Phonological errors in fluent and non-fluent aphasia:

A literature research comparing the phonological speech production errors of people with fluent and non-fluent aphasia

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Introduction

A lot is known about syntactical errors made in speech of people with aphasia. Not only syntax, but also semantics have often been the subject of linguistic analyses of aphasic language. In contrast, only a small amount of literature has been written about phonological aspects, even though these are well evident. This bachelor thesis will look at literature written on phonological errors made in speech of people with aphasia, in which the distinction between fluent and non-fluent aphasia will be drawn.

In making the distinction between fluent and non-fluent aphasia, some interesting conclusions might be connected to phonological errors made by each group. Fluent aphasia is characterized by normal to high speed of speech. Non-fluent aphasia is characterized by relative slow speed of speech. It is already known that people with fluent aphasia make less phonological mistakes than people with non-fluent aphasia. In this thesis, a possible relationship between speed of speech and types of phonological errors is investigated. It can be tested whether a high number of words produced per utterance, indicative of fluent aphasia, means a relative small range in types of phonological mistakes. Or: a low number of words produced per utterance, indicative of non-fluent aphasia, relates to many different types of phonological errors. Perhaps people with non-fluent aphasia make various phonological errors that are not found in speech of people with fluent aphasia. Or it might prove the other way around.

Besides the above hypotheses, the main focus of this paper will lay on drawing general conclusions about phonological errors made by people with fluent and non-fluent aphasia. As much as possible literature done in phonological aspects of speech of people with aphasia will be discussed and put together. This way, an overview will be given of literature that has been written about phonological aspects of aphasic speech. On one side, it will discuss the difference in errors made in fluent and non-fluent aphasia and, on the other side it will look for generalizations or common features that occur in the two groups of aphasia.

After drawing final conclusions some thoughts for further research are put forward, based on what is written in this paper. All together, this bachelor thesis will give more insight in the phonological patterns of aphasic speech.

Aphasia

'Aphasia', coming from the Greek word 'aphatos', meaning speechless, refers to a disorder that influences the ability to communicate by oral or written language, or both, as a result of brain damage (Goodglass, 1993). Many parts of language ability can be affected, such as word retrieval, spoken word production, auditory comprehension or reading. Most people with aphasia do not suffer from total language loss, but show selectively impaired aspects of language.

Over the last centuries multiple names have been given to this language disorder and several distinctions have been drawn between types of aphasia. The original distinction made in aphasia was based on the localizationist model. This model linked the type of aphasia to the specific area in the brain which had been damaged. However, this model led to disagreements among experts. Modern techniques and analyses show that precise connections between brain regions and symptom classification don't exist. The classification model is still used widely though.

In this paper the distinction between fluent and non-fluent is made, which is usually a 'first cut' in diagnostic classification (Goodglass, 1993).
Non-fluent aphasia is characterized by slow and slurred speech production. In their 1964 article, Goodglass, Quadfasel and Timberlake showed that people with non-fluent aphasia could be classified on the basis of the number of words they could utter as an uninterrupted string. People with non-fluent aphasia speak maximally three to four words per utterance group. Typical of this speech are frequent pauses, disturbed intonation patterns and the use of content words only, which means that articles, conjunctions, prepositions, auxiliary verbs and morphological inflections are commonly omitted. People with Broca's aphasia are classified as non-fluent.
Fluent aphasia is characterized by normal to high speed of speech with normal intonation. Impairments of people with fluent aphasia are mostly related to the input or reception of language. People with fluent aphasia frequently run on without interruption in strings of five or more words (Goodglass et al., 1964). Their speech contains numerous semantic and phonological paraphasia's. Wernicke's aphasia is classified as fluent.

It is important to keep in mind that there are and have been many discrepancies about the classification of aphasia. Every subtype of aphasia seems to be inadequate to some extent caused by a still high variation among patients who are classified with the same type of aphasia. Some experts even argue that up to 50% of people with aphasia cannot be classified.

Phonology

In analyzing the speech of fluent and non-fluent aphasia the focus lays on phonological aspects. In other words, the smallest sound-units, or phonemes, that make up words are the subject of this study. Phonology should be carefully divided from phonetics. Phonetic errors are caused by physical articulation deficits. In contrast, phonemic errors are not concerned

with physical structures, but with the production of mistargeted sounds. As a consequence, phonemes might be substituted, omitted or moved.
It has been proposed that the phonetic-phonemic distinction accounts for the difference between fluent and non-fluent aphasia (e.g., Lesser, 1995). Phonetic disintegration, an articulatory failure to realize sounds with the correct precision, would be characteristic for speech of non-fluent aphasia. Meaning, people with non-fluent aphasia would not so much have problems with selecting the right words, but in pronouncing them. People with fluent aphasia on the other hand would not suffer from phonetic, but from phonemic disintegration: the misplanning of phonemes while phonetic realization is still intact. However, this distinction cannot be so easily made. People with aphasia seem to suffer to some degree from both disintegrations, and not solely from one.

Concerning literature cited in this paper, it is important to keep in mind the difference in total number of phonological errors made by each group with aphasia. People with non-fluent aphasia make substantially more phonological errors than people with fluent aphasia do. For example, Blumstein (1973) reports in her research that the total number of phonological errors made by the group with Broca's aphasia is 1993, while the group of people with Wernicke's aphasia made only 219 errors. Even though this paper does not discuss the quantitative amount of phonological errors it should be kept in mind throughout this paper.
Also, all of the studies looked at phonological errors on content words, thus not including phonological errors on function words, connectives or other forms of the copula. People with non-fluent aphasia often eliminate these words. In addition, it is shown that phonological errors in aphasic speech generally occur on content words.

Vocabulary list

Assimilation:	A sound changing and becoming (more) like a neighbouring sound. This may occur in anticipation of a given phoneme (regressive assimilation), e.g. /ai θiŋk so/ 'I think so' → /ai siŋk so/, or it may occur after an already occurred phoneme (progressive assimilation), e.g. /rost bif/ 'roast beef' → 'rost bist'.
Blends:	See *assimilation.*
Coda:	The ending sound(s) of a syllable. The minimal syllable consists of a nucleus, with an optional onset and/or coda. In /bɛd/ 'bed', /b/ is the onset, /ɛ/ is the nucleus and /d/ is the coda.
Contextual errors:	Substitution of a phoneme with the source of the intruder found in the sentence. Including *metathesis* and *assimilation* errors.
Geminate:	A double vowel or consonant. E.g. in Italian the length of a consonant can distinguish words, /pala/ 'spade', but /paləa/ 'ball'.
Hiatus:	Two vowel sounds occurring in adjacent syllables without an intervening consonant. E.g., 'Rafael'.
Insertion:	The addition of an extra phoneme in a word. E.g. /papa/ 'papa' → /papra/.
Metathesis:	Two phonemes that switch position. E.g. /dəgriz/ 'degrees' → /gədriz/.
Omission:	The loss of a phoneme in a word. E.g. /prɪti/ 'pretty' → /pɪti/.
Onset:	The beginning sound(s) of a syllable. See *onset.*
Paraphasia's:	Related or unrelated word substitutions or smaller changes to a word. E.g. target word 'stethoscope'; response 'telescope'.
Perseveration:	See progressive *assimilation.*
Sonority substitutions:	The substitution of a phoneme by another one with higher sonority. Sonority refers to the amplitude of a speech sound.
Substitution:	One phoneme being replaced by another phoneme. The source of the intruder is not in the sentence. E.g. /timz/ 'teams' → /kimz/.

Literature

The following chapter describes studies that have been done on phonological aspects of speech from people with either fluent aphasia, non-fluent aphasia or studies done with both groups. The phonological findings are divided into six paragraphs: distribution, substitutions, omissions, insertions, place in word & frequency and features. The paragraph 'distribution' discusses the rate of the most common error types. Following, three of those error types are looked at separately (substitution, omission and insertion). The paragraph 'place in word & frequency' describes where in the word errors in general are made and whether frequencies of phonemes play a role. At last, the paragraph 'features' looks at errors concerning specific phonemes. Every paragraph finishes with a short summary.

One of the most covering studies that has been done in phonological aspects of aphasic speech comes from Blumstein (1973). Although it dates back to nearly forty years ago, '*A phonological investigation of aphasic speech'* describes many phonological patterns of aphasic speech. Blumstein reports not only error categories common to all people with aphasia, but also error categories specific for people with either Broca's or Wernicke's aphasia. Blumstein also looks at Conduction aphasia, but this will not be discussed here. Blumstein obtained data by conducting interviews with the patients with aphasia (spontaneous speech). All but one of the six paragraphs start with findings of Blumstein's study performed in 1973 with English people with aphasia.

Most studies used data elicited by single word production or single word repetition. Some other studies looked at sentence repetition, spontaneous speech or reading out a newspaper article. For all of the studies that have used data different than single word production/repetition it will be noted what kind of data is used. Also, in every research it is noted what language is spoken.

1. Distribution

This paragraph looks at the distribution of different error types. The most common error types are: substitution, omission, insertion and contextual errors like assimilation and metathesis. All of these error types will also be discussed individually in the following paragraphs.

Blumstein (1973) studied the distribution of speech errors in aphasic language, including the following error types: phoneme substitution, omission, contextual errors and insertion. Contextual errors include metathesis and progressive and regressive assimilation. The results Blumstein found are as following (see table 1):

Table 1: Distribution of aphasic errors (Blumstein, 1973)

	Broca	Wernicke
Phoneme substitution	48.7 %	35.2 %
Omission	24.7 %	30.3 %
Contextual	20.0 %	20.7 %
Insertion	6.6 %	13.8 %

Phoneme substitution is the dominant error type for people with fluent aphasia and for people with non-fluent aphasia. Also, the rank order of the error types is the same: first substitutions, then omission, followed by contextual errors and lastly insertion. Some differences between the groups are evident though. The percentage of substitution errors of people with Broca's aphasia is nearly 50%, which is significantly higher than the percentage for people with Wernicke's aphasia (35%). The percentage of the remaining error types (omission, contextual and insertion) show slightly higher numbers for people with Wernicke's aphasia but an otherwise quite even distribution.

Ferreres (1990) showed a somewhat similar distribution of error types for Spanish speaking people with Broca's aphasia. Substitutions were the error type most often made (59%), followed by omissions (29%), then insertions (10%) and at last metathesis/displacement (2%). The hierarchy of Ferreres' results differs from Blumstein's results in that insertions and contextual errors are switched. Percentages are not very different from Blumstein's group of people with Broca's aphasia.

Caramazza and Chialant (2000) researched two fluent Italian speaking people with aphasia. They also showed a predominance for substitution errors, with an average of 61.5% of the total errors made. Then, unlike the results from Blumstein and Ferreres, after substitutions one patient makes most mistakes on omissions (14%) and insertions (14%) and the other patient makes most errors on other types (12%), followed by omissions (5%) and insertions (5%). In this study contextual errors seem to play a less important role.

Goldman et al. (2001) carried out a research with one English person with Wernicke's aphasia. Data was obtained by spontaneous speech. They found the following distribution results: substitution errors 83%, omission errors 8% and insertion errors 7%. No contextual errors were found. Again, this research shows that the dominant type of errors lies in substitutions. Also, the rank order is comparable with the results found by Caramazza et al.

Romani et al. (2002) compared two Italian persons, one with non-fluent aphasia and one with fluent aphasia. Noteworthy, they looked at single word production of the person with non-fluent aphasia but at spontaneous speech and sentence repetition of the person with fluent aphasia. Both patients made most errors in substitutions (respectively 59% and 66%). After substitutions, omissions were the most common made mistakes (26% and 14%), followed by insertions (9% and 6%) and metathesis (7% and 8%). These results show the same rank order

as Ferreres found. Romani et al. also note that the errors of the person with Broca's aphasia show a wide distribution with some errors happening often and others not, while the person with Wernicke's aphasia shows a more equal distribution.

At last, Romani and Calabrese (1993) looked at phonological errors on geminate consonants. A geminate is a long or double consonant. One person from Italy with Broca's aphasia was researched. The findings were comparable to the results reported above by Ferreres and Romani et al. on phonological errors in general: the main type of error was substitution (56%), followed by omission (22%), insertions (15%) and metathesis (6%).

Summary:

- All studies found that substitution is the dominant phonological error type for both people with fluent and non-fluent aphasia.
- Four studies were done with persons with non-fluent aphasia, and all, except for Blumstein's research, show the following rank order: substitution, omission, insertion and contextual errors. Thus, there seems to be a specific distribution of phonological errors for people with non-fluent aphasia.
- Four studies were done with persons with fluent aphasia and the results show about the same rank order as for non-fluent aphasia, except that the percentages for omissions, insertions and contextual errors lay closer to each other compared to the Broca's group.

Interestingly, Blumstein reports that 35% of phonological errors made by people with Wernicke's aphasia are substitutions. In the three other studies the amount of substitutions lays a lot higher with 61.5% being the lowest percentage.

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2. Substitutions

Substitution is the most common error type made by people with fluent and non-fluent aphasia (see previous sector). Blumstein found some interesting results concerning substitutions. Firstly, she found that most phoneme substitution errors of people with Broca's aphasia occur when the target phoneme is in word-initial position (53.6%). Errors in word-final position make up 9.7%. The majority of substitution errors made by people with Wernicke's aphasia are found in both word-initial, word-final and between-vowel position with a distribution of respectively 27.7%, 29.3% and 19.6%.
Secondly, Blumstein found that substitution errors were mainly made on single consonants. Both people with Broca's aphasia and Wernicke's aphasia showed this pattern, with 77.7% and 76.7% of the errors occurring on single consonants. Also, the majority of substitutions of people with Broca's and Wernicke's aphasia involve the substitution of an unmarked for a marked consonant.

Romani and Calabrese (1998) conducted a research on one Italian person with Broca's aphasia and showed that significantly fewer substitutions are made in word-final position than in word-initial position, just like Blumstein found. They found no difference in the percentage of errors on simple onsets or complex onsets. This is slightly surprising because Blumstein found that substitution errors were made predominantly on single consonants.

Visch-Brink and Bastiaanse (1998) did a research with seven Dutch persons with non-fluent and fluent aphasia. Data was conducted by both spontaneous speech, word repetition and sentence repetition. They showed that sonority substitutions occurred more often in fluent aphasia than in non-fluent aphasia: 12% of the substitutions in fluent speech concern sonority substitutions, compared to only 4% in non-fluent speech.
Moreover, 22% of the vowel substitutions of the fluent patients concern phonological length substitutions, compared to 0% of the people with non-fluent aphasia.

Dressler and Stark performed a research in 1988 on substitution errors made by German people with Wernicke's and Broca's aphasia. The results are below:

Table 2: Substitution errors (Dressler & Stark, 1988)

Type of error	Broca's	Wernicke's
Perseverations	15.9	6.9
Substitutions	6.0	3.0

People with Broca's aphasia make considerably more perseverations than substitutions. This also counts for people with Wernicke's aphasia, although their percentage of errors is lower. In a previous study done by Dressler and Stark with Austrian aphasics (1981) it is reported that people with Broca's aphasia aspirated unaspirated stops in 28 instances, compared to only one instance of a person with Wernicke's aphasia.
They also report a study by Keller (1984) who found that substitution of less sonorous by more sonorous vowels especially takes place with people with Broca's aphasia. This is in contrast with the results found by Visch-Brink and Bastiaanse (see above) who found sonority substitutions to be more common in speech of fluent aphasia.

Environment
In her research, Blumstein (1973) classified the error types 'contextual' as well as 'phoneme substitution'. Contextual errors are also known as environment errors. Contextual errors are a type of substitution that shows influence of surrounding phonemes. In contrast, phoneme substitutions are characterized by the substitution of one phoneme for another without influence of surrounding phonemes. Blumstein found the following results in this category, which she divided into intra-morphemic blends, inter-morphemic blends and metatheses:

Table 3: Environmental errors (Blumstein, 1973)

	Broca	Wernicke
Intra-morphemic blends	52.6 %	31.5 %
Inter-morphemic blends	26.8 %	56.7 %
Metatheses	20.6 %	11.8 %

She found that people with Broca's aphasia make mostly intra-morphemic blends (52.6%), compared to a 31.5% for people with Wernicke's aphasia. Speech of Wernicke's aphasia contains mostly inter-morphemic blends (56.7%), compared to a 26.8% for speech of Broca's aphasia.
Blumstein also noted that regressive assimilation errors occur more often than progressive assimilation errors, especially evident in intra-morphemic errors. This holds for people with fluent and non-fluent aphasia.
Goldmann et al. (2001), who obtained data by narrative elicitation, confirm this finding with a research on an English person with Wernicke's aphasia who also makes significantly more anticipations than perseverations.

Summary:

- Two studies report that people with Broca's aphasia show a tendency to make substitution errors at word-initial position.
- One study notes that people with fluent aphasia make significantly more sonority substitutions than people with non-fluent aphasia. In contrast, a different study shows exactly the opposite concerning vowel sonority substitutions.
- As to environment errors, one study found that people with Broca's aphasia make mainly intra-morphemic blends, and people with Wernicke's aphasia make mainly inter-morphemic blends.
- Also, two studies found that regressive assimilation occurs more often than progressive assimilation in fluent aphasia.

Concluding, the results describe mainly different aspects of substitution errors.

3. Omissions

Omissions, as can be seen in the vocabulary list, are deletions of phonemes. It should be reminded that omissions are not always considered phonemic errors, but more importantly morphological errors. For example, when the third person form of a verb *–s*, as in *walks*, is deleted (resulting in *walk*), this might not so much be a phonemic error, but a grammatical error.

According to Blumstein (1973), consonant omission errors do not differ significantly between people with Broca's and Wernicke's aphasia. There is a fairly even distribution of omissions in initial, medial and final position. Also, Blumstein notes that the large majority of omission errors occur in the context of consonant clusters and not in the context of single consonants. In contrast, substitution errors occur mainly on single consonants (see above).

Romani and Calabrese (1998) report a study about a person from Italy with Broca's aphasia. Two remarks were made: in syllables with an onset, vowels were never deleted, plus, the majority of the omissions made by the person with Broca's aphasia involved liquids or glides. Visch-Brink and Bastiaanse (1998) also write about this: they found that liquids are deleted when it is part of an obstruent-liquid cluster.

Romani et al. (2002) showed that omissions for two persons from Italy with Broca's aphasia and with Wernicke's aphasia concentrated on complex onsets. For the persons with Broca's aphasia 80.1% of the omissions took place in complex onsets and 7.1% in simple onsets. The person with Wernicke's aphasia shows 74.1% omission rate in complex onsets and 3.7% in simple onsets. Of the vowel omissions made by the person with Broca's aphasia, 89% resulted in eliminating hiatuses, while none of the person with Wernicke's aphasia did. Noteworthy, Romani et al. looked at single word production of the person with non-fluent aphasia but at spontaneous speech and sentence repetition of the person with fluent aphasia.

Lindner (1985) in Dressler and Stark (1988) shows that people with Broca's aphasia make more omissions in the onset (61%) and people with Wernicke's aphasia make more omissions in the coda (62%). This is in contrast with the results found by Blumstein, who found there was an even distribution for both groups in initial, medial and final position.

In a study of Braber et al. (2005) it is noted that English people with Broca's aphasia produce a prominent type of error in verb production: omission of /t/ and /d/. Also, according to Braber et al., people with Broca's aphasia are more likely to preserve vowels than to preserve onset and offset consonants. The error rate between deleting onset consonants and offset consonants was not found to be significantly different.

Summary:

- Two studies (one study on a person with Broca's aphasia and one study on both groups of aphasia) found that omissions concentrated on liquids and glides.
- Two studies (one study on a person with Broca's aphasia and one study on both groups of aphasia) reported that omissions mainly take place in consonant clusters.
- Three studies each report different results in the distribution of omissions in initial, medial and final word position.
- In one study 89% of the vowel deletions made by a person with Broca's aphasia resulted in eliminating hiatuses, while none of the deletions of the person with Wernicke's aphasia did.

4. Insertions

According to Blumstein's research in 1973 insertion errors made by people with aphasia were the smallest category of errors made by both people with Broca's and Wernicke's aphasia. Blumstein notes that, likewise omission errors, insertion errors mostly take place in consonant clusters. Furthermore, she reports that of all insertion errors, only three error types recurred constantly:

- V → # CV: insertion of a consonant before an initial vowel. E.g. /armi/ 'army' → /jarmi/.
- Articulatory based: a consonant is added similar in place but different in manner to the consonant in the target syllable. E.g. /sawθ/ 'south' → /stawθ/.
- C → C {liquid; semi-C}: Insertion of a liquid or semi-consonant to a stop or continuant. E.g. /tami/ 'Tommy' → /trami/.

The frequency in which these errors occur is below:

Table 4: frequency of types of insertions (Blumstein, 1973)

	Broca	Wernicke
V → # CV	24.5 %	30.6 %
artic. based	23.5 %	19.5 %
C → C {liquid; semi-C}	26.9 %	10.7 %
Other	25.1 %	39.2 %

The distribution of these three types of errors is distributed evenly for people with Broca's aphasia. People with Wernicke's aphasia make most errors in type 1, and least errors in type 3. Blumstein does not give an explanation why it is these three error types that occur most often.

Romani and Calabrese (1998) performed a research with an Italian person with Broca's aphasia and found that liquids and glides were most commonly inserted. Moreover, in 87% of the cases, insertions eliminated hiatuses.
According to Beland and Favreau (1991) (in Romani and Calabrese, 1998) aphasic patients generally use dentals as epenthetic segments. However, the person with Broca's aphasia researched in Romani and Calabrese never inserted a /t/ and only once a /d/.

Interestingly, Romani et al. (2002) also found a possible relationship between insertions and hiatuses. They showed that 31% of the consonant insertions made by their Italian patients with Broca's aphasia eliminated hiatuses, compared to a 5.9% of the consonant insertions made by the person with Wernicke's aphasia. Noteworthy, they looked at single word production of the person with non-fluent aphasia but at spontaneous speech and sentence repetition of the person with fluent aphasia.

Dressler and Stark (1981) showed that in 22 cases of a person with Broca's aphasia vowel insertions were made, compared to only 2 cases of a person with Wernicke's aphasia, both patients speaking German. They also did research in the ratio of consonant insertions in codas and onsets. People with Broca's aphasia made 72% of consonant insertions in onset position, while people with Wernicke's aphasia made the majority of consonant insertions in coda position (65%).

Summary:

- Blumstein's study (1973) found that there are three different types of insertions recurring constantly for both groups of aphasia. A different study agrees that people with Broca's aphasia most commonly insert liquids and glides.
- Two studies report that people with Broca's aphasia use insertions to eliminate hiatuses.
- One study found that omissions *and* insertions are made most often in the onset by people with Broca's aphasia and most often in the coda by people with Wernicke's aphasia.

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5. Place in word & frequency

Firstly, many researches show that the chance of errors on consonants is higher than the chance of errors on vowels (Semanza et al., 2007; Golmann et al., 2001; Visch-Brink & Bastiaanse, 1998; and Ferreres, 1990). This counts for both fluent and non-fluent aphasia.

Moreover, Romani et al. (2002) show that their Italian person with Broca's aphasia makes least errors at the beginning of a word, while their person with Wernicke's aphasia has an equal error rate at both word beginning, middle and final position. In contrast, Goldmann et al. (2001) find that their English person with Wernicke's aphasia makes almost all errors on word-initial syllables.

Two studies also looked specifically at frequency effects in speech of people with aphasia. Romani et al. looked at consonant frequency effects (2002) for a person with Wernicke's aphasia and a person with Broca's aphasia, both coming from Italy. It should be noted that data from the person with Broca's aphasia consists of single word production, while data from the person with Wernicke's aphasia consists of sentence repetition or spontaneous speech. They showed that the person with Broca's aphasia made more errors on consonants with low frequency than consonants with high frequency. The patient also replaced consonants of lower frequency with consonants of higher frequency. Romani et al. do admit that this might have to do with the patient's tendency to simplify structures. The person with Wernicke's aphasia did not show any frequency effects. Romani et al also found that more errors are made when the

number of phonemes in a word grows, concerning both people with fluent and non-fluent aphasia.

In addition, in a study of Semenza et al. (2007) a person with Wernicke's aphasia, also from Italy, was tested on frequency effects on vowels. Vowel errors were made on words with low frequency, but also on extremely high frequent words. The patient's performance could therefore not be explained by a frequency factor. Data was obtained by reading out a newspaper article.

Summary:

- Four studies report that the majority of errors are made on consonants.
- There is no agreement about errors occurring in a specific position of the word linked to the two types of aphasia.
- One study found that a person with Broca's aphasia makes more errors on consonants with low frequency than on consonants with high frequency. This patient also replaced low frequency consonants by high frequency consonants. This frequency effect was not found for the person with Wernicke's aphasia. A second study confirms this last finding: a person with Wernicke's aphasia did not show any frequency effects either.

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6. Features

Blumstein (1973) concluded early in her work that errors occur primarily between closely related phonemes. In addition, Blumstein found that among the phoneme substitution errors that differ in more than one distinctive feature, there were a few consonant confusions that occurred more than theoretically predicted. These relatively frequent occurring error types are:

{r, l} ↔ w	n ↔ l	w ↔ m
{t, d} ↔ l	{v, b} ↔ w	{k, g} ↔ h

Of these six error types there were three that occurred most often, these are the ones in the upper row. She also noted that errors produced by people with Broca's aphasia have a tendency to go from dental to labial consonants (there was not enough data of people with Wernicke's aphasia to be able to draw conclusions about this group).

Romani et al. (2002) also note the special position of liquids and glides. Their Italian patient with Broca's aphasia makes errors concerning liquids or glides in 67% of his transpositions and in 76% of his insertions. Their patient with Wernicke's aphasia shows somewhat lower percentages with transposition errors involving in 30% liquids or glides and insertions

involving in 42% liquids or glides. It needs to be noted that data from the person with Broca's aphasia consists of single word production, while data from the person with Wernicke's aphasia consists of sentence repetition and spontaneous speech.
Furthermore, the person with Broca's aphasia showed a strong tendency to spare /a/, which is the most sonorous vowel. Instead, most vowel errors were made on /u/, which is the least sonorous vowel. The person with Wernicke's aphasia however shows an equal distribution of vowel errors with no specific preservation of /a/. Concerning consonants, the most common substitution error of the person with Broca's aphasia is /d/ → /t/ in 30% of the cases. Following is /r/ → /l/ in 12% of the cases.

Semenza et al. (2007) showed in a research done with an Italian person with Wernicke's aphasia that substitutions errors were made on /a/ (48%), /u/ (31%), and following /e/, /i/ and /o/ (22%, 19% and 18% respectively). Data was obtained by having the patient reading out a newspaper article.

Ferreres (1990) found that omissions in Spanish people with Broca's aphasia mostly affect the liquids /l/ and /r/, the fricative /s/ and the nasal /n/. The phonemes most affected in substitution were affricates (37%), followed by fricatives (21%), liquids (17%), occlusives (14%) and nasals (11%). Ferreres also found that the most commonly altered feature pairs were +/- continuous, then +/- strident and +/- acute. Least affected were +/- oral, +/- vowel and +/- consonant.

At last, several researchers reported the exceptional case of /s/ in a consonant cluster (Visch-Brink & Bastiaanse, 1998; Buchwald et al., 2007; and Romani & Calabrese, 1998). A cluster of /s/ + consonant(s) behaves different than other consonant clusters; /s/ is usually not omitted where other consonants would be.

Summary:

- Three studies found that most errors are made on liquids and glides and/or nasals, with two studies reporting this for Broca's aphasia and one for both groups of aphasia.
- One study reports that a person with Broca's aphasia tends to spare the most sonorous vowel /a/ but makes most errors on the least sonorous vowel /u/. Another study reports that a person with Wernicke's aphasia makes most substitution errors on /a/, followed by /u/.
- Three studies report the special status of /s/ in a consonant cluster: it is usually not omitted where other consonants would be.

Discussion/conclusion

Limitations

Before going on to the conclusions, some limitations of this research are discussed. As mentioned in the introduction, discrepancies about the classification of people with aphasia are noteworthy. No person with aphasia meets up to the exact criteria of a certain subtype. By choosing to divide people with aphasia into fluent and non-fluent aphasia in this paper, I have tried to solve this problem. Another important aspect of this paper is the little amount of literature that has been written about phonological errors in aphasic speech. Because there is so little literature and moreover, because most of the studies looked at different components of phonology in aphasic speech, it is hard to find studies that support each other's results. More research in the field of phonology of aphasic speech needs to be carried out before one is able to draw stronger conclusions.

In addition, in every study looked at in this paper it is noted which language the subjects spoke. Several studies were performed on English people with aphasia (Braber et al., 2005; Buchwald et al., 2007 and Goldmann et al., 2001) or on Italian people with aphasia (Romani et al., 2002; Romani & Calabrese, 1998; Romani & Calabrese, 1996; Semenza et al., 2007 and Caramazza & Chialant, 2000). One study was performed on Dutch people with aphasia (Visch-Brink & Bastiaanse, 1998), one study on Spanish people with aphasia (Ferreres, 1990) and one study on German people with aphasia (Dressler & Stark, 1988). Making comparisons and drawing general conclusions between these people with aphasia should be done with care because results of different languages cannot simply be taken together. Moreover, the goal of this paper is not to find cross-linguistic results and it should be kept in mind that the different languages might trouble the ability to find general comparisons across people with aphasia.

Besides a notation of the language spoken by the subjects, it is also noted how every study obtained data. This might be done by single word production, sentence repetition, spontaneous speech or reading out newspaper articles. It is very important what kind of data is used when analysing these studies because these different tasks allow different requirements in the language system. Single word repetition, for example, does not require lexical access and has the target phonological representation already provided to the patient, while spontaneous speech demands lexical selection and does not have the target phonological representation ready. It raises the possibility that differences between the fluent and non-fluent group of people with aphasia is not caused by different types of impairments, but by the data used throughout the studies analysed. Thus, making comparisons and drawing general conclusions between the different studies should, again, be done with care.

Discussion

Returning to the introduction of this thesis, it is said that the main focus of this paper is on drawing general conclusions about phonological errors made by people with fluent and non-

fluent aphasia. On one side, the goal of this paper is discussing the difference in errors made by both groups of aphasia, and, on the other side, it lays in looking for generalizations or common features in the distinct groups of aphasia. When this is done, possibly a relationship between speed of speech and diversity of errors can be drawn. It might be that speech of people with fluent aphasia, which contains less phonological mistakes than speech of people with non-fluent aphasia, also shows a small range of error types. Or the other way around: speech of people with non-fluent aphasia contains many phonological errors, and thus might contain a wide range or specific type of phonological errors.

A first general conclusion holds that the group of fluent aphasia and the group of non-fluent aphasia do not show many patterns that are inherent to one of them. In other words, a difference in types of errors has not been evident, except for the following two results. First, when looking at errors made in word initial, medial or final position, people with Broca's aphasia seem to make most errors in word-initial position. Three times it is reported that people with Broca's aphasia have a tendency to make errors in the onset of the word, and only once the opposite is reported: a person with Broca's aphasia who makes most errors in word-final position. Concerning people with fluent aphasia, the results tell us that errors are made in a more even distribution, with no dominance for onset, nucleus or coda. Thus, people with Broca's aphasia make more mistakes in the onset of a word than people with Wernicke's aphasia do. These results are striking, as Broca's aphasia is characterized by difficulty in the onset of entire sentences too. People with non-fluent aphasia often find it hard to initiate sentences and words. This is in contrast with fluent aphasia, which is characterized by easy and smooth speech. The phonological results found in this study seem to reflect this.

Secondly, two studies have reported that people with non-fluent aphasia eliminate hiatuses by deleting vowels or by inserting consonants. This probably has to do with the Sonority Dispersion Principle. The easiest syllable is made up by a consonant and a vowel (CV). A contrast in sonority between or within a syllable increases the ease of articulation. According to Romani et al. (2002), the most difficult contact between syllables is therefore a hiatus (VV); the contrast in sonority between two following vowels is null, and thus hard to articulate. This explains why these studies found that people with non-fluent aphasia eliminate hiatuses so often. The question remains why it is typical for people with non-fluent aphasia to eliminate hiatuses, and not for people with fluent aphasia. It might be explained by articulatory problems ascribed to people with non-fluent aphasia and not to people with fluent aphasia. As noted in the introduction, it is often suggested that people with non-fluent aphasia suffer from phonetic disintegration, while people with fluent aphasia suffer from phonemic disintegration. Whether this is actually the case, is still questionable.

Besides differences in phonological behaviour between people with fluent and non-fluent aphasia, there were interesting common features to both groups. First of all, apparent in the paragraph 'distribution' was the error type substitution. Every research that looked at the distribution of phonological errors found that most errors are made in substitutions, for both fluent and non-fluent people with aphasia. Interestingly, it is well known that in the domain of

morphology it is the error type omission that occurs predominantly. Morphological inflections such as subject-verb agreement and tense markings are often omitted (e.g. Benedet, Christiansen & Goodglass, 1998). Syntactically, speech of people with Broca's aphasia knows many omissions as well. Free function words such as determiners, conjunctions and auxiliaries such as 'if' and 'that' are often omitted (e.g. Penke, 2011). Thus, an interesting fact of phonological aspects of aphasic speech is that substitution is the most common error.

Furthermore, the types of errors follow the same order of impairment in almost every study done with people with non-fluent aphasia: substitution > omission > insertion > contextual errors. This also seems to count for people with fluent aphasia; in nearly all of the studies substitution is the dominant type of error, followed by omission, insertion and lastly contextual errors. Different in the group of people with fluent aphasia is that the percentages of omission, insertion and contextual errors lie in a closer range, and thus have a bigger chance of changing the rank order. But it might be said that the types of errors made follow the same order of impairment in each aphasic group. Consequently, it could be put forward that phonological errors in aphasic speech reflect a systematic break-down of phonology independent of a particular lesion site, as is already suggested by Blumstein (1973). In other words, it seems that phonological characteristics of aphasic speech show an ordered disorganisation that cannot be explained by a particular damaged part in the brain.

Liquids and glides play a central role in phonological speech errors of both fluent and non-fluent aphasia. Two studies report that insertions involve mainly liquids and glides and two other studies note that omissions also concentrate on liquids and glides. Several studies report that errors in general occur predominantly on /r/ and /l/ (liquids) and on /j/ and /w/ (glides). Some other studies also report that the nasals /n/ and /m/ are often subject to errors. There are no differences reported between the group of fluent and non-fluent aphasia. Thus, the phonemes /r/, /l/, /j/ and /w/ are the sound units on which most errors are made. This makes a link with child speech possible. In child language, the acquisition of consonants shows a clear line: first plosives are acquired, then fricatives, followed by nasals and at last liquids (Gillis & Schaerlaekens, 2000). Liquids and glides are the most difficult consonants and are thus last acquired. Furthermore, a typical phonological process of speech of children is 'gliding': substitution of a liquid by a glide. 'Vocalising' is also a process characterizing children's speech: replacing an /l/ or /r/ in word-final position by a vocal (Gillis & Schaerlaekens, 2000). It is striking to see that phonemes that children have difficulty with in acquiring speech are the same phonemes that people with aphasia make most errors in. Besides, these aspects of child speech are just a small set of the many resemblances that child speech shows with aphasic speech.

Another interesting observation made by several studies is the exceptional case of /s/ in a consonant cluster. /s/ + consonant(s) behaves different than other consonant clusters: in this position it is rarely omitted in speech of people with aphasia. The special status of word-initial /s/-consonant clusters is not only inherent to aphasic speech, but has been subject of many linguistic researches. /s/-initial sequences violate the Sonority Sequencing Principle, a

principle that outlines the structure of a syllable in terms of sonority, also, /s/ is the only consonant that may start a three element consonant cluster in for example English and Dutch. Recent studies have defined the initial /s/ as an element outside the initial syllable, termed 'extrasyllabic' (Trommelen & Zonneveld, 1994). However, the status of /s/-initial clusters is still controversial. Interestingly, the fact that /s/-initial clusters behave differently in speech of people with aphasia too, proves the special status of it.

Three studies also touch upon sonority in speech of people with aphasia. In a study of Romani et al. (2002) it is reported that a person with Broca's aphasia tends to spare the most sonorous vowel /a/ and makes most errors on the least sonorous vowel /u/. These results support the Sonority Dispersion Principle, which holds that the optimal syllable onset contains a maximal rise in sonority from the margin to the peak (Stenneken et al., 2005). The most sonorous phonemes are vowels, followed by glides, liquids, then nasals and at last obstruents. The preferred syllable onset would thus consist of an obstruent followed by a vowel. Sparing the most sonorous vowel /a/ causes a maximal rise to the top, while errors on the least sonorous vowel /u/ can be explained by a rise from margin to peak that is less sharp and thus not preferable. Noticeable, most phoneme errors in aphasic speech are made on liquids and glides (see above). Also, people with Broca's aphasia make the majority of errors in word-initial position (see above). The fact that it is commonly liquids and glides that are subject of errors in speech of people with aphasia, might thus be a result of not having a maximal rise between margin and peak when the onset of a word starts with a liquid or glide. More research should be done to verify this finding.

Several studies report that errors are predominantly made on consonants and not on vowels. This result is not unexpected: syllables always consist of a nucleus, which is nearly always a vowel. An onset or coda (which usually consists of consonants) is optional. In other words, the centre of a syllable or word is the vowel. It can be expected that errors are made mostly on the onset or coda, which are the elements in a syllable or word that are most changing and varying.

Lastly, Blumstein (1973) looked at the distribution of environment (or contextual) errors. She found that people with Broca's aphasia make mostly intra-morphemic errors, while people with Wernicke's aphasia make mostly inter-morphemic errors. In other words, people with Broca's aphasia make errors predominantly *within* words and people with Wernicke's aphasia make errors predominantly *between* words. Even though it is only Blumstein who has reported these results, they seem very plausible. Broca's speech is characterized by broken, non-fluent speech containing many empty words like 'eh' or 'hmm'. It seems logic that errors occur within individual words, because words are hardly connected. Wernicke's speech, on the other hand, is fluent with normal to high speed of speech. This can result in speech errors occurring between words.

Conclusion

Phonological errors of people with fluent aphasia and people with non-fluent aphasia differ in two aspects. People with non-fluent aphasia make most errors in word-initial position, while people with fluent aphasia have a more even distribution of errors in word initial, medial and final position. This reflects the difficulty people with non-fluent aphasia have in initiating words and sentences in general, while people with fluent aphasia do not have this problem. Secondly, in speech of people with non-fluent aphasia vowels are deleted or consonants are inserted in order to eliminate hiatuses. People with fluent aphasia do not seem to do this. The Sonority Dispersion Principle gives an explanation for the reason of eliminating hiatuses and articulatory problems ascribed to people with non-fluent aphasia might explain why it is only this group of aphasia who shows this pattern. Other differences in phonological errors between the two groups are difficult to draw because much of the literature does not support each other, either because it addresses different aspects of phonological errors or because the results are not congruent.

Common features to both groups are more substantial. Most prominent is the fact that both groups of aphasia make the majority of errors on substitutions. In other fields of linguistics, like morphology and syntax, it is omission errors that occur most often in aphasic speech. Also, both groups of aphasia show the same rank order in distribution of error types. This could mean that a particular lesion site is independent of a systematic break-down of phonological errors. Thirdly, liquids and glides are the phonemes that most errors are made on by people with fluent and non-fluent aphasia. This also shows up in child speech. Then, the special status of /s/-initial clusters is evident in aphasic speech. The little research done in sonority-effects of aphasic speech supports the Sonority Dispersion Principle. Perhaps this principle even explains why liquids and glides are the phonemes that most errors are made on. Both groups of aphasia also make most errors on consonants and not on vowels. Lastly, Blumstein's report (1973) of the distribution of assimilation errors seems quite plausible. People with non-fluent aphasia make predominantly assimilation errors within words and people with fluent aphasia make the majority of their assimilation errors between words.

To summarize: people with fluent and non-fluent aphasia make phonological errors different in quantity, but not so much in quality. Overall, type and place of errors seem to be similar in people with fluent and non-fluent aphasia.
Although this study has its limitations, it could serve as a good basis for further phonological research in aphasic speech. More research in the field of phonology of aphasic speech needs to be carried out before one is able to draw stronger conclusions.

Further research

This thesis gives a global overview of phonological errors made in speech of people with aphasia. To my knowledge, there are no previous studies that have compared and put together results of phonological studies in aphasic speech. To extend the overview and comparisons of phonological studies, and thus to strengthen the conclusions that are drawn in this paper, more researches can be added to this general overview. There are several studies that I could either not reach or were not written in English that could be of importance to this paper. When more research is put together, more valid conclusions can be drawn. Below some general thoughts for further research are given, for which this paper could be used as a basis.

As mentioned in the discussion, speech of people with aphasia shows many resemblances with speech of children. For over several decades it has been put forward that aphasic regression can be seen as a mirror of the child's acquisition of speech sounds. In other words, it shows the child development in reverse (e.g. Jakobson, 1971; Lesser, 1995). Little research has been done in comparing aphasic speech and child speech concerning phonology. It would be very interesting to do more research in these two fields and see if there is an evident 'phonological mirror' as well. One comparison I found in this study already: people with aphasia make most errors on liquids and glides, which are the phonemes that children acquire last of their speech sounds.

Another suggestion for further research lies in the variables frequency and sonority. I argued that the high error rate on /l/ and /r/ might be explained by the Sonority Dispersion Principle. This principle holds that liquids and glides are the most sonorous phonemes after vowels, which causes an only minimal rise in sonority when a syllable starts with a liquid or glide and is followed by a vowel. This would explain the majority of errors occurring on /l/ and /r/. Further research in this field, for example a study that looks at phonological behaviour on syllables/words with different sonority values, could give more insight whether sonority effects really play a role.
Frequency effects in naming are well-known in normal subjects and in aphasic subjects (e.g. Lesser, 1995; Nozari et al. 2010). In this study I therefore expected to find some results of frequency effects on phonological errors as well. Nevertheless, only two studies report shortly on the presence/absence of frequency effects in speech of people with aphasia. This probably is due to the little research that has been done in frequency effects on phonological errors of people with aphasia. A detailed experimental study or a large literature research in this area can reveal more on frequency effects and show whether this is of importance as well.

Another aspect that could be subject of further research is substitutions in speech of people with aphasia. As previously noted, in morphology and syntax it is not substitutions, but omissions that most phonological errors occur in. Omissions simplify the structure of a syllable, word or sentence, but substitutions do not necessarily have this function. A study that looks at substitutions in specific could give us more details about how, and maybe even why,

it is substitutions that is the major error type in aphasic speech. One could look at which phonemes are substituted by which and in what position of the word this takes place. Maybe some kind of simplification is evident in these substitutions, for example in sonority or frequency values.

Finally, this bachelor thesis looks at what goes wrong in actual speech of people with aphasia. In addition, it would be of great interest to find out what causes these speech errors or difficulties. Here speech production models come into view. Currently there is no single all-inclusive model of speech production, but the PALPA-model seems to be the most covering one. It would be interesting to see if and how errors made by the group of people with fluent aphasia and by the group of people with non-fluent aphasia can be explained in this model.

I hope this bachelor thesis will be of value to other research in phonological patterns of aphasic speech that might be carried out in the future. In enjoyed writing this paper and I most certainly learned a lot from it.

Acknowledgments

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