Exploring factors governing intervocalic glottalisation in Stockholm Swedish

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Abstract

The usage of glottal stops for different purposes has been documented in English through previous research (Lee 2018; Eddington & Taylor 2009; Lindsey 2019). However, only intuitive-based research and impressionistic observations are available as documentation for this consonant in Swedish. This study explored the factors governing the distribution of glottalisation in two-vowel sequences in Swedish. Material from 10 participants uttering stimuli designed by the author to elicit glottalisation in different word boundaries, vowel sequences, and speech types was gathered. A spectrogram analysis was done in Praat to categorise the level of glottalisation, ranging from no glottalisation, F0 dip, creaky voice, to glottal stop, using predetermined criteria. The results were that word-initial prevocalic glottalisation was very common, while glottal epenthesis as a form of hiatus resolution in heteromorphemic and tautomorphemic structures were much less common. Glottal epenthesis was slightly more likely to occur during emphatic speech for tautomorphemic and heteromorphemic structures. Emphatic speech had a larger impact on the word boundary structure sequences, increasing the amount of words uttered with a glottal stop. Optional glide epenthesis did not give conclusive results as to whether it had an effect on glottal epenthesis.

Keywords

Glottalisation, hiatus, glide, epenthesis, prosodic word, emphatic speech

Sammanfattning

Användningen av glottala klusiler för olika ändamål i engelska har dokumenterats i tidigare forskning (Lee 2018; Eddington & Taylor 2009; Lindsey 2019). Å andra sidan finns enbart forskning baserad på intuitiva och impressionistiska observationer tillgängliga som dokumentation för konsonanten i svenska. Denna studie utforskade faktorer som styr distributionen av glottalisering vid hiatus i svenska. Material av 10 deltagare som yttrade stimuli som konstruerades utifrån ändamålet att kunna framkalla glottalisering inom olika ord gränser, vokal sekvenser, och taltyper spelades in. En spektrografisk analys gjordes i Praat för att kunna kategorisera glottaliseringsnivån, med nivåerna ingen glottalisering, F0 dip, knarr, och glottal klusil, utifrån förbestämda kriterier. Resultaten var att ordinitial glottalisering var mycket vanligt, medans glottal epentes som en typ av hiatus upplösning tautomorfemiskt och inom affixerade ord var mycket mindre vanliga. Glottal epentes var något mer vanligt vid emfatiskt tal för enskilda ord än vid ledigt tal. Emfatiskt tal hade en större inverkan på glottalisering vid ordgränser. Valfri glide-epentes gav inga konkreta resultat angående dess inverkan på glottal epentes.

Nyckelord

Glottalisering, hiatus, glide, epentes, prosodiskt ord, emfatiskt tal

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1 Introduction

"It's levi'osa, not levio'sa!"

This utterance by Hermione in Harry Potter was portrayed in the film as an example of Hermione's characteristic perfectionism, as she speaks emphatically to exemplify the correct pronunciation of a spell which requires emphasis on the third, rather than the fourth, syllable. During the emphatic part of Hermione's speech, dictating the correct pronunciation of the spell, she uses a glottal stop to show which syllable to stress to achieve it.

The use of glottal stops for different purposes has been documented in English, (Lee 2018; Eddington & Taylor 2009; Lindsey 2019) and other languages (Bartůňková 2012) through previous research. However, only intuitive-based research and impressionistic observations are available as documentation for this consonant in Swedish. These intuitions have been gathered by two phonologists who have different views regarding the distribution of the consonant. The lack of clarity regarding its use as well as a lack of empirical research provided the incentive to explore the distribution of the glottal stop in Stockholm Swedish.

This paper explores the effect of morphological structure, vowel sequences, and speech type on intervocalic glottalisation in Stockholm Swedish through 10 recordings of stimuli designed to elicit glottalisation within various phonological settings.

2 Background

2.1 The Glottis

The passage between the vocal folds known as the glottis can be modified during speech production. During the formation of a glottal stop (IPA symbol [ʔ]), the vocal folds are pressed hard enough against each other that the air stream gets completely closed off (Garlén 1988, p. 26). The canonical glottal stop is often described by untrained listeners as 'a gap' in the case of intervocalic glottal stops (Bartůňková 2012, p. 10).

The glottis can otherwise also be completely open during, for instance, the production of voiceless sounds (Garlén, 1988, p.26). The glottis can also be used in production of creaky voice. It is formed when the rear part of the vocal folds are held together, letting only the the anterior part of the vocal folds to vibrate. This leads to a very low frequency of vibration for the vocal folds sometimes used by Swedish speakers, for instance utterance-finally (Garlén 1988, p. 26). During this type of phonation, the artyneroid cartilages are drawn together, allowing only the ligamental part to vibrate, causing various irregularities in the signal (Bartůňková 2012, p. 11)

2.2 Functions of the Glottal Stop

The glottal stop is used phonemically across many languages (Garlén 1988, p. 26). In Swedish, the glottal stop is not a phoneme, and does not distinguish minimal pairs. However, it could function as a marker that clarifies morphological structure by signaling word boundaries, and phonological structure, by signaling vowel hiatus. Vowel hiatus arises when two vowels are locally adjacent but heterosyllabified within words or across word boundaries (Lee 2018). The English language uses glottal stop epenthesis to resolve hiatus (Lee 2018). Word-initial contexts may be a particularly likely location for glottalisation to occur. For example, in German, previous research found that word-initial laryngealizations are frequent (58% of tokens studied), and one study reported a high probability of glottal onsets for vowel-initial morphemes internal to polymorphemic words as well (Dilley, Shattuck-Hufnagel, & Ostendorf 1996, pp. 424).

The function and distribution of the glottal stop in Swedish is somewhat disputed in modern research, but it is agreed that there are several situations in which glottalisation can be used. The Swedish glottal stop may, like in many other languages, occur before vowels at the beginning of words (Eliasson 2014, p. 66). However, this is not as strict of a rule as in other languages, such as North Standard German, where the glottal stop appears to be stronger (Eliasson 2014, p. 66). The following sections will discuss other possible situations that may allow for the use of a glottal stop in Swedish.

2.2.1 The Glottal Stop as a structure marker

The prosodic insertions of the glottal stop are epenthetic processes related to prosodic boundaries, among which Bartůňková (2012, p. 16) counts the glottal stop as the most frequent type. According to previous research, the glottal stop provides the otherwise missing onset needed for the ideal CV syllable (Bartůňková 2012, p. 17). This is in accordance to what Eliasson writes about the Swedish glottal stop: "the glottal stop in Swedish is perhaps also related to otherwise empty syllable onsets" (Eliasson 2014, p. 67). Furthermore, the fact that both vowels and glottal stops lack supraglottal constriction works in favour of their appearing together (Bartůňková 2012, p. 17). Findings from previous studies during the seventies, before explicit grammars of prosody flourished, are compatible with the view that prosodic factors influence the occurrence of glottalisation in word-initial vowels (Dilley et. al 1996, pp. 424-425). A glottal stop may be inserted between two vowels in Swedish as well. Examples based on intuition

are presented by Eliasson, showing that vowel hiatus resolution through glottal stop epenthesis is less likely to occur within a minimal prosodic word. Prosodic words, as discussed in Hildebrandt (2015) reference morphological information in a generalized manner, and can vary across languages. Its relevance has less to do with morphology and more to do with requirements on the minimal permissible size/weight of phonologically free units. Nevertheless, according to Eliasson, a glottal stop is less likely to occur tautomorphemically, although still having the ability to do so. This has been observed impressionistically by the author in spoken Swedish media. A simplified version of a table set up by Eliasson to represent this distribution is shown in Table 1.

Table 1: Simplified version of Eliasson's predictions regarding glottal stop insertion (Eliasson 2014, p. 67)

Transcription	Swedish Word	English Translation
[$^{(ʔ)}$a$^{x((ʔ))}$ɔt:a]	'aorta'	'aorta'
[$^{(ʔ)}$e$^{ˈ((ʔ))}$o:n]	'eon'	'eon'
[$^{(ʔ)}$u$^{ˈ((ʔ))}$ɑ:sər]	'oaser'	'oases'

The examples in Table 1 show optional insertion of a prevocalic glottal stop (within parentheses), as well as a less likely tautomorphemic hiatus epenthesis of a glottal stop (within double parentheses). In sum, Eliasson argues that the glottal stop in Swedish may primarily, though not exclusively, be a word boundary marker (Eliasson 2014, p. 67).

Riad is more restrictive than Eliasson when it comes to the distribution phenomenon. He states that epenthetic glottal stop insertion is possible, and more likely during emphatic or careful speech. However, he states that "the correct characterisation of glottal stop insertion is 'initial in the minimal prosodic word'" (Riad 2013, p. 275). Riad argues that glottal stop epenthesis, "where the onsetless syllable is stressed or unstressed but not initial in the prosodic word, insertion is not admitted" (Riad 2013, p. 276). Riad presents a similar table to Eliasson's, where glottal stop epenthesis within a minimal prosodic word, such as in *realism* and *ruin*, is not found in the Swedish language (Riad 2013, p. 276). A simplified version of this table is shown in Table 2.

Table 2: Simplified version of Riad's predictions regarding glottal stop insertion (Riad 2013, p. 275)

Transcription	Swedish Word	English Translation
(ˈʔäntligen)$_{ω}$	'äntligen'	'at last'
(be-(ˈʔ)akta)$_{ω})_{ω}^{max}$	'beakta'	'to consider'
*(ruˈʔin)$_{ω}$	'ruin'	'bankruptcy'

Furthermore, he states that glottal stop distribution may be governed more strictly by the appearance of the individual word structure rather than the binary distinction of stressed and unstressed syllables (Riad 2013, p. 275), which means that Riad believes the use of the glottal stop in Swedish has more to do with word structure than word prosody.

2.2.2 The role of the Glottal Stop in providing clarity

In Swedish, epenthetic glottal stops in onsets are more likely to occur during careful or emphatic speech, but their use also varies idiolectally (Riad, 2013, p. 275). Exploring the glottal stop in Czech, Bartůňková (2012, p. 19) observes that in actual usage, the frequency of glottal stops in various environments is rather individual, and it is preferred in formal situations and appears more frequently in slower speech rates and emphatic speech style. Eliasson (2014, p. 66) states that in Swedish, during highly, perhaps overly, emphatic pronunciation glottal stops might creep in. Several sources agree that, although the

use of the glottal stop varies idiolectically, the glottal stop can be used in situations where clarity and/or emphasis is a priority. This gives the glottal stop another possible function.

Glottal stops are claimed to be crosslinguistically the most frequent epenthetic consonants word initially and are used to fill empty onset positions in many of the world's languages (Shoemaker 2014, p. 714). Results from a study investigating the acquisition of allophonic variation as a word boundary cue in second language phonological acquisition demonstrated that participants showed greater sensitivity to the presence of glottal stops than aspiration, suggesting that glottal stops may represent a more perceptually salient segmentation cue for learners than aspiration (Shoemaker 2014, p. 715). These results suggest that glottal stops play an important role in promoting speech clarity.

2.3 Hiatus and Epenthesis

Vowel hiatus is dispreferred in many languages of the world (Kadenge & Vratsanos 2017, p. 175). As mentioned in section 2.1, English uses glottal stop epenthesis to resolve this clash. Another strategy in English is the use of glide epenthesis (Lee 2018). In Swedish, certain vowels create off-glides which occur, although not exclusively, as a form of hiatus resolution.

The long allophone [iː] often has an off-glide in Stockholm speech, transcribed as [iːʲ], and is particularly audible in hiatus (Riad 2013, p. 21). The same goes for the long allophone [ʉː], which often ends in a glide in hiatus, and can be transcribed as follows: [ʉːʷ] (Riad 2013, 28).

Thus, with the information gathered so far, it can be deduced that Swedish, like other languages, uses both glottal stop epenthesis and glide epenthesis as forms of hiatus resolution. However, the question regarding the distribution of these two forms as well as what linguistic factors govern them has yet to be explored thoroughly.

2.4 Aim and Research Questions

The aim of the current study is to explore untested theories regarding the circumstances that govern the distribution and frequency of glottal stops that occur between two vowels in spoken Swedish.
The following research questions have been formulated:

1. How often do speakers glottalise, and how does the frequency of occurrence of this phenomenon vary amongst individual speakers?
2. Is intervocalic glottalisation affected differently by the hiatus occurring tautomorphemically, affixated, or between separate words[1]?
3. Are speakers less likely to produce glottalised hiatus epenthesis given the hiatus provides optional glide epenthesis?
4. Is hiatus glottalisation more likely to occur during emphatic speech?

2.5 Hypotheses

Predictions made regarding the results of the current study include:

[1]The umbrella term "structure" is used to group these three terms together throughout the paper.

1. Epenthetic glottalisation in hiatus will occur most frequently between two separate words, less frequently while in the same word but in an affixated structure, and least frequently tautomorphemically.
2. The long allophones [iː] and [ʉ̟ː] will hinder glottalisation due to the production of off-glides.
3. Glottalisation will occur more frequently during emphatic speech.

3 Methodology

3.1 Material

The experiment consisted of recordings made in a laboratory setting as opposed to recordings of conversational speech in order to be able to control the desired variables. The material used in the current study consists of 10 recordings, each consisting of two different phases, an “emphatic" phase and a “casual" phase. The recordings were made in the anechoic chamber at the Stockholm University Phonetics Lab. The chamber contains a recording studio designed to completely absorb sound reflections, producing recordings with minimal extraneous disturbances. The studio is equipped with Brüel & Kjaer 1/2” Free-field Microphones (Type 4189) with preamplifiers (Type 2669). The microphones are connected to a Brüel & Kjaer NEXUS Conditioning Amplifier (Type 2692), which in turn is connected to a Motu 8M audio interface. Recordings in the studio are made using REAPER digital audio workstation software. The recording sessions were monitored from the control room outside the anechoic chamber, using a TV monitor showing the subject in the chamber, and via speakers. The set up also allows for two-way communication between the subject and the experiment leader through an audio intercom system (Stockholm University 2017).

3.1.1 Stimuli

The stimuli for the experiment were selected with the main aim of having a reasonable balance of focus between controlling possible factors that are irrelevant for the current research questions, and having enough material to answer each research question as adequately as possible.

To be able to explore the research questions, the online lexical database Om Svar Anhålles, or OSA, (OSA 2015) was used to gather legitimate and relatively simple words for participants to read out loud. OSA allows for advanced searching, such as searching for the desired vowel hiatus in order to gather words within different segmental contexts.

To control the possible effect of word prosody on hiatus resolution, words in which the second vowel within the hiatus is stressed were selected. A list of possible words with stress on the second vowel within the hiatus was then constructed. To be able to examine the possible effect of morphological structure, the list was then divided into words which contain the hiatus tautomorphemically, and words which contain the hiatus affixated. This distinction also allowed for the exploration of vowel hiatuses occuring in monomorphemic minimal prosodic words as well as across the morphemic boundaries of polymorphemic minimal prosodic words, to see if these have a unique effect on glottal epenthesis (something not explored in depth by Riad or Eliasson). This paper refers to Riad (2013, p. 120) when determining minimal prosodic words. Determining whether words were monomorphemic or polymorphemic was subjectively decided by the author and supervisor, with initial considerations taken from what OSA considers as nonaffixated words. Some allocations may seem somewhat arbitrary, for example treating trottoar as a derivation (on the basis of reservoir, pissoar and memoar) and thus polymorphemic. However, as the results section below shows, the division into affixated and tautomorphemic in this experiment turned out to be of little relevance since glottalisations in these two categories were so rare that no statements regarding their frequency of occurrence can be made. To examine the effect of vowel sequences on glottalisation when separated by word boundaries, a third structure was employed. The selection of words for this category was based primarily on how unobtrusive the words seem to a reader, as to not have odd words stick out during the experiment and have participants be thrown off. These words also contained the same vowel sequences used for the affixated and tautomorphemic categories.

During the "emphatic" phase of the experiment, participants were asked to read a sentence ending with an exclamation mark, designed to elicit emphatic/careful speech, in which the potential vowel hiatus appears within the last word(s) of the sentence. This was done in order to control for the possible following extraneous variables: utterance-final creaky voice, effect of different sentence types (imperative, interrogative, etc.), and effect of sentence prosody. This was also taken into consideration when selecting which words to use in the experiment, as the participants have to be able to utter them sentence-finally and with emphasis. During the casual phase, participants simply read the words without a given phrasal context, in order to ensure that as little emphasis as possible was elicited during articulation.

Filtering out the multitude of words leaves us with seven unique vowel sequences within these three different structures. The words used in the study are shown in Table 3.

Table 3: Vowel sequences used as stimuli, shown as [V_1]_[V_2], in different structures. The IPA symbol next to the given word shows which allophone is present in the given word. V1 and V2 allophone variation separated by /.

Vowel Hiatus	**Words Used in each Structure**		
	Tautomorphemic	Affixated	Word boundary
[iː]/[ɪ]_[eː]	*diet* [ɪ]	*kopiera* [ɪ]	*i elen* [iː]
[iː]/[ɪ]_[a]	*koriander* [ɪ]	*allians* [ɪ]	*i akt* [iː]
[ɛ̟]_[ɑː]	*teater*	*ideal*	*inte artig*
[ɛ̟]_[oː]	*meteor*	*beordra*	*inte ål*
[ʉ̟ː]/[ʉ̟]_[ɛ̟]	*silhuett* [ʉ̟]	*manuell* [ʉ̟]	*sju änglar* [ʉ̟ː]
[ʉ̟ː]/[ʉ̟]_[ɑː]/[a]	*Februari* [ʉ̟]_[ɑː]	*ritual* [ʉ̟]_[ɑː]	*du alltid* [ʉ̟ː]_[a]
[oː]/[uː]_[ɑː]/[a]	*oas* [uː]_[ɑː]	*trottoar* [uː]_[ɑː]	*på allt* [oː]_[a]

For some vowel sequences, both the short and long allophones of the same vowel occurred in different structures. For sequences with [oː]/[uː]_[ɑː]/[a], V_1 was not either the short or long allophone of the same phoneme. Instead, a different vowel was used due to the lack of appropriate words containing the V_1 [uː] that could be used for the "word boundary" structure. However, [oː] is still phonetically quite similar to [uː] as it is a close-mid back vowel.

An attempt to keep the affixated structures limited to suffixes was made. However, the sequence [ɛ̟]_[oː] provided no appropriate words with stress on the second vowel in the hiatus within a suffix. For this reason, a prefix was chosen instead. This prefix may behave differently than the suffixes, as it itself is a minimal prosodic word according to Riad (2013, p. 120). In Riad's analysis (2013, p. 120), all the words used as stimuli in this study that were categorised within the tautomorphemic and affixated structures, with the exception of *beordra*, are minimal prosodic words.

The words were put into a sentence in which the word is uttered sentence-finally for the emphatic phase. The primary consideration during the construction of the sentences was for them to sound as realistic and homogenous as possible, as to not have a certain sentence stand out lexically, semantically, or prosodically. These sentences were then randomised using an online randomiser (List Randomizer 2019). Finally, they were pasted into a word document and separated by one line per sentence. For the emphatic stimuli, there were three example sentences above the rest of the stimuli. They will be described in the following sections. On the back of the same page, the same words, this time without the corresponding sentences, were also randomised and pasted with one line separating each word. See appendix B for a full view of the stimuli used in the current study.

3.2 Process of Recordings

3.2.1 Participants

The participants for this study consisted of 4 men, 5 women, and one person who identifies as non-binary. The age range of the participants was 20-39. Requirements for participants was for them to be native speakers of Swedish and to have lived in Stockholm for a majority of their lives.

3.2.2 Procedure

All instructions were given in Swedish. The participants were placed in the anechoic chamber, and the printed document with the casual phase of the experiment was placed in front of the participants as soon as they sat down. The experiment leader made sure that all of the words on the paper were words that were familiar to the participants as to avoid difficulty of pronunciation. The experiment leader did this without articulating any of the words himself as to not prime the participants into a certain pronunciation. Half of the participants did the "emphatic" phase first, and half did the "casual" phase first. All participants did both phases. During the "casual" phase, participants were instructed to read the casual stimuli, pausing for a few seconds in between each word. During the emphatic phase, the experiment leader instructed the participants to read three example sentences, each portraying a different type of phrase emphasis in Swedish, to assure that the participants were producing the right type of emphasis. The experiment leader then instructed the participants to read the sentences with emphasis on the last word, while pointing out that each sentence ended with an exclamation mark.

3.3 Analysis

The data was annotated using annotation software ELAN (Max Planck Institute of Psycholinguistics 2018), where each participant's recording was imported to the software and then annotated according to which word, vowel hiatus, speech type, and glottalisation level (explained below) were present. Categorisation of glottalisation level was determined using Praat's spectrogram analysis (Boersma & Weeknink 2019). Prior to analysis, the recordings were high-pass filtered att 50 Hz using the filter function in Praat. This filtered out any low frequency disturbances that might be present in the recording. Statistical figures were made in Google Sheets, tables were made using the website TablesGenerator.com, and spectrogram figures were made using Praat.

3.3.1 Levels of Glottalisation

Glottalisation can be realised in different degrees. In this paper, three levels of glottalisation were annotated using predetermined criteria selected by the author. A complete glottal stop is considered the highest level, creaky voice is regarded as the second level and a dip in fundamental frequency (F0) is the third, and lowest, level. These levels were chosen to be included in the experiment design as the strength of glottalisation may play a role in the interpretation of the data later on. The following subsections detail each of the three levels' phonetic aspects.

3.3.2 Glottal Stop

In the present analysis, the definition of a glottal stop is when the vocal folds vibrate in intervals greater than 30 milliseconds. This distinction was chosen because of the difference limen for human listeners of at least 20 ms to correctly identify unrelated items auditorily (Moore 2012, p. 174). When the number of items in the sequence increase, the durations required for identification also increase (Moore 2012, p. 174). Applying this to the current study, 30 ms was considered a reasonable criterion for what should be considered as a glottal stop.

3.3.3 Creaky Voice

The denomination “creaky voice” was used to describe slower and irregular vibration of the vocal folds by pulse intervals of less than 30 ms. F0 can not be extracted from creaky voice, as the intervals of the vocal fold pulses occur irregularly, but this does not result in a glottal stop as the pulses occur in intervals of less than 30 ms. Creaky voice glottalisation has been explored in previous studies such as Bartůňková (2012, pp. 10-11).

3.3.4 F0 Dip

During an F0 Dip the F0 can be estimated (unlike creaky voice), but a dip in frequency during the hiatus can be detected which results in the perception of glottalisation. Thus the vocal folds vibrate at regular intervals, although at a lower frequency, before increasing in frequency again. F0 dips were judged in accordance to the description of F0 dips within similar contexts of glottalisation made in previous research such as in Dilley et. al (1996, p. 429).

4 Results

The results have been divided into four sections following the research questions provided in section 2.4. The research questions were:

1. How often do speakers glottalise, and how does the frequency of occurrence of this phenomenon vary amongst individual speakers?
2. Is intervocalic glottalisation affected differently by the hiatus occurring tautomorphemically, affixated, or between separate words?
3. Are speakers less likely to produce glottalised hiatus epenthesis given the hiatus provides optional glide epenthesis?
4. Is hiatus glottalisation more likely to occur during emphatic speech?

4.1 Frequency of Glottalisation

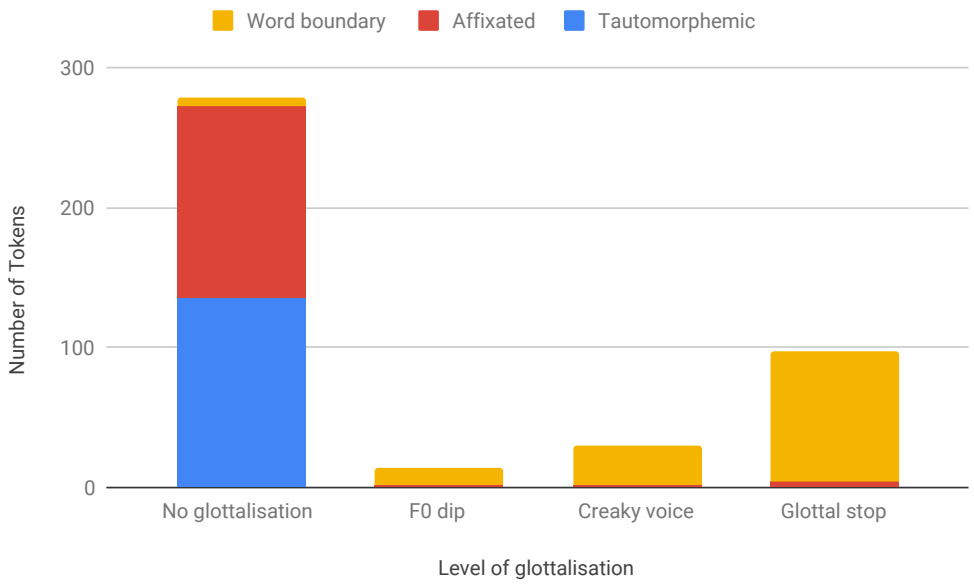


Figure 1: Number of tokens at each glottalisation level for all participants (4 male, 5 female, 1 non-binary) in different structures, (for casual and emphatic phase pooled).

Figure 1 shows the collected data for all 420 uttered sequences. A closer look at this data is presented in Table 4.

Table 4: Number of tokens at each glottalisation level for all participants at each structure, out of a total of 420 utterances (for casual and emphatic phase pooled).

Structure	**Level of glottalisation**			
	No glottalisation	F0 dip	Creaky voice	Glottal stop
Tautomorphemic	139	0	0	1
Affixated	133	2	2	3
Word boundary	7	12	28	93

Table 4 presents the data in Figure 1 in table form to show the glottalisation, or lack thereof, within each structure. 95% of the sequences in the word boundary structure were glottalised. 2.86% of the sequences in the tautomorphemic and affixated structures were glottalised. Gglottal stops were much more common than other levels of glottalisation for the word boundary structure.

4.1.1 Individual Variation

Male and female differences were not considered because the amount of participants did not allow for valid results regarding this difference.

Some individuals showed a tendency to glottalise more frequently than others. To illustrate this, the results of one such participant is shown in Figure 2.

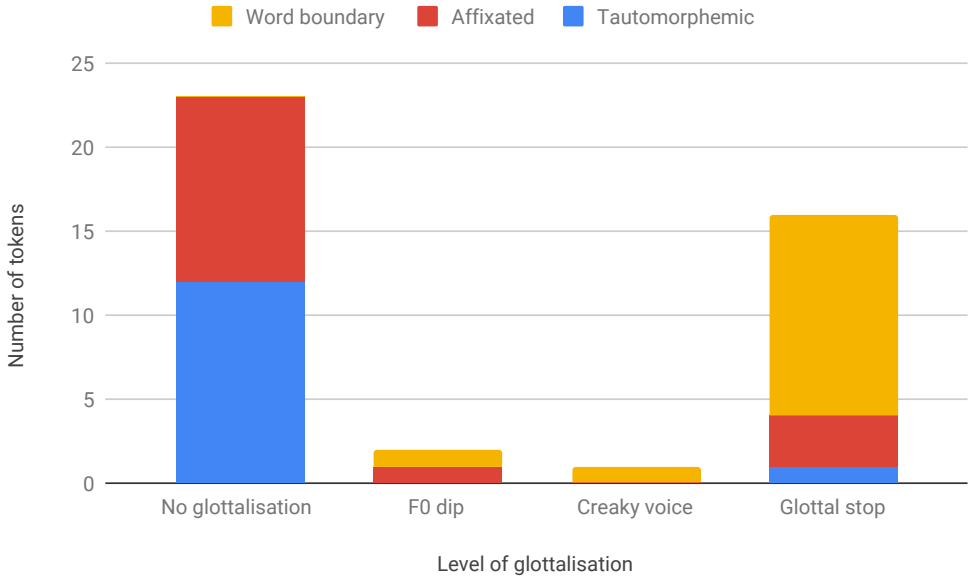


Figure 2: Number of tokens at each glottalisation level for female participant in different structures (for casual and emphatic phase pooled).

Compared to the composite result of all participants in Figure 1, this individual showed a much greater tendency towards glottalisation. Almost half of the utterances (19/42) were glottalised by this speaker. All tokens in the word boundary category were glottalised, usually using a glottal stop. Furthermore, this was the only speaker that exhibited glottalisation for the tautomorphemic structure.

Some individuals showed a tendency to rarely glottalise. The results from one such participant are shown in Figure 3.

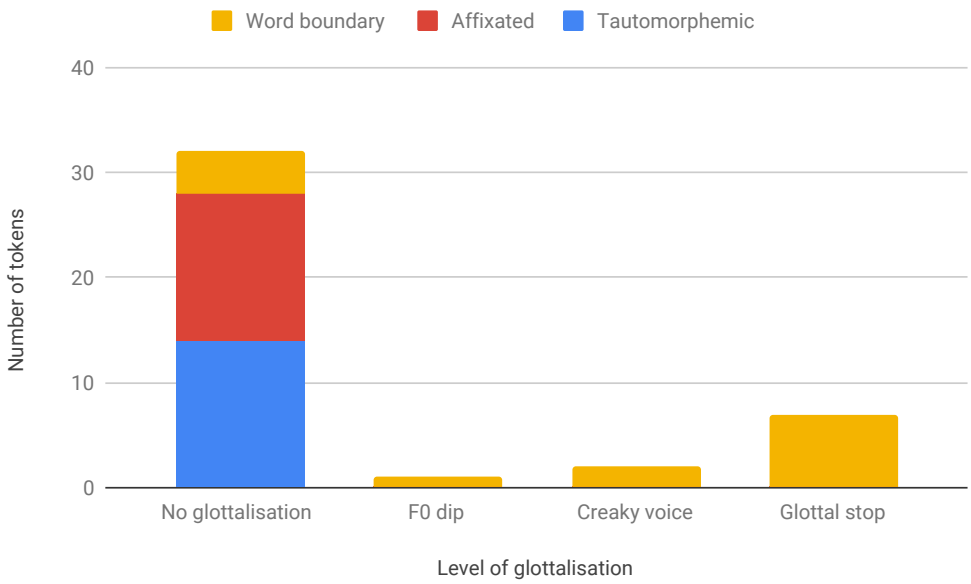


Figure 3: Number of tokens at each glottalisation level for male participant in different structures (for casual and emphatic phase pooled).

Out of 42 utterances, this speaker produced 10 instances of glottalisation. Also worth noting is that this participant only glottalised during the word boundary structure. This speaker also only exhibited one difference in glottalisation between the casual and emphatic phase; namely that one utterance which was glottalised through a F0 dip in the casual stage was glottalised through a full glottal stop during the emphatic stage.

This is in contrast to the female participant previously mentioned, who showed a bigger difference in glottalisation frequency between the casual and emphatic phase. During the casual phase this female speaker uttered six glottal stops, compared to ten in the emphatic phase. Furthermore, she uttered all seven word boundary structures with a glottal stop during the emphatic phase, compared to five during the casual phase. More affixated and tautomorphemic structures became glottalised during the emphatic phase as well.

These results indicate that glottalisation varies across idiolects, supporting the claim made by Riad (2013, p. 275), mentioned in section 2. 2. 2.

4.2 Effect of Structure on Glottalisation

Referring back to Figure 1 and Table 4, it is clear that vowel sequences separated by a word boundary were most often glottalised. They exhibited some level of glottalisation in 133/140 sequences, and full glottal stops across the word boundary structure counted for 93/140 tokens. This structure was glottalised to a far greater extent than the affixated or tautomorphemic structures. Most affixated and tautomorphemic structures were not glottalised.

Affixated hiatus glottalisations occurred slightly more often than tautomorphemic ones, but there is no substantial difference here. Neither F0 dips nor creaky voice were realised in the tautomorphemic structure, and only one word (*februari*) was realised with a glottal stop. The spectrogram showing the phonetic analysis of this sequence in Praat is shown in Figure 4.

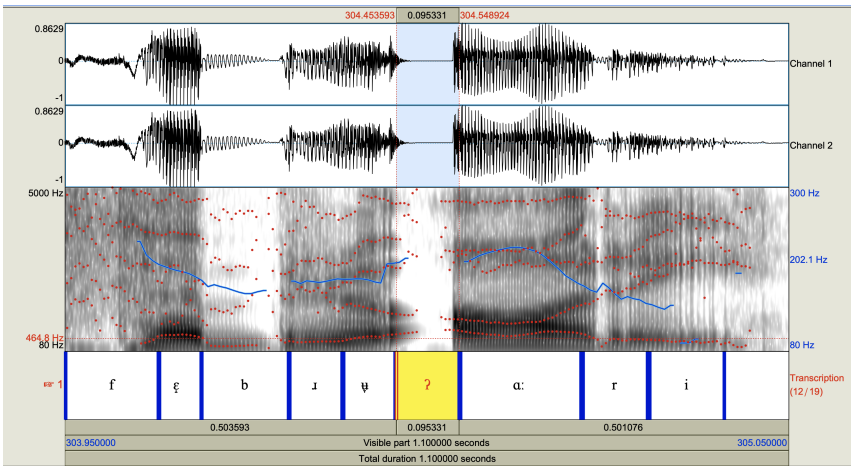


Figure 4: Glottal stop of about 95 ms produced by female participant in the sequence *februari* during the emphatic phase.

Figure 4 shows an interval of circa 95 ms between the vocal fold pulse ending the vowel [ʉ̟] and the one initiating the vowel [ɑː], resulting in a glottal stop within a monomorphemic minimal prosodic word. The blue line shows the tracing of F0, which is not present during the glottal stop.

Affixated structures were realised as F0 dips twice, as creaky voice twice, and as full glottal stops thrice. However, this is in part due to the word *beordra*, which counted for 2 out of the 2 instances in which affixated words exhibited creaky voice, 2 out of the 3 instances in which affixated words exhibited a full glottal stop, and 1 out of the 2 instances in which affixated words exhibited an F0 dip. *Ritual* counted for the other affixated word that exhibited a full glottal stop, and *kopiera* counted for the other affixated word that exhibited an F0 dip. Vowel sequences separated by word boundaries only yielded 7 instances without glottalisation.

In conclusion, the data show that vowel sequences across word boundaries are usually produced with glottalisation. They also show that glottalisation is quite rare in both affixated and tautomorphemic structures and that these two types of structure show no substantial differences in the frequency of occurrence of glottalisation. However, although rare, the data shows that glottalisation *can* occur in both affixated and tautomorphemic structures, as well as within a minimal prosodic word.

4.3 Effect of Optional Glide Epenthesis on Glottalisation

To explore the effect of optional glide epenthesis, the vowel sequences across word boundaries were explored. These contained the long allophones [iː] and [ʉ̟ː] (see Table 3 in section 3.1.1), which can end in an offglide, (as discussed in section 2.3). Vowels that do not produce off-glides were also explored.

Table 5 shows the distribution of glottalisation for each vowel sequence separated by a word boundary. The affixated and tautomorphemic structures are not considered further here, since, due to the rarity of glottalisations, it would have been hard to tell which instance of no glottalisation was due to glide epenthesis.

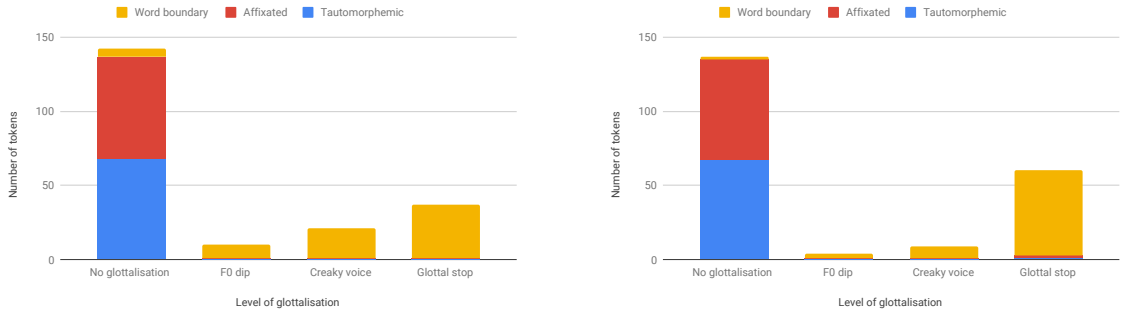
Table 5: Number of tokens at each glottalisation level for the vowel sequences in the word boundary structure, represented as [V_1]_[V_2], produced by all speakers (for casual and emphatic phase pooled).

Vowel hiatus	**Level of glottalisation**			
	No glottalisation	F0 dip	Creaky voice	Glottal stop
[iː]_[eː]	1	2	2	15
[iː]_[a]	4	2	4	10
[ɛ̰]_[ɑː]	1	1	5	13
[ɛ̰]_[oː]	0	0	5	15
[ʉ̰]_[ɛ̰]	1	5	2	12
[ʉ̰ː]_[a]	0	2	5	13
[oː]_[a]	0	0	5	15

No glottalisation only occurred one time each for vowel sequences [iː]_[eː], [ɛ̰]_[ɑː], and [ʉ̰]_[ɛ̰]. The rest of the sequences all produced some form of glottalisation for each sequence. The results show that there was no substantial difference in the frequency of occurrence of glottalisation between the vowel sequences that could produce an off-glide and those that do not produce an off-glide according to Riad.

4.4 Effect of Emphatic Speech on Glottalisation

Figure 5 shows the difference in glottalisation from all speakers between the casual and emphatic phase.



(a) Number of tokens at each glottalisation level for all participants in different structures during the casual phase.

(b) Number of tokens at each glottalisation level for all participants in different structures during the emphatic phase.

Figure 5: Difference in glottalisation between casual and emphatic phase for all participants.

A closer look at this data is presented in the Table 6, where the casual phase corresponds with Figure 5(a), and the emphatic phase with Figure 5(b).

Table 6: Number of tokens at each glottalisation level for each structure during the casual phase (above) and emphatic phase (below) for all participants.

Casual Phase

Structure	**Level of Glottalisation**			
	No glottalisation	F0 Dip	Creaky voice	Glottal stop
Tautomorphemic	70	0	0	0
Affixated	67	1	1	1
Word boundary	5	9	20	36

Emphatic Phase

Structure	**Level of glottalisation**			
	No glottalisation	F0 dip	Creaky voice	Glottal stop
Tautomorphemic	69	0	0	1
Affixated	66	1	1	2
Word boundary	2	3	8	57

The results show that the largest difference was the increase in full glottal stops for the word boundary category, from 36 out of 70 word boundary vowel meetings during the casual phase to 57 out of 70 word boundary vowel meetings during the emphatic phase. The affixated structure saw one difference between the two phases, namely that 2 affixated words were glottalised during the emphatic phase as opposed to 1 during the casual phase. The tautomorphemic structure saw one difference between the two phases, namely an increase from 0 to 1 sequences producing glottal stops from the casual to the emphatic phase.

5 Discussion

5.1 Discussion of Method

The method used in the current study expanded on the predictions of two phonologists regarding which linguistic factors govern the distribution of glottalisation in Swedish. The method of choice is inspired by these predictions and exhibits a strength in that it presents the opportunity to possibly provide evidence to these theories. Another strength of the method lies in its ability to explore several possible contributing factors regarding the frequency of glottalisation in Stockholm speech. In this strength lies also a weakness within the method, namely that adjusting the stimuli to be able to explore several phenomena also required selectivity.

This resulted in a quite narrow amount of linguistic material to work with, which made it harder to investigate each phenomenon in as much depth as one might have been able to if simply focusing on one aspect. This scarcity of material also resulted in inconsistencies within the stimuli; firstly, one prefixed word versus six suffixed words were used for the affixated category. Secondly, there was an inconsistency in the distribution of short and long allophones for the different structures (see Table 3). The possibility of the psychological connotation of the individual words (or sentences during the emphatic phase) possibly having an effect on willingness to emphasise and/or glottalise cannot be excluded. A challenge during the experiment design was to elicit emphatic speech without a natural speech setting or dialogue. Collecting data from previously recorded conversational speech or implementing the Lombard effect might have given a higher probability of eliciting glottalisation, as emphatic speech proved to be difficult to elicit in a laboratory setting. In fact, the author's impression is that many participants showed little difference in expressivity during the casual and emphatic phase. This suggests that participants that could adapt to the laboratory setting more easily and change speech type on command were more likely to glottalise.

Investigating fewer aspects of the glottalisation phenomenon more in depth would have allowed for a more nuanced and valid result, such as fully distinguishing the possible effect of minimal prosodic word boundaries versus morphological boundaries on glottalisation, but it would not have provided results for as many research questions.

5.1.1 Validity

Relying solely on recorded material provided a freedom of flexibility as to how to design the stimuli. However, the use of several different methods to investigate the same phenomenon would have increased the method's validity. Increasing the amount of participants also would have increased the validity. As mentioned in the previous section, gathering data from previously recorded material, particularly natural speech, could have been a way to increase the validity, especially if combined with the method used for this study.

5.1.2 Reliability

The same equipment was used throughout the experiment, which provided the ability to adjust recording instruments to each participant's individual differences prior to the start of the experiment. The recordings were done in an anechoic chamber which provided the same acoustic setting with virtually no reflected signals means that the data gathered is free from possible extraneous variables having to

do with the quality of the recording. This allowed for consistent analysis in the program Praat, which also allowed for adjustments in the analysis window according to individual differences in pitch.

5.1.3 Objectivity

Subjectivity impacted the experiment design in that the categorisation of certain monomorphemic words, as discussed in section 3.1.1, were categorised subjectively in order to simplify the experimental design and to be able to encompass words in different structures. However, this did not significantly impact the results, as affixation seemed to show close to no impact on the frequency of occurence of glottalisation compared to the tautomorphemic structure. In particular, none of the words that were discussed in section 3.1.1 as controversial regarding structure exhibited any glottalisation, rendering this weakness within the method inconsequential. Subjectivity also impacted the experiment design when choosing words and sentences as stimuli that seemed to stand out the least. This could have been improved upon by, for example, investigating the frequency of certain words to see how commonly they occur in spoken Stockholm Swedish.

5.2 Discussion of Results

The results will be discussed below in the same order that the results were presented, based on each research question previously stated.

5.2.1 Frequency of Glottalisation and Individual Variation

While 95% (133/140) of the sequences in the word boundary structure were glottalised, only 2,86% (8/280) of the sequences in the other two structures were glottalised. The results suggest that word-initial glottalisation is quite consistent within the Swedish language. This is not in complete agreement with Eliasson's claim the Swedish prevocalic glottal stop, particularly in word-initial position, is neither obligatory nor as strict as in other languages, although more research is needed to solidify this argument. Furthermore, there was no substantial difference of this result between the casual and emphatic phase.

This result is the product of data gathered from several participants who showed variation in frequency of glottalisation. This is in agreement with previous research, which argues that glottalisation varies idiolectically. One individual produced some level of glottalisation for 45,2% of the uttered sequences (19/42), and another for only 23,8% (10/42). For the word boundary structure, the same participants produced glottalisation for 100% (14/14) and 71,4% (10/14) of the sequences respectively. This inconsistency in results due to individual variation suggests that a greater amount of participants would provide a more consistent data that would take into account an even greater amount of idiolects.

5.2.2 Effect of Structure

Part of the experiment design was based on the predictions made by Eliasson and Riad, who argue that glottal stop epenthesis is less likely to occur within minimal prosodic words than across minimal prosodic word boundaries. The results support these claims. For the word boundary structure (across minimal prosodic word boundaries) 95% of utterances were glottalised, while only 2,86% of the words in the affixated and tautomorphemic structures (within minimal prosodic words with the exception of *beordra*, which is still counted here) were glottalised. A substantial difference was not present between the tautomorphemic and affixated word structures, suggesting that the presence of a morphological

boundary does not cause an increase in glottalisation compared to the lack of a morphological boundary, which contradicts the hypothesis.

Eliasson claims that glottal stop insertion may primarily, though not exclusively, be a word boundary marker, and that it may be related to otherwise empty syllable onsets. In other words, Eliasson believes that glottal stop insertion marks the boundaries between prosodic words (he does not distinguish between minimal or maximal in this case). He also believes that it could have an effect on syllables that otherwise have no onset, implying it could be a form of hiatus resolution. Riad claims that where the onsetless syllable is not initial in the prosodic word, insertion is not admitted.

The results show that glottalisation of certain words poked a hole in Riad's claim, as, for example, the onsetless syllable in *februari* as well as *ritual*, was not initial in the prosodic word, but still managed to produce a full glottal stop once each. Although these two stops were produced by the same participant, highlighting the amount of individual variation present for this phenomenon, these results demonstrate that a full glottal stop may occur in the middle of a minimal prosodic word. Such glottalisations have been observed impressionistically in other speakers by the author and one can surmise that Eliasson himself has observed them given that he proposes that they can occur.

Regarding the word *beordra*, which counted for five of the seven sequences that triggered some level of glottalisation for the affixated structure category, Riad's claims hold true. This has to do with the fact that the prefix divides the word into two separate prosodic words, such as for *beakta* in Table 3. In this case, Riad correctly predicts that epenthetic glottalisation may be admitted due to it being initial in the minimal prosodic word, represented as follows: $(\text{be-}(\text{ˈʔ})\text{ordra})_{\omega})_{\omega}{}^{\max}$.

5.2.3 Effect of Optional Glide Epenthesis

Riad (2013) describes the long allophones [ʉ̟ː] and [iː] often ending in off-glides [ʉ̟ːʷ] and [iːʲ] respectively, especially when they occur as V_1 during vowel hiatus in spoken Central Swedish. Riad suggests that Swedish uses both glottalisation and off-glide epenthesis to resolve vowel hiatuses, which are the same techniques used in English. These descriptions were taken into account when forming the hypothesis that [ʉ̟ː] and [iː] will prevent glottal epenthesis due to off-glide epenthesis being used by speakers in its stead. However, this hypothesis is not supported by the data. Table 5 shows that the vowel identity in different hiatuses had little to no effect on the amount of glottalisation. It would be too bold of a claim to say that the vowel hiatuses [iː]_[eː], [iː]_[a], [ʉ̞]_[ɛ̝], and [ʉ̟ː]_[a] (vowel sequences that produce the option for glide epenthesis), compared to [ɛ̝]_[ɑː], [ɛ̝]_[oː], and [oː]_[a] did restrict glottalisation. One vowel sequence that stands out is [iː]_[a], which in 4 cases out of a possible 20 produced no glottalisation whatsoever. Two of these instances were uttered by the male participant mentioned in section 4. 1. 2, who was one of the participants who produced the least amount of glottalisation generally. This strengthens the claim that glottalisation varies across idiolects. More research is needed to make solid claims regarding the effect of optional glide epenthesis on glottal epenthesis in hiatus.

5.2.4 Effect of Emphatic Speech

Both Riad and Eliasson predict that glottalisation occurs more frequently during careful or emphatic speech than in casual speech. The author also puts forth this hypothesis. These predictions are supported to some degree by the data for the word boundary structure. More words were glottalised during the emphatic phase, especially for the word boundary structure, but it was not a substantial difference. This may be because of the challenge of eliciting emphatic speech in a laboratory setting. Some participants showed little to no difference in phonetic realisation during the different speech types. However, one noteworthy result was the increase in full glottal stops for the word boundary structure from the casual phase to the emphatic phase, as shown in Table 6, which indicates that the participants were

trying to produce more perceptually salient glottalisations during the emphatic phase.

Another noteworthy result was the presence of a glottal stop within a minimal prosodic word, something that was considered less likely than across minimal prosodic word boundaries according to Eliasson, and considered as not being admitted in the Swedish language according to Riad. This shows that, despite the experiment design struggling to find an appropriate way to elicit emphatic speech, there still was a sign of this being a factor that contributed to an unlikely result according to previous research.

5.3 Discussion of Ethics

The participants were instructed of their right to terminate their participation in the experiment at any point, as well as the data remaining anonymous. No ethical problems came up during the experiment.

5.4 Practical Applications

The aim of this paper is to explore untested theories regarding factors governing the frequency and distribution glottal stop epenthesis. This paper contributes to the description of spoken Swedish. One practical application of the study could have to do with the typological documentation of the frequency of glottal versus glide epenthesis as a form of hiatus resolution.

5.5 Future Research

Future research within this subject should focus on each research question in more detail, with more participants and using different sources of recorded material. Expanding on more diverse examples of word and sentence prosody, sentence types, affixes, and vowel meetings would be a reasonable way to conduct further research on this topic. For example, because this study focused on morphological boundaries, more words containing several minimal prosodic words could be added as stimuli, to see whether glottalisation is more or less likely to occur within the same word in hiatuses across two prosodic words, or in hiatuses across two prosodic words, as two orthographically separated words (such as the distinction between *beordra* vs *inte ål*).

6 Conclusions

The results gathered from participants' recorded material showed that word-initial prevocalic glottalisation was very common, while glottal epenthesis as a form of hiatus resolution during affixated and tautomorphemic structures were much less common. Glottal epenthesis within affixated structures occurred only slightly more often than within tautomorphemic structures. Glottalisation is more likely to occur across minimal prosodic word boundaries, but can be admitted within minimal prosodic words as well, contradicting previous claims made by Riad.

Individual variation during the experiment was present, as some participants glottalised almost twice as much as other participants.

Glottal epenthesis is slightly more likely to occur during emphatic speech for tautomorphemic and affixated structures. This factor has an even bigger impact within the word boundary structure sequences. The word boundary structure sequences also produced more glottal stops during the emphatic phase than during the casual phase.

Optional glide epenthesis did not give conclusive results as to whether it had an effect on glottal epenthesis.

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Appendices

A Figures and Tables

List of Tables

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B Stimuli

trottoar

oas

silhuett

kopiera

ideal

februari

manuell

meteor

ritual

diet

på allt

teater

sju änglar

i akt

koriander

inte ål

i elen

beordra

allians

inte artig

du alltid

Arvid ska flyga till London på Lördag.
Arvid ska flyga till **London** på Lördag.
Arvid ska flyga till London på **Lördag**.

Nu får du ta tillfället i **akt**!

Den här växeln är ju **manuell**!

Jag såg endast en **silhuett**!

Ikväll går vi på **teater**!

Detta är ju vår **ritual**!

Säg inte att du går du på **diet**!

Ät vad du vill, bara inte **ål**!

Sätt inte gaffeln i **elen**!

Jag sade inte skriv ut, jag sa **kopiera**!

Där flyger sju **änglar**!

Det säger du **alltid**!

Jag ser en **oas**!

Det är ju redan **Februari**!

Titta, en **meteor**!

Han var ju verkligen inte **artig**!

Detta är ingen **trottoar**!

Hon blir arg på **allt**!

Du kan ju inte krydda med **koriander**!

Din plan är ju **ideal**!

Det kan du ju inte **beordra**!

Vi kan ju inte svika vår **allians**!

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