A phonetic-phonological account of hiatus resolution in Dutch

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Abstract

In Dutch, hiatuses can be resolved with two mechanisms: the insertion of glottal elements and the insertion of transitory glides. The distribution of those two mechanisms is different in hiatuses across the boundaries of prosodic words, on the on hand, and hiatuses within prosodic words, on the other hand. In the former case, glottal elements and transitory glides can appear in the same environments and the choice between the two is governed by speech rate. In the latter case, glottal elements and transitory glides are in complementary distribution, both at slow and fast speech rates.

Working within the theoretical framework of the Bidirectional Model of Phonology and Phonetics (Boersma 2007ab), this thesis presents an Optimality-Theoretic analysis of hiatus resolution in Dutch. It is argued that glottal elements and transitory glides do not have a segmental representation in phonology, and that they only appear in the Phonetic Form as the result of articulatory and cue constraints.

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1. Introduction

This thesis examines the resolution of hiatuses, i.e. sequences of two adjacent vowels, in Netherlandic Dutch (henceforth: Dutch). There are two mechanisms for hiatus resolution available in Dutch: the insertion of homorganic glides and the insertion of glottal elements. In the initial position of a prosodic word, they compete, and the choice between the two is governed by speech rate. Within prosodic words, glottal elements and homorganic glides are in complementary distribution. This thesis presents an Optimality-Theoretic analysis of these phenomena in the framework of Bidirectional Phonology and Phonetics (Boersma 2007ab).

Throughout this thesis, underlying phonological representations are given between pipes, phonological surface representations between slashes and phonetic representations between brackets. A more detailed characterizations of these levels of representations and why they are necessary can be found in Section 4.1.1.

2. The distribution of glottal elements and homorganic glides in Dutch

In Dutch, glottal stops can be found in two different positions: in the onset of otherwise vowel-initial p-words and in hiatus positions within p-words. Their distribution, however, cannot be seen independently from that of so-called homorganic glides. Based on the speech of one professional speaker, Jongenburger & Van Heuven (1991) show that after speech pauses, i.e. in the absolute onset, in the beginning of vowel-initial orthographic words, glottal stops surface in 100% of the cases. This effect is independent of the quality of the respective vowel. According to Booij (1999: 67) this concerns the onset of prosodic words (henceforth: words; whenever I am referring to orthographic or morphosyntactic words rather than to prosodic words, this is made explicit throughout the thesis). Examples for this context are shown in (1):[1]

[1] Following Collins & Mees (2003), Gussenhoven (2007) and Gussenhoven (2009), I transcribe |eː øː oː aː| as phonologically long, in contrast with the tense high vowels, which I transcribe as |i y u|. Stressed underlying |oː| takes the phonological surface form /ou/ (unless it is followed by |r|, which gives rise to the forms /ʊː/), in the same fashion as the other mid-closed vowels |eː| and |øː| take the diphthongized forms /ei/ and /øy/, respectively. Collins & Mees (2003: 131) point out that “the allophones of /eː/ and /øː/ before /r/ strongly resemble /ɪ/ and /ʉ/”, but that there still is a durational difference. For this reason, I phonetically transcribe |eː| as [ɪː] in front of |r| in example (4). According to Gussenhoven (2009: 183), “the duration of [eː, øː, oː, aː] in unstressed positions is equivalent to that of short vowels” and consequently I transcribe them as phonetically short in these positions. In the phonetic form stops are transcribed as the three articulatory gestures that they consist of: the formant transitions after the preceding vowel, e.g. [p˺], either a voiced ([‿]) or an unvoiced ([_]) closure phase, and the release of the closure, e.g. [ᵗ].

(1)	*appel*	|ˈɑpəl|	[_ˀ**ɑ**p˺_ᵖəɫ]	‘apple’
	analoog	|ˌa:na:ˈlo:χ|	[_ˀa:nal**ou**χ]	‘analogous’
	ezel	|ˈe:zəl|	[_ˀ**ei**zəɫ]	‘donkey’
	open	|ˈo:pən|	[_ˀ**ou**p˺_ᵖən]	‘open’
	olijf	|o:ˈlɛif|	[_ˀo(ʊ)l**ɛi**f]	‘olive’

Lexical stress is specified in the underlying phonological form throughout this thesis. Phonetically prominent vowels are shown in boldface. It should be noted here that affixes with a full vowel and their own main stress, such as |ˈɔn|- (‘un-’) and -|ˈɑχtəχ| (‘-like’), are words in their own right and thus do not form part of the same word as their morphosyntactic base (Booij 1999: 30). In that sense, prosodic words on the one hand and morphosyntactic and orthographic words on the other hand are not always necessarily coextensive in Dutch. For the case of the suffix -|ˈɑχtəχ| this means the insertion of glottal stops might also apply on its left edge (Booij 1999: 67; Ernestus 2000: 68). This is demonstrated in (2). The fact that this is not a hiatus phenomenon can be seen in (3). Here, a stem ending in a consonant is suffixed with -|ˈɑχtəχ|, but we still find a glottal stop in the onset of the suffix. When a prefix with main stress is combined with an underlyingly vowel-initial stem, there is a glottal stop in the onset of that stem since this is still a word-initial position. This can be seen in (4), where we find a glottal stop in the onset of the phonetic form of |ˈe:rlək|. Furthermore, there is also a glottal stop in the onset of |ˈɔn|- as it is also a word-initial position.

(2)	*koeachtig*	|ˈku| + |ˈɑχtəχ|	[k**u**_ˀ**ɑ**χ_ᵗəχ]	‘cow-like’
	(adapted from Booij 1999: 67)			
(3)	*rootachtig*	|ˈro:d| + |ˈɑχtəχ|	[r**ou**t_ˀ**ɑ**χ_ᵗəχ]	‘reddish’
(4)	*oneerlijk*	|ˈɔn| + |ˈe:rlək|	[_ˀ**ɔ**n_ˀ**ɪ**:rlək˺_ᵏ]	‘dishonest’

This means that phonetically the affixed words in (2)–(4) behave the same as morphological compounds, in (5) and sequences of several morphosyntactic words, as in (6). There, the various lexical stems are parsed as individual words and we find glottal stops at the word boundary in otherwise vocalic onsets.

(5) *zeearend* |ˈzeː| + |ˈaːrənd| [z**ei**_ˀ**a**ːrən˺_ᵗ] ‘sea eagle’
(adapted from Booij 1999: 67)

(6) *drie appels* |ˈdri| + |ˈɑpəls| [ᵈ̰r**i**_ˀ**ɑ**pəɫs] ‘three apples’

Jongenburger & Van Heuven’s (1991) findings for hiatus positions on left edges of vowel-initial orthographic words in connected speech, though, i.e. in cases like (6), are different from what they find in absolute onset position. In contrast to the absolute tendency to insert glottal elements in the absolute onset, they showed that in the position V#V, i.e. in hiatus positions across word boundaries, glottal elements were only inserted in 74.1% of the cases. When a vowel-initial word was preceded by a consonant rather than by a vowel, i.e. when there was no hiatus, this number further dropped to 44.6% (after voiced consonants) and 32.8% (after voiceless consonants) of the cases. Moreover, they found the insertion of glottal elements to be more frequent in prominent syllables (69.6%) than in non-prominent syllables (31.4%). Similarly, in the analysis of his stimulus material for a word segmentation task (consisting of recordings of 4 native speakers of Dutch), Quené (1992) found that 23 out of 37 tokens in the condition C#V contained a glottal element.

When speaking of inserted glottal elements, both Jongenburger & Van Heuven (1991) and Booij (1999) only mention glottal stops. Other studies such as Quené (1992), however, differentiate between various types of glottal elements that can appear in boundary positions: glottal stops, laryngealization and vocal fry. Similar differences are also drawn in studies of other languages. In their study of hiatus resolution in American English, Davidson & Erker (2014) differentiate between glottal stops, glottalization and various types of creakiness. Pompino-Marschall & Żygis (2010) in their analysis of German make a distinction between glottal stops and glottalization/creaky voice. In this paper, however, while accrediting the variation in the realization of such elements, I will collectively refer to them as glottal elements and use the symbols [_ˀ] in my phonetic transcriptions.

Aside from the left edge of words, glottal elements can also appear in word-internal hiatus positions in Dutch. Here, however, their distribution is more limited and restricted to two specific contexts. First, it appears when the first vowel of the hiatus is /a/ and it precedes a vowel carrying stress (Booij 1999: 65). This can be seen in (7).

(7) *chaotisch* |χaːˈotis| [χa_ˀ**ou**tis] ‘chaotic’

Whereas Booij (1999) claims that glottal elements in word-internal hiatus positions can only appear preceding a vowel with main stress, Gussenhoven (2007: 342) adds that this also applies when the second vowel of the hiatus has secondary stress, see (8).

(8) *Israël* |ˈɪsraːˌɛɫ| [_ˀ**ɪ**sra_ˀ**ɛ**ɫ] ‘Israel’
(adapted from Gussenhoven 2007: 342)

However, both agree that when |aː| is followed by an unstressed vowel, the hiatus remains unresolved and the two vowels remain in juxtaposition. This is demonstrated in (9).

(9) *chaos* |ˈχaːɔs| [χ**a**ːɔs] ‘chaos’
(adapted from Booij 1999: 65)

According to Gussenhoven (2007: 342), glottal elements also appear in the word-internal hiatus when the first vowel is [ə]. Since the sequence |əV| does not occur in monomorphemic roots, this only affects forms where a vowel-initial root is prefixed with either |bə|- or |χə|-. These two prefixes do not carry main stress. An example is given in (10).

(10) *beïnvloeden* |bə| + |ˈɪnvludə(n)| [‿bə_ˀ**ɪ**nvlu‿ᵈə(n)] ‘(to) influence’

In all other word-internal hiatus positions (i.e. in ones not containing |aː| or |ə| as the first vowel), the hiatus is resolved by homorganic glide insertion instead. The inserted glide corresponds to the preceding vowel in terms of roundness and backness, with the exception that back vowels are followed by a labiodental rather than by a bilabial glide (Gussenhoven 1980: 177; Booij 1999: 66). This means that front rounded vowels are followed by [ɥ], see (11); front unrounded vowels are followed by [j], see (12); and back vowels are followed by [ʋ], see (13). In contrast to the distribution of [_ˀ] in the hiatus, the insertion of glides in the hiatus does not depend on the stress pattern and applies before unstressed vowels, too.

(11)	*duo*	|ˈdyo|	[̮ᵈ**y**ɥou]	‘duo’
	reuen	|ˈrøən|	[r**ø**ɥə(n)]	‘male dogs’
	januari	|ˌjaːnyˈaːri|	[j**a**ːnyɥ**a**ːri]	‘january’
(12)	*bioscoop*	|ˌbiɔsˈkoːp|	[̮ᵇ**i**jɔs_ᵏ**ou**p˥_ᵖ]	‘cinema’
	reeën	|ˈreːən|	[r**ei**jə(n)]	‘deer (pl.)’
	dieet	|diˈeːt|	[̮ᵈij**ei**t˥_ᵗ]	‘diet’
(13)	*Ruanda*	|ruˈɑndaː|	[ruʋ**ɑ**n˥ ̮ᵈa]	‘Rwanda’
	(all adapted from Booij 1999: 66)			

Booij (1999: 67) formalizes this phenomenon of homorganic glide insertion as a series of phonological rules. First, an unspecified element is inserted between two vowels, given the first one is not low. Subsequently, this takes on the place and rounding features of the preceding vowel by means of spreading. Casali (1996), in a cross-linguistic study, only considers glide insertion as a means of hiatus resolution when the glide is generated from the first vowel. In Dutch, Booij (1999: 67) ascribes the phenomenon of homorganic glide insertion to the phonological domain of the prosodic word as it obligatorily applies in hiatuses within words, but not across words. Yet, he further points out that in “casual speech” homorganic glide insertion may indeed apply in hiatus positions across word boundaries. However, he does not define what he understands as “casual speech”.

In any case, this means that when glottal stop insertion fails to apply in hiatus positions across word boundaries due to whatever reason, homorganic glide insertion applies instead, see examples (14), (15) and (16) contrasting with the forms in (2), (5) and (6). This is in line with Jongenburger & Van Heuven’s (1991) finding of fewer glottal stops even in the onset of vowel-initial words in connected speech.

(14)	*koeachtig*	|ˈku| + |ˈɑχtəχ|	[_ᵏ**u**ʋ**ɑ**χ_ᵗəχ]	‘cow-like’
	(adapted from Booij 1999: 67)			
(15)	*zeearend*	|ˈzeː| + |ˈaːrənd|	[z**ei**j**a**ːrən˥_ᵗ]	‘sea eagle’
	(adapted from Booij 1999: 67)			
(16)	*drie appels*	|ˈdri| + |ˈɑpəls|	[̮ᵈr**ij**ɑ**p**əɫs]	‘three apples’

Berendsen & Den Os (1987), based on an auditory discrimination task, show that homorganic glide insertion in hiatuses across word-boundaries is somewhat more frequent at faster speech rates or, put the other way around, that glottal elements are inserted less readily at higher speech rates. However, they conclude that this is not due to the speech rate itself, but rather governed by other factors, which in turn depend on speech rates, such as the phonetic prominence of the second vowel involved in the hiatus.

Moreover, Pompino-Marschall & Żygis (2010) demonstrate that for German,[2] the insertion of glottal elements at the left edge of vowel-initial (orthographic) words decreases with increased speech rate. The analysis of connected speech produced by three speakers revealed that in slow speech 30.1% of the words did not have any glottal element, whereas in fast speech more than half of the (orthographically) vowel-initial words (53.2%) did not have any consonantal onset.

The findings from these two studies at least suggest that what Booij (1999: 67) characterizes as the effect of "casual speech" in Dutch might in fact depend on speech rate.

Regarding homorganic glides appearing in hiatuses across word boundaries as in (16), Van Heuven & Hoos (1991) demonstrate that those glides are phonetically different from the phonemic glides of Dutch, |j| and |ʋ|. The transitory glides found in the context |V#V| are between 46% and 52% shorter than the phonemic glides in the context |V#jV| and |V#ʋV|. In contrast to this durational difference, their formant measures did not reveal any definitive differences between the two contexts. However, due to their durational findings, Van Heuven & Hoos (1991) suggest that the insertion of homorganic glides between words is not phonological, but rather the result of phonetic coarticulation effects between the two vowels in the hiatus. Still, they do not refute the idea of glides in hiatuses within words being phonological, as they did not include this context in their experiment. To reflect their findings in my terminology, I will refer to the glides in hiatus positions as *transitory glides*, while referring to the contrastive glides in words like *zeewater* as *phonemic glides*.

To summarize, the distribution of glottal elements in Dutch cannot be characterized independently from that of transitory glides, as both can appear at left edges of words as well in word-internal hiatuses. However, these two contexts are fundamentally different in one important regard. In word-internal hiatuses, glottal elements and transitory glides are in complementary distribution. Glottal elements only appear after [a] and [ə] when the following vowel is stressed;

[2] The distribution of glottal elements in German is similar to that in Dutch. They can appear in the onset of (underlyingly) vowel-initial p-words and in hiatuses when the second vowel is stressed. In contrast to Dutch, this also applies after non-low vowels (Wiese 2000: 58-59).

when the following vowel is unstressed, the hiatus remains unresolved. In all other contexts we find transitory glides.

In the onset of vowel-initial words, on the other hand, glottal elements and transitory glides are in direct competition. This alternation is not complementary and is governed by the style of speech, as both can occur in the same context, as in (2), (5) and (6) and in (14)–(16).

Any comprehensive account of hiatus resolution and phenomena related to left edges of words in Dutch should be able to account for these facts. Further, it should account for the fact that hiatus resolution within words does not seem to be sensitive to stress patterns following non-low vowels, as we find glides independent of stress in (11), whereas we find a different realization depending on stress after [a], as in (7) and (9).

The objective of this thesis is to present such a complete analysis that can account for all the relevant linguistic facts in Optimality Theory. Before presenting my own analysis in Section 4, I will discuss the previous formalizations of glottal stop and homorganic glide insertion found in the literature in Section 3.

3. Previous takes on glottal stop and homorganic glide insertion

This section presents a review of previous (Optimality-Theoretic) accounts of hiatus resolution and glottal stop insertion in Dutch. While these accounts offer some interesting insights, they all fail to provide a comprehensive explanation of the data presented in Section 2.

Kager & Martínez-Paricio (2018) present an Optimality-Theoretic approach that manages to capture both the occurrence of glottal stops in word-internal hiatuses and in the onset of words with one overarching explanation. The insertion of glottal stops is argued to apply at the left edge of trochaic feet. As trochaic feet begin in a stressed syllable, this approach can explain why glottal stops can be found both word-initially, as in *ader* 'vein', analyzed as (ˈʔaː.dər)$_F$ as well as in word-internal hiatuses, as in *Caraïbisch*, analyzed as (ˌka.ra)$_F$.(ˈʔi.bis)$_F$. Here the glottal stops occur in the onset of stressed syllables. In unstressed position, as in *chaos*, glottal stop insertion does not occur, as the hiatus is foot internal. This basic explanation is similar to Hall's (1992) and Wiese's (2000) account of the distribution of glottal stops in German, which they also base on the metrical foot. In Kager & Martínez-Paricio's (2018) approach, the glottal stops in absolute onset position in unstressed syllables, such as in *aorta*, analyzed as (ʔa(ˈʔɔr.ta)$_F$)$_F$, are captured by assuming an internally-layered recursive foot. This means that the (unstressed) syllable /a/ is parsed as being foot-initial and therefore is eligible for glottal stop insertion. In their Optimality-Theoretic analysis this is expressed using the constraint ALIGN-FTONSET ("Align the left edge of every foot with a consonant", Goedemans 1996), governing a faithfulness constraint against the epenthesis of glottal stops, DEP-ʔ (Topintzi 2010), and a general ONSET constraint. Their analysis is demonstrated for the words *chaotisch* and *chaos* in (17) and (18). In the following tableaux parentheses are used to indicate foot boundaries.

(17) Hiatus resolution in *chaotisch* following Kager & Martínez-Paricio's (2018) account

/χa'ʔotis/	ALIGN-FTONSET	DEP-ʔ	ONSET
☞ (χa(ˈʔo.tis))		*	
(χa(ˈo.tis))	*!		*

(18) Hiatus resolution in *chaos* following Kager & Martínez-Paricio's (2018) account

/χaɔs/	ALIGN-FTONSET	DEP-ʔ	ONSET
(ˈχa.ʔɔs)		*!	
☞ (ˈχa.ɔs)			

However, if we refute their debatable assumption of recursive internally-layered feet, while still relying on the metrical foot in order to account for the distribution of glottal elements in Dutch, we would not be able to explain all of the data and an additional explanatory mechanism would be necessary to account for the occurrence of glottal elements in the unstressed vowel-initial syllable in the absolute onset in words like *aorta*.

Even though Kager & Martínez-Paricio (2018) assume that glottal stops are inserted phonologically, they nevertheless claim that the insertion of glottal stops applies optionally in all contexts (with a difference drawn between weak and strong preferences for glottal stop insertion). Yet, they do not provide any mechanism which could explain when such an inserted glottal stop appears on the phonetic surface and when it does not. This non-distinction between phonology and phonetics is apparent in tableaux (17) and (18), where the input is presented between (phonological) slashes, but the output is not specified as belonging to any specific level of representation. However, as the output includes phonological information, such as both foot and syllable boundaries, it seems like Kager & Martínez-Paricio (2018) aim to present a strictly phonological analysis.

The biggest flaw in their analysis is that they completely ignore homorganic glides. For the word-internal hiatuses, they conveniently only present the data where we indeed find glottal elements, i.e. after [a]. They disregard the other cases where such hiatuses are resolved with transitory glides after non-low vowels (see Section 2). Any account of glottal stop insertion in word-internal hiatus positions should always include homorganic glides in that same contexts, as both elements are in complementary distribution. If included into their analysis, the homorganic glides in the onset of stressed syllables within words, e.g. in *januari*, could be argued to satisfy the constraint ALIGN-FTONSET because those glides are necessarily always in the onset of a trochaic foot. Kager & Martínez-Paricio's (2018) approach crucially could not explain, though, why these homorganic glides also occur in the onset of unstressed syllables after a non-low vowel, i.e. within a metrical foot as in *duo*.

Whereas Kager & Martínez-Paricio's (2018) analysis accounts for glottal stop insertion both in word-initial and word-internal position, Smith (2002: 97–102) presents an approach that only focuses on word-internal hiatuses. Yet, her account includes an explanation of the occurrence of both glottal elements and glides. Rather than ascribing the distribution of glottal stops to the left edge of metrical feet, she relies on stressed syllables in her analysis. Her Optimality-Theoretic formalization can account for the facts the hiatus remains unresolved in (9), but is resolved with homorganic glides in (11), and that we find a glottal stop in the onset of a stressed vowel after [a], as in (7), but not after any other vowel preceding stress, as in (11) by assuming the following constraint ranking: {ONSET/σ́, *LOWGLIDE } >> DEP-SEG >> ONSET >> INTEGRITY, shown in (19)–(23). These constraints will be explained in the next paragraph.

The insertion of homorganic glides is not seen as a violation of DEP-SEG prohibiting epenthesis (McCarthy & Prince 1995) as they are argued to be generated from the preceding vowel and not to be inserted (cf. Rosenthall 1994). Instead, they violate INTEGRITY (McCarthy & Prince 1995), a constraint prohibiting that input segments have multiple output correspondents. The ranking of DEP-SEG over INTEGRITY, however, ensures that hiatuses are preferably resolved by means of a glide rather than with an inserted glottal stop, independently of where the stress lies, as can be seen in (19) and (20). The necessity to resolve hiatuses with a second stressed vowel arises from the constraint ONSET/σ́, demanding stressed syllables to have an onset. A high ranked constraint *LOWGLIDE[3] makes sure that a glide is not a possible solution in *chaotisch*, see (21), and

[3] Unfortunately, Smith (2002) does not provide a definition of this constraint other than the fact that it rules out forms with a low glide in the output. It remains unclear if she assumes it to be phonological or phonetic.

instead a glottal stop is inserted despite violating DEP-SEG. In unstressed syllables, *LOWGLIDE similarly causes a glide to be impossible in *chaos*. In that context, a hiatus resolution with a glottal stop is not possible, either, as a more general ONSET constraint is ranked lower than DEP-SEG, see (22).

(19) Hiatus resolution in *januari* following Smith's (2002) account

/janyari/	ONSET/σ́	*LOWGLIDE	DEP-SEG	ONSET	INTEGRITY
ˌja.ny.ˈʔa.ri			*!		
☞ ˌja.ny.ˈɥa.ri					*
ˌja.ny.ˈa.ri	*!			*	

(20) Hiatus resolution in *duo* following Smith's (2002) account

/dyo/	ONSET/σ́	*LOWGLIDE	DEP-SEG	ONSET	INTEGRITY
ˈdy.ʔo			*!		
☞ ˈdy.ɥo					*
ˈdy.o				*!	

(21) Hiatus resolution in *chaotisch* following Smith's (2002) account

/χaotis/	ONSET/σ́	*LOWGLIDE	DEP-SEG	ONSET	INTEGRITY
☞ χa.ˈʔo.tis			*		
χa.a̯o.tis		*!			*
χa.ˈo.tis	*!			*	

(22) Hiatus resolution in *chaos* following Smith's (2002) account

/χaɔs/	ONSET/σ́	*LOWGLIDE	DEP-SEG	ONSET	INTEGRITY
ˈχa.ʔɔs			*!		
ˈχa.a̯ɔs		*!			
☞ ˈχa.ɔs				*	

While Smith's (2002) approach is promising in some regards as it can reliably account for many of the linguistic facts, it has one big issue. It makes a wrong prediction for words with an unstressed syllable beginning in a vowel, such as *uniek* 'unique'. According to Jongenburger & Van Heuven

(1991) we expect glottal stops in this context in 100% of the cases. However, in Smith's (2002) ranking, this expected form is incorrectly ruled out by the ranking of DEP-SEG over INTEGRITY, see (23).[4]

(23) Treatment of the word onset in *ynik* following Smith's (2002) account

/ynik/	ONSET/σ́	*LOWGLIDE	DEP-SEG	ONSET	INTEGRITY
ʔy.ˈnik			*!		
☞ y.ˈnik				*	

Another weakness of her analysis is that she does not clearly differentiate between phonetics and phonology. She treats all of her constraint as phonological or at least applies them to the same input at the same time. As in Kager & Martínez-Paricio's (2018) analysis, the output forms in Smith (2002) represent syllable boundaries and phonological stress, which implies that they represent phonological surface representations. Whereas some constraints, such as ONSET/σ́, DEP-SEG, ONSET and INTEGRITY, have a rather straightforward phonological motivation, this is not so obvious for the constraint *LOWGLIDE. Smith (2002) does not provide any motivation for this constraint other than the fact that low glides do not appear on the surface. Yet, when motivating the impossibility of low glides, a phonetic motivation is more convincing (see Section 4.2.2).

As in Smith's (2002) approach, Rosenthall (1994: 190–196) interprets homorganic glide insertion as a mechanism to provide an onset for otherwise onsetless syllables in word-internal hiatuses. He posits that the features of a glide are linked to the features of the preceding vowel, similar to Booij's (1999) phonological rule (see Section 2). However, Rosenthall (1994) crucially disregards the occurrence of glottal elements in this position entirely, thus rendering his analysis insufficient. Rubach (2002) provides a similar flawed analysis of homorganic glides in hiatuses. He, too, entirely disregards glottal stops and concludes that the homorganic glides of Dutch must be segmental rather than subsegmental, albeit arguing phonologically only and not considering phonetic aspects.

4 Smith (2002) also presents an alternative analysis, which does not need the constraint Onset/σ́, but rather uses a dummy constraint *C* "that prevents glottal stop onsets from appearing in unstressed syllables" (p. 101). However, such an analysis would still incorrectly rule out the form ʔyˈnik. A similar analysis of glottal stop insertion in Dutch can also be found in McCarthy (2002).

To summarize, the previous accounts of hiatus resolution in Dutch provide some interesting insights, but none of them succeeds in presenting a comprehensive analysis covering all the relevant aspects pointed in Section 2.

4. A BiPhon account of glottal elements and transitory glides

4.1 The BiPhon model

A noteworthy disadvantage of the analyses presented above is that all of them argue phonologically only. Yet, an account of a phenomenon described to appear on the surface only and not to have any phonemic value must also consider phonetic details. In doing so, a clear line should be drawn between which effects can be accredited to phonology and which to phonetics. A theoretical framework that achieves this is Boersma's (2007ab) model of Bidirectional Phonology and Phonetics (henceforth: BiPhon), which is based on an earlier model called Functional Phonology (Boersma 1998, 2000). In addition to including both phonology and phonetics, BiPhon also accounts for both the listener's comprehension of linguistic input and their production in the very same model. A simplified version of the model can be seen in Figure 1.

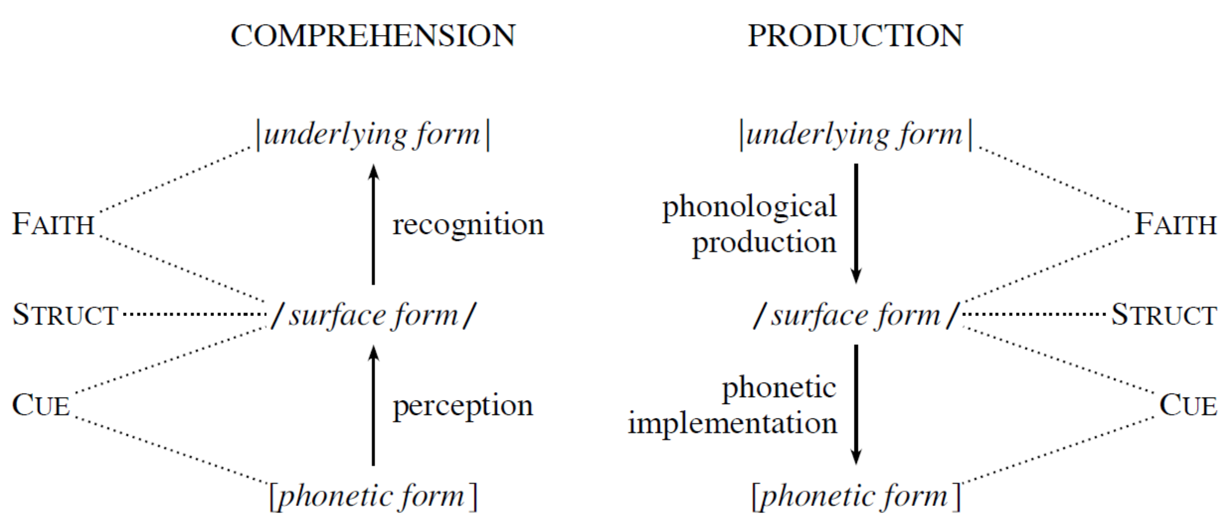

Figure 1. The BiPhon model (from Boersma & Hamann 2009: 1).

The model distinguishes four levels of representation. The most abstract level of representation is the Underlying Form (UF), which represents the phonemic level. In the process of phonological production, a UF input is mapped onto a phonological surface form (SF). In this mapping, faithfulness (FAITH) constraints apply. Furthermore, possible phonological surface representations are subject to structural (STRUCT) constraints. On the level of the SF, allophonic variation is encoded. However, this still represents an abstract phonological level, while discrete phonetic information is associated with the Auditory and the Articulatory Form. In the next step in the production direction, an SF input is mapped onto the Auditory Form, which, in turn, maps onto an Articulatory Form. The latter mapping is subject to sensimotor constraints (Boersma 2007a: 2031–2032) and represents discrete articulatory gestures (Boersma 2007a: 2017). In a more simplified version of the model, Auditory and Articulatory Form can be subsumed under the label Phonetic Form (PF) (Boersma & Hamann 2009). This simplified model is the one used in the formalizations in this thesis. The mapping from the abstract phonological SF onto the discrete articulatory gestures represented as the PF is called phonetic implementation. In this mapping, CUE constraints apply. Furthermore, the PF must comply with articulatory (ART) constraints, which formalize articulatory restrictions on the phonetic output (cf. Boersma & Hamann 2009: 22). The model is bidirectional as it does not need an additional module to represent the comprehension of phonetic input. Instead, the same levels of representations and the same types of constraints as in the production direction apply. In perception, a PF input is mapped onto an optimal SF candidate via CUE constraints. In addition, STRUCT constraints evaluate this SF. In recognition, an SF is mapped onto a UF, being evaluated by FAITH constraints (Boersma 2007a: 2031–2032; Boersma & Hamann 2009: 11–12). The advantage of the BiPhon model is that it draws a clear line between a phonology module, with abstract representations, and a phonetic module, with discrete representations, while still accounting for the interaction between the two via CUE constraints. The fact that both comprehension and production are represented in the same unifying model also entails that any constraint that is argued to apply in production must make the correct predictions in comprehension, too, and vice versa.

4.2 Optimality-Theoretic analysis

This section presents a comprehensive account of hiatus resolution in Dutch in BiPhon, accounting both for effects pertaining to the left edge of words and to those in word-internal hiatus positions. The main functional load of those phenomena is argued to take place in phonetic implementation and in perception, i.e. in phonological surface representations and in the Phonetic Form via ART, CUE and STRUC constraints.

4.2.1 Phonological production

The mapping from the UF onto the SF, i.e. the phonological production, is rather straightforward. The faithfulness constraint IDENT makes sure that no UF segment is replaced with another one in the SF. DEP militates against the deletion of segments and MAX militates against the insertion of segments not represented in the UF. The application of these constraints means that the UF input |ˈɑpəl| is produced as surface (.ˈɑp̣əɫ.)/, as can be seen in (24). In contrast to the analyses presented in Section 3, a phonological ONSET constraint is not necessary in my analysis and neither glottal elements nor transitory glides appear in the SF. Instead, they appear in phonetic implementation only, see Section 4.2.2. Lexical main stress is represented in the UF and is mapped onto stress in the SF, too. Underlying |l| has the allophone /ɫ/ in coda position (Collins & Mees 2003: 58).[5] This allophony and mapping of stress are not formalized with constraints in tableau (24), however, as they are not relevant for my argument. The same holds for the syllabification, which is generated by means of STRUCT constraints, allowing for ambisyllabic consonants such as /p̣/. What is worthwhile mentioning, however, is that according to Booij (1988; 1995: 29) the domain of syllabification is coextensive with the word. In the following tableaux, word boundaries are represented as parentheses in the SF. Word boundaries always align with syllable boundaries and therefore only word-internal syllable boundaries are represented in the SF representations.

(24) Phonological production of *appel*

|ˈɑpəl|	DEP	IDENT	MAX
☞ /(ˈɑp̣əɫ)/			
/(ˈɑp̣ə)/	*!		
/(ˈɑp̣ər)/		*!	
/(ˈɑp̣ə.lə)/			*!

The STRUCT constraint 1MAINSTRESS (“a prosodic word should have only one main-stressed syllable”) makes sure that elements with main stress, such as |ˈroːd| and |ˈɑχtəχ|, are each mapped onto one word respectively, even if they form one word from a morphosyntactic perspective.

Booij (1999: 22–23) argues that all obstruents in syllable-final position are voiceless. In my model, this is expressed as STRUCT constraint */+voice./ (“a syllable-final obstruent should be

[5] In fact, Collins & Mees (2003: 58) argue that coda |l| is phayngealized /lˤ/ in Netherlandic Dutch, whereas in Belgian Dutch we find velarized or even palatalized variants in this position. However, I follow their practical suggestion and use the symbol /ɫ/ instead.

voiceless). As a result of that, /(ˈrout)(ˈɑχ.təχ)/ is preferred over /(ˈroud)(ˈɑχ.təχ)/ in (25). We need to assume that this final devoicing applies in phonology, i.e. in the SF, and not in phonetics, as we can find devoiced segments in fast speech in forms such as [h**œy**t̚_ᵗ**ɑ**rts] (|ˈhœyd| + |ˈɑrts|, ‘dermatologist’), where the devoiced obstruent phonetically appears in the onset of a syllable and not in coda position. Here, the voiceless alveolar closure is released into the vowel [**ɑ**] with no pause intercepting the consonant and the vowel. If final devoicing only applied phonetically and not phonologically, we would expect the unattested form *[h**œy**d̚_̬ᵈ**ɑ**rts] with a voiced alveolar closure being released into the vowel in fast speech, instead.

(25) Phonological production of *roodachtig*

|ˈroːd| + |ˈɑχtəχ|	1MAINSTRESS	*/+voice./	DEP	IDENT	MAX
☞ /(ˈrout)(ˈɑχ.təχ)/					
/(ˈrout.ˈɑχ.təχ)/	*!				
/(ˈroud)(ˈɑχ.təχ)/		*!			
/(ˈrout)(ˈʏχ.təχ)/				*!	

4.2.2 Phonetic implementation

In phonetic implementation, i.e. the mapping from an abstract phonological representation of the SF onto the discrete PF, the word-internal hiatus in /(ˈdy.ou)/ is solved with the articulation of a weak glide [ᶣ] between the two vowels. This transitory glide corresponds to the formant transitions between the stable phases of the vowels [y] and [o].

(26) Phonetic implementation of *duo*

/(ˈdy.ou)/	*[a̯]	/ˈσ/[**V**]	*[_ˀ]	*[VV]
☞ [_ᵈ**y**ᶣou]				
[_ᵈ**y**ou]				*!
[_ᵈ**y**_ˀou]			*!	

Any alternative strategies for the resolution of this hiatus, such as the articulation of a glottal element or the juxtaposition of the two vowels are ruled out by the ART constraints *[_ˀ], militating against any glottal element in the output, and *[VV], disallowing hiatuses in the PF. Furthermore, the CUE constraint /ˈσ/[**V**] applies. It ensures that a phonologically stressed syllable is phonetically implemented as high phonetic salience (high amplitude, high relative F0) of the vocalic nucleus of the respective syllable. In the PF, I represent this type of salience by boldfacing the vowel. None of the output candidates in (26) violates /ˈσ/[**V**]. In the following tableaux this constraint is not represented to keep them concise until it will be relevant again for my argumentation. However, it is still assumed to always apply in phonetic implementation and all output candidates shown in the following comply with it.

In contrast to /(ˈdy.ou)/, /.ˈχaː.ɔs)/ is not implemented with a transitory glide and now we see why a violation of *[_ˀ] must outrank a violation of *[VV] in order to correctly predict that /(ˈχaː.ɔs)/ is implemented as [χ**a**ːɔs] in (27).

(27) Phonetic implementation of *chaos*

/(ˈχaː.ɔs)/	*[a̯]	*[_ˀ]	*[VV]
☞ [χ**a**ːɔs]			*
[χ**a**ːa̯ɔs]	*!		
[χ**a**ː_ˀɔs]		*!	

In (26) the optimal candidate used a weak transitory glide to resolve the hiatus. However, in the phonetic implementation of /(ˈχaː.ɔs)/ in (27), this is not an option since a low glide [a̯] is articulatorily impossible.

In Smith (2002), this effect was formalized as the phonological constraint *LOWGLIDE. Similarly, Rubach (2002) formulates a positive phonological constraint HIGHGLIDE positing that all glides must be high. However, this effect is clearly articulatory in nature. When articulating a low vowel such as [a] the jaw is too widely open for the other articulators to create sufficient oral constriction to effectively produce a glide. In the specific case of a hiatus position, this does not mean that there will not be any formant transitions between [a] and the following vowel, but these cannot be constricted into glide.[6] As the ban on low glides is clearly articulatory in nature, I formalize it as the ART constraint *[a̯] here. Due to the general articulatory impossibility to produce such low glides, this constraint must be ranked very high. Consequently, the candidate [χ**a**ːᵃoɔs] is ruled out. An unresolved hiatus is preferred over the insertion of a glottal element and [χ**a**ːɔs] is the winner.

[6] Mazaudon (2007) shows that the languages Marphali and Gurung feature a low glide [ʌ̯] or [a̯] However, in contrast to the Dutch vowel [a], they are characterized as being back and they do not appear in hiatus positions, but only in the context C_V. Furthermore, the constriction is argued to take place in the pharyngeal or uvular area, thus with a different shape and position of the tongue (more retracted) from that in the transition between [a] or even [ɑ] and any following vowel.

As shown by Jongenburger & Van Heuven (1991), in word-initial position vowels are phonetically preceded by a glottal stop. This is the result of two effects: a phonetic one formalized as the ART constraint SUDDENONSET and a more phonological one formalized as the CUE constraint */#/[ ] ("a left boundary of a prosodic word should not correspond to a phonetic zero").[7]

(28) Phonetic implementation of *appel* after a speech pause

/(ˈɑpə̣ɫ)/	*[a̭]	SUDDENONSET	*/ /[h]	*/#/[ ]	*[_ˀ]	*[VV]
☞ [_ˀ**ɑ**p˺_ᵖəɫ]					*	
[**ɑ**p˺_ᵖəɫ]		*!		*		
[h**ɑ**p˺_ᵖəɫ]			*!			

As can be seen in (28), the optimal candidate for the SF input /(ˈɑpə̣ɫ)/ is [_ˀ**ɑ**p˺_ᵖəɫ]. The CUE constraint */#/[ ] ensures that an optimal PF output maps the left word boundary in /(ˈɑpə̣ɫ)/ on a phonetic element. This means that the form [**ɑ**p˺_ᵖəɫ] is ruled out. In addition, the candidate [**ɑ**p˺ᵖ_əɫ] also violates the ART constraint SUDDENONSET. The idea behind this constraint is that the phonetic salience of a vowel, due to its high amplitude, goes hand in hand with a stronger buildup of subglottal pressure. This pressure is released suddenly resulting in a more abrupt release than in unstressed syllables, in turn resulting in a stronger constriction of the air flow. This constriction entails the production of a more constricted onset, in this case a glottal element.

The candidate [h**ɑ**p˺ᵖ_əɫ] neither violates */#/[ ] nor does it violate SUDDENONSET. However, the articulation of a glottal fricative in this onset position poses problems, especially in the perception direction, as it would imply the insertion of phonetic cues to a phonologically contrastive element. This is formalized as the cue constraint */ /[h]. The insertion of a glottal stop, on the other hand, does not pose this kind of problem since the glottal stop has no representation in phonology, see tableau (38). For that reason, */ /[h] is ranked higher than */#/[ ] since a violation of the former would entail the insertion of a phonologically contrastive element, whereas the latter does not. The winning candidate [_ˀ**ɑ**p˺ᵖ_əɫ] violates *[_ˀ], but this violation is not fatal.

[7] In this CUE constraint the left edge of a p-word is represented by a hash rather than by an opening parenthesis as in the input candidate. However, the only reason for this is the improved readability of the constraint. In SF transcriptions, parentheses are preferred as this way both the left and the right edges of words can be indicated easily.

(29) Phonetic implementation of *roodachtig*

/(ˈrout)(ˈɑχ.təχ)/	*[a̯]	SUDDENONSET	*/ /[h]	*/#/[ ]	*[_ˀ]	*[VV]
☞ [r**ou**t˺_ᵗ_ˀ**ɑ**χ_ᵗəχ]					*	
[r**ou**t˺_ᵗ**ɑ**χ_ᵗəχ]				*!		

Tableau (29) shows the phonetic implementation of /(ˈrout)(ˈɑχ.təχ)/.The candidate [r**ou**t˺ _ᵗ_ˀ**ɑ**χ_ᵗəχ] is favored over [r**ou**t˺ _ᵗ**ɑ**χ_ᵗəχ] because the latter does not implement the word boundary phonetically, thus violating */#/[ ]. It does not violate SUDDENONSET, though, because here we find the release of the alveolar closure in the onset before [**ɑ**], and this closure entails a maximum occlusion of the vocal tract. The winning candidate [r**ou**t˺_ᵗ_ˀ**ɑ**χ_ᵗəχ] does not violate this constraint either as here a glottal element is produced. This is a violation of *[_ˀ], but not fatal.

(30) Phonetic implementation of *koeachtig*

/(ˈku)(ˈɑχ.təχ)/	*[a̯]	SUDDENONSET	*/ /[h]	*/#/[ ]	*/#/[glide]	*[_ˀ]	*[VV]	*/#/[ˀ]
☞ [_ᵏ**u**_ˀ**ɑ**χ_ᵗəχ]						*		*
[_ᵏ**u**ʋ**ɑ**χ_ᵗəχ]					*!			
[_ᵏ**uɑ**χ_ᵗəχ]		*!		*			*	

As shown in Section 2, hiatuses across word boundaries are resolved with a glottal element in careful speech. For the word *koeachtig*, this means that we find the PF [_ᵏ**u**_ˀ**ɑ**χ_ᵗəχ] in careful speech. As this concerns the realization of the left edge of a word, in this case /(.ˈ**ɑ**χ.təχ.)/, the same mechanism as in (28), i.e. a joint effect of the constraints SUDDENONSET and */#/[ ], is at work. The candidate [_ᵏ**uɑ**χ_ᵗəχ] is ruled out since its second stressed vowel violates SUDDENONSET. Furthermore, it violates */#/[ ] by not marking the onset of the second word and *[VV] by juxtaposing two vowels. In order to rule out the form [_ᵏ**u**ʋ**ɑ**χ_ᵗəχ] with a transitory glide in the hiatus in favor of the expected form [_ᵏ**u**_ˀ**ɑ**χ_ᵗəχ], we need to introduce another constraint concerning the left edge of words: */#/[glide]. This constraint is short for {*/#/[j]; */#/[ʋ]; */#/[ɥ]} ("a left edge of a prosodic word should not correspond to [j], [ʋ] or [ɥ]"). For the sake of completeness, I also assume a parallel constraint */#/[ˀ] ("a left edge of a prosodic word should not correspond to a glottal element"). However, this constraint must be ranked very low since glottal elements are the standard means for marking otherwise vocalic onsets in Dutch, at least in slow speech. The ranking */#/[glide] >> */#/[ˀ] thus expresses the notion that marking a left edge of a word with a glide is less favorable than marking it with a glottal element. This ranking is also grounded in perception, where a glottal element poses no problems as it is never mapped onto a phonological segment, whereas this is less straightforward for transitory glides (see Section 4.2.4). In (30) */#/[glide] must also be ranked higher than *[_ˀ] and despite violating the latter, [_ᵏ**u**_ˀ**ɑ**χ_ᵗəχ] is the winner.

(31) Phonetic implementation of *januari*

/(ˌja.ny.ˈa.ri)/	*[a̯]	SUDDENONSET	*/ /[h]	*/#/[ ]	*/#/[glide]	*[_ˀ]	*[VV]	*/#/[_ˀ]
☞ [janyɥ**a**ri]								
[jany**a**ri]		*!					*	
[jany_ˀ**a**ri]						*		
[janyᶣ**a**ri]		*!						

As shown in (31), just as demonstrated for *duo* in tableau (26), in word-internal hiatus positions transitory glides are favored over glottal stops, which are ruled out by *[_ˀ]. However, the difference between *januari* and *duo* is that in (31) the second vowel involved in the hiatus is phonologically stressed and hence is mapped onto phonetic prominence of the concerning vowel. In this tableau, I distinguish between weakly constricted transitory glides, indicated by a superscript symbol, and more constricted transitory glides, indicated by a normal-sized symbol. The form [janyᶣ**a**ri] with a weak transitory glide, just like the form [jany**a**ri] with a juxtaposition of the vowels in the hiatus, does not meet the requirements of the articulatory effect represented as SUDDENONSET. Only the forms with a more constricted glide [ɥ] and with a glottal element [_ˀ] satisfy this ART constraint. The candidate [jany_ˀ**a**ri] with a glottal element is ruled out by the articulatory constraint *[_ˀ]. The CUE constraint */#/[glide], which ruled out the forms with glides (7), does not affect [janyɥ**a**ri] because it only refers to glides at word-boundaries and not to word-internal glides.

(32) Phonetic implementation of *chaotisch*

/(χaː.ˈou.tis)/	*[a̯]	SUDDENONSET	*/ /[h]	*/#/[ ]	*/#/[glide]	*[_ˀ]	*[VV]	*/#/[_ˀ]
☞ [χa_ˀ**ou**t˺_ᵗis]						*		
[χa_a̯**ou**t˺_ᵗis]	*!							
[χa**ou**t˺_ᵗis]		*!					*	
[χah**ou**t˺_ᵗis]			*!					

In a word like *chaotisch*, where the second syllable involved in the hiatus is stressed and where the first vowel is [a], the hiatus cannot be resolved with a strong transitory glide, because that is articulatorily impossible (*[a̯]). The violation of *[a̯] is fatal and [χa_a̯**ou**t˺_ᵗis] is ruled out. Instead, we find a glottal element in the hiatus after [a]. Crosslinguistically, the articulatory properties of open vowels seem to favor their cooccurrence with glottal stops. Furthermore, glottalized vowels tend to be perceived as lower (Brunner & Żygis 2011). For [a] this does not pose any problems as it is low already. The candidate [χa**ou**t˺_ᵗis] with an unresolved hiatus is overruled for the same reasons as in (31). A PF like [χah**ou**t˺_ᵗis] with an inserted [h] is ruled out by the constraint */ /[h] and despite violation the ART constraint *[_ˀ], [χa_ˀ**ou**t˺_ᵗis] is the winning candidate.

Similarly, we also find glottal elements in the word-internal hiatus when a phonetically salient vowel is preceded by [ə] (Gussenhoven 2007: 342). As pointed out in Section 2, this only affects forms that are prefixed with |bə|- or |χə|-. Booij (1999: 47–48, 68) provides conflicting evidence whether to treat the prefix |bə|- as its own word or not. Yet, as both prefixes undoubtedly do not have their own phonological stress, they are parsed as one word with the root that they are prefixed to in accordance with the constraint 1MAINSTRESS. This means we are in fact dealing with a word-internal hiatus here and the glottal element in the PF cannot be explained by the CUE constraint */#/[ ]. Instead, a phonetic explanation is necessary. In Dutch, all vowels that are followed by homorganic glides in the hiatus are high or mid-high (the mid-high vowels are even diphthongized and end in a high second element). The lax (more open) vowels, which are closer to [ə] in terms of their quality, as they are more open and centralized than the tense high vowels, never appear in open syllables and therefore are never involved in a hiatus. This means that even if [ə] is not as low as [a] it is still reasonable to assume an ART constraint against glides is generated from constricted vowel transitions after [ə]. This is formalized as the high ranked constraint *[ə̯] in tableau (33).

(33) Phonetic implementation of *beïnvloeden*

/(bə.ˈɪn.vlu.də(n))/	*[a̯]	*[ə̯]	SUDDENONSET	*/ /[h]	*/#/[ ]	*/#/[glide]	*[_ˀ]	*[VV]	*/#/[_ˀ]
☞ [b̰ə_ˀ**ɪ**nvlu‿ᵈə(n)]							*		
[b̰əə̯**ɪ**nvlu‿ᵈə(n)]		*!							

4.2.3 Phonetic implementation in fast speech

As demonstrated in Section 2, in fast speech the distribution of glottal elements is different than in slow speech and they occur less often, namely only in the onset of words after a pause and in word-internal hiatus positions of the shape [aˈV]. In fast speech, we see the same kind of hiatus resolution with transitory glides across word-boundaries as in word-internal hiatuses in slow speech. Furthermore, when there is no preceding vowel, the coda consonant of the preceding syllable phonetically moves into the onset instead, see example (11), section 2. In my analysis this effect can be explained as the higher ranking of the ART constraint *[_ˀ] in fast speech (cf. the higher ranking of *EFFORT in fast speech in Hamann (2020)). The explanation for this changed ranking is that it is more difficult to produce a glottal stop when the speech rate is higher as this disrupts the air flow and stream of voicing as the vocal cords are shut.[8]

This means that in slow speech /(ˈrout)(ˈɑχ.təχ)/ is phonetically implemented as [r**ou**t˺_ᵗ_ˀ**ɑ**χ_ᵗəχ], whereas in fast speech it is produced as [r**ou**t˺_ᵗ**ɑ**χ_ᵗəχ].

(34) Phonetic implementation of *roodachtig* in fast speech

/(ˈrout)(ˈɑχ.təχ)/	*[a̯]	*[ə̯]	SUDDENONSET	*/ /[h]	*[_ˀ]	*/#/[ ]	*[VV]
[r**ou**t˺_ᵗ_ˀ**ɑ**χ_ᵗəχ]					*!		
☞ [r**ou**t˺_ᵗ**ɑ**χ_ᵗəχ]						*	
[r**ou**t˺_ᵗh**ɑ**χ_ᵗəχ]				*!			

In this formalization, the only difference between the ranking in (29) and (34) is that *[_ˀ] is ranked higher now. It must be ranked higher than */#/[ ] because the first candidate, which has a phonetic cue for the word boundary, is ruled out by *[_ˀ]. Still, a form like [r**ou**t˺_ᵗh**ɑ**χ_ᵗəχ] is less optimal than [r**ou**t˺_ᵗ**ɑ**χ_ᵗəχ]] even though it complies with */#/[ ] because */ /[h] is ranked higher than */#/[ ]). None of the candidates violates SUDDENONSET. This also holds for the winning candidate

[8] Yet, see the discussion in Section 5 on the fact that the exact articulation of glottal elements varies between fully and less occluded forms depending on speech rate.

[r**ou**t¬_^{t}**ɑ**χ_^{t}əχ]. Here the alveolar closure is released into the stressed vowel [**ɑ**]. In (34) the constraints */#/[glide] and */#/[_^{ʔ}] are not shown to make the difference with (29) more evident, but they are still assumed to apply.

(35) Phonetic implementation of *koeachtig* in fast speech

/(ˈku)(ˈɑχ.təχ)/	*[a̯]	*[ə̯]	SUDDENONSET	*/ /[h]	*[_^{ʔ}]	*/#/[ ]	*/#/[glide]	*[VV]	*/#/[_^{ʔ}]
[_^{k}**u**_^{ʔ}**ɑ**χ_^{t}əχ]					*!				*
☞ [_^{k}**u**ʊ**ɑ**χ_^{t}əχ]							*		
[_^{k}**uɑ**χ_^{t}əχ]			*!			*		*	

As reported in Booij (1999: 67), /(ˈku)(ˈɑχ.təχ)/ is realized as [_^{k}**u**ʊ**ɑ**χ_^{t}əχ] in "casual speech". This can be seen in (35), where now the constraints */#/[glide] and */#/[_^{ʔ}] are included again. Because of the higher ranking of *[_^{ʔ}], [_^{k}**u**_^{ʔ}**ɑ**χ_^{t}əχ] is now ruled out and the hiatus is resolved with a transitory glide despite the violation of */#/[glide].

(36) Phonetic implementation of *chaotisch* in fast speech

/(χa.ˈou.tis)/	*[a̯]	*[ə̯]	SUDDENONSET	*/ /[h]	*[_^{ʔ}]	*/#/[ ]	*/#/[glide]	*[VV]	*/#/[_^{ʔ}]
☞ [χa_^{ʔ}**ou**t¬_^{t}is]					*				
[χa_a̯**ou**t¬_^{t}is]	*!								
[χa**ou**t¬_^{t}is]			*!					*	
[χah**ou**t¬_^{t}is]				*!					

A comparison of (32) and (36) reveals that the faster speech rate does not change the outcome for /(χa.ˈou.tis)/ and [χa_^{ʔ}**ou**t¬_^{t}is] is still the winner. The other candidates are still ruled out by *[a̯], SUDDENONSET and */ /[h], respectively, and the violation of *[_^{ʔ}] still is not fatal. In (35), the faster speech rate forces the hiatus to be resolved with a transitory glide since this is articulated more easily at a faster speech rate. In (36), however, this is not possible, because no such transitory glide is possible after [a], even in fast speech.

(37) Phonetic implementation of *appel* in fast speech

/(ˈɑp̣əɫ)/	*[a̰]	*[ə̰]	SUDDENONSET	*/ /[h]	*[_ˀ]	*/#/[ ]	*/#/[glide]	*[VV]	*/#/[_ˀ]
☞ [_ˀ**ɑ**p˺_ᵖəɫ]					*				*
[**ɑ**p˺_ᵖəɫ]			*!			*			
[h**ɑ**p˺_ᵖəɫ]				*!					

In the absolute onset, we always find a glottal stop before a vowel (no matter the speech rate) (cf. Jongenburger & van Heuven 1991). This is captured by our constraint ranking, which renders [_ˀ**ɑ**p˺_ᵖəɫ] the winner both in slow (28) and in fast speech (37). This is the case, as after a pause there is no preceding consonant that could be syllabified in the onset as in (10) nor is the vowel in a hiatus position, which would mean that constricted vowel transitions could satisfy SUDDENONSET and */#/[ ]. As a consequence, a candidate with a glottal stop is selected despite the high ranking of *[_ˀ] in fast speech.

The difference between slow and fast speech can only be seen when there is a preceding element, for example in *drie appels*. In slow speech *[_ˀ] is ranked low and [ᵈ̰r**i**_ˀ**ɑ**p˺_ᵖəɫs] is the winning candidate, whereas in fast speech [ᵈ̰r**ijɑ**p˺_ᵖəɫs] wins. This is the result of the same mechanism as shown for the input /(ˈku)(ˈɑχ.təχ)/ in (30) and (35), with the difference that the transitory glide has the quality [j].

4.2.4 Phonetic perception

The basic assumptions of the BiPhon model entail that the same constraint rankings applying in production are also at work in comprehension. In this section, this is demonstrated for phonetic perception, i.e the mapping from a PF input onto the SF.

In the constraint ranking in phonetic perception, there is no difference between slow and fast speech. In phonetic implementation, the difference at different speech rates was formalized as a change of the ranking of the ART constraint *[_ˀ]. In phonetic perception, the listener only relies on CUE and STRUCT constraints with the result that this ART constraint does not play a role. Still, the model entails that the ranking of the CUE constraint must be the same in phonetic implementation and phonetic perception, meaning that the ranking established in Sections 4.2.2 and 4.2.3 must ensure, e.g., that the PF [_ˀ**ɑ**p˺_ᵖəɫ] is mapped onto the SF /(ˈɑp̣əɫ)/. This is demonstrated in (38).

(38) Phonetic perception of *appel*

[_ˀ**ɑ**p˺_ᵖəɫ]	*[_ˀ]/ʔ/	*/ /[h]	*/#/[ ]	*/#/[glide]	*/#/[_ˀ]
☞ /(ˈɑpə̩ɫ)/					*
/(ˈʔɑpə̩ɫ)/	*!				

The phonetic input contains a glottal element [_ˀ] and the model must illustrate that it is not perceived as a phonological segment. This arises from the fact that I argue in this thesis that glottal elements are only the result of a combined effect of the ART constraint SUDDENONSET and the CUE constraint */#/[ ] and consequently do not have segmental grounding in phonology.

For phonetic perception this means that we have to assume an additional CUE constraint */ʔ/[_ˀ], which prevents a phonetic glottal release from being perceived as a phonological segment by being mapped onto phonological glottal stop /ʔ/. In that sense, this CUE constraint also implies a STRUCT constraint */ʔ/, which is not formalized here. This newly introduced CUE constraint must also be at work in phonetic implementation. However, this does not pose a problem at all because the SF input will never contain /ʔ/ and none of the PF output candidates will ever violate *[_ˀ]/ʔ/. In (38), the candidate /(ˈʔɑpə̩ɫ)/ is ruled out as it violates *[_ˀ]/ʔ/. The winning candidate /(ˈɑpə̩ɫ)/ violates the low ranked constraint */#/[_ˀ], but this is not fatal.

(39) Phonetic perception of *januari*

[janyɥ**a**ri]	*[_ˀ]/ʔ/	*/ɥ/[ɥ]	*/ɥ/[ᶣ]	*/ /[h]	*/#/[ ]	*/#/[glide]	*/#/[_ˀ]
☞ /(ˌja.ny.ˈa.ri)/							
/(ˌja.ny.ˈɥa.ri)/		*!					

Parallel to the assumption of */ʔ/[_ˀ], I assume the two CUE constraints *[ɥ]/ɥ/ and *[ᶣ]/ɥ/ to make sure that a labiopalatal transitory glide (no matter if weakly or strongly constricted) never maps onto an underlying segment /ɥ/ in the SF. Again, this is because there is no phonological element /ɥ/ in Dutch in my analysis and the CUE constraint *[ɥ]/ɥ/ implies a STRUC constraint */ɥ/, which is not formalized here. This rules out the candidate with a phonological labiopalatal glide in (39).

Despite not mapping onto a segment in the SF, a phonetic glide [ɥ] or [ᶣ] still serves as a secondary cue for the listener about other information in the SF: it reliably indicates that there must be a preceding front-rounded vowel and further that this vowel must be part of a hiatus in the SF, i.e. it is phonologically immediately followed by another vowel. In addition, the degree of constriction of the transitory glide ([ɥ] or [ᶣ]) indicates whether this following vowel is phonologically (and phonetically) accentuated. These secondary cues are not formalized in my model. On a similar note, a phonetic input [_ˀ] provides a secondary cue for a word boundary in the SF by satisfying */#/[ ].

(40) Phonetic perception of *koeachtig*

[_ᵏ**u**ʋ**ɑ**χ_ᵗəχ]	*/ʔ/[_ˀ]	*/ɥ/[ɥ]	*/ɥ/[ᶣ]	*/ /[h]	*/#/[ ]	*/#/[glide]	*/#/[_ˀ]
/(ˈku)(ˈɑχ.təχ)/						*!	
☞/(ˈku)(ˈʋɑχ.təχ)/							

As shown in (35), there are transitory glides in hiatuses across word boundaries in fast speech, such as the glide [ʋ] in [_ᵏ**u**ʋ**ɑ**χ_ᵗəχ]. In contrast to the constraints concerning the labiopalatal glide (*[ɥ]/ɥ/ and *[ᶣ]/ɥ/), we cannot assume a high-ranked CUE constraint *[ʋ]/ʋ/ or *[j]/j/ since /ʋ/ and /j/ are phonemes of Dutch and such a constraint would make wrong predictions for the mapping of words like *zeewater* ([ˈz**ei**ʋ**a:**t̚_ᵗər], 'sea water'), where the intervocalic glide is in fact phonologically contrastive. For the input [_ᵏ**u**ʋ**ɑ**χ_ᵗəχ], this means that the violation of */#/[glide] is fatal for /(ˈku)(ˈɑχ.təχ)/ even though this was the SF input in (35) and hence would also be the expected output in perception. Instead, the candidate /(ˈku)(ˈʋɑχ.təχ)/ wins. With the constraint ranking shown in (40) in phonetic perception, the disambiguation of /(ˈku)(ˈʋɑχ.təχ)/ as |ˈku| + |ˈɑχtəχ| must then take place in the mapping from SF onto UF, i.e. in recognition. In this process, |ˈku| + |ˈɑχtəχ| will win because there is no lexical entry for |ˈʋɑχtəχ|.

An alternative explanation to solve this issue in phonetic perception would be to assume phonetic differences between the transitory glides in *koeachtig* and the phonemic glides in *zeewater*. This is in line with Van Heuven & Hoos' (1991) finding that phonemic glides on average are between 46% and 52% longer than transitory ones (see Section 2). With the assumptions made above about the phonetic prominence of the following vowel affecting the constriction of the transitory glides, this would mean that we would have to postulate a phonetic ternary division into phonemic glides (strong constriction and longer duration, indicated by [**ʋ**]), transitory glides before stressed vowels (strong constriction and short duration, indicated by [ʋ]) and transitory glides before unstressed vowels (weak constriction and short duration, indicated by [ᶹ]). In a next step, the ranking of three corresponding CUE constraints */ʋ/[ᶹ] >> */ʋ/[ʋ] >> */ʋ/[**ʋ**] relative to

*/#/[glide] must ensure that the glide in *koeachtig* is not perceived as a segment in the SF, whereas the phonologically contrastive glide in *zeewater* would be. In the same way, the three constraints */j/[ʲ] >> */j/[j] >> */j/[**j**] are necessary since there are both phonemic and transitory palatal glides in Dutch. The constraint */ʋ/[**ʋ**] and */j/[**j**] must be ranked very low as the long, strongly constricted glides [**ʋ**] and /j/ should always be mapped onto the phonologically segment /ʋ/ and /j/, respectively. The constraints concerning the SF segments /ʋ/ and /j/ must be ranked lower than those concerning /ʔ/ and /ɥ/ as the latter two are impossible in the SF. This is formalized in tableau (41).

(41) Alternative phonetic perception of *koeachtig*

[_ᵏ**u**ʋ**ɑ**χ_ᵗəχ]	*/ʔ/ [_ˀ]	*/ɥ/ [ᶣ]	*/ɥ/ [ɥ]	*/ʋ/ [ᶹ]	*/j/ [j]	*/ʋ/ [ʋ]	*/j/ [j]	*/ / [h]	*/#/ [ ]	*/#/ [glide]	*/#/ [_ˀ]	*/ʋ/ [**ʋ**]	*/j/ [**j**]
☞/(ˈku)(ˈɑχ.təχ)/										*			
/(ˈku)(ˈʋɑχ.təχ)/						*!							

If we now compare tableaux (40) and (41), the CUE constraint */ʋ/[ʋ] makes sure that the candidate /(ˈku)(ˈʋɑχ.təχ)/ is ruled out before the violation of */#/[glide] is fatal for the candidate /(ˈku)(ˈɑχ.təχ)/.

What (40) and (41) did not show is how the phonetic input was mapped onto two words in the SF. In order to demonstrate this, we need to reintroduce the constraints /ˈσ/[**V**] and 1MAINSTRESS, which were first formalized in (25) and (26). In the perception direction /ˈσ/[**V**] now expresses that a phonetically prominent vowel should be perceived as phonological stress on the respective syllable. In (42) this is demonstrated for the input [_ᵏ**u**_ˀ**ɑ**χ_ᵗəχ], i.e. an item produced in slow speech. /ˈσ/[**V**] rules out the candidates that do not map both salient vowels [**u**] and [**ɑ**] onto stress in the SF. In addition, the STRUCT constraint 1MAINSTRESS makes sure that there can only be one syllable with main stress per word. This constraint rules out the candidates /(ˈku.ˈʔɑχ.təχ)/ and /(ˈku.ˈɑχ.təχ)/, which correctly perceive phonetically stressed vowels as phonologically stressed ones, but parse both into the same word. The remaining two candidates /(ˈku)(ˈʔɑχ.təχ)/ and /(ˈku)(ˈɑχ.təχ)/ correctly perceive the input as two words. The former is ruled out because it violates *[_ˀ]/ʔ/ by mapping the glottal stop onto a phonological segment as was already demonstrated in (38). The CUE constraints concerning glides in the SF are left out to make the tableaux easier to read but are still assumed to apply here.

(42) Phonetic perception of *koeachtig*; parsing as two words

[_^{k}**u**_ˀ**ɑ**χ_^{t}əχ]	/ˈσ/[**V**]	1MAINSTRESS	*[_ˀ]/ʔ/	*/ /[h]	*/#/[ ]	*/#/[glide]	*/#/[_ˀ]
☞ /(ˈku)(ˈɑχ.təχ)/							*
/(ˈku)(ˈʔɑχ.təχ)/			*!				
/(ˈku.ˈɑχ.təχ)/		*!					
/(ˈku.ˈʔɑχ.təχ)/		*!	*				
/(ˈku.ɑχ.təχ)/	*!						
/(ˈku.ʔɑχ.təχ)/	*!		*				

In (42) as well as in (38) a glottal element [_ˀ] was perceived as a word boundary in the SF. When such a segment appears in the word-internal hiatus, however, as in [χa_ˀ**ou**t˺_^{t}is], it should not map onto a word boundary. This phenomenon can be accounted for with the current constraint ranking, see (43).

(43) Phonetic perception of *chaotisch*

[χa_ˀ**ou**t˺_^{t}is]	/ˈσ/[**V**]	1MAINSTRESS	*[_ˀ]/ʔ/	*/ /[h]	*/#/[ ]	*/#/[glide]	*/#/[_ˀ]
☞ /(χa.ˈou.tis)/							
/(χa)(ˈou.tis)/		*!					*
/(χa.ˈʔou.tis)/			*!				

The output candidate /(χa)(ˈou.tis)/ violates */#/[_ˀ] by mapping the glottal element in the phonetic input onto a word boundary. However, this violation is not the fatal one as parsing the unstressed syllable /χa/ as its own word violates the higher ranked 1MAINSTRESS. The form /(χa.ˈʔou.tis)/, maps the glottal element in the input onto the segment /ʔ/ in the SF I ruled out by *[_ˀ]/ʔ/. The expected output candidate /(χa.ˈou.tis)/ remains as the only viable option. The same mechanism also applies to PF inputs, with a glottal stop in the word-internal hiatus after [ə], as in [b̰ə_ˀ**ɪ**nvlṵ^{d}ə(n)]. The constraint ranking in (43) would correctly predict that they are perceived as one word in the SF.

In this section, I presented an Optimality-Theoretic account in the BiPhon model, which can account for all the linguistic facts concerning the alternations between glottal elements and homorganic glides in word-internal hiatus positions and word onsets in Dutch. Still, this model is a simplification in some regards. The following section discusses some further phonetic and distributional details, which should be investigated in future studies in order to validate my assumptions and to make a more fine-grained analysis possible.

5. Discussion and desiderata

The analysis presented in the previous section is largely based on descriptive accounts of the distribution of the relevant sounds found in the literature and a limited number of experimental studies. However, those only provide phonetic data for some of the relevant linguistic contexts and do not cover all assumptions made in the descriptive literature as well as in my analysis. It would be desirable to be able to further support some other linguistic details with more phonetic studies on homorganic glides and glottal elements in Dutch in future research.

Van Heuven & Hoos (1991) found strong durational differences between phonemic and transitory glides across word boundaries. I assumed the same differences to also hold between phonemic and transitory glides within words. However, this condition was not included in Van Heuven & Hoos' (1991) experiment and should be confirmed in future research. On a similar note, based on the labels used in the descriptions by Booij (1999) and Gussenhoven (1980), in terms of quality, I distinguish only among three homorganic glides [ʋ], [j] and [ɥ]. In a rule-based phonological analysis where the glides are argued to be generated from the preceding vowel these labels are sufficient. In my analysis, using these same symbols, however, is a simplification. As I argue that these homorganic glides result from the constriction of the formant transitions between the vowels in hiatus positions, I expect the exact quality, despite always being high, to depend on the quality of the surrounding vowels at least somewhat. Hence, the glide transcribed as [ɥ] both in the words *duo* and *reuen* might turn out not to be exactly the same in a more fine-grained phonetic analysis of speech data. Relatedly, my analysis presumes durational differences and difference in terms of the degree of the glides depending on the stress pattern of the vowels in the hiatus. In this sense, I use the symbols [ʋ], [j] and [ɥ] as descriptive umbrella terms that do not necessarily capture all fine phonetic details of the transcribed sounds. To account for these durational and potential differences in degree of constriction in my analysis, I employed different symbols in the phonetic form, with a distinction made between strongly constricted and longer glides corresponding to phonemic glides ([**ʋ**], [**j**]), shorter, constricted transitory glides preceding prominent vowels ([ʋ], [j], [ɥ]) and short, less constricted transitory glides preceding non-prominent vowels ([ᶹ], [ʲ], [ᶣ]). As mentioned above, Van Heuven & Hoos (1991) confirm only durational differences between phonemic and transitory glides. To validate the assumptions made in my analysis, future studies should also find durational differences within transitory glides predicted by the factor stress, as well as differences in the degree of constriction.

Another point where my analysis would benefit from further development is the treatment of what I call *glottal elements*. I consistently transcribe them as [_ˀ] in the PF. The reduced prevalence of glottal elements in fast speech is explained by the higher ranking of the ART constraint *[_ˀ]. What Pompino-Marschall & Żygis (2010) show, at least for German, however, is that in fast speech not only the overall glottal marking of vocalic word onsets increases, but also that the relative number of creaky voice/glottalization increases from 22.0% to 30.6% when comparing slow and fast speech.[9] If the same phonetic facts should be replicable in Dutch, my analysis should be adjusted by accounting for such a change of glottal marking in fast speech in a more continuous rather than in a categorical way.

The analysis presented in Section 4.1 assumes that glottal marking in word-initial position disappears in faster speech rates, whereas it is retained in word-internal hiatuses after [a] and [ə]. Gussenhoven (2007: 342), though, claims that glottal elements appear only optionally in this position (and in any other position, too). Experimental data should confirm whether glottal elements are in fact obligatory in this position or if an unresolved hiatus [χa**ou**t˺_ᵗis] is viable in Dutch. Furthermore, other hiatus resolution strategies might be eligible in very fast speech, such as the elision of one of the vowels, e.g. [χ**ou**t˺_ᵗis]. Again, this is a tentative assumption only and needs further experimental backing.

This thesis argued that glottal elements and homorganic glides are both the result of an articulatory mechanism and further provide phonological cues for word boundaries. An alternative analysis of glottal stops in Dutch, which attributes to those elements a more prominent phonological role, would be to treat them as a phoneme. This view is forwarded by Reker (1983). However, this view is problematic in various regards. First of all, an important issue is in what positions an underlying glottal stop should be assumed. This is especially problematic given such intraparadigmatic alternations between a phonetic zero and a glottal element as in [χ**a**ːɔs] and [χa_ˀ**ou**t˺ _ᵗis]. If we assume an underlying glottal stop here, it must be phonetically or phonologically outruled in [χ**a**ːɔs]. Further, Reker (1983) argues that all forms with word-internal

[9] In the same data, umarked onsets, i.e. those neither having a glottal stop nor employing creaky voice increase from 30.1% in slow speech to 53.2% in fast speech.

homorganic glides should be analyzed as having an underlying glottal stop, which is phonetically implemented as a glide. However, such an analysis poses problems in terms of learnability. It is not very convincing to argue that a learner could deduce an underlying glottal stop in all these positions, given that there are more contexts where no cues for such a glottal stop or cues for other segments occur. Even if we do not assume word-internal homorganic glides to be derived from a glottal stop, it is still hard to maintain the status of a phonemic |ʔ|. In the remaining positions, i.e. in the onset of vowel-initial words after a speech pause and in the word-internal hiatus after [a] and [ə] its occurrence is fully predictable and it never meaningfully contrasts with forms without such glottal marking. The difference between, e.g., the PF [ɛŋəɫ] and [_ˀɛŋəɫ] without and with glottal marking is not meaningful as both would be ultimately comprehended as |ˈɛŋəl| ('angel'). On the other hand, the difference between a form without an onset and that with another segment, e.g. [h] in the onset, i.e. the difference between [ɛŋəɫ] and [hɛŋəɫ] is meaningful, with only the former being comprehended as |ˈɛŋəl| ('angel') and the latter as |ˈhɛŋəl| ('fishing rod').

Different theoretical frameworks differ as to whether they treat the mapping from phonology onto phonetics (and vice versa) as automatic or language-specific (cf. Hamann 2011). A comparison of the Dutch facts concerning hiatus resolution with those presented for American English by Davidson & Erker (2014) reveals that language-specific mechanisms are easier to justify. In American English, hiatuses, just like in Dutch, can be either left unresolved or be resolved with glottal elements or the insertion of glides. However, the exact realizations and the distribution of these sounds crucially is different than in Dutch. Within words there is a strong tendency to leave hiatuses unresolved, whereas across word boundaries the insertion of a glottal element is the preferred resolution strategy. These differences can easily be accounted by means of a language-specific ranking of CUE and ART constraint, whereas an automatic interface between phonology and phonetics would predict the same PF realization of hiatuses in both languages.

Noske (2005, 2007a, 2007b) argues that the distribution of glottal elements in Belgian Dutch (BD) is different from that in Netherlandic Dutch. Whereas he shows that the distribution in word-internal hiatus positions is the same, i.e. when [a] or [ə] is followed by a prominent vowel, he points out that the behavior in compounds and affixed forms is different. Rather than inserting a glottal stop at the left edge of an otherwise vowel-initial word, the preceding coda segment appears in the onset of the following syllable. This is demonstrated for the word *uiteindelijk* ('finally') in (44), morphologically consisting of the prefix *uit-* and the stem *eindelijk*.

(44)	*uiteindelijk*	|ˈœyt| + |ˈɛindələk|	ND	[_ˀ**œy**t̚_ᵗ_ˀ**ɛi**n̰ᵈələk̚_ᵏ]
			BD	[_ˀ**œy**t̚_ᵗ**ɛi**n̰ᵈələk̚_ᵏ]

(adapted from Noske 2005: 476)

This means that hiatuses are resolved differently in Belgian Dutch than in Netherlandic Dutch and we have to assume a different constraint ranking for this variety. However, the PF in Belgian Dutch is the same as we would expect in fast speech in Netherlandic Dutch and the constraint ranking shown in (34) with a higher ranking of *[_ˀ] captures the Belgian data when assumed to apply independently of speech rate.

6. Summary

To conclude, this thesis presented an Optimality-Theoretic account of hiatus resolution in Dutch within the framework of the Bidirectional Model of Phonololgy and Phonetics. The occurrence of both glottal elements and transitory homorganic glides was argued to be the result of mechanisms applying in the mapping from the phonological Surface Form onto the Phonetic Form via CUE constraints and ART constraints. More specifically, glottal elements can be the result of an articulatory mechanism requiring a constricted segment to precede a phonetically prominent value. This is due to the sudden release of a relatively higher subglottal pressure and was formalized as the ART constraint SUDDENONSET. The occurrence of glottal elements in the onset of otherwise vowel-initial words required an additional explanation: besides the constraint SUDDENONSET, a CUE constraint */#/[ ] necessitates the explicit implementation of left word edges in the PF. The occurrence of homorganic glides preceding prominent vowels could also be accounted for with the same constraint SUDDENONSET. It is satisfied by constricting the formant transitions between the two vowels. The somewhat constricted vowel transitions in all other word-internal hiatuses are the result of a disfavoring of unresolved hiatuses. At faster speech rates, glottal elements are produced less readily due to articulatory reasons and instead the same mechanism for hiatus resolution as within words applies in hiatuses across word boundaries. Since the functional load of this analysis is in phonetics rather than in phonology, no phonological constraint ONSET was necessary to account for the linguistic facts as was done in previous analyses (Kager & Martínez-Paricio 2018; Rosenthall (1994); Rubach (2002); Smith (2002)).

In perception, the same constraint ranking that was used in production made the correct predictions, too. Here, however, glottal elements and the labiopalatal glide [ɥ] in a hiatus are less ambiguous than the glides [j] and [ʋ] as the former two never map onto a phonological segment, whereas the latter two can. For the cases with phonetic [j] and [ʋ] two possible solutions were suggested: either the disambiguation takes place at a level of representation where lexical knowledge plays a role or there are durational differences between these glides depending on if there are transitory only or correspond to an underlying segment.

In short, this thesis provided a full Optimality-Theoretic analysis of hiatus resolution accounting for all relevant linguistic facts. Still, some details ought to be confirmed in future phonetic studies.

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