Constraints and Repairs in Aphasic Speech: 
A Group Study

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1. Introduction
Aphasia refers to an impairment of language processing resulting from brain damage. A very common symptom observed in aphasic speech is the presence of phonemic paraphasias, i.e., phonemic errors involving the substitution, addition or syncope of one (or more) segment(s) in a word stimulus. Phonemic paraphasias can be found across multiple tasks (repetition, reading aloud, spontaneous speech, picture naming) that require a subject to produce a word sound. They are not specific to a particular type of aphasia since Broca’s aphasics, Wernicke’s aphasics, conduction aphasics, and mixed aphasics all produce phonemic paraphasias (see Lecours et al 1983).

In this article we aim at explaining phonemic paraphasias produced in heterosyllabic consonant clusters by a group of 23 French-speaking aphasic subjects in repetition. A list of stimuli was made up of words and non-words

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that all include such a consonant cluster. Data collected from subjects' repetition performance were analyzed according to the Theory of Constraints and Repair Strategies (TCRS; see Paradis 1988a, 1988b, 1990, this volume), which, as we will see, allows us to make many important new predictions concerning paraphasia patterns.

The article is organized as follows. A short summary of the relevant theories on phonemic paraphasias in aphasiology and the theoretical framework are presented in Sections 2 and 3 respectively. Section 4 discloses our hypotheses concerning paraphasia patterns while Section 5 describes the methods we used. Analyses and results are reported in Section 6 and our interpretation in Section 7.

2. Aphasiological Literature on Phonemic Paraphasias

In this section, we summarize the main aphasiological studies that propose hypotheses for the origin of phonemic paraphasias (see Dressler and Stark 1988, and Caplan 1992 for a detailed review and a synopsis of recent research).

2.1. Regression hypothesis

In the very beginning of linguistic work in aphasiology, a parallel was drawn between regression in aphasic speech and language acquisition in children. Alassanine et al (1939) reported that recovery of Broca's aphasics and anarthric speakers follows the evolution of phonetic acquisition in children. Jakobsen and Halle (1956) claimed that the regression observed in aphasic speech is the mirror image of first-language acquisition: the last phonemes acquired by the child are the first ones lost by the aphasic. According to this hypothesis, aphasics produce phonemic paraphasias because their phonological competence is regressing. Specifically, they cannot produce a target phoneme because their phoneme inventory is reduced. Consequently, they omit the phoneme or replace it by a less marked phoneme, that is, one acquired earlier. We will see in Section 7 that this hypothesis is at least partially compatible with the proposal we will make further.

2.2. Markedness hypothesis

Other aphasologists looked for markedness effects in aphasic speech in order to explain the occurrence of phonemic paraphasias. The most commonly reported result is the tendency of some aphasic subjects to replace marked voiced consonants by unmarked voiceless consonants (Blumstein 1973; Ireland et al 1977; Kilani-Schoch 1982; Nespolous et al 1984; Dressler 1988). Extending the markedness effects to place features, Blumstein (1973) reported that English-speaking aphasics tend to replace marked plosives (alveolars) by unmarked plosives (labials). However, a different conclu-

sion was reached by Puel et al (1980:253) as well as Béland and Favreau (1991:218), who tested French-speaking aphasics from Quebec, and by Ferreres (1991:198), who tested Spanish-speaking aphasics from Argentina. They all pointed out that dentals/alveolars, not labials, correspond to the unmarked place specification in aphasic speech, as is the case in normal speech (see Paradis and Prunet 1991). When found, markedness effects are interpreted as reflecting the difficulties that aphasics have coping with complex segmental or syllabic structures.

Nevertheless, Nespolous et al (1984) and Kilani-Schoch (1982) insist on the fact that not all phonemic paraphasias show these markedness effects since some paraphasias result in a form that is more marked (complex) than the original word stimulus. Similar results are found in Dressler (1988:14), who reports cases where anterior aphasics (Broca's aphasics) sometimes produce phonemes that are not part of their phoneme inventory. For instance, German anterior aphasics produce phonemes such as [θ, φ], which are nonexistent in German. According to Dressler (1988:20), substitutions of unmarked for marked phonemes can be attributed to universal, natural phonological processes, whereas substitutions in the opposite direction (replacement of unmarked phonemes by marked phonemes) result from language-specific constraint relaxation (see Section 2.3). In the following sections, we will see that the production of a form that is more marked than the original word stimulus can be readily accounted for in the TCRS. Paraphasias normally tend to reduce complexity in restricted environments. This does not mean that complexity of a whole word will necessarily be reduced, a point discussed in (7e).

2.3. The constraint relaxation hypothesis

Dressler (1979) maintains a distinction between phonological substitutions in natural languages that are subject to universal restrictions (constraints), normal speech errors (slips of the tongue) and aphasic errors (phonemic paraphasias). According to Dressler, the main difference between normal speech substitution errors (slips of the tongue) and phonemic paraphasias is that slips of the tongue rarely (if ever) violate language-specific constraints whereas phonemic paraphasias often do. Dressler (1988) proposes a classification of phonological paraphasias. He distinguishes two types of paraphasic substitutions: a) those corresponding to backgrounding (lengthening, deletion, weakening, assimilation and fusion constitute backgrounding processes while lengthening, vowel insertion, ephenthesis), strengthening and polarization (diphthongization) make up the foregrounding processes. Within the Natural Phonology approach, backgrounding and foregrounding are natural and universal
processes, language-specifically suppressed in languages without such processes. Dressler (1988:15) construes the occurrence of these processes as the result of relaxed (i.e., partially or totally suppressed) language-specific constraints in aphasic speech. In other words, Dressler claims that constraint relaxation accounts for aphasics producing backrounding and foregrounding effects not found in normal speech. For instance, the author has induced experimentally the production of phonological paraphasias in a German-speaking Broca's aphasic. The patient was requested to repeat a list of words containing r-r-l (e.g., Korpself 'corporal') and l-l-r (e.g., Lautelele 'phonetics') sequences. The word stimuli were chosen to test if aphasics substitutions violate the following cross-over constraint:

In a phonological substitution process where phonemes of a certain class affect phonemes of the same class, in the direct or indirect neighborhood of the affecting phoneme, no phoneme of the same class may intervene between the affecting phoneme and the affected phoneme. (Dressler 1979:20)

This constraint is somehow equivalent to the following autosegmental convention: harmonizable elements cannot be freely skipped by a harmony process (see Goldsmith 1976). Thus the cross-over constraint is violated when the patient harmonizes an r-r-l sequence into an l-r-l one since a phoneme of the same class as the one targeted by the process (the liquid r) intervenes between the affecting phoneme (l) and the affected phoneme (r). In the same way, the patient violates the cross-over constraint if he turns a l-l-r sequence into a r-l-r one. Altogether, Dressler observes 17 violations of the cross-over constraint and only one non-violation. He interprets these results as evidence that phonemic paraphasias are different from transformations observed both in normal speech and normal-speech errors: phonemic paraphasias violate constraints, even universal ones like the cross-over constraint. Note that Dressler's set of examples is not only small but it is also questionable. As we will see in Sections 6 and 7, the results reported in this study and in Béland and Paradis (1993a, 1993b) lead to entirely opposite conclusions, i.e., they show that aphasics have more constraints than normal subjects.

2 For instance, violation of the cross-over constraint is not obvious in paraphasias such as Lilenkrums 'wreath of lilies' —> [ri], Korpself 'corporal' —> [lekorare], Schriftrolle 'scroll' —> [fl] (Dressler 1978:21). Furthermore, the 17 violations occur in only nine distinct words since a single word counts for more than one violation when the patient repeats the same error on the same word, a questionable procedure indeed.

2.4. The impaired buffer hypothesis

In the last decade, cognitive neuropsychologists (see Seidenberg 1988 for a critical review) have proposed functional architecture models (Dub and Kertesz 1982; Caramazza et al 1986; Dub and Lecours 1987) to capture the different components involved in normal speech production for different combinations of input and/or output modalities (oral versus written). The cognitive neuropsychology approach consists in validating the proposed functional architecture by assessing brain-damaged patients. If the model were adequately designed, one could find a patient who shows selective impairment affecting one specific subcomponent of the model. Moreover, the model should predict the pattern of errors to be observed following the appropriate functional lesion of that subcomponent.

Based on a single-case study, Caramazza et al (1986) propose a functional architecture model for reading, repetition and writing. They report that phonemic paraphasias produced on non-word stimuli can originate from an impairment of the so-called 'phonological output buffer', a subcomponent of their model. According to this model, a buffer (a working memory system) is needed each time the size of a processed unit (e.g., a non-word) needs to be segmented into smaller units (i.e., phonemes). Oral production of words involves preassembled lexical representations, and, for this reason, the phonological output buffer plays no role in their production. On the other hand, the production of non-words, which have no preassembled lexical representations, requires an intact phonological buffer with a phonological code (undefined by the authors, however). In this view, error patterns originating from a malfunctioning of this buffer should be explorable in terms of phonological principles. Substitution errors produced by their patient on non-word stimuli indicate a manner-articulation relationship between the substitute phoneme and the target phoneme. These results lead Caramazza et al (1986) to define more specifically the impairment of the phonological output buffer. They argue that information in the phonological buffer is underspecified because the buffer is actually damaged (note that "underspecification" here has no relation with underspecification theories in phonology). Thus either information decays too rapidly in the buffer or it is incorrectly written. According to the "impaired buffer hypothesis", only non-word stimuli involve on-line phonological processing, which should result in different error patterns for word and non-word stimuli. We will see that this prediction is disconfirmed by our data. Our view is incompatible with Caramazza et al (1986) for another reason. The impaired buffer hypothesis does not recognize the existence of abstract phonological processes that affect accessed phonological representations in major ways. We will see in Section 6 that, in contrast with what these authors predict,
abstract phonological processes play a crucial role and allow us to make major predictions regarding phonemic paraphasia patterns.

2.5. The impaired mapping hypothesis

As reported in Section 2.4, neuropsychologists consider that accessed phonological representations are very close to their surface form and tend to minimize the amount of processing involved in speech sound production. Accessed representations either are entered into a "speech output buffer" (Morton and Patterson 1980) or directly activate articulatory mechanisms (Caramazza et al. 1981; Caramazza et al. 1986). In contrast, phonologists generally consider at least two levels of representation which differ in their degree of abstractness: the underlying representation (UR), where items are unspecified for their redundant/unmarked phonological features, and the surface representation (SR), where items are fully specified. Mapping of a UR onto an SR involves different processes such as insertion of the redundant/unmarked features, syllabification, and application of morphological rules (see, e.g., Mohanan 1986; Archangeli 1984). Furthermore, since word sounds are represented at various levels (UR, SR and LR, i.e., lexical representation), it is therefore difficult to experimentally manipulate SRs independently from URs or LRs in normal speech.

Speech pathology, and specifically the production of phonemic paraphasias, may constitute data relevant to this question. If sound planning involves phonological processes proposed by phonologists, the conversion of URs into SRs must be complex for some aphasic patients, and entail the production of errors that are influenced by the complexity of the involved processes. Therefore, the analysis of error patterns produced can bring evidence for an on-line application of these processes in normal sound production.

Béland (1985), Béland et al. (1990) hypothesize that phonemic paraphasias originate from difficulties aphasics have in mapping URs onto SRs. In a single-case study, Béland et al. (1990) show that phonemic errors produced by a conduction aphasic are not produced at random; specific error patterns are related to two word-level phonological processes found in French: insertion of redundant values of distinctive segmental features and syllabification. Regarding feature filling, the authors observe that the patient tends to replace marked feature values by default ones. The patient's errors are also predictable according to the inherent difficulties of the French syllabification algorithm proposed by the authors. Béland et al. (1990), in contrast with Mohanan (1986), conclude that URs play an important role in oral word production. They claim that most of their patient's phonemic paraphasias result from an impairment in the application of the syllabification algorithm, i.e., a breakdown in the mapping between URs and SRs.

2.6. The constraint increase hypothesis

This final proposal holds that phonemic paraphasias, comparable to phonemic alternations, originate from a dysfunction of the phonological component itself (Béland and Paradis 1993a, 1993b). According to this proposal, the one adopted in this study, a neurological disease can impair the normal functioning of the phonological component. The phonological parameter settings are thus affected: parameters that are normally positively set are momentarily or permanently negatively set by aphasic patients, resulting in an increase of negative constraints in comparison with normal subjects. As posited by the TCRS, negative constraints stem from principles and negative parameter settings. Given their additional negative parameter settings, aphasics perceive constraint violations in well-formed French words when requested to repeat or read aloud word stimuli. Like normal subjects, they fix up constraint violations with "repair strategies", to be described in Section 3. The TCRS posits that all genuine phonological (i.e., non-morphologically conditioned) alternations, including phonemic paraphasias, result from constraint violation repair. Phonemic paraphasias, like any other phonological alternation, are thus simply the surface effect of repair strategy applications.

3. Theoretical Framework

The TCRA (Paradis 1988a, 1988b, 1990, this volume) claims that languages are governed by constraints, which are themselves preserved by repair strategies. The application of a repair strategy is always motivated by a constraint violation, which can be caused by a morphological operation (the majority of cases), underlying ill-formedness or a constraint conflict. Here we will be concerned with word stimuli perceived as ill-formed by aphasics. Repair strategies consist in only two universal processes, insertion and deletion, which are context-free since they always apply according to the location of the problem detected by a given constraint. Repair strategies are also minimal in the sense that they apply at the lowest possible phonological level, as required by the Minimality Principle in (1).

We make a distinction between positive and negative constraints along the lines of Stanley (1967), although it is not clear that constraints need at all to be formulated in positive terms in the TCRA. However, see LaCharité (this volume) on the need for negative constraints.
(1) **Minimality Principle:**
A repair strategy must apply at the lowest phonological level to which the violated constraint it preserves refers.

For instance, if the lowest level a constraint refers to is the skeleton, the minimal repair in case of a violation will involve material located no higher than this level. Phonological levels are ranked according to the following scale, which is merely the projection of an independently needed phonological organization.

(2) **Phonological Level Hierarchy (PLH):**
metrical foot > syllable > skeleton > root node > place node > articulator > terminal feature.

As can be seen in (2), the TCRS integrates the feature geometry approach (Clements 1985; Sagey 1986; among many others), where segments are represented with an internal structure as in (3). Here it suffices to know that a segment consists of a root node (RN), which is normally attached to a place node (PN). The PN itself dominates one or two articulators—Labial, Coronal or Dorsal—which in turn dominate terminal binary features such as [-anterior] or [-round]. As illustrated in (3), articulators and terminal features lie on autonomous tiers, i.e., they are unordered with respect to each other.

(3)

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   RN
   i
Labial  Coronal  Dorsal
   [-round]  [-anterior]
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The TCRS also integrates a version of radical underspecification where only marked values of distinctive binary features are present in UR (for more details on underspecification models, see Archangeli 1988 and Paradis and Prunet 1991; see also Béland and Favreau 1991 for an application of this approach to aphasic speech). This model predicts that consonants that surface as anterior coronals, here dentals, the universally least marked consonants, lack a PN in UR, as shown in (4c). In contrast, non-anterior coronals, shown in (4d), which are specified [-anterior] in UR, the marked value of the feature, have a Coronal articulator along with a PN at all levels of representation, since terminal features must be dominated by appropriate nodes. In French, the anterior and non-anterior coronals are, respectively,

/\d n l r s z/ and /\s 3 n/. Labials /p b m v l/ and velars /k g/, like [-anterior] coronals, are always specified for their articulator in UR.

   RN   RN   RN   RN
   PN   PN   PN
   Labial  Dorsal  Coronal
   [-anterior]

Consonants unspecified for a PN are filled in with the default articulator, Coronal, in the course of a derivation, by the redundancy rule in (5) (Paradis and Prunet 1989):

(5) **Redundancy Rule:**
θ PN → Coronal

As seen in Section 2.6, the TCRS also makes crucial use of the parameter approach, where principles are universal linguistic constraints while parameters are linguistic options offered to all languages by universal grammar (see, e.g., Kaye et al 1985 for another application of this approach to phonology). Parameters represent linguistic limits to human speech whereas parameter settings (negative or positive) correspond to language-specific characteristics. It was already mentioned in Section 2.6 that negative parameter settings correspond to negative language-specific constraints. In this study, we focus on one negative language-specific constraint, inspired by the Cluster Condition of Yip (1991), which limits the maximal number of place specifications allowed within a consonant cluster. As shown in (6), Yip’s constraint is reinterpreted here as a negative setting of a parameter restricting the number of PNs within a consonant cluster (see also Béland and Paradis 1993a, 1993b for this parameter).

(6) **Cluster Parameter:**
More than one PN in a consonant cluster?

- **Menomini:** no (unmarked setting)
- **Fula:** yes (marked setting)
- **French:** yes (marked setting)
- **Aphasic Patients:** ?

Despite its uvular pronunciation (/R/) in many Quebec French idiolects, the French liquid /r/ is analyzed as an anterior coronal in UR since it behaves as a default consonant and does not contrast with any differently articulated rhotic.
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4. Hypotheses

4.1. The origin of phonemic paraphasias

As mentioned in Section 2.6, we assume the constraint increase hypothesis, couched in the TCRS, which claims the following (see Béland and Paradis 1993a, 1993b):

(a) Brain damage impairs the normal functioning of the phonological component.

(b) The processing of marked (complex) structures cannot be achieved because parameters that are normally positively set are momentarily or permanently negatively set by the patient, which results momentarily or permanently in more constraints for him/her. Note that in the vast majority of cases, positive settings correspond to marked settings while negative settings correspond to unmarked ones. This is why we claim that aphasics have constraints that normal subjects lack, i.e., aphasics have more constraints.

(c) Well-formed stimuli in his/her native language thus become problematic for the patient since they violate his/her personal constraints.

(d) Phonemic paraphasias are nothing but the surface manifestation of a repair strategy application, which fixes up a constraint violation. In other words, a repair strategy in aphasic speech reduces the complexity of a given structure in order for the structure to conform to a negative parameter setting present in aphasic speech.

(e) However, the application of a repair strategy does not necessarily result in the simplification of a whole word (structure) since the simplification of a structure may increase the complexity of an adjacent structure, not targeted by the constraint activated. For instance, the insertion of a nucleus within a branching onset (a marked onset type, which may be interpreted as ill-formed by aphasics) results in a longer word, i.e., a word with more syllables. Nuclear eponymy thus reduces the complexity of a given syllabic constituent, but increases altogether the complexity of the whole word.

(f) Minimal repair strategies in aphasic speech have priority over non-minimal ones.

(g) Since phonemic paraphasias result from negative parameter settings, we predict that the negative constraints they generate should be found in at least some world languages.

4.2. Consonant clusters

As stated in (7d), phonemic paraphasias are the surface manifestation of the application of repair strategies, which aims at reducing complexity in aphasic speech. However, one should keep in mind that many other non-phonological variables may interfere. Factors, such as the lexical frequency of the stimulus, its proximity to analogical forms (this holds also for non-word stimuli), the number of its semantically related forms, as well as individual variables, like the patient's familiarity with the stimulus, may contribute to the error rate observed in a phonological context. Since it is not possible to control all these non-phonological variables, a result based on only the number of errors produced in a given context will always be questionable. One way to insure that the phonological aspect alone is responsible for the observed effect is to predict, not only the error rate, but also the error pattern.

Findings that show contrasting phonological error patterns for two contexts will indicate that we can manipulate the phonological factor in such a way that some errors are more likely to be produced in one context than in another. If the error pattern is strictly defined in terms of phonological constraints, then the probability that non-phonological variables are responsible for such a contrasting error pattern is very low. Recently, in a single-case study of a progressive aphasic patient (a patient presenting an isolated speech deficit in the context of Alzheimer's disease), Béland and Paradis (1993a, 1993b) reported that both error contexts and error patterns are predictable on the basis of the TCRS. In this study, we will see that the TCRS allows us to make strong predictions about error patterns found in word stimuli comprising heterosyllabic clusters with one versus two PNs.

4.2.1. Clusters with two PNs:

As indicated in (6), consonant clusters comprising two different PNs are normally accepted in French (e.g., augmenter /ɔ̃ɡmēr/ 'to increase'), which is not the case in Menomini (Yip 1991), for instance. Since clusters with two distinct PNs constitute marked clusters, aphasics tend to set the Cluster Parameter negatively, resulting in an additional constraint for them, as already mentioned in (7b). A word stimulus such as augmenter /ɔ̃ɡmēr/ 'to increase' violates the patient's Cluster Constraint (i.e., his/her negative setting of the Cluster Parameter) since the consonant cluster gm is made up of a velar and a labial, i.e., two distinct adjacent consonants with both their own PN in UR, as indicated in (4). As stated in (7d) and (7f), we posit that the patient fixes up the ill-formedness s/he perceives in the cluster by means of a minimal repair. Since the only level the Cluster Constraint refers to is the PN level, the Minimality Principle in (1) states that the repair must apply at no higher level. Note that a repair application below the PN would have no effect on the problem, which explains why it is not an available strategy. And since the problem consists specifically in having two PNs instead of one, deletion of one of the two consonant PNs (as opposed to the insertion of an extra one) is selected. The redundancy rule in (5) fills in the gap at a further derivational level with the default articulator Coronal, and
he consonant surfaces as a dental (e.g., *augmenter* /oɡmàtə/ ‘to increase’ → *[ɔ̃mâťe]*).

Deletion of a whole segment, i.e., that of a RN, which is also likely to fix up the constraint violation (e.g., /oɡmàtə/ → *[ɔ̃mâťe]*) does not have priority because the Cluster Constraint does not refer to the RN level. Even when the constraint is a multilevel one referring to both levels, the PN and the RN, such a repair would not be minimal because RNs are located higher than PNs in the PLH in (2). Recall that the Minimality Principle in (1) states that a repair always applies at the lowest level to which the constraint it preserves refers. Vowel ephenthesis, i.e., insertion of a vowel RN, between the two consonants within the problematic cluster (e.g., *augmenter* /oɡmàtə/ → *[pɡɔmâte]*) constitutes an even more costly repair since it implies the generation of a new syllable, a top level in the PLH. In accordance with our hypothesis in (7), we therefore maintain that the distribution of errors in 2 PN clusters will be the following:

(8) Deletion of a consonant PN (i.e., substitution of a dental PN for a non-dental) > Deletion of a consonant RN (syncope of a non-dental) > Insertion of a vowel RN (vowel ephenthesis).

4.2.2. Clusters with one PN:
Heterosyllabic consonant clusters made up of a dental followed or preceded by a velar, a labial or a non-anterior coronal are far more common in French than 2 PN clusters. The 1 PN cluster, a less marked cluster, is used in this study as a control context since it is not problematic for patients' Cluster Constraint. Even though we have not yet identified precisely the cause(s) of paraphasias in this context, we strongly suspect that it concerns the nature of the consonants within the cluster and thus predict that the error distribution in 1 PN clusters will be different from that in 2 PN clusters. This is because the cause of the paraphasias in 1 PN clusters is obviously not the Cluster Condition. Indeed, we will see an important difference between the two types of clusters in their error distribution. Since the constraint involved in 2 PN clusters refers to the PN level, we predict that the most frequent repair strategy in such clusters will be the deletion of one of the two PNs, resulting in the substitution of a dental for a non-dental (labial, velar, non-anterior coronal). In contrast, in 1 PN clusters, the replacement of a labial, a velar or a non-anterior coronal by a dental should not be the most frequent substitution. We therefore hypothesize that the error distribution in 1 PN clusters will be the following:

(9) Substitution of a non-dental PN for another non-dental one ≥ Substitution of a dental PN for a non-dental one > Deletion of a consonant RN (syncope of a non-dental) > Insertion of a vowel RN (vowel ephenthesis).

5. Methodology

5.1. Subjects and stimuli

A total of 23 aphasic subjects, described in Appendix 1, participated in this study. The stimuli set included words and non-words. The justification for the use of non-word stimuli was twofold: a) non-word stimuli eliminated possible interferences between phonological, orthographic, semantic or morphological representations, and b) allowed us to verify, as suggested by the authors of functional architecture models in Section 2.4, whether error patterns produced on word and non-word stimuli are different or not. Word stimuli were either bisyllabic or trisyllabic whereas non-word stimuli were bisyllabic only. The distribution of word and non-word stimuli for each cluster type is given in (10).

The stimuli list was a subset of a larger list designed for the testing of multiple tautosyllabic and heterosyllabic clusters. In this larger protocol, many other stimuli characteristics were controlled, precluding our getting an even distribution of 2 PN and 1 PN heterosyllabic clusters. As already mentioned, this asymmetry is also accounted for by the fact that words with a 2 PN cluster are much less frequent in French than those with only one PN.

5.2. Testing and error classification

Aphasic subjects were requested to repeat word and non-word stimuli. They were informed that some of the stimuli do not correspond to real words but that they should repeat them just as heard. Testing sessions were limited to 20 minutes. Some patients repeated all stimuli during one testing session, while others needed as many as three testing sessions to complete the task. In such cases, testing sessions were administered within a month. All patients' responses were tape-recorded, and written transcriptions were prepared subsequently for detailed analysis.

Only erroneous responses were collected. Analogy cases (e.g., *admisjɔ̃/‘admission’ → addition ‘addition’ [ɔdʒiʒ]; /kaʃyil/ → cachemire [kɑ̃mir] ‘cashmere’), which represented 12% of the total responses, were eliminated from the data analysis. Responses that were too different from a word or a non-word stimulus were also left out. For instance, a production such as *[nɛzəl] for the word stimulus *magiquement* [maʁikm̩] ‘magically’ was eliminated. Such responses correspondence to only 1.4% of total errors collected.

In all analyses, we considered errors on stimuli not on phonemes. Thus the number of responses for quantitative analyses was expected to be equal to the number of presented stimuli. However, some patients gave more than one response to a stimulus. Since all responses were kept for analyses, each
6. Results

As predicted by the Minimality Principle (see Sections 4.2.1 and 4.2.2), the table in (11) shows that the distribution of errors in both 2 PN and 1 PN clusters is the following: consonant substitution > consonant syncope > vowel epentheses.

(11) Error Types  2 PN Cluster  1 PN Cluster
Consonant Substitution  87  374
Consonant Syllable  47  208
Vowel Epentheses  9  58

In both contexts, the most frequent applied repair strategy affects a structure located no higher than the PN level. However, as predicted in (8) and (9) specifically, the distribution of consonant substitution error pattern should differ according to the type of cluster. The distribution of substitution error patterns for 2 and 1 PN clusters is given in (12).

(12) Mean error ratios and SD for 2 and 1 PN clusters for each substitution error pattern

<table>
<thead>
<tr>
<th>Substitution error pattern</th>
<th>2 PN cluster</th>
<th>1 PN cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Loss of one PN</td>
<td>0.1011</td>
<td>0.0653</td>
</tr>
<tr>
<td>No change in the number of PNs</td>
<td>0.0219</td>
<td>0.0250</td>
</tr>
</tbody>
</table>

The four mean error ratios were obtained by dividing the sum of the error ratios (ratio = number of errors/number of stimuli) by the number of subjects (19: four aphasic subjects, 15, 17, 18, and 21 in Appendix 1, were eliminated because they did not produce errors in both clusters). Values of the four error ratios for each aphasic subject are given in Appendix 2. In (12), for stimuli (both word and non-word) comprising a 2 PN cluster, the most frequent substitution error pattern (mean error ratio = 0.1011) results, as expected, in the loss of one PN, that is, aphasics replace a non-dental (a consonant with a PN) by a dental (a PN-less consonant); e.g., abjure /abyre/ 'to renounce' → [abyre]. And, as expected, the least frequent substitution error pattern (mean error ratio = 0.0219) results in no change in the number of PNs, that is, aphasics replace a non-dental by another non-dental (i.e., a 2 PN cluster replaced by another 2 PN cluster); e.g., objet /obje/ 'object' → [obje].

For word and non-word stimuli with a 1 PN cluster, the reverse pattern of substitution error was also correctly predicted. In other words, the more

---

*See Section 3.2 for the adjustment of number of stimuli when a patient produced more than one response to a stimulus.

*These subjects were kept in the analysis for results reported in (11).
frequent substitution pattern (mean error ratio = 0.0384) in this context resulted in a cluster that still contained a PN, i.e., a cluster where no consonant PN was deleted (e.g., *canneberge* /kanberg/ ‘cranberry’ → kalberg), whereas the least frequent error pattern (mean error ratio = 0.0520) consists in the loss of a PN (e.g., *bourgogne* /burgon/ ‘burgundy’ → [burdon]). In sum, we correctly predicted contrasting substitution error patterns for 2 PN versus 1 PN clusters. Substitutions affecting the number of consonant PNs within a cluster was more frequent in 2 PN clusters than in 1 PN clusters.

In order to verify whether the mean error ratios are statistically significant, the mean error ratio for each error pattern produced in each cluster type were compared using an ANOVA (Analysis of Variance). ANOVA results indicate a significant interaction between the two factors (cluster type and substitution error pattern) (F<sub>1,18</sub> = 17.25, p < .01). Decomposition of the interaction reveals a significant error pattern effect in 2 PN clusters. Deletion of one PN occurs significantly more often than no deletion of a PN in 2 PN clusters (F<sub>1,18</sub> = 18.38, p < .01). In 1 PN clusters, no significant difference is found between the mean error ratios for the two substitution error patterns (loss of one PN versus no change in the number of PNs) (F<sub>1,18</sub> = 2.60, p = .12). This interaction is illustrated in (13).

(13) Mean error ratio in 2 PN cluster (→) and 1 PN cluster (⇒) as a function of substitution error pattern.

![Substitution error pattern graph](image)

Clearly, slopes in (13) corresponding to the two cluster types are very different. Mean error ratios vary both in function of cluster types and error patterns. An analysis based only on the number of errors produced in one context (2 PN clusters) versus the other (1 PN clusters) would miss that important distinction. Aphasics do not merely produce more errors in 2 PN clusters but, more importantly, they produce a different substitution error pattern in each context. The replacement of labials, velars or non-anterior coronals occurs significantly more often in a 2 PN cluster. In other words, the presence of a non-dental segment in a word did not by itself trigger the substitution error. If it were the case, the two lines in (13) would be parallel and the ANOVA would show no significant interaction. Results indicate that the co-occurrence of the two non-dental segments within the cluster triggers the substitution of a PN-less segment for a PN segment. Examples of substitutions within 2 PN versus 1 PN clusters are given in (14).

(14) Examples of Substitution Errors:

<table>
<thead>
<tr>
<th>Words</th>
<th>Non-words</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. 2 PN clusters with no change in the number of PNs</td>
<td></td>
</tr>
<tr>
<td>objet /objɛ/ to object' → objɛ /gabɔ/ → gabɔ</td>
<td></td>
</tr>
<tr>
<td>achever /afɛ/ to finish' → afɛ /pekmä/ → pekmä</td>
<td></td>
</tr>
<tr>
<td>alignment /aljmä/ to alignment' → aikmä /diyman/ → diygan</td>
<td></td>
</tr>
<tr>
<td>b. 2 PN clusters becoming 1 PN clusters</td>
<td></td>
</tr>
<tr>
<td>augmenter /ɔgnmɛ/ to 'to increase' → ɔrmɛ /kagmir/ → kadmir</td>
<td></td>
</tr>
<tr>
<td>achever /afɛ/ to 'to finish' → asve /pekmä/ → pekmä</td>
<td></td>
</tr>
<tr>
<td>abjurer /a拜yɛ/ to 'to renounce' → abdyre /pekmä/ → pekmä</td>
<td></td>
</tr>
<tr>
<td>suggérer /syɡɛʁɛ/ to 'to suggest' → sydjɛre /gabɔ/ → gabto</td>
<td></td>
</tr>
<tr>
<td>c. 1 PN clusters with no change in the number of PNs</td>
<td></td>
</tr>
<tr>
<td>phosphate /fɔsfɛt/ to 'phosphate' → fɔsfɛt /padɔ/ → padɔ</td>
<td></td>
</tr>
<tr>
<td>calmer /kalme/ to 'to calm' → kadme /kogre/ → kogle</td>
<td></td>
</tr>
<tr>
<td>Hector /ekɔʁɛ/ to 'Hector' → ekɔʁ /kapy/ → kapy</td>
<td></td>
</tr>
<tr>
<td>cognitif /kɔgnitiʃ/ to 'cognitive' → kɔgdiʃ /tɔbɛr/ → tɔbɛr</td>
<td></td>
</tr>
<tr>
<td>offusquer /ɔfyɛʁɛ/ to 'to offend' → ɔfyɛʁ /pɔnbɛr/ → pɔnbɛr</td>
<td></td>
</tr>
<tr>
<td>échelon /ɛfɛlɔ/ to 'level' → eʃnɔ /tɔpsɛ/ → tɔpsɛ</td>
<td></td>
</tr>
<tr>
<td>banjo /bɛŋɔ/ to 'banjo' → bala /lɔsef/ → lɔsef</td>
<td></td>
</tr>
<tr>
<td>diphtongue /dɪfɛʁʒ/ to 'diphthong' → diktɛʁ /tɔbrɛʃ/ → tɔbrɛʃ</td>
<td></td>
</tr>
<tr>
<td>abdomen //&gt;abdomen/ to 'abdomen' → əbdɔmɛn /pɔlɛʁ/ → pɔlɛʁ</td>
<td></td>
</tr>
</tbody>
</table>

Mean error ratio could be lower in 1 PN clusters since that context includes one PN-less segment in comparison to two in 2 PN clusters.
repair the constraint violations they perceive according to their particular parameter settings (see 7b).

We also depart from the impaired buffer hypothesis because the error pattern we observed in word stimuli is identical to that found in non-word stimuli, a fact which is incompatible with the impaired buffer hypothesis. More importantly, our data disconfirm the proposal of Morton and Patterson (1980) and Caramazza et al (1981, 1986) according to which abstract phonological processing plays no major role in phonemic paraphasias. Our results show that phonological processing is involved in all phonemic paraphasias addressed in this study (in word as well as in non-word stimuli).

As predicted by the impaired mapping hypothesis, the interaction between the substitution error pattern and the cluster type indicates that patients do not substitute consonantal segments randomly. The fact that we obtain a reverse pattern of error depending on the context implies that aphasics are sensitive to the abstract phonological representations of stimuli, a conclusion which is in keeping with Bélard et al's (1990) hypothesis.

We have seen that paraphasias tend to be as inexpensive as possible, which is predicted by our hypothesis in (7f) that repairs tend to apply minimally according to the Minimality Principle and the PLH. This can be accounted for only in a framework like the TCMS, where markedness is encoded in a universal approach (the parameter approach) and where phonological processes are motivated (they apply so as to preserve violated constraints).

Finally, another important finding in this study is that only a theory which assumes a radical underspecification approach (see Paradis and Prunet 1991), where anterior coronals (dentals) are the only PN-less segments, can account for our data. Without the special status of coronals, it is impossible to explain the observed error pattern, i.e., the replacement of a 2 PN cluster by a 1 PN one. A hypothesis based only on either the frequency of dentals in languages or the ease with which we articulate them, would be unable to explain why these segments are more frequently used as substitutes in 2 PN than in 1 PN clusters.8

7. Conclusion
The goal of this paper was to explain the origin of phonemic paraphasias found in aphasic speech. Some of the major proposals in the literature on phonemic paraphasias were presented in Section 2. In this section, we will address their compatibility with the results obtained in this study.

According to the regression hypothesis, aphasic data are comparable to acquisition data. If language acquisition implies that a negative parameter setting is acquired before a positive marked setting, then identical error patterns should be found with children. We are actually testing preschool children with the same material in order to verify this hypothesis.

Given the markedness hypothesis, aphasic data tend to replace marked phonemes by unmarked ones, a prediction also made by the TCMS through its parameter approach. As shown in (6) and stated in (7b), a parameter setting is either marked or unmarked. For the Cluster Parameter, we hypothesized that aphasic patients tend to substitute an unmarked setting for a marked setting, which was confirmed by our results: aphasics replace a positive marked setting in Quebec French by an unmarked negative one.

However, our results are incompatible with Dressler's hypothesis that aphasics violate language-specific constraints. In our study, 15 of the 19 aphasic subjects tended to reduce the complexity of a phonological structure by replacing a 2 PN cluster by a 1 PN cluster (see Appendix 2). In 1 PN cluster stimuli, we collected 166 examples where a 1 PN cluster remained as is versus 52 examples where a PN was added (e.g., algeb̃e /algeb̄/ 'algebra' → [algeb̃], /d[om;r̃]/ → [dokmar]). In other words, aphasics tend to reduce complexity in both contexts much more often than they increase complexity of a stimulus, which is accounted for by our hypothesis that aphasics tend to

8In order to verify whether our results hold cross-linguistically, we are conducting the same experiment with Algerian Arabic-speaking and Brazilian Portuguese-speaking aphasic subjects.
### Appendix 1
Description of Aphasic Population

<table>
<thead>
<tr>
<th>ID</th>
<th>Diagnosis</th>
<th>Sex</th>
<th>Age</th>
<th>Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Broca's aphasia</td>
<td>F</td>
<td>42 years</td>
<td>8 years</td>
</tr>
<tr>
<td>2</td>
<td>Broca's aphasia</td>
<td>F</td>
<td>67 years</td>
<td>11 years</td>
</tr>
<tr>
<td>3</td>
<td>Broca's aphasia</td>
<td>F</td>
<td>81 years</td>
<td>10 years</td>
</tr>
<tr>
<td>4</td>
<td>Broca's aphasia</td>
<td>M</td>
<td>35 years</td>
<td>11 years</td>
</tr>
<tr>
<td>5</td>
<td>Broca's aphasia</td>
<td>M</td>
<td>44 years</td>
<td>18 years</td>
</tr>
<tr>
<td>6</td>
<td>Broca's aphasia</td>
<td>M</td>
<td>58 years</td>
<td>11 years</td>
</tr>
<tr>
<td>7</td>
<td>Broca's aphasia</td>
<td>M</td>
<td>59 years</td>
<td>12 years</td>
</tr>
<tr>
<td>8</td>
<td>Broca's aphasia</td>
<td>M</td>
<td>59 years</td>
<td>8 years</td>
</tr>
<tr>
<td>9</td>
<td>Broca's aphasia</td>
<td>M</td>
<td>60 years</td>
<td>7 years</td>
</tr>
<tr>
<td>10</td>
<td>Wernicke's aphasia</td>
<td>F</td>
<td>73 years</td>
<td>10 years</td>
</tr>
<tr>
<td>11</td>
<td>Wernicke's aphasia</td>
<td>F</td>
<td>80 years</td>
<td>10 years</td>
</tr>
<tr>
<td>12</td>
<td>Wernicke's aphasia</td>
<td>M</td>
<td>48 years</td>
<td>not available</td>
</tr>
<tr>
<td>13</td>
<td>Wernicke's aphasia</td>
<td>M</td>
<td>59 years</td>
<td>13 years</td>
</tr>
<tr>
<td>14</td>
<td>Conduction aphasia</td>
<td>F</td>
<td>32 years</td>
<td>18 years</td>
</tr>
<tr>
<td>15</td>
<td>Conduction aphasia</td>
<td>F</td>
<td>54 years</td>
<td>9 years</td>
</tr>
<tr>
<td>16</td>
<td>Conduction aphasia</td>
<td>M</td>
<td>63 years</td>
<td>10 years</td>
</tr>
<tr>
<td>17</td>
<td>Mixed aphasia</td>
<td>F</td>
<td>52 years</td>
<td>6 years</td>
</tr>
<tr>
<td>18</td>
<td>Mixed aphasia</td>
<td>F</td>
<td>64 years</td>
<td>not available</td>
</tr>
<tr>
<td>19</td>
<td>Mixed aphasia</td>
<td>F</td>
<td>70 years</td>
<td>7 years</td>
</tr>
<tr>
<td>20</td>
<td>Mixed aphasia</td>
<td>M</td>
<td>59 years</td>
<td>8 years</td>
</tr>
<tr>
<td>21</td>
<td>Mixed aphasi</td>
<td>M</td>
<td>53 years</td>
<td>18 years</td>
</tr>
<tr>
<td>22</td>
<td>Progressive aphasia</td>
<td>M</td>
<td>67 years</td>
<td>8 years</td>
</tr>
<tr>
<td>23</td>
<td>Diagnosis not available</td>
<td>F</td>
<td>not available</td>
<td>not available</td>
</tr>
</tbody>
</table>

### Appendix 2
Error Ratios for the 19 Aphasic Subjects

<table>
<thead>
<tr>
<th>2 PN cluster</th>
<th>1 PN cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error ratio</td>
<td>Error ratio</td>
</tr>
<tr>
<td>2 PN → 1 PN</td>
<td>2 PN → 2 PN</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
<td>0.18</td>
</tr>
<tr>
<td>3</td>
<td>0.05</td>
</tr>
<tr>
<td>4</td>
<td>0.18</td>
</tr>
<tr>
<td>5</td>
<td>0.00</td>
</tr>
<tr>
<td>6</td>
<td>0.10</td>
</tr>
<tr>
<td>7</td>
<td>0.07</td>
</tr>
<tr>
<td>8</td>
<td>0.24</td>
</tr>
<tr>
<td>9</td>
<td>0.06</td>
</tr>
<tr>
<td>10</td>
<td>0.15</td>
</tr>
<tr>
<td>11</td>
<td>0.16</td>
</tr>
<tr>
<td>12</td>
<td>0.05</td>
</tr>
<tr>
<td>13</td>
<td>0.08</td>
</tr>
<tr>
<td>14</td>
<td>0.08</td>
</tr>
<tr>
<td>16</td>
<td>0.10</td>
</tr>
<tr>
<td>19</td>
<td>0.18</td>
</tr>
<tr>
<td>20</td>
<td>0.05</td>
</tr>
<tr>
<td>22</td>
<td>0.15</td>
</tr>
<tr>
<td>23</td>
<td>0.05</td>
</tr>
</tbody>
</table>

The value in the second column is the error ratio in 2 PN cluster corresponding to the "loss of one PN" error pattern. For instance, this value, for aphasic subject 10, is 0.15, because she produced 6 erroneous responses out of 41 stimuli (6/41). The same patient did not produce any error corresponding to the second error pattern (no change in the number of PNs) thus giving a 0 value in the third column.
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Caplan, David

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