process, because the initial change is a minor change.

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