Feature Distance in Consonantal Slips of the Tongue -

Psycholinguistic and Methodological Aspects

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Abstract

This paper deals with contextual phonological errors in a corpus of elicited German slips of the tongue. Emphasis is laid upon the analysis of the role of feature distance in contextual phonological errors. It turns out that feature distance is an essential factor determining phonological errors. From a methodological point of view, we tried to determine which of two feature systems is more appropriate to analyze and describe such errors, namely that of Kloeke (1982) or the IPA. Some criteria of evaluation were worked out. The vast majority of errors are one-feature errors. Additionally, the relation of feature distance and syllable distance between target and intruder segment is analyzed in detail.

Introduction

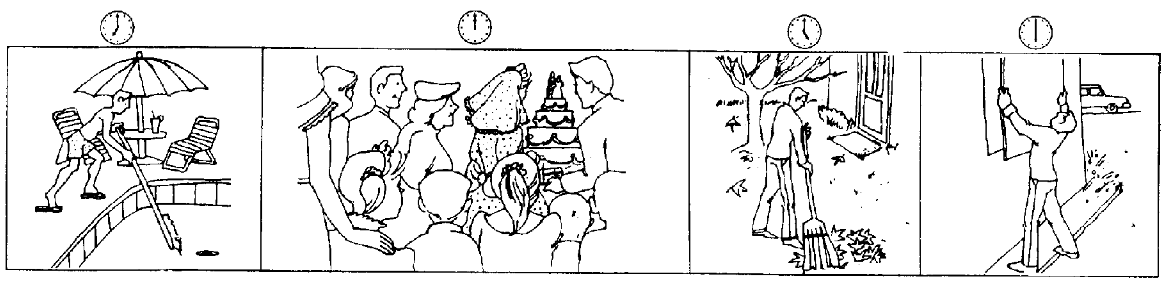
This study was carried out within a research project by the German Science Foundation (Deutsche Forschungsgemeinschaft (DFG)) on modality dependent and independent aspects of language production in the scope of the DFG main focus "language production".[1] In this project, slips of the tongue and hand are compared in order to assess modality dependent and independent effects in language production. There exist two parallel corpora, one for errors of Spoken German, and one for errors of German Sign Language (Deutsche Gebärdensprache (DGS)). In the following, I will only consider the spoken phonological consonantal slip data.

In particular, we investigate the role of feature distance in contextual phonological slips which seems to be a crucial factor determining this error type. For segmental errors, the phonological similarity of error and intruder element is well-documented. There is a large degree of consent concerning the result that segments tend to be phonetically similar if they interact in a speech error (van den Broecke and Goldstein, 1980, Ellis, 1980, Garcia-Albea, del Viso & Igoa, 1989, MacKay, 1970, Shattuck-Hufnagel, 1979, 1987, 1992, Shattuck-Hufnagel & Klatt, 1979). Especially, van den Broecke and Goldstein (1980) compared four feature systems in order to find out which of them is the most appropriate to analyze phonological errors. Due to the fact that speech errors are production phenomena in the first place, they reflect systematic properties which depend on the language processor. It seems to be obvious that the language processor tends to incur itself with cognitive load which is as small as possible. Consequently, a feature change of only one feature should be less expensive for the system than errors with a higher feature change. With respect to these speculations, we searched for the most adequate feature system being able to explain essential principles of phonological language production processes.

[1] This project (LE 596/6-3) is based on a grant to Prof. Dr. Helen Leuninger.

Method

The slip data were not accumulated in the traditional paper-and-pencil fashion but rather elicited by means of a more restricted experimental method. The deaf and hearing subjects were asked to sign or to tell, respectively, 14 picture stories under seven cognitive stress conditions. The picture stories vary in length and condition. There are seven short and seven long picture stories each of which are combined with one or two of these seven stress conditions. The following illustration shows one of the 14 picture stories.



The subjects were video- and/or audiotaped, a method which guarantees a higher degree of reliability than the usual slip collections. As opposed to the traditional paper-and-pencil method which leads to some extent to biases, the method described above provides bias-free corpora by virtue of the objective experimental procedure.

The two dependent variables are the slips of the tongue as well as the corresponding corrections. By additional cognitive stress conditions the error rate is increased; the probability of producing a slip of the tongue amounts to 0,73%. By contrast, Fromkin predicts a probability of 0,01% (Fromkin, 1980).

Classification of slips of the tongue

In total, we elicited n=944 slips of the tongue which can be classified in twelve different types of error as follows.

type of error	N	%
Anticipation	184	19.49
Perseveration	214	22.67
Harmony	48	5.08
Substitution	56	5.93
Semantic	156	16.53
Formal	31	3.28
Sem. + form.	3	0.32
Blend	188	19.92
Fusion	1	0.11
Exchange	11	1.17
Deletion	43	4.56
Addition	9	0.95
Sum	944	100

Table 1: Type of error

The following table shows which entities can be affected. As can be seen easily, words are the most affected unit followed by phonemes. But still, these findings are not exactly confirmed in the literature. Generally phonemes are considered being the most affected entity (Poulisse, 1999, p. 9). In spite of this difference, the frequency of phonemes is nearly as high as expected.

Affected entity	Sum	word	Phoneme	morpheme	phrase	grammtical feature	Semantic feature	others
Sum	944	328	285	108	151	66	2	4
%	100	34.74	30.19	11.44	15.9	6.99	0.21	0.42

Table 2: Affected entity

Phonological errors and feature distance

The following section focuses on phonological errors (n=285) which were scrutinized for nearly all of the effects known from the literature, as summarized in Poulisse (1999). In particular, we investigate feature distance as a factor determining contextual phonological errors such as anticipations and perseverations. In the literature, the research starts with the observation that consonants only interact with consonants and vowels only interact with vowels which is caused by the smaller feature distance in both cases and the same syllable position. Thus, it has been found that onsets interact with onsets, nuclei with nuclei, and codas with codas. This “syllable position contraint” is one of the strongest effects reported in the slip literature (Poulisse, 1999). It is assumed that the more similar two segments are the more likely they are to be substituted in a speech error. There are various studies which have shown that most phonological errors differ in only one feature from their target segment (van den Broecke & Goldstein, 1980, Klein & Leuninger, 1988), the most affected one being the place-feature. Note that this paper mainly concentrates on consonantal phonological errors.

In order to find out if our data can verify the findings stated in the literature, we examine contextual phonological errors such as anticipations or perseverations. We only take into account such errors which are considered to be phonological substitutions. Otherwise it is not possible to calculate the feature distance. Therefore unmotivated formal substitutions, deletions, and additions are omitted. After excluding these data, there remains a set of n=172 consonantal errors.

Besides this, there are methodological issues related to the feature systems which we used for computing the feature distance. We want to find out which among competing feature systems is the most appropriate one to characterize our data. In order to assess the appropriateness of the feature systems we compare the two most common ones, namely the International Phonetic Alphabet (IPA) and the one Kloeke (1982) and also Wiese (1996) proposed for German. As will be shown, the determination of the feature distance varies depending on the feature system.

Determination of the feature distance according to the IPA

The IPA system distinguishes three major features, namely place, manner, and voice. Place is divided into eleven subfeatures (bilabial, labiodental, dental, alveolar, postalveolar, retroflex, palatal, velar, uvular, pharyngeal, glottal), manner is separated into eight subfeatures (plosive, nasal, trill, tap/flap, fricative, lateral fricative, approximant, lateral approximant), whereas voice is a binary feature, which has one of two values, indicated by + and –, respectively.

THE INTERNATIONAL PHONETIC ALPHABET (revised to 1993, updated 1996)

CONSONANTS (PULMONIC)

	Bilabial	Labiodental	Dental	Alveolar	Postalveolar	Retroflex	Palatal	Velar	Uvular	Pharyngeal	Glottal
Plosive	p b			t d		ʈ ɖ	c ɟ	k ɡ	q ɢ		ʔ
Nasal	m	ɱ		n		ɳ	ɲ	ŋ	ɴ		
Trill	ʙ			r					ʀ		
Tap or Flap				ɾ		ɽ					
Fricative	ɸ β	f v	θ ð	s z	ʃ ʒ	ʂ ʐ	ç ʝ	x ɣ	χ ʁ	ħ ʕ	h ɦ
Lateral fricative				ɬ ɮ							
Approximant		ʋ		ɹ		ɻ	j	ɰ			
Lateral approximant				l		ɭ	ʎ	ʟ			

Where symbols appear in pairs, the one to the right represents a voiced consonant. Shaded areas denote articulations judged impossible.

Figure 1: Classification of consonants according to the IPA

We investigated n = 172 phonological errors with regard to one- to three-feature changes. With the IPA coding, we obtain 120 one-feature changes (69.76%), followed by 41 two-feature changes (23.83%) and only 11 three-feature changes (6.39%). The findings correspond with other results found in the literature. Although maximally 516 (170x3) feature changes are possible overall to be made, there are only 235. This means that only 45.5% of the potential changes actually occurred. From a statistical viewpoint, this may be seen as a first hint that only a small part of the possible changes is exhausted. The next diagram shows the distribution of one-, two-, and three-feature changes.

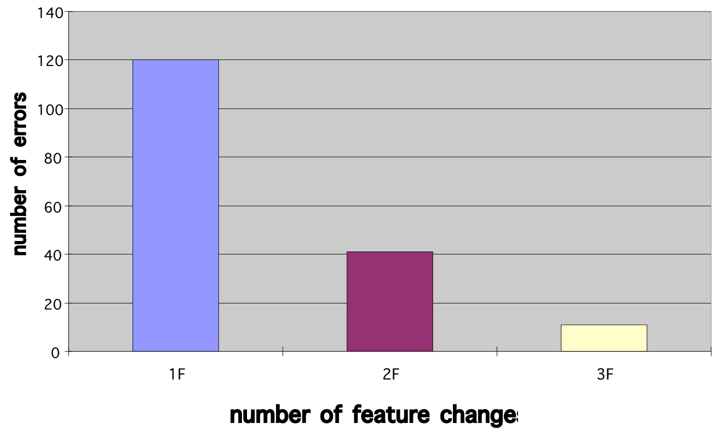


Figure 2: Number of 1-3 feature-changes

This distribution demonstrates that one-feature changes occur most frequently. Especially in the case of one-feature changes, place stands out compared with manner and voice. Strikingly, there is a high number of one-feature changes due to frequent m/n substitutions (n=33). Both [m] and [n] are nasals, but differ in the place feature bilabial and alveolar, respectively. 28 out of 33 m/n substitutions occur in the coda which leads to the assumption that in this case the feature distance interacts with the syllable position. The remaining 51 place features are distributed nearly equally with regard to onset and coda.

Considering the two-feature changes it turns out that place remains the most affected feature. However, in this case it co-occurs with the manner feature. This result will be discussed below. Table 3 summarizes the prevalence of place, manner, and voice in 1-, 2-, and 3-feature errors.

1-feature changes			2-feature changes			3-feature changes		
P	M	V	P	M	V	P	M	V
84	20	16	39	29	14	11	11	11
120 (120 errors)			82 (41 errors)			33 (11 errors)		
70%	16.6%	13.3%	47.6%	35.1%	17.1%	33.3%	33.3%	33.3%

Table 3: Feature distance in consonantal errors

Now, the question arises why it is the place feature which is affected mostly. According to the IPA system, place comprises eleven subfeatures. Thus, it is the most differentiated feature within the IPA. The more features are available in the set of place subfeatures the higher is the probability of a mis-selection. However, this cannot be the only explanation for the frequent occurrence of the place feature because manner also contains an extensive set of subfeatures. Recall that there are eight manner features. In spite of this, the manner feature is considerably less affected than the place feature. Actually, the number of single feature changes for both manner and voice is nearly equal (20 manner-errors vs. 16 voice-errors). Recall that voice contains only two specifications.

Another possible explanation may be the neural representation of the place features. Whereas place-features are organized in a single dimension (front-to-back) in the vocal tract, they may be distributed in a completely different manner within the brain. Assuming the fact that the place features are arranged on a topological cortical map in a certain way, it is conceivable that they are represented very closely to each other according to the close arrangement in the vocal tract. Lotze et al. (2000) have shown that during articulating the syllables /pa/, /ta/, and /ka/ various representational locations in the motoric cortex and the sensory cortex are activated. However, the representation of the manner-features is supposed to be more distinguished than that of the place-features. For instance, a plosive differs from a nasal to a higher degree than a bilabial feature from a labiodental feature does. Whereas plosives are made by releasing the airstream all of a sudden which causes an explosive sound, nasal sounds are produced by lowering the velum so that the air is released through the nose. That makes a great difference. In contrast to this, place features are determined by the position of the tongue in the vocal tract by which the air-stream is obstructed in the production of a consonant. As already mentioned above, the position of the tongue varies only little which can lead to the selection of the wrong place-feature.

A third explanation could be that segments are underspecified for the place features. Whereas segments are specified for manner and voice, the place feature is inserted in dependence of the phono-logical context as soon as the phonological processes start off. Still, the disadvantage of this assumption is that segments are not substituted due to their phonological context generally but rather due to their small feature distance and syllable position.

Only in a two-feature error it is possible to find out pairs of features which prefer to interact with each other. Even in such cases the place feature is the most affected one. Thus, this feature plays a crucial role. It most likely combines with manner (65.85%) and not with voice (29.27%) although the number of single feature changes for both manner and voice is nearly equal. As opposed to these findings, feature changes for both manner and voice hardly occur. Thus, this distribution shows a steep decline between the three (possible) feature combinations. The following table shows the feature combination in two-feature errors.

	Place x Manner	Place x Voice	Manner x Voice
	27	12	2
	65.85%	29.27%	4.88%

Table 4: Feature combination in 2-feature errors

A possible explanation for the frequent place-manner combination is that there is a higher number of both place and manner subfeatures whereas the voice feature is only binary. As a result, the number of possible feature combinations of place and manner increases. The following example (anticipation) shows a place-manner error.

(1) um an einer Hochzeits**t**ei//**f**eier teilzunehmen. (f → t)

in order to take part in a wedding ceremony

In this case the place subfeature changes from labiodental to alveolar whereas the manner subfeature fricative becomes plosive.

Place: [labiodental] → [alveolar]

Manner: [fricative] → [plosive]

The next example represents a place-voice error. This type of slip of the tongue is a harmony error that is that there are several intruder segments in the left and right context.[2]

(2) Dann ist der Kuchen fertig, kann mein **K**e// **B**esuch kommen. (b → k)

Then is the cake ready, can my visitors come.[3]

When the cake is ready, my guests can come.

In this case the place subfeature changes from bilabial to velar whereas [+voice] becomes [-voice].

Place: [bilabial] → [velar]

Voice: [+voice] → [-voice]

The following slip of the tongue (anticipation) shows one of the few manner-voice errors.

(3) Ta//natürlich (n → t)

Ta//naturally

[2] Segments which are candidates to be an intruder element have to occur as close as possible to the target segment. A slip of the tongue can be described as a harmony error only if there is an intruder segment in the left as well in the right phonological context showing the same syllable distance to the target segment. Because of this, in example (2) only [k] of "kann" and "kommen" can be regarded as potential intruder elements whereas [k] of "Kuchen" has no impact on the target phoneme.

[3] This is an interlinear translation of the slip of the tongue which shows the German word order. The same applies to the slip example on page 11.

In this case the manner subfeature changes from nasal to plosive whereas [-voice] becomes [+voice].

This kind of error only occurs rarely. Assuming that many segments are distinctive for manner, but not for voice one can conclude that manner and voice are not in the position to interact. E.g., nasals (m, n), approximants (j), laterals (l), and trills (R) are voiced in principle. Therefore voice does not occur as an independent feature. On the one hand these segments can change their manner feature, on the other hand they are not to be transformed from a voiced pronunciation into an unvoiced one.

Determination of the feature distance according to Kloeke and Wiese

As mentioned above, we aim at determining the most appropriate feature system in order to assess the feature distance. Whereas the IPA posits only three major features, namely place, manner, and voice, Kloeke's matrix comprises nine features: sonorant, back, high, low, high, coronal, nasal, continuant, and tense. All these features are specified as either + or -. Note that the feature [consonantal] can be ignored for our purposes. Besides, we do not exclude the feature [low], although not being distinctive for nearly all consonants. We include this feature because it is specified positively for the segments [h] and the glottis stop [¶] which we classify as consonants in accordance with Wiese (1996) but not with Kloeke. This seems to be an appropriate classification because both [h] and the glottis stop interact with other consonants, indeed, as in the following example.

Der Vater hat eine <u>D</u>i// [¶]Idee und schaut im Auto nach.

The father has an Di// idea and looks in the car after.

The father has an idea and looks into the car.

	m	n	_	l	R	p	b	f	v	t	d	s	z	_	_	_	_	ç	j	k	g	x
Cons	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Son	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Back	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+
Low	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
High	-	-	+	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+
Lab	+	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Cor	-	+	-	+	-	-	-	-	-	+	+	+	+	+	+	+	+	-	-	-	-	-
Nas	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cont	-	-	-	+	+	-	-	+	+	-	-	+	+	-	-	+	+	+	+	-	-	+
Tense	-	-	-	-	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+

Figure 3: Feature system for consonants according toKloeke (1982) in Keller/Leuninger (1993: 29)

Apart from that, due to the syllable-position-constraint, vowels and consonants never interact. Therefore, consonants only appear in onset- or coda positions, respectively, whereas vowels only occur in the nucleus (Poulisse, 1999, p. 13).

By considering the Kloeke system we examine a number of 163 contextual phonological errors. Recall that the number of inquired errors with the IPA amounts to 172. This difference is caused by the uvular fricative as in „de**r**“ (the, masc.) or „seh**r**“ (very) which does not belong to Kloeke’s feature system. Overall, there is a maximum of 1521 (169x9) feature changes. However, only 356 (23.4%) feature changes actually occur which indicates that there are only few feature changes per error. The distribution of feature changes is shown in the following table. Note that the figures in brackets refer to the number of feature changes whereas the others refer to the number of 1- to 9-feature errors (n = 163).

	1F	2F	3F	4F	5F	6F	7F	8F	9F
n: feature	53 (53)	53 (106)	37 (111)	15 (60)	4 (20)	1 (6)	0	0	0
%	32.52%	32.52%	22.7%	9.02%	2.45%	0.13%	-	-	-

Table 5: 1-9 feature changes according to Kloeke

According to Kloeke’s coding, we obtain an equal distribution of one- and two feature changes (32.52%) and a constant decrease of increasingly distant errors.

Interestingly, errors changing more than six features do not occur. Thus, the maximal number of feature changes is not exhausted which leads to the assumption that the Kloeke system makes available too many feature changes (up to nine) which are not needed to accommodate the data. Regarding the frequency distribution of the nine consonant features there is no strong prevalence of one single feature.

	Son	Back	low	High	Lab	Cor	nas	Cont	tense
n	15	39	11	54	66	78	12	43	38
%	4.2	11	3	15.2	18.5	22	3.3	7.7	10.7

Table 6: Frequency distribution of the nine consonant features according to Kloeke

Because of the complexity of combinatorial possibilities, we did not investigate in which way the features prefer to interact with each other. Apparently, such a sophisticated feature system is not relevant for psycholinguistic issues, especially not for phonological processes as in slips of the tongue.

Comparison of the feature systems: IPA and Kloeke/Wiese

First of all, it is important to describe the differences between both the IPA and the Kloeke matrix in order to assess the outcome of the respective systems. Note that both the IPA and the Kloeke system do not correspond to each other in a one to one fashion.

The IPA is a phonetic system which defines the segments in a descriptive manner. It is for identifying and differentiating both phonemes and phonetical properties concerning all existing languages. By applying the IPA, it is possible to describe all segments which imply distinctive functions due to their different features. In contrast, the Kloeke matrix is a phonological system which derives specifications by applying phonological rules. The segments are characterized as feature bundles as in figure 3. E.g., “word-final devoicing” (“Auslautverhärtung”) is a phonological rule of German which describes the process leading from an underlying voiced segment ([d]) to a devoiced one ([t]) in the word final position as in “Kind” (child) → /kint/. By comparison, [d] in “Kinder” (children) is pronounced as [d]. Thus, [d] and [t] are two variants of one underlying segment. All feature specifications defining [d] and [t] are the same except for [tense].

Recall that the IPA is characterized by three major features, namely place, manner, and voice. The first two contain a multitude of subfeatures whereas only the latter one is binary. In comparison, the Kloeke system operates with nine binary features. The last-mentioned feature system contains features partially corresponding to subfeatures of place and manner in the IPA. Such a combination of different feature classes results in a hybrid system implying feature implications and redundancies within the system. For instance, the place feature of the IPA is divided into the features [labial], [coronal], [back], and [high], whereas the manner feature of the IPA is separated into the features [tense], [nasal], and [continuant]. Note that the feature [-sonorant] pertains to the class of obstruents which can be divided into plosives, fricatives, and affricates. The differentiation of these three features requires an additional classification by means of other features. Furthermore, the feature [-nasal] also has to be described by virtue of other features. Considering the feature [+continuant], it is comparable to the subfeature fricative of the IPA. Using the Kloeke system, it is necessary to apply a higher number of features in order to distinguish the segments than using the IPA. Note that it is not admissible to simply compare the results derived from phonological rules as in the Kloeke system with the descriptive phonetic feature determination by using the IPA. Both systems have been designed to serve different purposes. As stated in the introduction we are searching for that feature system which can characterize phonological errors by a minimum of feature changes. Our conjecture is: The less similar two segments are the more “expensive” it is for the system to change these features.

As the findings show, both systems attain a different distribution of the number of feature changes per error. In case of an m-n substitution, we obtain a two-feature change in the Kloeke system whereas this error is classified as a one-feature error in the

IPA system. Recall that there is a high number of m-n substitution which contributes to the different distributions. According to the IPA, the segments [m] and [n] differ in one feature, that is place. However, the Kloeke system needs two features, namely [coronal] and [labial] to indicate the difference between the two segments. Considering the feature substitution b-g within Kloeke's system, we even observe a feature change of three features, namely back, high, and labial. In contrast, using the IPA we obtain a one-feature error concerning place.

In spite of the differing results obtained by means of the IPA and the Kloeke system, respectivly, both of them show the same tendency: the more similar two segments are the more likely they are to be substituted in a speech error.

Concerning the decision of the most appropriate system in order to analyze phonological errors, we clearly prefer the IPA analysis. This system suffices with only three features which capture all actually occurring errors whereas the Kloeke system overgenerates by providing too many potential feature changes (up to nine) which are not needed to evaluate the data. The former system is able to compute the feature distance on phonological errors more easily due to its uncomplicated usage. In spite of this, the IPA is not less differentiated with respect to the characterization of feature changes. Rather, the detailed classification of features takes place on the level of subfeatures. Compared to the Kloeke system, the IPA is even more precise because the major features place and manner are subdivided in a more elaborated way. E.g. the feature coronal of the Kloeke system corresponds to four features (dental, alveolar, postalveolar, and retroflex) of the IPA. (The IPA contains six manner features refering to German, whereas the Kloeke systems comprises only three. In the same vein, the IPA contains eight place features accepted for German, whereas the Kloeke system comprises only four.)

Obviously, the single subfeatures are not relevant to determine the feature distance. It seems to be more suitable to explain phonological processes by applying the major features.

Interaction of feature distance and syllable distance

Presently, there are not many studies concerning the linear distance in contextual errors. Ellis (1979) found out that there is a syllable distance of maximally eight syllables between two exchanged segments. Moreover, Garrett (1980) found out that phonological exchanges take place between neighbouring words disregarding word classes, whereas word exchanges can occur across phrases but only affect words of the same word class. Thus, the former happen at a rather small distance; whereas the latter happen at a higher distance. These distinctions have lead to the assumption of two different processing levels on which word exchanges and phonological exchanges occur, namely the functional level and the positional level.

Additional to the feature distance, we also explored into the possible interaction of feature distance (according to the IPA) with syllable distance as a second determining factor of contextual phonological errors. Due to the syllable position constraint, the syllable can be used as the smallest unit with which the linear distance between target and intruder segment can be measured. Our hypothesis is the following: With increasing syllable distance between target and intruder segment, the feature distance is assumed to decrease. This is because both temporal distance and feature distance determine the likelihood of a phonological error. With increasing temporal distance and with decreasing feature similarity the likelihood of an error decreases overall. With increasing syllable distance only those intruder phonemes which are most similar to the target phoneme have a high enough impact to substitute for the target phoneme. Additionally, the greater the distance between the target and intruder segment, the higher the likelihood of there being such a similar phoneme.

In order to supply evidence for this assumption, we analyzed n=165 contextual consonantal slips of the tongue with regard to the distance between error and intruder element from 1 to >8 syllables.[4] Note that vowel errors, deletions, additions, substitutions, and harmony errors are omitted. The results are shown in the following table.

	Syllable distance	Feature distance
N: cases	165	129
∅	2.46	1.23

Table 7: Syllable distance in consonantal errors

Considering the 165 phonological errors, there is an average syllable distance of 2.46 syllables. This result indicates that contextual phonological errors occur in a small time window. The average feature distance of these errors amounts to 1.23 features. Moreover, this result points out that phonological similarity is a determining factor in phonological slips.

Determining the frequency distribution of errors with regard to the syllable distance (1 to 8), the structural measure yields the impressive result that most errors are only one syllable away from their intruder segments. The next table shows the resulting distribution which is illustrated by figure 4.

	1 S	2 S	3 S	4 S	5 S	6 S	7 S	8 S	>8 S	n: errors	n: syllables
n	70	48	20	6	6	7	1	3	4	165	406

Table 8: Syllable distance in contextual consonantal errors

[4] The structural analysis in terms of syllables is based on written transcripts of the slip sequences. We chose syllables as a structural measuring unit because they are prosodic units with a structure of their own which, however, is neutral with regard to the respective structure of words, morphemes, and segments. Recall that syllables do not figure as affected entities in slips. This is attributable to the fact that syllables are no planning units in the early production process but are generated ‘on the fly’ (Levelt, Roelofs & Meyer, 1999) in the very process of articulation. Concerning the measurement we start counting the syllable distance from the onset, nucleus, or coda of the intruder element to the respective onset, nucleus, or coda of the error element (but not including it). The direction of counting depends on the type of segmental error. In case of anticipations, the intruder element occurs to the right of the target element. Thus, it is counted from the right to the left. In case of perseveration the reversed counting method applies, i.e. it is counted from the left to the right.

The following discrete curve (fig. 4) can be characterized as a strictly monotonic and strongly decreasing function from one to four syllables. Beyond the distance of four syllables, the curve stays constantly on a low level. Interpreting the shape of the curve, one can conclude that phonological errors mainly occur within a time window from one to four syllables. The time window ends at the point where the curve does not continue to fall. Beyond the limit of four syllables, phonological errors are very rare. Overall, we agree with Ellis' findings (1979) that there is a maximal distance of eight syllables between target and intruder segment.

Estimating the duration of a syllable being 250 ms, phonological processes seem to take place within one second. In order to verify this assumption, we have carried out a temporal analysis of the distance between the intruder segment and the error segment. Noteworthy, the results confirm our hypothesis that phonological processes occur in a time window of one second.

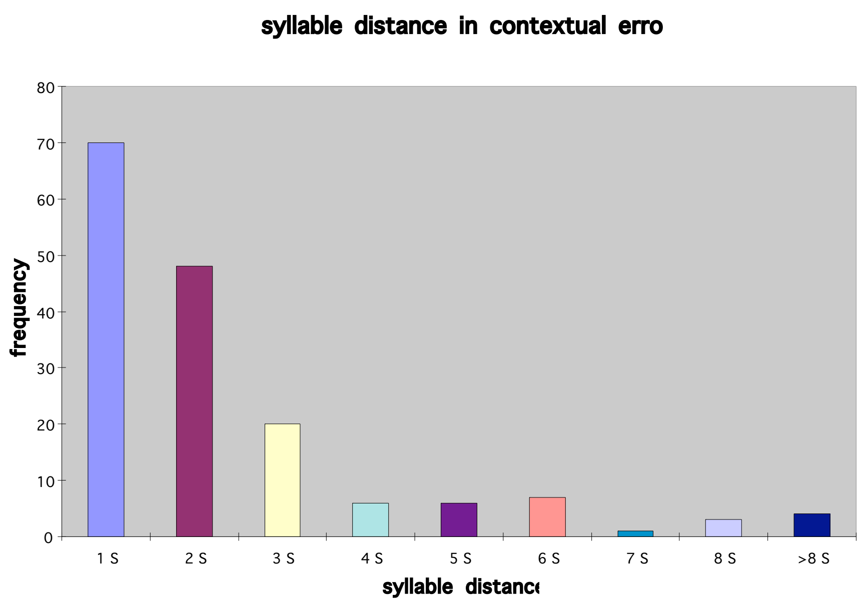


Figure 4: Syllable distance in contextual consonantal errors

Thus, phonological planning seems to be a strictly local process. Assuming as a thought experiment, that phonological processes took place within an extended time window of more than four syllables, the error rate would increase because more segments similar to each other would be available. Conceivably, a time window of four syllables represents an optimal temporal frame in which phonological processes are executed at a relatively low error rate.

In order to verify our hypothesis regarding the correlation of feature distance and syllable distance, we compared the two factors by computing the quotient. The following table shows the results.

	1 S	2 S	3 S	4 S	5 S	6 S	7 S	8 S	>8 S
Quotient	1,2	1,24	1,3	1,2	1	1,3	1	1,6	1,6

Table 9: Proportion of syllable distance and feature distance

There does not seem to be an interaction of the kind that the longer the syllable distance is the closer the feature distance is. Rather, the syllable distance stays the same despite increasing syllable distance. However, there are two restrictions concerning the syllable distance. Firstly, according to the IPA, there is only a small change of feature distance (up to three features) possible at all so that the differences between the syllable distances can hardly become statistically significant. Secondly, the feature distance exceeding eight syllables increases. This outcome is even contrary to our expectations. Possibly, errors with a distance more than eight syllables are no phonological errors at all. Rather, such kinds of errors are to be regarded as errors on the word level. Presumably, these few cases were misclassified.

Outlook

In conclusion, we want to emphasize that feature distance is a main determining factor of contextual phonological errors and thus highly relevant in the process of language production. We have pointed out that the most phonological errors show a feature distance of one. The more similar two segments are the more likely they are substituted for each other. Although we regard the IPA —on the basis of our results so far— to be the most appropriate one to determine the feature distance, the Kloeke system also demonstrates the tendency of the interaction of similar phonemes in a segmental error.

In spite of our clear results, it may be necessary to reconsider the findings drawn from the error analysis of the Kloeke system. As explained above, this feature system contains a certain number of redundancies. From a psycholinguistic point of view, it seems logical to hypothesize that the processor is able to compute the phonological implications automatically. This means that the lexicon does not contain redundant but only distinctive features. According to economical requirements of the lexicon redundant features are supposed to be derived automatically. What remains to be done is to reanalyze the phonological errors by considering the redundancies included in the Kloeke system. Feature changes which can be generated due to implications can be disregarded. Consequently, the number of feature changes is expected to decrease such that both the IPA and the Kloeke system should yield similar results.

Besides, the measurement of syllable distance defines the frame within which phonological processes take place. Note that pre-articulatory corrections concerning phonological errors can only be executed within the time window determined by the syllable distance between intruder and target segments. In structural terms, phonological errors take place in the time window of one to four syllables. Due to our audio-taped slip data we were able to carry out a temporal analysis in clock time. Based on this measurement we could verify the size of the time window of maximal four syllables which corresponds approximately to one second (Hohenberger & Waleschkowski, to appear).[5]

[5] The mean length amounts to 232 ms which is nearly identical to the usual estimation of 250 ms (Levelt et al., 1999).

By virtue of our objective experimental method we are able to draw valid inferences from our quantitative results to the actual phonological processes underlying human language production.

References

Ellis, N.C. (1979). Speech production and short-term memory. In: J. Morton & J. C. Marshall (eds.), *Psycholinguistics series, Vol 2: Structures and Processes*, London: Paul Elek/ Cambridge: MIT Press, 157-187.

Fromkin, V.A. (ed.) (1973). *Speech Errors as Linguistic Evidence*. Den Haag.

Fromkin, V.A. (ed.) (1980). *Errors in Linguistic Performance: Slips of the Tongue, Ear, Pen, and Hand*. New York.

Garcia-Albea, J.E., del Viso, S. & Igoa, J.M. (1989). Movement errors and levels of processing in sentence production. *Journal of Psycholinguistic Research*, 18, 145-161.

Garrett, M. F. (1980a). Levels of Processing in Sentence Production. In: B. Butterworth (ed.), *Language Production. Volume I. Speech and Talk*. New York: Academic Press, 177-220.

Garrett, M. F. (1980b). The Limits of Accommodation: Arguments for Independent Processing Levels in Sentence Production, In: Victoria A. Fromkin (ed.), *Errors in Linguistic Performance*. New York: Academic Press, 263-271.

Hohenberger, A. & Waleschkowski (to appear). Computational windows in language production: Words, morphemes, and segments.

Keller, J. & Leuninger, H. (1993). *Grammatische Strukturen*. Kognitive Prozesse. Tübingen.

Klein, M. & Leuninger, H. (1988). Gestörtes und nicht gestörtes Sprachverhalten. Zur Struktur lautlicher Fehlleistungen. *Frankfurter Linguistische Forschungen (FLF)* 4, 1-19.

Kloeke, W. van Lessen (1982): *Deutsche Phonologie und Morphologie. Merkmale und Markiertheit*, Tübingen.

Levelt, W. J. M, Roelofs, A. & Meyer, A. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences*, 22, 1-75.

Lotze, M., Seggewies, G., Erb, M., Grodd, W. & Birbaumer, N. (2000). The representation of articulation in the primary sensorimotor cortex. *NeuroReport* Vol. 11, No 13, 2985-2989.

MacKay, D.G. (1970). Spoonerisms: The structure of errors in the serial order of speech. *Neuropsychologica*, 8, 323-350.

Poulisse, N. (1999). Slips of the Tongue. Speech Errors in First and Second Language Production. In Kees de Bot & Thom Huebner (Eds). *Studies in Bilingualism* (SiBil) Volume 20, Amsterdam, Philadelphia: John Benjamins.

Shattuck-Hufnagel, S. (1979). Speech errors as evidence for serial-ordering mechanisms in sentence production. In W. Cooper & E. Walker (Eds.), *Sentence Processing: psycholinguistic Studies presented to Merrill Garrett*, 295-342, Hillsdale, NJ: Lawrence Erlbaum.

Shattuck-Hufnagel, S. (1987). The role of word-onset consonants in speech production planning: New evidence from speech error patterns. In: E. Keller & M. Gopnik (Eds.). *Motor and sensory Processes of language*, 17-51. Hillsdale, NJ: Lawrence Erbaum.

Shattuck-Hufnagel, S. (1992). The role of word structure in segmental serial ordering. *Cognition*, 42, 213-259.

Shattuck-Hufnagel, S. & Klatt, D. H. (1979). Distinctive feature constraints on phoneme errors of different types. In *Proceedings of the ninth international Congress of phonetic Sciences, Copenhagen*, Eli Fischer-Jørgensen (ed.). Copenhagen, Institute of Phonetics.

Van den Broecke, M., P. R. & Goldstein, L. (1980). Consonant Features in Speech Errors. In: Fromkin 1980, 47-65.

Wiese, R. (1996). *The Phonology of German*. Oxford: Clarendon Press.