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Nasal Consonant Speech Errors: Implications for 'Similarity' and Nasal Harmony at a Distance

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Introduction. Recent investigations in phonological theory have spotlighted the observation that similarity impacts phonemes' potential to interact in certain processes. A case in point involves phonological patterns of long distance nasal harmony. In such patterns, certain consonants are produced as nasal stops when a nasal stop occurs elsewhere in the word. The harmony is 'long distance' in the sense that the original nasal stop and the affected consonant may be separated from each other by at least a vowel. (In this respect 'long distance' nasal harmony is distinguished from patterns of 'strictly local' nasal harmony, which affect continuous strings of segments, including vowels (Walker, 1998).) Several studies of long distance nasal harmony across and within languages have revealed its propensity to affect phonemes that are highly similar to nasals in articulatory and/or auditory terms, namely, voiced stops and liquids. Furthermore, homorganic consonants are more likely to interact in long distance nasal harmony than heterorganic consonants (Walker, 2000; Hansson, 2001; Rose and Walker, 2001). In the present study we explore whether a parallel is found in the sets of consonants that show a tendency to interact with nasals in an area of language performance – specifically, phonological speech errors. While it is widely agreed that 'similar' consonants are more prone to participate in speech errors, our study investigates whether the same groupings of similar consonants identified by phonological long distance nasal harmony phenomena are relevant in patterns of error production.

Our research question is connected to a theoretical proposal in phonological theory. A body of recent work has suggested that long distance consonant harmony patterns, including long distance nasal harmony, have functional roots in the area of production processing, in particular, the phonological encoding of speech (Walker, 2000; Hansson, 2001; Rose and Walker, 2001). This work has identified several parallels between long distance consonant harmony patterns and speech errors. One key area of commonality is the role of similarity: highly similar consonants are more likely to interact in long distance consonant harmony and to participate together in a speech error. If long distance nasal harmony and speech errors show a true affinity with respect to phonological similarity, then we expect to find a parallel in the groupings of similar consonants relevant for these phenomena.

Background. Before detailing our current study, we exemplify the patterns of long distance nasal harmony and the resulting similarity scale with which they are consistent. The Bantu languages, Kikongo and Ganda, serve to illustrate. We focus here on the favored participation of voiced stops and homorganic consonants. In Kikongo, the voiced stop in the perfective active suffix *-idi* becomes a nasal stop when preceded by a nasal stop anywhere in the preceding stem (Bentley, 1887; Ao, 1991; Odden, 1994; Piggott, 1996; Rose and Walker, 2001):

(1) /-nat-idi/ → [-nat-ini] 'carry'
/-sim-idi/ → [-sim-ini] 'prohibited'
cf. /-suk-idi/ → [-suk-idi] 'washed'

Intervening voiceless stops do not block the process and are unaffected by nasal harmony.

In Ganda, nasal harmony operates as a static pattern restricting possible combinations of consonants in roots. Previous researchers have categorized the Ganda root restrictions as long distance nasal harmony operating within the morphological root (Hansson, 2001; Rose and Walker, 2001). In canonical CV(V)C roots of this language, a homorganic nasal stop and voiced stop may not occur together, i.e. words such as [-meb-a] and [-nod-a] are ill-formed. However, identical nasal stops or voiced oral stops are acceptable; hence, homorganic stops matching in nasality are permitted (Katamba and Hyman, 1991):

(2)	[-non-a]	'fetch, go for'
	[-bab-ula]	'smoke over fire to make supple'

In addition, Ganda prohibits roots containing a nasal stop followed by a homorganic voiceless stop, i.e. words such as [-not-a] are ill-formed.

The following implications emerge from the long distance nasal harmony patterns across languages: *participation of heterorganic voiced stops implies participation of homorganic voiced stops; participation of homorganic voiceless stops implies participation of homorganic voiced stops*. Assuming the claim that similarity to nasals favors participation in harmony, the similarity scaling statement in (3) is obtained:

(3) Nasal similarity scaling:
A nasal is more similar to a homorganic voiced stop than to a heterorganic voiced stop or a homorganic voiceless stop.

We regard the nasal similarity scaling as situated within a broader framework of phonological similarity. Following Rose and Walker (2001), we view phoneme similarity as determined by shared phonological features, some of which weigh more heavily than others. For details, see Rose and Walker (2001) and precursors cited therein.

The role of similarity in shaping patterns involving speech sounds is not limited to phonological processes. It has been observed that phonological similarity between linguistic units, such as phonemes or words, increases the likelihood of a speech error (e.g. Nooteboom, 1967; MacKay, 1970; Fromkin, 1971, 1973; among others). Furthermore, as noted above, work in phonological theory has suggested a link between the relevance of similarity in speech errors and in long distance harmony, specifically, that grammaticized patterns of long distance consonant harmony are grounded in production processing principles (Walker, 2000; Hansson, 2001; Rose and Walker, 2001). This provokes a question regarding the existence of parallel similarity across the areas of phonology and language production. The present study examines whether the sounds that are closer to nasals according to the similarity scale in (3) show an increased potential to participate in speech errors involving nasals. In particular, this study investigates whether the favored interaction of voiced and homorganic stops with nasals observed in nasal harmony is also evident in the speech error pattern of a language without nasal harmony. We examine a language that does not have nasal harmony, because in languages for which nasal harmony operates as a fixed generalization in the grammar, there will be inevitable interference with speech error patterns involving nasals. We conducted this research with speakers of English, a language in which the stop consonant inventory is roughly comparable to that of Kikongo and Ganda.

Experiments. Two production experiments were conducted using the SLIPS speech error induction technique (Baars and Motley, 1974; Baars *et al.*, 1975; applications include Dell, 1984, 1990; Stemberger, 1991 a, b).

Experiment 1: Voicing. Experiment 1 investigated the hypothesis that there will be more errors involving nasals and voiced stops than nasals and voiceless stops. It also asks three sub-questions: (i) does place of articulation in homorganic consonants affect the error rate? (ii) does the order of nasal-oral phonemes affect the error rate? and (iii) does the earliness of production of a word pair in the experiment effect the error rate? This experiment partially replicates a previous study by Stemberger (1991b).

SLIPS error induction technique. Subjects are presented with word pairs shown one at a time on a video screen. Some word pairs are followed by a cue for the subject to say that word pair aloud. Critical pairs are cued pairs that are immediately preceded by three primer pairs designed to encourage a phonological speech error. Primer pairs are not cued. In the priming structure used here, the words in the first priming pair rhyme with those in the critical pair but have different initial consonants. In the second and third priming pairs, the initial consonant and vowel match those of the words in the critical pair but in the opposite order. Table 1 shows an example.

Table 1. Sample priming structure, Experiment 1

rug sad	primer, rhymes with critical pair
mash putt	primer, same initial CV sequences as critical pair, but reverse order

mat puck	primer, same initial CV sequences as critical pair, but reverse order
pug mad	critical pair
?????	Cue to recall and speak critical pair, *pug mad*

The initial consonants in the two immediately preceding priming pairs are [m] - [p]; however those in the critical pair are reversed, [p] - [m]. Under these conditions, subjects are more prone to make an error in production of the initial consonants in the critical pair, for example, *mug pad*.

Method.

Materials. The stimuli were pairs of monosyllabic English words. All words were of the form consonant-vowel-consonant. The word list contained 160 critical pairs and 480 primer pairs, with priming structure designed as in Table 1. All critical pairs changed into real words of English when subjects produced an exchange, anticipation or perseveration error involving the initial consonants. The composition of the critical pairs was controlled for five factors, fully crossed:

(4) i. Voicing: initial nasal and voiced stop word pairs vs. initial nasal and voiceless stop.
ii. Place: bilabial vs. alveolar initial consonants within a word pair.
iii. Order: nasal-initial word first vs. oral stop-initial word first.
iv. Vowel: same vs. different vowels within words in a pair.
v. Earliness: word pair cued in first half or second half of the experiment.

Among the words appearing in critical pairs, all words within a place of articulation, i.e. those with an initial bilabial [p, b, m] or an initial alveolar [t, d, n], had relatively equal mean frequency and similar standard deviations. Two databases were used to compute mean frequency: word frequencies were drawn from Carroll *et al.* (1971) and Zeno (1995). If a word did not appear in both databases, it was excluded. Moreover, within a critical pair, words were balanced for lexical frequency.

The word lists also contained 500 filler pairs, 200 of which were cued. Cued filler pairs were preceded by between zero and three uncued pairs, which were not organized around a phonological priming structure. The order of critical pairs (together with their primers) in the list was pseudo-randomized – sequences of critical pairs containing the same word were prevented. Filler pairs were interspersed pseudo-randomly to obscure the critical pair priming structure. Within the word list, each word occurred exactly six times. Word pairs that formed special phrases were eliminated (e.g. 'love sick'). The list was split into two equal halves, parts A and B, equally balanced for the factors listed in (4).

Procedure. Subjects sat in front of a video screen controlled by a computer. Each word pair was presented on the center of the screen for 900 ms followed by 100 ms of blank screen. Subjects were instructed to read pairs silently and prepare to say them aloud as quickly as possible if cued. After cued pairs, a sequence of question marks appeared on the screen for 600 ms followed by 500 ms of the message 'Finish speaking now' and 350 ms of blank screen. All subjects were exposed to the same word list, although alternating subjects were given part A or part B of the word list first. Subjects were trained on 12 word pairs, four of which were cued, including fillers. None of the words used in the training period were included in the actual experiment. The entire experiment took 35-40 minutes including an optional five-minute break halfway. Responses were audio-recorded for later analysis and coded (see below) during the course of the experiment by an investigator using a button box.

Subjects. Subjects were 35 undergraduates at the University of Southern California who were native speakers of English.

Results and discussion. Each subject's production of a critical pair was assigned a code: *correct production*, assigned in cases of no audible error, *initial consonant error*, assigned in cases where one consonant participated in an exchange error or one consonant apparently replaced the other, or *other*, assigned to errors that did not fall into the initial consonant error category. Button box coding, performed by an investigator during the experiment, was verified later by listening to the audio recording of responses. Table 2 illustrates the types of initial consonant errors.

Table 2. Initial Consonant error types, examples from Experiment 1

Type		*Examples*
Exchange	– Consonant:	near tail → tear nail
	– Word:	mutt puff → puff mutt
Anticipation:		bone mode → moan mode
Perseveration:		numb deck → numb neck
False start:		mile pad → pi — mile pad

meat beak → beat —

We note that the level of linguistic organization at which the errors take place is ambiguous in certain cases. For example, the anticipation error in Table 2 could take place at the segmental level, substituting [m] for [b] (e.g. Fromkin 1971), or at the subsegmental level, wherein the lowered velum gesture intrudes on the initial consonant in the first word (e.g. Pouplier *et al.*, 1999; Frisch and Wright, in press; note also Fromkin 1971 on featural errors). Similarly, in the word exchange example, the error could arise from word reversal, exchanging all phonemes, or from simultaneous reversal of the initial and final consonants. Nevertheless, since the initial consonants are involved in all of these errors, their degree of similarity has the potential to contribute to the error rate.

There were 159 initial consonant errors, yielding an error rate of 2.83%. There were 95 errors in critical pairs containing an initial nasal and an initial voiced stop (either order) vs. only 64 errors in critical pairs containing an initial nasal and an initial voiceless stop (either order). This difference is significant ($\chi^2(1)=6.044$, $p=.0139$), confirming the principle hypothesis examined in this experiment. In Table 3, the data are broken down by voicing and place of articulation.

Table 3. Results of Experiment 1: Number of errors

Voiced stop	95	
Bilabial (b-m/m-b)		47
Alveolar (d-n/n-d)		48
Voiceless stop	64	
Bilabial (p-m/m-p)		29
Alveolar (t-n/n-t)		35
Total	159	

The findings in regard to our sub-questions were as follows. Place of articulation in homorganic initial consonants did not have a significant effect on the error rate ($\chi^2(1)=.308$, ns). The order of nasal-oral phonemes was also not significant ($\chi^2(1)=.006$, ns), nor was the earliness factor ($\chi^2(1)=.308$, ns).

In summary, the findings of Experiment 1 are that the voicing factor is significant: more errors occurred involving nasals and voiced stops than nasals and voiceless stops. This is consistent with the results of Stemberger (1991b). Discussion in terms of theoretical implications follows the report on Experiment 2 below.

Experiment 2: Place. Experiment 2 investigated the hypothesis that there will be more errors involving nasals and homorganic voiced stops than nasals and heterorganic voiced stops. It also asks three sub-questions: (i) does nasal place of articulation affect the error rate? (ii) does the order of nasal-oral phonemes affect the error rate? and (iii) does the earliness of production of a word pair in the experiment effect the error rate?

Method.

Materials. The stimuli were designed in the same way as in Experiment 1. For Experiment 2, the composition of critical pairs was controlled for the following five factors, fully crossed:

(5) i. Place: initial nasal and homorganic voiced stop word pairs vs. initial nasal and heterorganic voiced stop.
ii. Nasal place: bilabial vs. alveolar nasal.
iii. Order: nasal-initial word first vs. oral stop-initial word first.
iv. Vowel: same vs. different vowel within words in a pair.
v. Earliness: word pair cued in first half or second half of the experiment.

Procedure. The procedure was the same as in Experiment 1.

Subjects. Subjects were 37 undergraduates at the University of Southern California who were native speakers of English.

Results and discussion. Coding followed the same format as in Experiment 1. There were 132 initial consonant errors, yielding an error rate of 2.2%. There were 91 errors in critical pairs containing an initial nasal and an initial homorganic voiced stop (either order) and only 41 errors in pairs containing an initial nasal and an initial heterorganic voiced stop (either order). This asymmetry is significant ($\chi^2(1)=18.939$, $p<.0001$) and confirms the principle hypothesis tested by this experiment: more errors occurred involving nasals and homorganic voiced stops than nasals and heterorganic. Table 4 shows the data broken down by initial consonant place (homorganic / heterorganic) and nasal place.

Table 4. Results of Experiment 2: Number of errors

Homorganic	91	
Bilabial (m-b/b-m)		48
Alveolar (n-d/d-n)		43
Heterorganic	41	
Bilabial (m-d/d-m)		21
Alveolar (n-b/b-n)		20
Total	132	

In regard to the sub-questions, nasal place was not a significant factor ($\chi^2(1)=.273$, ns), nor was the order factor ($\chi^2(1)=.030$, ns). However, the earliness factor was significant: more errors occurred in the first half of the experiment than in the second half ($\chi^2(1)=16.030$, $p<.0001$). Table 5 shows the error rate in each half of Experiment 2 broken down by place of articulation. The earliness and place factors did not show a significant interaction ($\chi^2(1)=.296$, ns).

Table 5. Timing of Errors in Experiment 2: Number of errors

Early (first half)	89	
Homorganic		60
Heterorganic		29
Late (second half)	43	
Homorganic		31
Heterorganic		12
Total	132	

To summarize, the findings of Experiment 2 are that same place of articulation significantly increases the likelihood of an initial consonant error. Furthermore, production of a word pair in the first half of the experiment increases the likelihood of an initial consonant error.

Discussion and conclusions. We have examined whether the phonological similarity scaling suggested by cross-linguistic patterns of long distance nasal harmony also plays a role in language performance. Focusing on stops, we hypothesized there would be a parallel between the sounds that participate in more speech errors involving nasals and the consonants that show an increased tendency to be affected in long distance nasal harmony. This was borne out. Assuming that greater similarity increases the likelihood that phonological units will interact in each of these phenomena, this study finds support for a parallel in sound similarity across the area of language performance and the area of phonology. In particular, the oral consonants identified as similar to nasals according to language production phenomena appear to match those identified as similar in long distance nasal harmony.

Bringing this to bear on previous research in phonological theory, we observe that these findings are consistent with the proposal that phonologized patterns of long distance nasal harmony – and long distance consonant harmonies in general – are grounded in production processing principles (Walker, 2000; Hansson, 2001; Rose and Walker, 2001). In connection with this proposal, we suggest that the parallel between the participant segments in long distance nasal harmony and speech errors goes beyond a simple correlation – we interpret it as bearing on the motivation for nasal harmony. The explanation runs as follows. Phonological speech errors are known to have an increased tendency to occur between similar speech sounds. In the domain of phonology, it has been suggested that the existence of a high degree of similarity between a nasal and another consonants has the capacity to stimulate the construction of a formal relation between them (Walker, 2000; Hansson, 2001; Rose and Walker, 2001). This relation mediates the feature matching imposed in consonant harmony patterns. Similar but different sounds are known to present special difficulty in production processing. By requiring sounds that are similar to nasals to match in nasality, long distance nasal harmony preemptively reduces the potential for a production error involving nasalization. In this respect, we posit that nasal harmony has functional roots in facilitating ease of production processing. For example, root morphemes containing combinations of consonants which are more prone to participate a speech error, such as m-b or n-d, would be excluded from the lexicon; this could take place diachronically or in a synchronic grammar. Furthermore, when affixation brings consonants together in a word that are excluded within morphemes, the generalization could be straightforwardly extended to the entire word. This could stimulate an alternation in the affix consonant, e.g. causing nasalization of a suffix /d/ when preceded by a nasal in the word. It is conceivable that improving the ease of perceptual processing is an additional factor that figures in the motivation for long distance harmony (see Rose and Walker, 2001, and citations therein). This is a question that awaits further research.

Returning to the sub-questions investigated in our research, our experiments had the following results. First, place of articulation of initial homorganic stops or nasals in word pairs did not have a significant effect on the speech error rate. In addition, the order of the initial nasal - oral phonemes in word pairs did not have a significant effect on the error rate. However, the earliness of production of a critical pair in the experiment did have an effect on the error rate, but in experiment 2 only.

The lack of effect of place shows a correlation with patterns of long distance nasal harmony. We do not know of any case of long distance nasal harmony that is restricted to nasal - oral stops in a proper subset of the available places of articulation. This is consistent with our interpretation of the functional basis for long distance nasal harmony. Since we did not find that either bilabial or alveolar homorganic stops or nasal stops were more prone to participate in speech errors, neither appears to present a greater production processing difficulty, and thereby, neither is singled out in a case of phonological nasal harmony.

The lack of effect of nasal - oral phoneme order does not conform as well with nasal harmony patterns. In long distance nasal harmony, there is either no detectable directionality (e.g. in certain root structure constraints), or there is a tendency for harmony to operate progressively, i.e. from a nasal to following oral consonants, but not preceding ones (see, e.g., Rose and Walker, 2001).[1] This lack of correlation across speech error patterns and long distance harmonies might indicate that directionality conditions in harmony are not grounded in production processing but rather are an independent property that may be parameterized in grammar. Alternatively, it may be the case that the SLIPS paradigm is not the optimal technique to test effects of phoneme order in errors. Whether directionality conditions have roots in the domain of psycholinguistic and/or phonetic principles is an issue that remains for further research.

Finally, in Experiment 2, we found that there were more initial consonant errors in the first half of the experiment than in the second half. This suggests that subjects got better at producing critical pairs over time. In Experiment 1 there were also fewer errors in the second half of the experiment, but the difference was not significant (83 initial consonant errors produced in the first half of Experiment 1 vs. 76 errors in the second half). The improvement pattern observed in the second part of Experiment 2 bears on a point of methodology for future experiments: it suggests that an experiment that is half as long and performed with twice as many subjects would elicit more errors.

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[1] We make the uncontroversial assumption that patterns in which a nasal in the morphological root controls harmony in a prefix or suffix but not the reverse is not the result of directional harmony but rather primacy of root material.

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