Stop! Hey, what's that sound? the representation and realization of Danish stops

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Part I

The big picture

CHAPTER 2

Previous research on Danish stops

2.1 Preliminaries

Standard Danish has six contrastive stops /b d g p t k/. In pre-vocalic onset position, the distinction between the two laryngeal series is uncontroversially based on aspiration.[1] /b d g/ are realized as voiceless unaspirated, /p t k/ are realized as voiceless aspirated. /b d g/ are sometimes claimed to have voiced medial allophones. /t/ has a salient affricated release, and is usually transcribed phonetically with superscript *s* [tˢ]. The most common phonological analysis of Danish stops suggests that the unaspirated stops show complex alternations with semivowel and zero allophones. All of these patterns are subject to variation in traditional dialects, although existing sources focus mostly on variation in categorical phonological patterns.

In this chapter, I aim to provide a comprehensive literature review of the history, phonetics, phonology, and variation of Danish stops. As discussed in the previous chapter, these are a very well-described set of sounds, although a number of open questions still remain. Relevant parts of the history of the language are covered in Section 2.2, since

[1]This is at least the case at the phonetic level (see Section 2.4.3).

diachronic developments will be important in interpreting the standard analysis of synchronic stop gradation, and will play a key role in the reanalysis proposed in Chapter 3; see Section 1.3 for a more general sketch of the history of Danish. In Section 2.3, I cover the results of previous studies of acoustic and articulatory phonetics. In Section 2.4, I turn to phonology, covering positional allophones and distributional properties of the stops, and the mechanisms that have been taken to be relevant in their underlying representation, before moving to the complex gradation processes whereby the voiceless unaspirated stops are usually taken to have semivowel or zero allophones in weak prosodic position. Finally, I give an overview of what we know about social and regional variation in the phonology and phonetics of stops, as well as phonetic reduction, on the basis of the existing literature in Section 2.5. Many of these topics will also be relevant in later chapters, but some are simply covered in this chapter in order to give as comprehensive an overview as possible of previous research on Danish stops.

2.2 History

In this section, I will briefly cover the history of the Danish stops and their main (proposed) allophones, namely semivowels. There is a long established and broad research tradition in Germanic historical linguistics, so this overview will not be comprehensive; I mostly stick to presenting facts which will become important in later chapters. Here, I will cover the historical sources of the current Modern Standard Danish stops and their allophones (Section 2.2.1), and recently attested changes in these (2.2.2).

2.2.1 Historical sources of stops and semivowels

This section covers the gross historical changes that led to the current inventory of stops and semivowels. There are of course counter-examples, and several well-described patterns of sounds behaving differently in e.g. consonant clusters, which I will not cover here. For more comprehensive overviews of these sound changes, see e.g. Brøndum-Nielsen (1928–1973), Skautrup (1944–1970), Hansen

(1962–1971), Brink and Lund (1975), Bandle et al. (2002–2005), and Hjorth (2017–2022).

Ancient Nordic largely retained the consonant inventory from Proto-Germanic (Braunmüller 2002), including the set of stop phonemes that is still retained in the modern Scandinavian languages: /b d g p t k/. These were also the stops found in Old Danish (Brøndum-Nielsen 1928–1973).

Old Danish /p t k/ developed from the Proto-Indo-European (PIE) voiced stops *b d g, which lost their voicing as a consequence of Grimm's law (Ringe 2006). These are now aspirated in onset position, but there is disagreement in the literature regarding when they developed aspiration, as discussed further in Sections 2.2.2 and 3.5.3; in German, they variably developed further into affricates as part of the Second Consonant Shift. An example is PIE *dn̥ǵ^{h}wéh$_2$- > Proto-Germanic *tungōn- > Norse *tunga* > Modern Standard Danish [ˈt^{h}ɔŋ] *tunge* 'tongue', cf. German [ˈtsʊŋə] *Zunge* (Ringe 2006: 81; DSL 2018).

Old Danish /b d g/ developed from different sources, but mostly from PIE breathy voiced stops *b^{ɦ} d^{ɦ} g^{ɦ}, which in some contexts were retained as stops in Proto-Germanic.[2] An example is PIE *g^{ɦ}óstis 'stranger' > Proto-Germanic *gastiz 'guest' > Norse *gestr* > Modern Standard Danish [kɛst] *gæst* (Ringe 2006: 97; DSL 2018). Many of the current words with initial /b d g/ were later borrowings. They are no longer phonetically voiced in onset position, and it is unclear when voicing was lost (as discussed further in Section 3.5.3). The laryngeal contrast in especially /b p/ has historically been rather unstable.

The PIE voiceless stops *p t k developed into Proto-Germanic voiceless fricatives *f θ x with Grimm's law, and as a result of Verner's law, these were voiced in medial and final position *v ð ɣ; both developments can be seen in in the development of PIE *ph$_2$tḗr 'father', which further developed into *faþḗr, and is reflected in Norse as *faðir* and Danish as [fɑː] *far*, or [ˈfæːɣ̞ɐ] *fader*, which is still used in e.g. biblical contexts (Ringe 2006: 102).[3] The dental fricative [θ], which was retained in Old Danish, hardened to a voiceless stop in Early Modern Danish

[2] According to Hansen (1962–1971: II), they were variably assibilated during this stage.

[3] [ɣ̞] is the modern reflex of [ð], as discussed in Section 2.2.2 below.

and in the other East Scandinavian languages (Boeck 2018), significantly increasing the number of /t/-initial words; see for example Norse *þing* > Modern Standard Danish [tʰeŋˀ] *ting* 'thing'. A similar development took place in Frisian (Laker 2014).

Germanic developed a quantity contrast between singleton and geminate stops. The sources of gemination are somewhat controversial, and there are many open questions (Goblirsch 2018). The mechanisms differed between branches of Germanic, but a common suggested mechanism was the development of geminates from stop + nasal clusters; this is referred to as Kluge's law (Kluge 1884; Lühr 1988). In the East Nordic languages, geminates further developed from some stop + glide clusters, where the glide was originally retained but is lost in Modern Standard Danish; see Proto-Germanic *ligjaną > Norse *liggja* > Modern Standard Danish [ˈlekə] *ligge* 'lie' (Ringe 2006: 253; DSL 2018). Other geminates derived from /h/ + stop clusters (Nielsen and Stoklund 2018). Old Danish had a distinction between voiceless geminates [pː tː kː] and voiced geminates [bː dː gː], but this contrast was rather unstable, and neutralized in favor of the voiceless set sometime early in the Middle Danish period (Sørensen 2012). Occasionally, this happened in concert with compensatory lengthening of the preceding vowel, as in Norse *skegg* 'beard' > Modern Standard Danish [skɛːˀk] *skæg*, cp. Norse *bekkr* 'stream' > Modern Standard Danish [pɛk] *bæk* (DDO 2018).

In the beginning of the Middle Danish period (ca. 1100–1500), final devoicing leads to positional neutralization of the laryngeal contrast in stops (Frederiksen 2018). First attested around the year 1400 and continuing throughout Early and Late Modern Danish (Boeck 2018; Brink and Lund 2018), a number of important lenition processes take place, including what is known as *spirantsvækkelsen* 'spirant weakening' and *klusilsvækkelsen* 'plosive weakening'. Spirant weakening describes a series of related changes, whereby voiced fricatives (found only post-vocalically) changed into approximants or were lost. The processes are shown in (1), following (Frederiksen 2018).

(1)	[v]	→	[w]		
	[ð]	→	Ø or [j]		
	[ɣ]	→	Ø	/	_ [+high]
			[j]	/	_ [-back, -round]
			[w]	/	_ [+back]
			[j] or [w]	/	_ [+round]

The different outcomes for [ð] in (1) were largely regionally determined, and not consistent; [ð] was often retained. The precise place of articulation of [ɣ] likely already varied greatly by place of articulation of the preceding vowel; the tongue position in velars is generally highly dependent on surrounding vowels (e.g. Vilain et al. 1998), and the distribution in (1) is similar to the well-known distribution of *ich-Laut* and *ach-Laut* in German; cf. Hall's (1989) rule of German Fricative Assimilation. The consequences of this are discussed in further detail in Section 3.5.2.5 below.

A corresponding plosive weakening chain was consistent across the Danish-speaking area, although realized in various ways in different regional varieties. Here, I cover the outcome in the area around Copenhagen, but see Section 2.5.3 for an overview of different outcomes of plosive weakening. In Copenhagen Danish, plosive weakening was a chain of sound changes with much the same end result as spirant weakening: following a series of well-motivated sound changes (see Section 3.5.2), the stops [p t k] lenited to voiced fricatives in post-vocalic position, following the patterns in (2).

(2)	[p]	→	[v]
	[t]	→	[ð]
	[k]	→	[ɣ]

These voiced fricatives subsequently lenited to approximants in analogous ways to spirant weakening (1), although as with spirant weakening, [ð] was largely retained as a voiced fricative (until the 20th century; see Section 2.2.2). The change [p] → [ʊ] was presumably largely complete in earlier stages of the language, but this change was later rolled back in many varieties including Modern Standard Danish, such that most of these words are again realized with [p] (see Chapter 3, in particular Section 3.5.2.5).

The geminate stops underwent degemination sometime after the plosive weakening chain was completed, and were not affected by it; in West Jutlandic varieties, these developed into preglottalized stops, a phenomenon known as *vestjysk stød* 'West Jutlandic stød' (Ringgaard 1960). West Jutlandic stød parallels preaspiration in Icelandic and Faroese (e.g. Thráinsson 1978; Page 1997).[4] In Modern Standard Danish, these are plain voiceless stops [p t k].

2.2.2 Recent changes in stops and semivowels

According to Brink and Lund (2018), voicing in /b d g/ was lost sometime before 1700. This conclusion is rather controversial. Several scholars have argued that Proto-Germanic did not have distinctive voicing, but rather distinctive aspiration (e.g. Iverson and Salmons 1995, 2003a; Honeybone 2002). The bulk of the modern daughter languages do indeed have an aspiration-based contrast. However, there *are* traces of a voicing-based contrast in regional varieties of Danish (see Setion 6.6), and the results of spirant weakening and plosive weakening are arguably easier to explain if a voicing-based contrast is assumed in earlier stages of the language. This is tricky to resolve, but will be discussed further in Chapter 3, in particular Section 3.5.3. If we assume that Brink and Lund (2018) are right, and Danish had voicing until relatively recently, it is unclear if aspiration in /p t k/ developed simultaneously or was already present.

The 19th century saw the loss of the final vestiges of velar fricatives in Copenhagen Danish (Brink and Lund 1975). [ɣ] was either lost or replaced entirely by [j w] following the distribution in (1). [x], which occurred only before [t] in post-vocalic consonant clusters, hardened to [k].

A number of changes affected [ð], which is usually considered an allophone of /d/ (see Section 2.4): sometime before the 19th century, it weakened to a very open approximant or semivowel (the 'soft d'; see Brotherton and Block 2020), which is described as alveopalatal by Grønnum (1998). There is no fitting IPA symbol, so usually [ð] (or

[4] In fact, Kortlandt (1985) argues on the basis of a.o. West Jutlandic stød that preaspiration and glottalization in present-day Germanic languages are reflexes of glottalic stops in PIE.

[ð̞]) are used, mostly for historical reasons. The approximant has more recently developed a secondary dorsal articulation (Brink and Lund 2018); an ultrasound tongue imaging study by Siem (2019) suggests that this dorsal gesture is actually often of a greater magnitude than the coronal gesture. I follow Schachtenhaufen (2022) in using [ɤ̯] to transcribe the semivowel as realized in Modern Standard Danish.[5] The soft d participates in a number of frequent and obligatory schwa assimilation processes of the form /əɤ̯, ɤ̯ə/ ⟶ [ɤ], so it is often realized as fully syllabic (e.g. Brink and Lund 1975: 191ff., Basbøll 2005: 293ff.). In a recent development, the soft d has begun to assimilate not just with schwa, but also with preceding front vowels, such that it appears as syllabic *and* stressed; Brink (2013) mentions neutralization of the contrast between /i e æ/ in *bid bed bad* 'bite pray bathe', all of which can be realized as [pɤˀ].

2.2.3 Summary

The Modern Standard Danish initial unaspirated stops mostly developed from PIE breathy-voiced stops, and there is no agreement in the literature regarding when they lost their voicing. The current initial aspirated stops mostly developed from PIE voiced stops. The PIE voiceless stops developed into fricatives, but the coronals later hardened to aspirated stops. In medial and final position, both fricatives and stops weakened dramatically in earlier stages of Danish, eventually eliding or becoming approximants. In Germanic, medial and final geminates developed from a number of sources; these resisted post-vocalic lenition, and are now retained as medial and final voiceless unaspirated stops.

[5] This seems a better fit than [ð̞], but is still rather imprecise. The sound is centralized relative to the canonical position of [ɤ] (Juul et al. 2016; see also Section 1.4), and the tongue blade is somewhat raised. Anecdotally, non-native listeners often perceive the soft d as lateral, possibly due to the coronal component.

2.3 Phonetics

This section provides an overview of existing research on the phonetics of stops in Modern Standard Danish. This research can be divided into a number of subcategories. I will discuss, in turn, existing research on aspiration and voice onset time (Section 2.3.1); closure voicing (Section 2.3.2); actions of the glottis and larynx during stop production (Section 2.3.3); affrication during release (Section 2.3.4); articulatory force (Section 2.3.5); and finally, perturbations of fundamental frequency (F_0) resulting from the laryngeal setting of preceding stops (Section 2.3.6).

2.3.1 Aspiration and voice onset time

Grønnum (2005: 303ff.) has claimed that the only relevant difference between the two laryngeal stop series is aspiration. This applies only to onset position, as there is no (phonetic) laryngeal contrast in syllable-final stops;[6] the phonological situation may be more complicated, as discussed in Section 2.4.4 and further in Chapter 3. According to Grønnum, the only articulatory difference between /b d g/ and /p t k/ in onset position is the degree of glottal opening at the time of release. For /p t k/, the glottis is spread widely apart; for /b d g/, the vocal folds are adducted and tensed. As we will see in the coming paragraphs and chapters, there are a number of reasons why the claim that this is the only relevant difference must be an oversimplification.

Jespersen (1906: 60ff.) made a distinction between two sets of aspirated sounds, *bepustede* ('blown') and *beåndede* ('breathed'). The 'blown' aspirated sounds are found in strong, stressed position, and 'blown' probably refers to the salient burst that is found in this position.[7] The 'breathed' aspirated sounds are found in unstressed onset position, and have no salient burst, but they still have delayed voicing onset. This idea illustrates an important point about the phonetics of Danish stops: aspiration is always possible in onset

[6]Syllable-final stops may also be aspirated, especially if they are in phrase-final position, but this is not contrastive (Grønnum 2005: 49).

[7]According to Jespersen (1906: 61), at the time of release, the "air pressure behind the closure is so much stronger than that outside, that an explosion happens and a bang is heard" (my translation).

position, regardless of stress or position within the phrase. This is illustrated by words like [p^{h}æˈt^{h}eːˀt^{h}isk] *patetisk* 'emotive, pathetic'.

A common method for classifying laryngeal stop contrasts based on pre-voicing and aspiration is voice onset time (VOT), popularized by Lisker and Abramson (1964). In this seminal paper, the authors investigate stop contrasts in 12 different languages, and conclude that stops generally fall into four categories, which can mostly be summarized with reference to the timing of voicing onset: voiceless unaspirated, voiced unaspirated, voiceless aspirated, and voiced aspirated. In voiced stops, vocal fold vibration begins at some point during the closure (negative VOT); in voiceless unaspirated stops, vocal fold vibration begins very shortly after the release (near-zero positive VOT); in voiceless aspirated stops, vocal fold vibration is delayed (high positive VOT). Only voiced aspirated stops cannot be easily defined on the basis of VOT. VOT measurements remain very prevalent in the phonetics literature, and as more languages have been studied, Lisker and Abramson's neat three-way VOT distinction has been put increasingly into question. In Cho and Ladefoged's (1999) study of 18 languages, they make a four-way categorization of positive VOT: unaspirated, slightly aspirated, aspirated, and highly aspirated. Ladd (2011) points out that as more and more languages are added to these typologies, any kind of categorization of the VOT continuum is likely to become increasingly moot. On a related note, in recent years, large-scale studies using VOT measurements have often relied exclusively on positive VOT (e.g. Stuart-Smith et al. 2013, 2015; Chodroff and Wilson 2017; Chodroff et al. 2019). There are a number of reasons for this: negative VOT is difficult to measure automatically (Sonderegger and Keshet 2012), and determining the starting point for measuring negative VOT is problematic in anything but absolute initial position.

Studies of the relative timing of voicing onset in Danish stops precede Lisker and Abramson (1964). The duration of aspiration in Danish stops (i.e. positive VOT) is measured by both Abrahams (1949) and Fischer-Jørgensen (1954), and VOT in Modern Standard Danish has been measured in several studies since. The results of some of these studies are compared in Table 2.1. Fischer-Jørgensen (1954) worked with a corpus of roughly 3,000 spectrograms from 10 speakers, although it is not clear how many of these were measured to arrive

Table 2.1: *Overview of mean positive voice onset time in ms in different studies. The numbers in parentheses indicate ranges of individual averages. Mortensen and Tøndering (2013) do not provide absolute means, but only means by vowel height and vowel aperture. Range of means by vowel height are reported here.*

	FJ (1954)	FJ (1980:a)	FJ (1980:b)	FJ (1980:c)	MT (2013)
/b/	14	17	22	12	13–19
/d/	17	23	23	24	18–26
/g/	23	30	34	30	27–36
/p/	66 (53–97)	60 (51–76)	69 (54–76)	93 (78–103)	65–70
/t/	79 (64–98)	75 (71–89)	84 (75–93)	115 (88–135)	84–86
/k/	74 (60–91)	73 (64–96)	81 (64–94)	106 (94–118)	63–80

at the VOT means in Table 2.1. Her results conform well to those of Abrahams (1949). Based on this, she classifies /p t k/ as strongly aspirated, and /b d g/ as unaspirated or lightly aspirated.

It is not clear from Fischer-Jørgensen (1954) how aspiration is delimited, but this is something she has discussed at length in later writings (Fischer-Jørgensen and Hutters 1981). In later papers, and likely also in the 1954 paper, her acoustic landmark for delimiting aspiration is the appearance of higher formants. This makes the measurements reported by Fischer-Jørgensen (1979, 1980) relatively difficult to compare to typological overviews of VOT, since recent studies commonly use the onset of periodicity in the waveform to delimit aspiration, and Fischer-Jørgensen and Hutters (1981) show that there are non-trivial and unpredictable differences between these two methods. Francis et al. (2003) find that the onset of periodicity in the waveform is the landmark that most closely corresponds to the physiological onset of vocal fold vibration; however, Fischer-Jørgensen and Hutters (1981) rightly point out that measurements made at the onset of higher formants are more stable across vowel heights. It is worth pointing out that relying on higher formants only works when measuring VOT in CV-sequences, and that waveforms display higher temporal accuracy than spectrograms.

Fischer-Jørgensen (1979, 1980) investigated the relationship between a number of temporal cues to the laryngeal contrast in stops. She measured both VOT, closure duration, and following vowel duration. She found consistently longer VOT and shorter vowel duration in /p t k/, which is in line with expectations; she also found consistently shorter closure duration in /p t k/, which is cross-linguistically uncommon (this is discussed in more detail in Section 2.3.5). Interestingly, she also found social stratification of the aspiration cue. She split her informants into three groups: a) non-Copenhageners, b) older Copenhageners (born before 1938), and c) younger Copenhageners (born after 1938). She only worked with a total of 18 participants, so it is a limited data basis, but her results quite stably show that Copenhageners had longer VOT values than non-Copenhageners, and that VOT was longest for younger Copenhageners. This suggests a change in progress at the time: very strong aspiration is a recent Copenhagen-based innovation. This is in line with an historical account where the transition from a voicing system to an aspiration system is relatively recent (Brink and Lund 2018; see Section 2.2).

Mortensen and Tøndering (2013) is the most recent account of VOT in Danish stops, based on roughly 3,000 tokens of stressed CV syllables in the DanPASS corpus of spontaneous speech (see Section 4.5.1). Mortensen and Tøndering follow Fischer-Jørgensen in using the appearance of higher formants as their acoustic landmark for VOT measurements. Interestingly, the results of Mortensen and Tøndering's VOT measurements are more in line with Fischer-Jørgensen's (1980) findings for older speakers outside the Copenhagen area. This is obviously inconsistent with an account of VOT increasing with time, but there may be a number of possible explanations. For example, Mortensen and Tøndering's measurements come from spontaneous recordings, and Fischer-Jørgensen's measurements are seemingly from read word lists. This highlights the difficulty with comparing VOT measurements across studies with different designs.

In Chapter 5, I also report VOT measurements of /p t k/ from the DanPASS corpus, using the onset of periodicity in the waveform to delimit aspiration; unlike Mortensen and Tøndering (2013), these measurements are not exclusively taken from stressed syllables. Unsurprisingly, I find average VOT values that are significantly shorter than those in Table 2.1. These are later compared to VOT measurements from traditional Jutlandic varieties of Danish in Section 6.5.

A number of linguistic and extralinguistic factors are known to influence VOT, and many of these are covered in some detail in Section 6.5. Mortensen and Tøndering's (2013) study explicitly investigates the effect of following vowel height on VOT, comparing the traditional IPA-based classification (high, mid, and low) with a physiological four-way classification of aperture in Danish vowels suggested by Grønnum (2005: 105). They find similar effects across the two different ways of categorizing vowels, but only find a significant influence of vowel height/aperture on VOT in /b d g/, where VOT is generally longer before high/close vowels, and shorter before low/open vowels. Fischer-Jørgensen (1980) found this in both aspirated and unaspirated stops. Additionally, Andersen (1981a) investigated the influence of speech rate on the articulation of /p/, and found that VOT was shorter in quick speech. He also found shorter closure duration in quick speech, and less glottal aperture.

Fischer-Jørgensen (1972d) reports a series of perception experiments investigating the relative weighting of cues in determining laryngeal and place contrasts in Danish stops. She shows that an aspiration phase is a necessary and sufficient cue for perceiving the laryngeal contrast. Long VOT is not found to be sufficient: the study compares perception of stops with regular aspiration noise to stops with an equally long silent phase preceding voicing onset, and finds that /p t k/ are only consistently correctly identified if aspiration noise is present during the release. She furthermore finds that a threshold of roughly 35 ms VOT is required for consistent correct identification of /p t k/.

The alveolar stops have drawn particular interest in the area of second language acquisition, in part due to problems caused by the salient affrication of /t/ in Modern Standard Danish (see Section 2.3.4). For this reason, further studies have measured VOT in /d t/: Garibaldi and Bohn (2015) report surprisingly high mean VOT values of 28 ms and 140 ms for /d t/, respectively; Yan (2016) reports mean VOT values of 15 ms and 96 for /d t/ respectively; Puggaard (2020c) reports a mean VOT of 93 m in /t/. Given the nature of the material, these values are expected to be higher than in the spontaneous speech measured by Mortensen and Tøndering (2013), but even with that caveat, the values reported by Garibaldi and Bohn (2015) are extremely high.

In syllable-initial clusters of aspirated stops and sonorant consonants, the sonorants are usually said to devoice categorically as an allophonic realization of aspiration. This observation goes at least as far back as Jespersen (1890, 1906), who notes voiceless realizations of /l r n/ after underlyingly aspirated stops. He also notes that /r/ devoices after /f/. Finally, he notes that /j/ alternates with a voiceless palatal fricative [ç] in words like [ˈkʰjoːl̩] *kjole* ‘dress’, which Jespersen transcribes as [ˈkçoːlə].[8] Note that the phonetic alveopalatal fricatives and affricates [ɕ tɕ] are usually analyzed as underlying clusters of /sj/ and /tj/, and this can also be considered a case of phonologized devoicing (Basbøll 2005; Grønnum 2005). More recent treatments of Danish phonetics maintain that non-nasal sonorants devoice after aspirated stops, but do not mention nasals (Heger 1981; Grønnum 2005). Grønnum’s transcriptions in particular indicate that devoicing of non-nasal sonorants is categorical following /p t k f s/.

In a recent article, Juul et al. (2019) investigate the extent of sonorant devoicing acoustically by comparing the duration of voiced and voiceless portions in e.g. /gæ glæ kæ klæ/. They do not find evidence of categorical devoicing – there is little difference in the duration of the voiced portion in sets like /glæ klæ/. As such, they suggest to dispense with the tradition of transcribing this contrast as [klæ kl̥æ]. Unfortunately, they do not look into the spectral characteristics of the release; in a study of the same phenomenon in English, Tsuchida et al. (2000) found that liquids are partially devoiced following aspirated stops; the entire voiceless release in clusters like /kl/ is lateral, but voicing does set in during the final third of the lateral; they found only negligible devoicing after voiceless fricatives. This discrepancy suggests that the explanation for sonorant devoicing lies in articulatory overlap: liquids (partially) overlap with stop aspiration, but can hardly overlap with fricatives. The measurements given by Juul et

[8]Jespersen’s transcription is ‘translated’ from Dania. He further notes that sonorant consonants can devoice in coda following stød, but intuitively, this does not happen in Modern Standard Danish.

al. (2019) suggest that the situation in Danish may be similar to the situation in English. As I discuss further in Section 2.4.3.1, the (lack of) categoricity in sonorant devoicing has implications for how the stops can be represented phonologically (see Puggaard-Rode et al. forthc.).

2.3.2 Closure voicing

Voicing is not generally considered an important cue to the laryngeal contrast in Danish stops. Because of this, little has been written about closure voicing. To my knowledge, no quantitative studies have been carried out investigating the topic. Abrahams (1949), Fischer-Jørgensen (1954) and Spore (1965) all briefly mention the occurrence of intervocalic voicing; post-pausally, stops are never voiced, but all stops show some degree of closure voicing intervocalically. This has a universal phonetic explanation: there is high subglottal pressure immediately after a vowel, which naturally results in voicing during (at least) the initial part of a post-vocalic closure, unlike closures that are not post-vocalic (Westbury and Keating 1986). Fischer-Jørgensen (1954, 1980) assumes that medial stops before inflectional suffixes are archiphonemic – in the 1954 paper, she uses the notation /B D G/ – and writes that these are "often completely voiced" (1954: 44) and "almost always pronounced as (very) weakly voiced" (1980: 208). Keating et al. (1983) write that /b d g/ are spirantized medially, and that /p t k/ are voiced medially; this is an oversimplification both phonetically and phonologically, and one I will return to in Section 2.4.

As such, several scholars have mentioned in passing that Danish stops are voiced intervocalically, either categorically or near-categorically. However, Jessen (1999, 2001) and Beckman et al. (2013) assume that Danish stops are categorically voiceless in all positions. Neither camp provide empirical evidence for their claims. As we will see in Chapter 4, this significantly influences how the laryngeal contrast in Danish stops is modeled phonologically (as also discussed below in Section 2.4.3.1). The overall lack of interest in closure voicing in Danish is surprising; the two major corpus studies of phonetic reduction in Danish (Pharao 2009; Schachtenhaufen 2013) consider many patterns of variation in the realization of consonants, but do not look into voicing.

2.3.3 Actions of the larynx

Frøkjær-Jensen et al. (1971) studied the actions of the glottis during the production of Danish stops using a photo-electric glottograph. Comparing /b/ with /p/ in intervocalic onset position in stressed syllables, they find that there is a glottal opening gesture lasting throughout the closure phase of /p/, resulting in a fully spread glottis just after the stop release. This is unsurprising, and accounts for the aspirated release. More surprisingly, they also find a glottal opening gesture during the production of /b/, although this gesture has a shorter duration and smaller magnitude. The authors hypothesize that the smaller glottal opening gesture during /b/ follows naturally from the transition from vowel to consonant, and is not “effectuated by neural commands” (Frøkjær-Jensen et al. 1971: 134).

Hutters (1978, 1984, 1985) carried out similar studies using electromyography (EMG) and fiberoptic stills, and found support for Frøkjær-Jensen et al.'s findings: /b/ has a glottal opening gesture which peaks relatively early during the closure, and is of smaller magnitude than that of /p/. However, she questions Frøkjær-Jensen et al.'s proposed explanation that the small opening gesture in /b/ is a purely aerodynamic artifact of the vowel–consonant transition, since both her own EMG results and EMG results from Fischer-Jørgensen and Hirose (1974) show that the posterior cricoarytenoid muscles are active in achieving it.[9]

There are other reasons to doubt a purely aerodynamic explanation of the glottal opening gesture in /b/. In Westbury and Keating's (1986) model of closure voicing, they show that initial subglottal pressure in intervocalic position is high enough that vocal fold vibration should continue throughout a significant portion of the closure, assuming the vocal folds are adducted and tensed. By way of comparison, in the production of intervocalic /b/ in English, Hirose and Gay (1972) find no activity of the posterior cricoarytenoids, and Sawashima (1970) finds that there is usually no interruption of voicing and no arytenoid separation. Hutters (1985) proposes that the intervocalic

[9] Frøkjær-Jensen et al. (1971) was reprinted in 1973, and the reprint has an added note recognizing the forthcoming work of Fischer-Jørgensen and Hirose (1974), and that it throws doubt on their explanation of the findings.

glottal opening gesture in Danish is a measure taken to reinforce voicelessness in /b/, although she leaves the question relatively open. I return to this question in Chapter 4, when discussing why intervocalic voicing in Modern Standard Danish is so relatively rare.

The actions of the glottis result in aspiration, but also in other cues to the laryngeal contrast. Fischer-Jørgensen (1972d) reports that the first voicing pulses after /p t k/ are irregular in low vowels, and that it takes longer for higher vowel formants to appear after /p t k/ relative to /b d g/. Listeners demonstrably use these as cues to the laryngeal contrast before low vowels. Fischer-Jørgensen explains these phenomena with reference to the position of the vocal cords at the time of the burst.

Petersen (1983) has investigated whether there are vertical movements of the larynx during stop production in Danish. Petersen's motivation for looking into this is that larynx lowering has been found to correlate negatively with F_0 (e.g. Shipp 1975). Some studies suggest that F_0 is locally conditioned by the laryngeal setting of preceding stops in Danish (see Section 2.3.6), so Petersen tests whether larynx lowering is a likely explanation for this finding. He finds a (weak) correlation between local F_0 and larynx lowering, but does not find conclusive evidence of larynx lowering during /b d g/. Westbury (1983) identifies larynx lowering as one of several means to maintain voicing during closure; by lowering the larynx, the size of the supraglottal cavity is increased, which slows the increase in air pressure. This is perhaps not very relevant in Danish, where voicing plays little to no role in maintaining the laryngeal stop contrast (see Section 2.3.3 above).

I argue in later chapters that the seemingly marked laryngeal behavior found during stop production in Modern Standard Danish can help account for many of the interesting patterns we see in the acoustic signal, including the relative rarity of intervocalic voicing (Chapter 4) and the prevalence of affrication in aspirated stops (Chapter 5). Relatedly, I argue that different patterns of VOT, closure voicing, and affrication in regional varieties of Danish likely reflect differences in laryngeal behavior (Chapter 6).

2.3.4 Burst and affrication

Recall from Section 2.3.1 that Jespersen (1906) describes hearing an "explosion" immediately after the release of "blown" aspirated stops. This presumably refers to the release burst, which is well-known to be a crucial acoustic cue to place features of (particularly) aspirated stops (e.g. Blumstein and Stevens 1979). A salient release burst is the result of air escaping through a narrow gap becoming turbulent. The spectral characteristics of bursts are overall similar to fricatives at the same place of articulation, although significantly shorter in duration. Stop affrication serves to enforce cues for place of articulation, but also weakens cues for manner of articulation (see e.g. Repp et al. 1978).

Fischer-Jørgensen (1954) makes a number of observations about the acoustics of releases and release bursts, a.o. providing details about intensity and spectral characteristics of bursts. She finds that burst intensity decreases in the order /k/ > /p/ > /t/ although the difference between /k ~ p/ is blurred before rounded vowels. She also notes that the spectral characteristics of bursts are highly dependent on the quality of the following vowel. In a perception experiment, Fischer-Jørgensen (1972d) finds that there are sufficient place cues in the bursts of aspirated stops for listeners to determine the place of articulation if the aspiration phase is removed, and *vice versa*, that there are sufficient place cues in the aspiration phase if the burst is removed. The latter is especially true for /t/; if the aspiration phase of /t/ is superimposed on a bilabial or velar stop, it is still consistently perceived as /t/. Cues to the place of articulation of /b d g/ interact with the following vowel in complicated ways. Sometimes place is cued primarily from the characteristics of the burst; sometimes from the initial formant transitions in the following vowel. By comparison, formant transitions are a more stable cue to place of articulation in syllable-final stops (Fischer-Jørgensen 1972a), which are often unreleased except in phrase-final position (Grønnum 2005: 49).

Fischer-Jørgensen finds that the frequency range of the aspiration noise in /t/ is very similar (actually "exactly the same", 1954: 50) as the noise in /s/. Similar results had been found for /t/ in English, with the crucial difference that /s/-like noise in English /t/ continues only for roughly 25 ms (Jakobson et al. 1951), and /s/-like noise in Danish /t/

continues twice as long. Taking the VOT measurements reported in Table 2.1 into account, this implies that /t/-affrication is followed by aspiration proper, but that affrication takes up the bulk of /t/-releases. Fischer-Jørgensen finds no signs of affrication in /p/, and limited signs of affrication in /k/, where high-frequency noise is somewhat more prominent than in /h/ and /p/-releases.

Jespersen (1897–1899: 335) already noted that Danish /t/ was highly affricated, and that foreigners were likely to perceive it as an affricate before high front vowels (see also Hansen 1956: 56). He also noted that /t/ was affricated to some extent regardless of the following vowel, and suggested that this indicated a sound change in progress: /t/ ⟶ /ts/, as occurred earlier in High German with the Second Consonant Shift. He envisioned it as a sound change in progress for all aspirated stops, with /t/ ⟶ /ts/ being quite advanced, and /p k/ ⟶ /pf kx/ much less so.

Brink and Lund (1975) tracked the development of affrication in /t/ across more than a century's worth of recordings from Copenhagen. They found that it was already a widespread phenomenon in High Copenhagen Danish in the mid-19th century, and that it was an exceptionless feature of /t/ one century later. They even report cases of /t/ having lost closure altogether among younger speakers. Brink and Lund use [d^{s}h] when transcribing this sound, thus recognizing that the affricated portion of the release is followed by aspiration proper.[10] This transcription is in line with Hjelmslev's (1951) phonological analysis of the aspirated stops, where they are considered underlying clusters of /b d g/ + /h/ (see Section 2.4.2).

Basbøll and Wagner (1985) transcribe /t/ phonetically as [ts^{h}], which is in line with Fischer-Jørgensen's (1954) findings. It is unclear why, but in recent years, [t^{s}] has emerged as the standard transcription, indicating affrication but no aspiration (e.g. Grønnum 1998; Basbøll 2005). Schachtenhaufen (2022) has recently proposed transcribing the sound as a true affricate [ts]. This downplaying of aspiration is not in line with recent studies from Yan and Sloos (2019) and Puggaard (2020c), who both find that a sizable portion (20–25 ms on average) of /t/ releases is unaffricated.

[10] Brink and Lund's use of [d] does not indicate closure voicing; they transcribe using Dania, where sounds transcribed with [b d g] are not inherently voiced.

/t/ releases have been explored in some detail in previous studies, although the highly complex nature of the information in stop releases means that there are certainly still open questions. The properties of /p k/ releases remain largely unknown. In Chapter 5, I explore affrication patterns and spectral characteristics of aspirated stop releases further, and propose a method of data analysis that arguably allows us to statistically model this complex information without sacrificing the complexity of the data.

2.3.5 Articulatory force

Articulatory force is a problematic term in phonetics, because it has a large number of partially overlapping acoustic and articulatory correlates, some of which have been discussed already. Jaeger (1983) summarizes the phonetic properties that have been assumed to cue articulatory force in the literature. Fortis ('strong') consonants are variously claimed to have relatively greater pulmonic force; greater force or pressure of the articulators; rapid release of closures; longer duration; and no voicing. Because there is no general agreement in the literature about what articulatory force actually refers to, Henton et al. (1992) argue that the associated terms should be used very carefully. Henton et al. use the term only in the sense of increased respiratory effort, of which there are only few well-established examples, the most well-known one being the fortis stops of Korean.

Some approaches to phonological representation subsume the phonetic cues mentioned by Jaeger (1983) under a binary distinction between fortis and lenis.[11] In phonological descriptions of two-way laryngeal contrasts in stops, 'lenis' is usually straightforwardly taken to refer to /b d g/, and 'fortis' to /p t k/. For example, Kohler (1984) uses the feature [fortis] as a cover term for similar stop contrasts in Germanic languages, including Danish, where the contrasts involved have a wide variety of phonetic correlates. This is discussed further in Section 2.4.3.1.

[11] A number of largely equivalent terms are used in the literature; 'fortis' is sometimes used interchangeably with 'tense' or 'strong', and 'lenis' is sometimes used interchangeably with 'lax' or 'weak'.

Fischer-Jørgensen (1968, 1969) argues that articulatory force as a phonetic parameter should be kept separate from voicing and aspiration, since all three may show independent behavior. In acoustic studies, she finds that the closure duration in /b d g/ is consistently longer than /p t k/ (Fischer-Jørgensen 1972b), and EMG studies comparing /b ~ p/ show a tendency for greater organic pressure in /b/, although this is not significant for all speakers (Fischer-Jørgensen and Hirose 1974). In a questionnaire study, Fischer-Jørgensen (1972b) shows that speakers of Danish consistently judge /b d g/ to be produced with stronger organic pressure than /p t k/. She takes these findings as evidence that /b d g/ are actually 'more fortis' than /p t k/, at least as pertains to supraglottal articulatory force – although this is unlikely to affect perception much. Articulatory force, however, appears to be highly language-specific; Fischer-Jørgensen (1968) also finds that, on a number of parameters, the difference in articulatory force between French 'lenis' /b d g/ and 'fortis' /p t k/ is much greater than that between the Danish laryngeal series, and that all Danish stops are produced with less force than French /b d g/. Given that voicing and short duration are commonly associated with 'lenis' stops, it is remarkable how much both Danish laryngeal series resist voicing (Section 2.3.2). I will return to this problem in later chapters; in Chapter 5, I argue that the lack of sharp releases in /p t k/ may help to explain affrication patterns.

I am unaware of more recent research into articulatory force in Danish stops, but it is often mentioned in newer publications that Danish stops are all lenis (e.g. Basbøll and Wagner 1985; Basbøll 2005; Grønnum 1998, 2005). The most common way of transcribing the stressed syllable-initial allophones of /b d g/ is [b̥ d̥ g̊], with the devoicing diacritic used to indicate that they are phonetically lenis (Grønnum 1998). This strategy is also used in some traditions of narrow transcription of English (e.g. Lodge 2009). The syllable-initial allophones of /p t k/ are usually transcribed as [p^h t^s k^h], but it is sometimes claimed that more accurate transcriptions would be [b̥^{h} d̥^{s} g̊^{h}], since these are also phonetically lenis (e.g. Grønnum 1998; Basbøll 2005).

Schachtenhaufen (2022) proposes getting rid of the devoicing diacritic in Danish transcription. The *Handbook of the International*

Phonetic Association (IPA 1999: 24) briefly mentions the use of the devoicing diacritic with voiced obstruent symbols:

> "The voiceless diacritic can be used to show that a symbol that usually represents a voiced sound in a particular language on some occasions represents a voiceless sound."

This is clearly not the case in Danish (see Section 2.3.2 and Chapter 4), and IPA guidelines never indicate that the diacritic may be used to indicate articulatory force. As such, I am strongly in favor of the proposal to abandon [b̥ d̥ g̊] in favor of [p t k].

2.3.6 Fundamental frequency

It is well-known that laryngeal contrasts tend to influence F_0 in the initial part of a subsequent sonorant sound (e.g. House and Fairbanks 1953). This is well-established for languages with voicing-based contrasts (so-called 'true voicing' languages; Kirby and Ladd 2016), but has also been found for languages with aspiration-based contrasts (see Hanson 2009 and references therein), and in the case of Swiss German, even for a singleton–geminate contrast (Ladd and Schmid 2018). There is disagreement in the literature about the phonetic mechanism causing F_0-perturbations. Some argue that F_0 is lowered by voiced stops, due to e.g. the larynx lowering gesture discussed in Section 2.3.3 above (e.g. Kingston and Diehl 1994). Others argue that F_0 is raised locally by voiceless stops, since F_0 is similar after voiced stops and nasals (e.g. Hanson 2009). This suggests that voiceless stops are the ones showing exceptional behavior, since nasals should have no impact on F_0.

F_0-perturbations have sometimes been considered crucial in determining underlying representations, because they are a relatively stable feature of laryngeal two-way contrasts, regardless of how that contrast is otherwise realized. This prompted Keating (1984a) and Kingston and Diehl (1994) to incorporate it into their otherwise abstract [voice] features. On the other side of the debate, Goldstein and Browman (1986) assume that the F_0-perturbations are purely an artifact of glottal gestures.

Danish is interesting in this respect, since both laryngeal stop series are characterized by some degree of glottal opening (see Section 2.3.3). Several studies have investigated F_0-perturbations in Danish with inconclusive results. Fischer-Jørgensen (1969) finds no evidence of laryngeally induced differences in F_0 immediately after stops, while other studies have found evidence of higher F_0 after aspirated stops relative to unaspirated stops (Jeel 1975; Petersen 1978, 1983). The study by Petersen (1983) is of particular interest here, since he compares stops with a number of other consonants. He finds a tendency for negligibly higher F_0 after aspirated stops relative to unaspirated stops; however, he also finds a more stable tendency for increased F_0 after all obstruents relative to nasals. These findings suggest that the slight glottal opening gesture found for /b d g/ (see Section 2.3.3) causes a local spike in F_0, and the complete glottal opening gesture found for /p t k/ and voiceless fricatives causes a greater local spike in F_0. This is not well in line with a categorical featural explanation, such as Kingston and Diehl's (1994).[12] I return to the phonological implications of F_0-perturbations in Section 2.4.3.1.

2.3.7 Summary

Danish stops fall into two categories: unaspirated /b d g/ and aspirated /p t k/. Both categories have quite high VOT from a cross-linguistic perspective. Intervocalically, both series are described as showing some degree of initial closure voicing, and the medial allophones are generally (weakly) voiced. Both series are accompanied with a glottal opening gesture – likely to enforce voicelessness – but the magnitude of this gesture is quite small in /b d g/. There is salient affrication during the release in the realization of /t/, regardless of phonetic context. Surprisingly, the unaspirated series have longer overall longer closure duration and higher organic pressure, which are often taken as correlates of greater articulatory force. There is some evidence for differences in F_0-perturbations caused by the two laryngeal series, but also

[12] Kingston and Diehl (1994) cite Petersen (1983) and others as evidence for [voice] acting as an F_0-depressor in Danish, but do not engage with the intricacies of Petersen's findings.

evidence that F_0 is locally raised after both stop series, possibly due to the glottal opening gestures.

2.4 Phonology

Having covered the existing literature on the phonetics of Danish stops, I now turn to the existing literature on their phonology. I cover which processes the stops participate in, and previous proposals regarding their underlying representation. This requires a general overview of the Danish consonant inventory and phonotactics, which I give in Section 2.4.1.

In Section 2.4.2, I review previous descriptions of the stops' combinatorial possibilities, which in some cases include consonant clusters that only exist at an abstract underlying level. In Section 2.4.3, I review accounts of how the stops are underlyingly represented, focusing on the laryngeal contrast and place contrasts. Finally, alternations between stops and semivowels remain a tricky problem in Danish phonology, and in Section 2.4.4, I provide an overview of how this phenomenon (which is usually called *consonant gradation*) has previously been analyzed in the literature. Chapter 3 is further dedicated specifically to this issue.

2.4.1 Consonant inventory and positional allophones

Positional allophones in Danish are usually described in terms of 'strength' rather than syllabic position. Following Jakobson et al. (1951), 'strong' allophones are found in absolute initial position, and 'weak' allophones are found in either syllable-final position or syllable-initially in unstressed syllables before the central vowels [ə ɐ], as well as unstressed [i] in some specific morphemes.

The strong consonant allophones are shown in Table 2.2, along with the phonemes that they are commonly taken to represent. The place labels given in the table are simplified for reasons of space, and diacritics are kept to a minimum; for more information on the transcription conventions and more precise place labels, see Section 1.4.

Table 2.2: *Strong allophones of Danish consonants and the phonemes they are commonly assumed to represent.*

	Labial	Alveolar	Palatal	Dorsal	Glottal
Unaspirated stop	[p] /b/	[t] /d/		[k] /g/	
Aspirated stop	[pʰ] /p/	[tʰ] /t/		[kʰ] /k/	
Affricate			[tɕ] /tj/		
Fricative	[f] /f/	[s] /s/	[ɕ] /sj/		[h] /h/
Nasal	[m] /m/	[n] /n/			
Approximant	[ʋ] /v/	[l] /l/	[j] /j/	[ʁ] /r/	

The alveopalatals [tɕ ɕ] are usually (unproblematically) treated as surface mergers of underlying /tj sj/ clusters (e.g. Basbøll 2005). This is phonetically reasonable, and serves to explain why [j] is found after all obstruents syllable-initially *except* [tʰ s], which would otherwise be a structural gap.

As discussed in Section 2.3.2, the unaspirated stops are often transcribed as [b̥ d̥ g̊], but I follow the proposal of Schachtenhaufen (2022) in abandoning this convention and representing them with [p t k] instead, for reasons outlined above and in Chapter 4. Further, as discussed in Section 2.3.4, the strong allophone of /t/ has been transcribed in a number of different ways, but in recent years most Danish phoneticians have converged on [tˢ]. I go for the simple solution [tʰ] here to emphasize the class behavior of the aspirated stops; this problem will be discussed further in Chapter 5.

[ʋ] and [ʁ] are sometimes described as voiced fricatives (e.g. Heger 1981; Haberland 1994; Grønnum 1998), and [ʋ] is often transcribed with the [v] symbol in other sources. However, both Grønnum (1998) and Basbøll (2005) explicitly note that both sounds lack friction,

Table 2.3: *Weak allophones of Danish consonants and the phonemes they are commonly assumed to represent.*

	Labial	Alveolar	Palatal	Dorsal
Stop	[p] (/b ~ p/)	[t] /t/		[k] (/g ~ k/)
Fricative	[f] /f/	[s] /s/	[ɕ]* /sj/	
Nasal	[m] /m/	[n] /n/		[ŋ] (/ng/)
Approximant	[ʋ]* /v/	[l] /l/	[j]* /j/	[ʁ]* /r/
Semivowel	[ʊ̯] (/v ~ b ~ g/)	[ɤ̯] (/d/)	[ɪ̯] (/j ~ g/)	[ɐ̯] /r/

logically making them approximants.[13] I stick to the more precise phonetic transcriptions here. There are no IPA symbols for uvular or pharyngeal approximants, but a narrow transcription of the rhotic could be [[ʁ̞ ~ ʁ̠˕ ~ ʕ̞]].

The weak allophones are shown in Table 2.3, along with the phonemes they are commonly taken to represent. Phonemic associations which will later be contested are given in parentheses. Allophones which are found only marginally in weak position are marked with an asterisk *. As above, more precise place labels and discussion of transcription conventions can be found in Section 1.4.

There is only one series of surface stops in weak position. This does not (necessarily) mean that the contrast is neutralized; as discussed in Section 2.4.4 and Chapter 3, the 'traditional' phonological analysis of Danish holds that the semivowels sometimes derive from /b d g/.

The semivowels frequently syllabify in unstressed syllables due to schwa assimilation, e.g. /rə/ ⟶ [ɐ] (see Brink and Lund 1975: ch. 32; Basbøll 2005: ch. 11; Schachtenhaufen 2010b). Grønnum (e.g. 1998) assumes that only [ɐ̯] is a phonetic semivowel, and otherwise uses the approximant symbols [w j] rather than [ʊ̯ ɪ̯]. As discussed in Section 2.2, the so-called 'soft d' [ɤ̯] is a very open semivowel with

[13]Basbøll (2005) uses [v], which has the unfortunate consequence that he must postulate a feature [voice] which is only distinctive for labiodental fricatives.

both coronal and dorsal articulatory components (Siem 2019; Brotherton and Block 2020). Grønnum (1998) describes it as alveopalatal and does not mention a dorsal gesture; Basbøll describes it as alveolar with a secondary velar component (2005; see also Ejstrup 2010); Brink and Lund (2018) describe the secondary articulation as pharyngeal. In fact, the precise articulatory targets of the coronal and dorsal gestures are unknown, and difficult to pinpoint since the tongue is relatively far from the roof of the mouth at all points. The more commonly used transcription is [ð], and Basbøll (2005) proposes the narrow transcription [[ð̞ ˠ̞]], under the (arbitrary) assumption that the dorsum most closely approximates the velum. I follow Schachtenhaufen (2022) in using a vocalic transcription, as this is more in line with the phonetic substance, and also highlights the class behavior of the four semivowels. Schachtenhaufen (forthc.) proposes the narrow transcription [[ɤ̯̈]].

The central approximants [ʋ j ʁ] and the fricative [ɕ] are found only marginally in weak position. [ʋ j] are only found after [l] in a small number of words, such as [ulˀʋ] *ulv* 'wolf' and [ʋælˀj] *valg* 'choose'. These clusters were historically more wide-spread, but have been lost in many cases where they are still reflected in writing, e.g. [hælˀ] *halv* 'half'. Particularly the remaining [lj] clusters are highly unstable, with realized [j] only found in highly distinct speech (see relevant entries in the pronunciation dictionary of Brink et al. 1991). [ʁ] is only found in weak position in a small set of imperatives (Basbøll 2018). Danish infinitive verbs are usually minimally disyllabic and have underlying word-final schwa; the regular imperative is formed by removing the final schwa, which in some cases leads to clusters with highly marked sonority slopes. In very conservative Danish, the imperative of a verb like [ˈkʰlætʁɐ] *klatre* 'to climb' would thus be monosyllabic [kʰlætʁ̥] *klatr!* 'climb!' with devoiced [ʁ̥]. The syllable structure of these imperatives runs counter to that predicted by any sonority hierarchy (see Parker 2002). Most speakers nowadays use syllabic weak allophones to avoid sonority reversals, as in [ˈkʰlætɐ].[14] Finally, [ɕ] is only found in weak position in a small number of recent loans, such as [hæɕ] *hash* 'hashish'.[15]

[ŋ] is sometimes assumed (by e.g. Grønnum 2005) to be derived from underlying /ng/. This is discussed in further detail in Section 2.4.2.2. The phonemic associations of particularly final [p k ʊ̯ ɪ̯] are problematic and highly complex, with multiple potential phonemes associated with single allophones, and often no sure way to determine the underlying representation of allophones. This is discussed further in Section 2.4.4 and Chapter 3.

2.4.2 Combinatorial possibilities

In this section, I will discuss the phonotactics of stops. I review possible initial and final consonant clusters and analyses of these, as well as medial behavior, in Section 2.4.2.1. Subsequently, I discuss phonological analyses that have assumed abstract consonant clusters including stops in Section 2.4.2.2.

2.4.2.1 Surface clusters

Danish phonotactics are relatively permissive. Most possible combinations of stop + sonorant are found syllable-initially. Vestergaard (1967) gives the following attested stop-initial consonant clusters:

(3)

/b/	+	/	j	r	l			/
/d/	+	/	j	r		v		/
/g/	+	/	j	r	l		n	/
/p/	+	/	j	r	l			/
/t/	+	/	j	r		v		/
/k/	+	/	j	r	l	v	n	/

[14] The pattern is similar in other sonority-reversing imperatives. The imperative of [ˈʋeklə ~ ˈʋekl̩] *vikle* 'to wrap' is [ʋekl̥] *vikl!* 'wrap!' in highly conservative Standard Danish, but disyllabic [ʋekl̩] is much more common in Modern Standard Danish. Due to schwa assimilation in the infinitive, this may lead to neutralization between some infinitive–imperative pairs.

[15] Some speakers nativize this word as [hæs] to avoid [ɕ] in weak position (Brink et al. 1991).

The possible combinations in (3) are in agreement with versions of the sonority hierarchy that treat (voiceless) obstruents as a class (e.g. Basbøll 1977; Clements 1990); stops are never found before other voiceless obstruents, but frequently before sonorants. There are a number of further restrictions, many of which can be explained with reference to the Obligatory Contour Hierarchy (OCP; Goldsmith 1976): /b p + v/, /d t + l/, and /d t + n/ are not found due to shared place of articulation. /n/ is more restrictive than non-nasal sonorants, and /m/ is not found in clusters at all, which is not too surprising: nasals are often taken to be the 'least sonorous sonorants' (Krämer and Zec 2020), but coronals are generally very phonotactically permissive (e.g. Yip 1991). The lack of /gv/-clusters is more difficult to explain. There are at least two examples of syllable-initial (but not word-initial) /gv/-clusters, derived from the same root: [leŋ.ˈkʋist] *lingvist* 'linguist' and [leŋ.kʋi.ˈstik] *lingvistik* 'linguistics'. This suggests that the lack of word-initial /gv/-clusters is an accidental gap.

/s/ occurs quite freely in initial clusters, and most of the combinations in (3) are also found after /s/, exceptions being [stʋ-] and [skn-].[16] The laryngeal contrast in stops is neutralized after /s/, and only (phonetically) unaspirated stops are found. Uldall (1936) argues that only /p t k/ are found after /s/ underlyingly, since [skʋ-] *is* a possible cluster, as in e.g. [skʋæt] *skvat* 'wimp' – like /kv-/, but unlike /gv-/ (although note the exception above).

It is cross-linguistically common for /s/ to display this kind of phonotactic behavior (e.g. Goad 2012). This is often modeled phonologically by assuming that /s/ is not attached to the syllable, but rather to a higher level of prosodic structure (e.g. Goldsmith 1990). Basbøll's (e.g. 1994, 1999, 2005) model of Danish (and general) phonotactics, the Sonority Syllable Model, gets around this problem by assuming an unconventional set of 'order classes'. They are defined as in (4), which shows the order classes from most to least sonorous, where each lower order class is a proper subset of higher classes. [ ] covers all segments, regardless of underlying representation.

(4) [+vocoid] > [+sonorant] > [+voice] > [-spread glottis] > [ ]

[16] [skl-] is marginal and found only in [skleˈʁoːsə] *sklerose* 'sclerosis'.

More sonorous segments occur closer to the center of the syllable, and less sonorous segments occur closer to the edges. This is a maximal general sonority hierarchy; in Danish, the three innermost classes can be collapsed with minimal loss in explanatory value, as in (5).

(5) [+voice] > [-spread glottis] > [ ]

Basbøll assumes that the features in (4) and (5) need to apply at the level of positional allophone. As mentioned above, only unaspirated stops, which are [-spread glottis], are found after /s/. As such, his Sonority Syllable Model predicts clusters with peripheral /s/ without additional formal machinery. On the other hand, the model also predicts a large number of non-occurring clusters, and has trouble explaining why /s/ is the only possible [+spread glottis] segment in three-member clusters; at least /f/ and /h/ should be equally likely.

Vestergaard (1967) also gives a list of possible final clusters. He lists phoneme combinations, but due to the problems with determining phonemes from weak allophones (see Sections 2.4.1 and 2.4.4), I list positional allophones instead. Recall that there is no laryngeal contrast in weak position. Possible two-member clusters with final stops are listed in (6):

(6)

[	ʊ̯		ɐ̯	l	m				s			]	+ [p]
[	ʊ̯	ɪ̯	ɐ̯	l	m	n	ŋ	f	s	p	k	]	+ [t]
[		ɪ̯	ɐ̯	l			ŋ		s			]	+ [k]

[t] occurs very freely as the final member of final clusters. The only weak allophone not found before [t] in monomorphemes is [ɣ̯].[17] The lack of [ɣ̯t] clusters can be historically explained with reference to the OCP, since [ɣ̯] developed from an alveolar stop (see Section 2.2). Synchronically, such an OCP constraint cannot carry too much weight, as [ɣ̯t] should be no problem to produce; such clusters are indeed found in certain polymorphemic monosyllables, such as [leːˀɣ̯+t] *ledt* 'cruel (indefinite neuter)'.

/p k/ only cluster with homorganic nasals, whereas all nasals are found before /t/. There are similar restrictions for semivowel + stop

[17] The marginal final allophones [ɕ ʋ ʁ] are also not found before [t].

clusters. This kind of phenomenon has often been explained with reference to 'coronal underspecification' (e.g. Avery and Rice 1989; Paradis and Prunet 1989); if [t] is assumed to have no underlying place features, there can be no requirements for place sharing. As is the case syllable-finally, [s] occurs freely before all stops, but otherwise, obstruents are only found before [t]. Stop + stop clusters occur freely, as long as the final segment is [t]. Apart from coronal underspecification, another likely explanation for this freedom is analogy with polymorphemic syllables: [-t] is a neuter suffix in adjectives, so it is found freely in word-final position at the surface level.

Final three-member clusters are much more free than initial ones, and Basbøll's Sonority Syllable Model cannot explain the order of these. Most clusters ending in /-st -sk/ are possible, including clusters of three obstruents, such as [tʰɑkst] *takst* 'fare'. The situation becomes all the more complex if polymorphemic syllables are taken into account. These complex final clusters will not be discussed further in this dissertation, but they are discussed in great detail by Basbøll (2005: ch. 7).

When clusters of two homorganic stops are found at morpheme boundaries, they are realized as geminates, as in e.g. [pʰukːɒːˀˈʁoːɤ] *Puggaard-Rode.* If the second stop is aspirated, the result is an aspirated geminate, as in [ˈpʰlæstekːʰiʁuːˀ] *plastikkirurg* 'plastic surgeon'. Compounding and derivational morphology do not otherwise affect phonotactics, although they do affect allophone selection in the traditional analysis of gradation patterns, as discussed in Section 2.4.4.

2.4.2.2 Underlying clusters

Early attempts at categorizing the distinctive phonemes of Danish were much more interested in distributional properties than distinctive features (Fischer-Jørgensen 1952). Accounts by Uldall (1936), Hjelmslev (1951), and to a lesser extent Basbøll (1968) seem primarily interested in arriving at the lowest possible number of phonemes, and are relatively unconcerned about the level of abstraction needed to arrive at that number.

Hjelmslev (1951) and Basbøll (1968) both assume that there are only three phonemic stops /b d g/, and that surface aspirated stops are underlyingly clusters of /b d g/ + /h/. This solution is abandoned by Basbøll in later writings (e.g. Basbøll and Wagner 1985), because it causes serious problems in explaining the distribution of /h/. Hjelmslev (1951) acknowledges this problem, and solves it by assuming that initial aspirated stops are underlyingly /h/-initial, such that a word like [kʰænˀ] *kan* 'can' is underlyingly /hgand/.[18] Nowadays, presumably everyone assumes that there are two series of phonemic stops in Danish, and aims to distinguish them by means of e.g. distinctive features instead, as discussed in Section 2.4.3.1.

Hjelmslev (1951) also assumed that stød is not an underlying property but rather structurally derived from e.g. final consonant clusters. This led him to propose that words with stød but no clear 'stød basis' according to his criteria must have abstract underlying final clusters, specifically of the type /ld rd nd/. An example is the word [lønˀ] *løn* 'salary', which Hjelmslev assumes is underlyingly /lønd/; cp. words with similar surface structure but no stød, like [kul] *guld* 'gold', which he assumes is underlyingly /gul/. Hjelmslev's analysis of stød was not particularly influential. The current mainstream account (as laid out in Basbøll 1985, 2003, 2005) affords no special role to final consonant clusters, but assumes that stød follows from a bimoraic rhyme, i.e. a long vowel, diphthong, or short vowel + sonorant consonant; Basbøll assumes that obstruents are never moraic in Danish.[19] In this account, words like [kul] *guld* 'gold' lack stød because the final sonorant is underlyingly specified as extraprosodic, and thus not parsed as moraic.

Another abstract consonant cluster rooted in structuralist phonology which has had more staying power is the analysis of [ŋ] as underlying /ng/ (e.g. Uldall 1936; Vestergaard 1967; Grønnum 2005). One (abandoned) reason for this analysis was the glossematic principle that all phonemes must appear in both onset and coda position (Hjelmslev 1936). A more compelling reason is that high

[18]This kind of analysis would probably be deemed overly abstract by most phonologists nowadays, but if the goal is to arrive at the lowest possible number of phonemes, Hjelmslev is undeniably successful: he ends up with a system of only 18 phonemes in Danish.

[19]See Vázquez-Larruscaín (2021) for an argument that all consonants are moraic, and a 'stød filter' rules out obstruents with stød.

vowels are lowered before any nasal + consonant cluster *and* before [ŋ], causing neutralization between high and mid-high vowels, as in (7).

(7) /i y u/ →[e ø o] / _ C[+nasal] C)σ, *or*
_ [ŋ])σ

Similarly, the vowel length contrast is neutralized before final consonant clusters *and* [ŋ], where only short vowels are found. Both rules can be formalized more economically if we assume that [ŋ] is underlyingly a nasal + consonant cluster.

These patterns are undoubtedly found because [ŋ] historically developed from nasal + stop clusters. Since Chomsky and Halle (1968), it has been a topic of much debate how much diachronic information is available to current speakers of a language. Hale and Reiss (2000) and Scheer (2015) argue that there is no principled limit on the abstractness of underlying representations, while Blevins (e.g. 2004) argues that explanations for phonological patterns should generally be found in diachrony, and that diachronic information is not available to current speakers. I tend strongly towards the second position here: even if [ŋ] behaves like a nasal + stop cluster, that is not sufficient evidence that speakers still store it as such.

Grønnum (2005: 308) points out that that the /g/ in /ng/ actually surfaces in some [ŋ]-final roots in few morphological contexts, namely before the verbalizing suffix [-ˈeːˀɐ] *-ere* and the demonym suffix [-ˈɛnˀsɐ] *-enser*, both of which cause stress shift, as in (8).

(8)	[tifˈtʰʌŋ]	*diftong*	‘diphthong’
	[tiftʰʌŋˈkeːˀɐ]	*diftongere*	‘diphthongize’
	[ˈkʰʌleŋ]	*Kolding*	(city name)
	[kʰʌleŋˈkɛnˀsɐ]	*koldingenser*	‘person from Kolding’

These are taken as evidence that /g/ in /ng/-clusters deletes in final position after the application of a place assimilation rule, and /g/ surfaces only if resyllabified to a subsequent stressed syllable. The number of such alternations is extremely limited, and /g/ does not surface before unstressed syllables, as evidenced by the alternation in

(9) and several imperative–infinitive alternations in verbs with final [ŋ].

(9)	[ˈsɑŋˀ]	*sang*	'song'
	[ˈsɑ.ŋɐ]	*sanger*	'singer'

It can be discussed whether the alternations in (8) provide evidence that *diftong* and *Kolding* have /g/ specified at some level of representation, but it does not seem sufficient to posit that all instances of [ŋ] have underlying /g/. For comparison, consider the city names *Esbjerg* and *Hamborg* and their demonyms in (10):

(10)	[ˈɛspjæɐ̯ˀ]	*Esbjerg*	(city name)
	[ɛspjæɐ̯ˈkɛnˀsɐ]	*esbjergenser*	'person from Esbjerg'
	[ˈhɑmpɒːˀ]	*Hamborg*	'Hamburg'
	[hɑmpɒˈkɛnˀsɐ]	*hamborgenser*	'person from Hamburg'

The names of *Esbjerg* and *Hamborg* are both in principle decomposable: *bjerg* translates as 'mountain', *borg* as 'castle'. It is unlikely that speakers store them as compounds, though; the first syllables are cranberry morphemes, and the second parts are phonetically reduced and semantically hardly associated with these place names.[20] In their unreduced forms, these two words are realized as [pjæɐ̯ˀʊ̯] *bjerg* and [pɒːˀʊ̯] *borg*, respectively. Recall from Table 2.3 that [ʊ̯] is sometimes analyzed as a weak allophone of /g/; [k] surfacing in the demonyms *esbjergenser* and *hamborgenser* may be considered evidence that /g/ is still present in the underlying forms of these particular city names, even if it is never otherwise realized[21] – but it should certainly not be considered evidence that every instance of [ɐ̯] is derived from underlying /rg/.[22] Since the analysis does not work in (10), I propose that it also does not work in (8).

[20] In fact, the area around Esbjerg is notoriously flat.

[21] I would not actually argue in favor of this. The *-enser* suffix is unproductive and quite rare, even in demonyms; more likely, the demonyms are stored separately rather than actively derived.

[22] Note that there are multiple reasons to assume that [ɒː], as seen finally in *Hamborg*, is underlying /ɔr/. This is evidenced by fully productive verb alternations like infinitive [stɔːˀ] *stå* 'to stand' and present tense [stɒːˀ] *står*.

2.4.3 Underlying representation

Determining how phonemes are underlyingly represented is a key priority in phonology; most commonly, this is done with distinctive features, but I discuss other mechanisms as well. Two sets of features are relevant in distinguishing the Danish stops: place features, in order to group the stops into classes of /b p/, /d t/, and /g k/; and laryngeal features, in order to group the stops into classes of /b d g/ and /p t k/. There has been little discussion of how place of articulation is underlyingly represented, even though this is actually crucial in order to account for the gradation patterns discussed in Section 2.4.4 and Chapter 3. The specific nature of the laryngeal contrast has been subject to much discussion. This is due to a.o. differences in opinion about what phonological patterns should be accounted for, and how phonetically substantial the representational mechanism should be.

2.4.3.1 Representation of laryngeal contrast

Danish stops have frequently come up in discussions about how the distinction between /b d g/ and /p t k/ should be underlyingly represented. Kohler (1984) assumes the feature [fortis]; Keating (1984a) and Kingston and Diehl (1994) assume an abstract feature [voice] with variable phonetic correlates; Iverson and Salmons (1995), Basbøll (2005), Grønnum (2005), and Beckman et al. (2013) use [spread glottis] with clear phonetic correlates;[23] Goldstein and Browman (1986) use gestural scores; Puggaard-Rode et al. (forthc.) model the contrast as a quantity difference in subsegmental representational units. There are several other proposals concerning laryngeal representation in the literature that do not touch on Danish in particular, which I will not discuss here, including Chomsky and Halle (1968), Halle and Stevens (1971), Lombardi (1995), and Avery and Idsardi (2001).

Kohler's (1984) use of the feature [fortis] (a 'power' feature as opposed to a laryngeal feature) was already mentioned in Section 2.3.5 above. The feature is intended to broadly cover laryngeal contrasts in obstruents, but also to have clear phonetic correlates. Kohler clarifies some of these, and discusses some phonological processes associated with the feature. [+fortis] has two primary articulatory correlates:

[23]This approach is termed 'laryngeal realism' by Honeybone (2005).

1) Greater articulatory power in oral stricture formation, which is a.o. cued by quicker movement towards closure, and leads to the common sound changes of vowel shortening and vowel lowering before [+fortis] obstruents ('pre-fortis clipping'); and 2) greater activity of glottal muscles, implemented either as tensing of the vocal cords or wide opening of the glottis, and cued by e.g. closure voicing, aspiration, and F_0-perturbations. The feature can also be implemented in various other ways. Kohler notes that closure voicing is an "extreme manifestation" (1984: 163) of [-fortis], since air stream power and articulatory tension are necessarily very low during closure voicing.

Kohler's treatment of Danish is somewhat contradictory. On the one hand, he assumes that a lower degree of oral stricture in lenis stops (/b d g/) is the cause of the historical plosive weakening chain discussed in Section 2.2, as well as the stop–semivowel alternations still found synchronically (see Section 2.4.4 and Chapter 3): since /b d g/ are lenis, they are produced with less tight stricture than /p t k/, and are thus more likely to lose that stricture during quick, spontaneous speech (Kohler 1984: 156–158). On the other hand, Kohler is aware of and cites the research by Fischer-Jørgensen and Hirose (1974) showing that Danish /b d g/ are *not*, in fact, produced with a less tight stricture than /p t k/ (see Section 2.3.5). According to Kohler (1984: 164–165), this is due to a trade-off between the oral and glottal correlates of [fortis]: a long aspiration phase is correlated with short closure duration and *vice versa*, and since aspiration in Danish fortis stops is very long and prominent, closure duration is correspondingly short, and the force of closure is correspondingly weak. These two positions are seemingly incompatible; the first requires /b d g/ to have weaker relative organic pressure, while the second acknowledges that /p t k/ have weaker relative organic pressure and seeks to explain why. Finally, recall from Section 2.3.6 that studies of F_0-perturbations in Danish are inconclusive, and F_0 is locally raised after all stops. Kohler asserts to explain Danish stop gradation with [fortis], but the relevant phonetic correlates of [fortis] seemingly do not apply to the Danish contrast.

Keating (1984a) criticizes the idea that phonological features should necessarily be phonetically substantial. She argues that such an approach unavoidably results in too many features, which have no generalizability beyond one or a few languages. She argues for a three levels of representation: 1) a universal phonological level, where only possible phonologically active contrasts are specified; 2) a universal phonetic category level, where only possible phonetically distinct contrasts are specified; and 3) a continuous phonetic level, where the phonetic categories are implemented according to language-specific rules. At the phonological level, the abstract feature [voice] is sufficient to account for all two-way laryngeal contrasts in obstruents. This can be implemented with the phonetic categories {voiced} and {voiceless unaspirated}, or {voiceless unaspirated} and {voiceless aspirated}[24] – these contrasts should play no role at the phonological level. [voice] is argued to be active in at least three common phonological processes, regardless of which phonetic categories it maps onto: vowel duration effects, F_0-perturbations, and assimilation. Danish is specifically mentioned here as a language with progressive [voice] assimilation, as opposed to Polish, which has regressive [voice] assimilation. Keating does not go into any detail here, but she presumably refers to progressive devoicing of sonorants after aspirated stops (as discussed in Section 2.3.1) – i.e. progressive assimilation of [-voice]. Her account of assimilation is short, and misses important assymetries in laryngeal assimilation: [+voice] spreads in languages where [+voice] is cued with closure voicing, and [-voice] spreads in languages where [-voice] is cued with aspiration, as pointed out by Iverson and Salmons (1995). The direction of spreading is also asymmetrical, such that voicing usually spreads regressively (Lombardi 1999), while aspiration usually spreads progressively (Iverson and Salmons 1995).

Kingston and Diehl (1994) also argue that all Germanic languages have a [voice] distinction in obstruents, with two main correlates: [+voice] has earlier voicing onset relative to release than [-voice], and [+voice] always acts as an F_0-depressor.[25] There is certainly a difference in relative voicing onset between the two laryngeal series in Danish, but as mentioned several times above, there is little (and conflicting) evidence for laryngeally induced F_0-perturbations. Kingston and Diehl *do* assume a feature [spread glottis] for e.g. languages with three-way

[24]See Vaux and Wolfe (2005) for a discussion of the other logical combination, {voiced} and {voiceless unaspirated}, which is not mentioned by Keating (1984a).

[25]Recall from Section 2.3.6 that the directionality of F_0-perturbations assumed by Kingston and Diehl (1994) has been contested by e.g. Hanson (2009).

laryngeal contrasts and a number of Chinese languages. When they analyze Danish as having contrastive [voice], it is ostensibly due to categorical intervocalic voicing in Danish (ibid.: fn. 16). Recall from Section 2.3.2 that this is actually understudied; I return to this issue in Chapter 4, where it is shown that Modern Standard Danish does not have categorical intervocalic voicing in /b d g/. The specific issues with Kingston and Diehl's treatment of the Danish data would likely be solved if Danish was analyzed as having a [spread glottis]-based contrast rather than a [voice]-based contrast.

Iverson and Salmons (1995) opt for a less abstract representation of the laryngeal contrast. They use [spread glottis] as the feature responsible for the laryngeal contrast in most Germanic languages, with the notable exception of Dutch. This approach accounts for a number of phonological processes and restrictions. Key among them is devoicing of sonorants following [+spread glottis] segments, which is analyzed as progressive assimilation of [+spread glottis], and which does not occur in so-called 'true voicing' languages, where the laryngeal contrast is cued with closure voicing. However, recall from Section 2.3.1 that acoustic studies of both Danish (Juul et al. 2019) and English (Tsuchida et al. 2000) find that this devoicing process is much less categorical than often assumed. In particular, these studies found very little evidence for sonorant devoicing after voiceless fricatives. Iverson and Salmons' approach also accounts for the loss of aspiration in /s/ + stop clusters, by assuming that a single [+spread glottis] feature is linked to both consonants. Other work has also proposed that onsets can have only one glottal gesture or laryngeal feature (Browman and Goldstein 1986; Anderson and Ewen 1987; Kehrein and Golston 2004).

Beckman et al. (2013) follow Iverson and Salmons in assuming that only [spread glottis] is active in languages with aspiration-based stop contrasts. They go on to suggest, following a proposal by Chomsky and Halle (1968), that + and - values for features are converted to numerical values on a language-specific basis during phonetic implementation. In an aspiration language like German, /b d g/ are [-spread glottis] and /p t k/ are [+spread glottis]. During phonetic implementation, [+spread glottis] is converted to a high numerical value like [9sg] and [-spread glottis] to a low numerical value like [1sg]. The low value assigned to /b d g/ allows for passive voicing in intervocalic position.

In Danish, [+spread glottis] is also converted to a high value of [9sg], while [-spread glottis] is converted into a medium-high value like [5sg]. This ostensibly accounts for why passive voicing in Danish /b d g/ is blocked (following Jessen 2001) – recall that Kingston and Diehl (1994) sought to explain essentially the opposite pattern, namely that intervocalic voicing in Danish /b d g/ is categorical; recall also from Section 2.3.2 that there is actually no consensus about the extent of passive voicing in Danish. Kirby and Ladd (2018) provide a critique of Beckman et al.'s (2013), particularly as pertains to F_0-perturbations.

Grønnum (2005) also assumes that the relevant laryngeal feature is [spread glottis], and that this accounts for sonorant devoicing. She assumes a separate feature [aspirated], which is added to [+spread glottis] stops syllable-initially, as in (11) (ibid.: 403):

(11) [+spread glottis, -continuant] ⟶ [+aspirated] / σ(_

F_0-perturbations should be a problem to a [spread glottis] account, since they are often taken as evidence of a more abstract [voice] feature. However, as Goldstein and Browman (1986) point out, F_0-perturbations can be interpreted as a direct result of laryngeal activity during stop articulation. They argue that an articulatory account of F_0-perturbations provide a better explanation of the Danish data. Their proposal for underlying representation of the Danish laryngeal contrast is in line with their Articulatory Phonology framework (Browman and Goldstein 1986, 1992), which framework abandons discrete segments altogether, and instead assumes continuous underlying representations consisting of gestural scores of varying magnitudes.

Puggaard-Rode et al. (forthc.) account for the Danish laryngeal contrast using a novel representational framework called Q-CV. Q-CV is an extension of Q-theory (Inkelas and Shih 2017; Shih and Inkelas 2019a), which proposes a quantized approach to phonological representation. Traditional segments are divided into distinct units (subsegments) which may carry separate sets of distinctive features, and traditional segments are emergent from these (Shih and Inkelas 2019b). The earliest papers suggested that all traditional segments consist of three subsegments, but it has more recently been argued that quantity contrasts can be modeled by varying the number of subsegments (Garvin et al. 2018, 2020; Schwarz et al. 2019). The innovation of Q-CV is that subsegments are anchored by root nodes which are defined in terms of simple head–dependency relationships between C and V components, inspired by Dependency Phonology (e.g. Anderson and Ewen 1987). A root node C is defined as a complete closure with no outgoing air, and C_V is defined as a prominent constriction resulting in turbulent airflow. Puggaard-Rode et al. propose that most attested laryngeal contrasts in stops (see Ladefoged 1973; Henton et al. 1992) can be represented by varying the number and order of C and C_V nodes.

The plain unaspirated stops /b d g/ in Danish are represented as in (12), where 'pl' represents any place feature, and co-indexing indicates that the place feature is the same throughout.

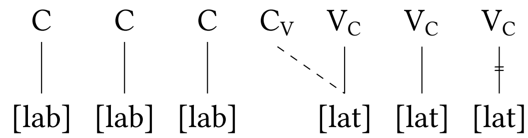
(12)
$$\begin{array}{ccc} \mathrm{C} & \mathrm{C} & \mathrm{C} \\ | & | & | \\ \mathrm{pl}_i & \mathrm{pl}_i & \mathrm{pl}_i \end{array}$$

The aspirated stops /p t k/ are represented as in (13). The prominent aspirated release is modeled as a bare C_V node with no associated place features.

(13)
$$\begin{array}{cccc} \mathrm{C} & \mathrm{C} & \mathrm{C} & \mathrm{C_V} \\ | & | & | & \\ \mathrm{pl}_i & \mathrm{pl}_i & \mathrm{pl}_i & \end{array}$$

An advantage of this approach is that it elegantly captures the gradient nature of sonorant devoicing in Danish. A [p^hl] sequence is shown in (14). Rather than a feature like [spread glottis] spreading from the stop to the liquid, partial liquid 'devoicing' is modeled as the feature [lateral] spreading into the bare C_V node of the stop release. (The other root nodes of the lateral are marked as V_C, which is defined as a constriction which does not significantly obstruct air flow.)

(14)



In (14), the final [lateral] feature delinks from its root node due to a process of 'compensatory shortening'. This happens because the feature [lateral] retains a fairly distinct spectral profile when voiceless (e.g. Maddieson and Emmorey 1984), unlike nasals, which do not have a significantly shortened voiced phase after aspirated stops (Juul et al. 2019).

The approach of Puggaard-Rode et al. can also account for why sonorant devoicing is negligible after /f s/. Voiceless fricatives, like aspirated stop releases, have C_V root nodes, but they have associated place features, which inhibit features like [lateral] from spreading to them.

Summing up, Kohler (1984) assumes that the laryngeal distnction is modulated with the feature [fortis], but his approach cannot account for findings relating to articulatory force in Danish stop production (see Section 2.3.5). Keating (1984a) and Kingston and Diehl (1994) assume a [voice]-based distinction, where feature values are cued by language-internal relative differences in voicing onset rather, laryngeally induced F_0-perturbations, and the presence of intervocalic voicing, rather than actual closure voicing. The first criterion certainly holds for Danish, but the second is not fully supported by the literature (see Section 2.3.6), and the extent of the third is rather overestimated (see Section 2.3.2 and Chapter 4). Iverson and Salmons (1995) assume the feature [spread glottis] modulates the contrast, and this ostensibly explains patterns of sonorant devoicing, although this effect has also been rather overestimated (see Section 2.3.1). Beckman et al. (2013) assume that [-spread glottis] in Danish is assigned a medium-high value during phonetic implementation, accounting for why passive intervocalic voicing is blocked – i.e. assuming a different set of phonetic facts than Kingston and Diehl (1994). Goldstein and Browman (1986) use gestural scores to represent the contrast, and argue that this can account for the gradient patterns of F_0-perturbations reported in the literature (see Section 2.3.6). Puggaard-Rode et al. (forthc.)

Table 2.4: *Overview of proposals regarding the representation of laryngeal contrast in Danish.*

Proposal	**Feature or mechanism**	**Phonetic correlates**	**Explained phonological patterns**
Kohler (1984)	[fortis]	Articulatory force in oral stricture and glottal activity	Stop gradations
Keating (1984a)	[voice]	No correlates required	Progressive devoicing of sonorants
Kingston and Diehl (1994)	[voice]	Relative voicing onset and F_0-perturbations	Intervocalic voicing
Iverson and Salmons (1995)	[spread glottis]	Aspiration	Progressive devoicing of sonorants
Beckman et al. (2013)	[spread glottis]	Aspiration	No passive voicing
Goldstein and Browman (1986)	Gestural scores	Voicing, aspiration, F_0-perturbations	–
Puggaard-Rode et al. (forthc.)	Additional C_V root node	Aspiration	Gradient sonorant devoicing

represent the contrast with the presence or absence of a bare C_V root node in the novel framework of Q-CV. This approach can account for the gradient nature of sonorant devoicing found by Juul et al. (2019). In Table 2.4, I give an overview of the different proposals.

The proposals regarding laryngeal representation aim to account for different, sometimes conflicting, phonetic phenomena and phonological processes. Some issues could be resolved if we had a clearer idea about the extent of passive voicing in /b d g/; in Chapter 4, I summarize the predictions of different approaches regarding intervocalic voicing, and discuss them again in the light of new data from a corpus study.

2.4.3.2 Representation of place contrasts

Grønnum (2005) follows Chomsky and Halle (1968) and most later work in distinctive feature theory (see Broe 1992) in using place features that refer to the active articulator: /b p/ are [labial], /d t/ are [coronal], and /g k/ are [dorsal]. Basbøll (2005), somewhat untraditionally, refers to the passive articulator in phonological feature labels, such that /d t/ are [alveolar] and /g k/ are [velar]. In spite of this difference at face value, the choice of active vs. passive articulator has no major consequences for their respective phonological analyses, at least not as pertains to stops. As we will see in the next section, this is partially because neither of them attempt to account for the concomitant changes in place of articulation that result from stop–semivowel alternations. I argue in Section 3.4.2 that the labels LABIAL, CORONAL, and DORSAL (as used in Feature Geometry; e.g. Sagey 1986) can more readily account for the stop–semivowel alternations than the features used by Basbøll and Grønnum.

2.4.4 Gradation patterns

The Danish stop gradation patterns have already been briefly covered in Section 2.4.1 above, and a critique and reanalysis will follow in Chapter 3. Here, I will cover the history of the traditional analysis of Danish stops and their allophony, and the main arguments usually presented in favor of the analysis. I will also exemplify the relevant patterns.

Uldall (1936) hinted at part of the analysis when he proposed that the phonemes /d g/ were realized as [t k] in strong position and [ð ɣ] in weak position.[26] As Jakobson et al. (1951) point out, this results in an analysis where the phonemic affiliation of an unaspirated [t] depends on its prosodic position – [t] in strong position derives from underlying /d/, while [t] in weak position derives from underlying /t/. Interestingly, around the same time, Martinet (1937: 41ff.) noted the possi-

[26] I use the symbols [ð ɣ] here as the sounds were likely less vocalic at the time.

Table 2.5: *Realizations of stop phonemes, following Grønnum's (2005) analysis.*

Phoneme	*Strong*	*Weak*
/b/	[p]	[p ~ ʊ̯]
/d/	[t]	[ɣ̞ ~ Ø]
/g/	[k]	[k ~ ɪ̯ ~ ʊ̯ ~ Ø]
/p/	[pʰ]	[p]
/t/	[tʰ]	[t]
/k/	[kʰ]	[k]

bility of an analysis similar to Uldall's, but argued explicitly against it on the grounds that it would be excessively abstract.

Hjelmslev (1951) also analyzes [ð ɣ] as allophones of /d g/, although recall from Section 2.4.2.2 that he assumed only one series of stop phonemes. As a result, for Hjelmslev, [ð ɣ] in weak position are analyzed as /d g/, while [t k] in weak position in weak position are analyzed as abstract clusters of /hd hg/.

Rischel (1970a) was the first to propose a generative analysis of the full system, drawing on morphophonological alternations. Rischel's analysis still relied heavily on the presence of the 'soft g', a velar voiced fricative or approximant [ɣ ~ ɰ]. Recall from Section 2.2 that the soft g is no longer found in Modern Standard Danish, although it would have been found in conservative varieties at the time. Rischel also incorporated alternations between /g/ and [ɪ̯ ʊ̯]. This indicates that his analysis covers a previous diachronic stage, where stylistic alternations between [ɣ ~ ɰ] and the semivowels [ɪ̯ ʊ̯] were still observed. This latter point is made explicit in the similar analysis by Basbøll (1975: 65–67), where he mentions stylistic alternations of the form [lɔːˀv ~ lɔːˀʊ̯] *lov!* 'promise!' and [lɔːˀɣ ~ lɔːˀʊ̯] *låg* 'lid'. Such stylistic alternations were a strong argument in favor of the traditional analysis, but they are no longer found in Modern Standard Danish.

The analysis given by Grønnum (2005) is similar to Richel's and the early analysis by Basbøll, except it no longer relies on the soft g, which had been completely lost at this point. Grønnum's analysis yields the strong and weak realizations of stop phonemes seen in Table 2.5. Since stylistic alternations that support the traditional analysis are no longer observed, support for the analysis can only be found in morphophonological alternations. Evidence for the traditional analysis of /p t k/ comes from alternations with e.g. the verbalizing suffix [-ˈeːˀɐ] *-ere*, which causes stress shift, as in (15).

(15)	[kæˈlʌp]	*galop*	'gallop (n.)'
	[kælʌˈpʰeːˀɐ]	*galopere*	'to gallop'
	[ʋæt]	*vat*	'cotton wool'
	[ʋæˈtʰeːˀɐ]	*vattere*	'to apply cotton wool'
	[lɑk]	*lak*	'lacquer (n.)'
	[lɑˈkʰeːˀɐ]	*lakere*	'to lacquer'

[p ~ ʊ̯] alternations are found to varying extents throughout the speech community, but are generally considered less 'standard' than the other stop–glide alternations (as evident from relevant entries in the pronunciation dictionary of Brink et al. 1991). When /b/ can be a realized as [ʊ̯], there is stylistic variation between [ʊ̯ ~ p]; this is unlike /d ɡ/, where replacing semivowels with stops is generally ungrammatical.[27] Evidence for [p ~ ʊ̯] alternations comes from strong declension in verbs, in particular the present participle [-t] *-t* suffix and the past tense [-tə] *-te* suffix; usually, strong allophones are found in coda position before these suffixes, as in (16).[28] The strong verbal declension is both irregular and unproductive.

(16)	[ˈkʰøːøp ~ ˈkʰøːʊ]	*købe*	'to buy'
	[ˈkʰøptə, *ˈkʰøʊ̯tə]	*købte*	'bought'

Note that the vowel copy in [ˈkʰøːøp] and syllabicity of [ʊ̯] in [ˈkʰøːʊ] are due to schwa assimilation; see Brink and Lund (1975: ch. 32), Basbøll (2005: ch. 11), and Schachtenhaufen (2010b, 2012, 2013) for overviews of these complex phenomena. Note also that [ˈkʰøʊ̯tə] is certainly acceptable in some varieties of Danish, but in these varieties, there is

[27] A notable counterexample is found in the suffix [-ɤ] *-et*, which may be either a past participle suffix in verbs or a neuter definite suffix in nouns. This suffix displays stylistic (and largely regional) variation between [-ɤ ~ -ət] (Petersen et al. 2021).

[28] Note that weak allophones are found before the otherwise homophonous neuter gender [-t] *-t* suffix in adjectives.

no evidence to suggest that the consonant in question is underlyingly /b/.

Evidence for stop–semivowel alternations in /d/ generally comes from unproductive morphological derivations in Latinate loanwords, as in (17).[29] As with [-ˈeːˀɐ] *-ere*, the suffixes [-iˈtʰeːˀt] *-itet* and [-ˈik] *-ik* both cause stress shift.

(17)	[soˈliɣ̞ˀ]	*solid*	'solid'
	[solitiˈtʰeːˀt]	*soliditet*	'solidity'
	[meˈtʰoːɤ]	*metode*	'method'
	[metʰoˈtik]	*metodik*	'methodology'

/d/ is often left unrealized, because there are several phonological environments where [ɣ̞] is not allowed. For example, /d/ is usually deleted before [t], as in (18), where the neuter suffix [-t] *-t* is added to a [ɣ̞]-final root. This is ostensibly due to an OCP constraint, but recall from Section 2.4.2.1, though, that there is little reason why a synchronic OCP constraint should rule out a surface cluster of [ɣ̞t]. More likely, this is the result of an OCP constraint operating historically.

(18)	[soˈliɣ̞ˀ]	*solid*	'solid'
	[soˈlit]	*solidt*	'solid (neu.)'

[ɣ̞] is consistently not found in coda position after other consonants, but in Rischel's (1970a) analysis, /d/ is Ø-realized but phonologically present in a number of words where it emerges in the derivational morphology. His examples come from the adjectivizing suffixes [-i] *-ig* and [-isk] *-isk*, as in (19).

(19)	[sønˀ]	*synd*	'sin'
	[ˈsønti]	*syndig*	'sinful'
	[joːˀɐ̯]	*jord*	'earth'
	[ˈjoɐ̯tisk]	*jordisk*	'earthly'

[29] I will use the established term Latinate (e.g. Plag 1999: 54ff.) throughout the dissertation to refer to loanwords of either Greek or Latin origin.

A problem with this, as Rischel also notes, is that these suffixes are usually preceded by weak consonant allophones (including [ɣ̞]) in other words, as demonstrated in (20).

(20)	[tyɣ̞ˀ]	*dyd*	'virtue'
	[ˈtyːɣ̞i]	*dydig*	'virtuous'
	[ˈjøːɤ]	*jøde*	'Jew'
	[ˈjøːɣ̞isk]	*jødisk*	'Jewish'

This could be an argument in favor of analyzing the [t ~ Ø] alternations in (19) as evidence for suppletive roots rather than the result of a synchronically active phonological process.

Evidence for stop–semivowel alternations in /ɡ/ comes from both strong declension of verbs and derivations of Latinate loanwords. In accordance with historical spirant weakening as shown in (1), a very rough system for the realization of weak /ɡ/ can be expressed as in (21).

(21)	/ɡ/	⟶	[ɪ̯]	/	after front vowels
			[ʊ̯]	/	after back vowels

Note, however, that /ɡ/ is not realized if the process in (21) results in a diphthong with minimal movement, i.e. *[iɪ̯ yɪ̯ uʊ̯ oʊ̯].[30] In some cases, the patterns in (21) only reflect older stages of Danish; historical changes in vowel quality have not necessarily led to corresponding changes in /ɡ/-allophone. An example is the word [ˈstɑːɪ] *stege* 'fry' which has a back vowel in Modern Standard Danish, but surfaces with a front vowel and [k] when it undergoes (strong) declension, as in [stekt] *stegt* 'fried'. This suggests that the rule in (21) may not be synchronically active.

Both [ɪ̯] and [ʊ̯] alternate with [k] in the morphology of words like *bage* 'to bake'. Here, morphophonologically induced vowel shortening causes vowel backing [æ ⟶ ɑ] in the highly lexicalized compound

[30] [eɪ̯ øɪ̯] are found in conservative Copenhagen Standard Danish, but not in younger Copenhagen Standard Danish or in my variety. In conservative Copenhagen Standard Danish, the words *hø* 'hay' and *høg* 'hawk' are pronounced as [høːˀ] and [høːˀɪ̯], respectively; in younger Copenhagen Standard Danish, the distinction is neutralized, and both are pronounced [høːˀ] (Schachtenhaufen 2020–). In (my variety of) Jutlandic Standard Danish, however, there seems to be a distinction between length and overlength in such pairs: [høːˀ] *hø*, [høːːˀ] *høg*.

bagværk 'baked goods' and in the strong declinations, as seen in (22); unlike in the *stege* example above, this [ɑ] clearly patterns as a back vowel.

(22)	[ˈpæːɪ]	*bage*	'to bake'
	[ˈpɑʊ̯ʋæɐ̯k]	*bagværk*	'baked goods'
	[ˈpɑktə]	*bagte*	'baked'

Evidence for [k ~ Ø] alternations are found in the derivational morphology of some Latinate loanwords, as in (23).

(23)	[filoˈloːˀ]	*filolog*	'philologist'
	[filoloˈkiːˀ]	*filologi*	'philology'

This particular alternation between [oˈloːˀ] and [oloˈkiːˀ] is found in several pairs of words denoting scientific fields and practitioners of those fields, such as *antropolog* ~ *antropologi* 'anthropologist ~ anthropology', *psykolog* ~ *psykologi* 'psychogist ~ psychology', *fonolog* ~ *fonologi* 'phonologist ~ phonology'. It is possible that speakers have reanalyzed the original stress-shifting [-iːˀ] *-i* suffix as a stress-shifting [-kiːˀ] *-gi* suffix in this group of words.

Rischel (1970a: 472) derives the gradation patterns with the ordered set of rules in (24).

(24) a. [+obstruent, -continuant] ⟶ [-voiced] / strong position
b. [+voiced] ⟶ [+continuant]

He assumes that the feature modulating the laryngeal contrast is [voiced]. In (24-a), non-continuant obstruents are devoiced in strong position. In (24-b), any remaining [+voiced] sound, i.e. any [+voiced] obstruent in weak position, is weakened to a continuant.

Grønnum (2005: 402) derives the gradation patterns with the simple rule in (25).

(25) [-spread glottis, -continuant] ⟶ [+voiced, +continuant] / _)σ

In prose, unaspirated stops are realized as voiced continuants syllable-finally.

These rules have little explanatory value and appear functionally unintuitive, but otherwise capture the concomitant changes in manner features quite well. They do not, however, capture the changes in place features. Grønnum even specifically notes that this rule captures the process /g/ ⟶ [ɣ], but requires another step (which she does not formalize) to derive the semivowels that are actually realized; in other words, the rule requires speakers to reconstruct a lost allophone in the process of derivation. This problem is not limited to /g/; in fact, the rules cannot straightforwardly account for the places of articulation of any of the derived semivowels. I discuss this problem further in Section 3.3.2.

Pharao (2004) reports a psycholinguistic production study where speakers were asked to form morphologically complex nonce words in order to test the productivity of the gradation patterns. For example, a participant would be asked to form a verb from the nonce noun [slyɣ̯ˀ] with the verbalizing [-ˈeːˀɐ] suffix; [slyˈteːˀɐ] would be taken as evidence for the productivity of stop gradation, [slyˈɣ̯eːˀɐ] as evidence against it. His results show that productivity of the gradation pattern is speaker-specific: some reproduce it, others do not. In any case, this may not be evidence of a productive phonological rule, but could just as well be considered evidence of highly specific productive morphological schemas, following Bybee (e.g. 1985, 2001; Bybee and Slobin 1982)

Basbøll (1968, 2005, 2015) assumes a strict division between phonology and morphophonology, and does not require core phonology to account for stop gradation. He requires that all allophones of the same phoneme share distinctive feature(s), and that a phoneme can be determined for each allophone on the basis of purely phonological principles. As such, he analyzes /ɣ̯/ as a separate phoneme, and [ʊ̯ ɪ̯] as allophones of /v j/ – always. He also has a further level of representation, where morphophonemes like |b d g| can be realized as phonemes like /v ɣ̯ j/. Morphophonemes are established from phonemes on the basis of morphological alternations. In this model, the units of lexical storage are morphophonemes, but Basbøll remains skeptical of the psychological validity of this construct. Basbøll’s analysis is otherwise essentially identical to the analysis of Grønnum (2005), but the division of labor between different grammatical modules is quite different.

Ács et al. (2008; see also Ács and Jørgensen 2016) reanalyze the stop–semivowel alternations in a pair of papers that weigh the Natural Phonology notion of biuniqueness very highly; namely, the notion that phone–phoneme correspondences are as transparent and uniform as possible (e.g. Stampe 1969). In their analysis, each distinctive sound translates into a separate phoneme. Accordingly, they propose a much higher number of distinctive phonemes, but do not require an elaborate set of rules to arrive at positional allophones.

In this section, I have provided an overview of the traditional analysis of Danish stop gradation. I will return to this analysis in Chapter 3, where I argue that the traditional analysis reflects sound change rather than synchronic phonology, and that the patterns of stop gradation do not play a role in synchronically active phonology.

2.4.5 Summary

Danish positional allophones are best analyzed as belonging to a 'strong' series and a 'weak' series. Two laryngeal series of stops are found in strong position, and only one is found in weak position. Danish is a phonotactically quite permissive language, and the stops are found in a large number of surface clusters. The stops have been assumed to play a role in a number of abstract clusters, and it is often assumed that [ŋ] is derived from an underlying /ng/-cluster; I have argued against such an analysis. A number of different representational mechanisms have been claimed to modulate the laryngeal contrast in stops – [fortis], [voice], [spread glottis], gestural scores, and subsegmental quantity. Most of these accounts run afoul of some of the phonetic facts presented in Section 2.3 above. Finally, there is a long tradition for subsuming aspirated stops in strong position with unaspirated stops in weak position, and unaspirated stops in strong position with semivowels in weak position. I have given an overview of the (morpho)phonological evidence in favor of this analysis, and will return to arguments against this analysis in Chapter 3.

2.5 Variation

The dicussion of phonetics and phonology of Danish stops has so far been based on a rather narrow conception of 'Danish'. The studies summarized in Section 2.3 mostly characterize the phonetics of distinct Standard Copenhagen Danish as spoken in the laboratory. Descriptions of the phonology of Danish (Section 2.4) are also frequently concerned with a conservative, distinct form of Standard Copenhagen Danish. This is not an accident: modern-day Denmark has sometimes been described as one of the most radically standardized speech communities in Europe (Pedersen 2003, but see also Maegaard and Monka 2019). This does not, however, mean that Danish is without internal variation – nor that the traditional dialects, many of which are now moribund, have gone undescribed or undocumented. Peculiarities in the realization of stops play a salient role in certain sociolinguistic varieties of Danish, and differences in the phonetic realization and the phonological trajectories of stops abound in regional varieties and traditional dialects.

In Section 2.5.1 below, I summarize research intophonetic reduction of stops in Modern Standard Danish. Section 2.5.2 summarizes research into the social significance of different realizations of stops, while Section 2.5.3 provides a brief summary of existing descriptions of regional variation in stop phonetics and phonology.

2.5.1 Phonetic reduction

Pharao (2009, 2011, 2012) and Schachtenhaufen (2013) both studied reduction patterns in spontaneous Modern Standard Danish on the basis of the DanPASS corpus (Grønnum 2009; see Section 4.5.1). These in-depth studies are based on the relatively narrow transcriptions accompanying the recordings, rather than on the actual acoustic signal. Pharao focuses only on consonants, while Schachtenhaufen gives a more holistic overview of how all distinctive sounds behave in spontaneous speech. In what follows, I use parentheses around transcriptions to indicate that they are neither phonetic nor phonemic, but rather refer to study variables: (p t k) refer to stops that would be realized as aspirated in careful distinct speech, and (b d g) as unaspirated. This does not presuppose a phonological analysis.

The results of Pharao and Schachtenhaufen, insofar as they pertain to stops, are similar. Both find quite low rates of reduction in (p t k) and (b). (g) is reduced at very high rates – roughly half of all word-internal tokens of (g) are reduced in some way, although outright deletion is rare. The mechanisms responsible for (b g) reduction seem to be similar. (b g) both show highest reduction rates intervocalically, and speakers who reduce at high rates tend to do so for both sounds. The mechanism responsible for reduction in (d) is seemingly different. (d) deletes at quite high rates (22% of all word-internal tokens), while other forms of (d)-reduction are rare (Pharao 2011). The most common context for (d)-deletion is interconsonantal position, presumably as a result of cluster simplification. This may be because coronal stops are found frequently in affixes. Probabilistic deletion of particularly coronal stops in clusters is a well-known phenomenon in English (e.g. Guy 1991; Tanner et al. 2017; Holtz 2021), where coronal stops are also common in affixes.

Except in (d), reduction typically entails an increase in aperture: stops are realized as fricatives, or less commonly sonorants. Relatively speaking, (p t k) are much more likely than (b d g) to reduce to voiceless fricatives. Apart from deleting very commonly, (d) is commonly realized as a tap or semivowel [ɾ ɹ], and less commonly as a fricative [ð] (Schachtenhaufen 2013: 196).

Pharao et al. (2017) report a study testing listeners' ability to perceive words with reduced (g). They show that regardless of whether a categorical or continuous measure of reduction is used, listeners show significantly better perception of non-reduced (g). However, reduced and non-reduced (g) are both correctly perceived at high rates.

2.5.2 Social variation

Characteristics in the realization of /t/ which differ saliently from Modern Standard Danish have often been attributed to varieties spoken in ethnically diverse neighborhoods in Copenhagen ('multiethnolect'; e.g. Quist 2000). Features from these varieties are overall negatively stereotyped, and other speakers of Danish make quite specific characterizations of people on the basis of what is sometimes referred to as the 'street' register (Møller 2009). A key feature that distinguishes these varieties from others is prosody: Copenhagen's multiethnolect is perceived as staccato, and does not maintain a contrast between long and short vowels (Pharao and Hansen 2005; Møller 2009; Hansen and Pharao 2010).

Another key feature is palatalized affricated release of /t/, often transcribed [t^j] (e.g. Maegaard 2007; Madsen 2008, 2013; Lillelund-Holst and Pharao 2014; Hyttel-Sørensen 2017); <tj> is also frequently used in place of <t> in informal written speech parodying this variety (Stæhr 2015). Hyttel-Sørensen (2017) reports that the use of [t^j] is much more common among male speakers of multiethnolect, while Ag (2010) finds that [t^j] is frequently used among adolescent female speakers of multiethnolect. Lillelund-Holst et al. (2019) show that the use of [t^j] is associated with traits like non-Danish ethnicity and "playing tough" in the speech of adolescent girls, regardless of whether they also use the prosodic frame associated with multiethnolect; however, listeners judge the combination of [t^j] and a non-multiethnolect prosodic frame to be unnatural.

Pharao et al. (2014) showed that a fronted variant of [s] with high spectral center of gravity, sometimes transcribed [s^+], signals a feminine and homosexual register in male speakers when combined with a fairly neutral 'modern' Copenhagen prosodic frame. However, [s^+] is also a feature of multiethnolect, and any association with femininity and homosexuality disappears when combined with a multiethnolect prosodic frame. In a follow-up study, Pharao and Maegaard (2017) showed that male speakers using [s^+] are less likely to be evaluated as feminine and homosexual if listeners have already heard that speaker use [t^j]; if the order is swapped, and the speakers are first heard using [s^+], the use of [t^j] makes no difference. Speakers are also more likely to be evaluated as immigrants or 'gangsters' if they are heard using [t^j] before [s^+], but not if the order is swapped.

2.5.3 Regional variation

In the traditional regional varieties of Danish, many of which are now extinct or moribund (see Section 1.3), the stops often show different phonological behavior from Standard Danish, and the patterns of

Figure 2.1: *Map showing varying outcomes of /p/ weakening in traditional varieties of Danish. Adapted from Bennike and Kristensen (1898–1912: map 49) in slightly simplified form.*

plosive and spirant weakening discussed in Section 2.4.4 often had different outcomes than in Modern Standard Danish.

The current stop–semivowel alternations in Modern Standard Danish are largely a result of plosive and spirant weakening, which was found to various extents throughout the country. An overview of the precise outcomes throughout the country is given visually in maps 42–60 in Bennike and Kristensen (1898–1912), some of which are reproduced below; see also K4.1–K4.3 in Skautrup et al. (1970–) for more recent maps covering the Jutland peninsula, specifically. Sørensen (2012) also gives a detailed account of sound changes in different varieties.

In earlier stages of Standard Danish, Old Danish weak /p/ lenited into [ʊ̯], although this was later largely rolled back, such that Modern Standard Danish has relatively free variation between [p ~ ʊ̯] (see

Figure 2.2: *Map showing varying outcomes of /t/ weakening in traditional varieties of Danish. Adapted from Bennike and Kristensen (1898–1912: map 50) in slightly simplified form.*

Section 2.4.4). In different parts of the country, the sound developed consistently into bilabial and labiodental fricatives [β v f], as shown in Figure 2.1.[31] This map is limited to the present-day national borders, but the Danish-speaking area continues somewhat further south in the Jutland peninsula. The original map includes a small area further south, near present-day Viöl in Germany, where a stop [b ~ p] was retained.

Old Danish /t/ weakened into a semivowel [ɣ̯] in Modern Standard Danish.[32] In other parts of the country, it weakened in a variety of different ways, as mapped in Figure 2.2. Old Danish /t/ was generally

[31] The transcriptions in Figure 2.1 are 'translated' from Dania transcriptions; note that there is no way to determine whether the sound transcribed as [b] was actually voiced, nor whether the sound transcribed as [v] was actually a fricative.

[32] The development from [ð] to [ɣ̯] is quite recent (Brink and Lund 2018), so [ð] is used in Figure 2.2.

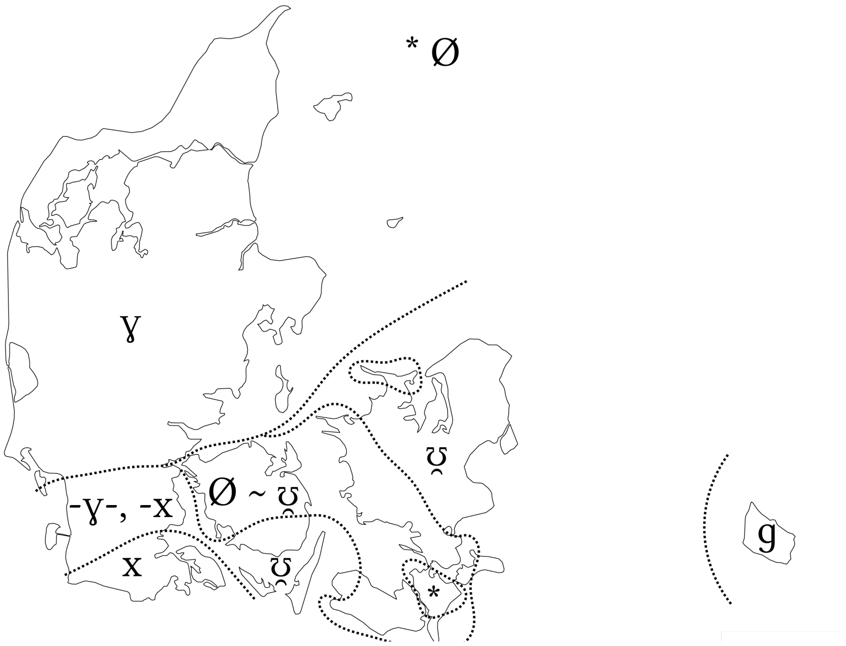


Figure 2.3: *Map showing varying outcomes of /k/ weakening after back vowels in traditional varieties of Danish. Adapted from Bennike and Kristensen (1898–1912: map 51) in slightly simplified form.*

quite unstable. In addition to the soft d (the precise pronunciation of which may vary across regions), it developed into a number of different glides or semivowels [ɪ̯ ʊ̯ ɣ ɹ],[33] and was lost entirely in large parts of the country. Similar to the development of Old Danish /p/, a small area in present-day Germany retained a stop [t] in some contexts.

Just as the development of Old Danish /k/ in Modern Standard Danish varied significantly by phonetic context, there are different regional outcomes by phonetic context. The map in Figure 2.3 shows

[33]It is difficult to say exactly what the transcription [r] in Bennike and Kristensen (1898–1912) refers to, but Veirup (1955) specifically describes it as a "fronted soft d", and classifies it as Dania [ṛ], which Jespersen (1890: 49) describes as very similar to American *r*, i.e. [ɹ].

the different outcomes after back vowels.[34] In some varieties the sound was lost entirely, in others it developed into fricatives [ɣ x] or the semivowel [ʊ̯]. In the area marked [Ø ~ ʊ̯], Old Danish [k] was lost completely after [u ɑ]. The map in Figure 2.4 shows the different outcomes after front vowels. Vocalization after front vowels resulted in [ɪ̯]. In areas marked [Ø ~ ɪ̯], the sound was lost entirely after high vowels [i y]. Old Danish /p k/ showed some class behavior, in that reduction to fricatives had similar outcomes – in areas where /p/ developed into a voiceless fricative [f], /k/ also developed into a voiceless fricative [x], and *vice versa* for voiced fricatives. This may be due to historical differences in closure voicing in these varieties, as I discuss in Section 6.6.

Old Danish medial geminates were generally retained as stops in insular dialects, including Standard Danish (as discussed in 2.2.1), but underwent a number of lenition processes in peninsular Danish. In some varieties, Old Danish [kː] developed into [c] or [ɣ] on a lexical basis, while [tː] developed in different ways, most often into [ɪ̯]. Recall from Section 2.2.1 that the laryngeal contrast in geminates was lost early on in the variety that developed into Standard Danish, due to devoicing of [bː dː gː]. In Jutlandic varieties, however, [bː dː] instead degeminated early on, and underwent the same plosive weakening processes as singletons; this caused some systematic differences between these varieties and Standard Danish. [gː] also degeminated in most varieties, but in some western and southern varieties, it devoiced instead, and merged with [kː], as in Standard Danish (Sørensen 2012).

Stops in simple onset have generally been quite stable, with a few systematic exceptions. Onset /d/ lenited to a voiced fricative in northern parts of the Jutland peninsula, and in a few areas it developed further into a rhotic or was lost completely. /g k/ underwent a number of palatalization processes before front vowels, such that they were realized as [gj kj] in most of the country (although not the variety from which Modern Standard Danish developed); in some areas, this resulted in alveopalatal affricates, fricatives, or glides [tɕ ɕ dʑ j].

[34] As in Figure 2.1, I cannot determine whether the sound transcribed as [g] was actually voiced. The sound transcribed as [x] may have been uvular [χ].

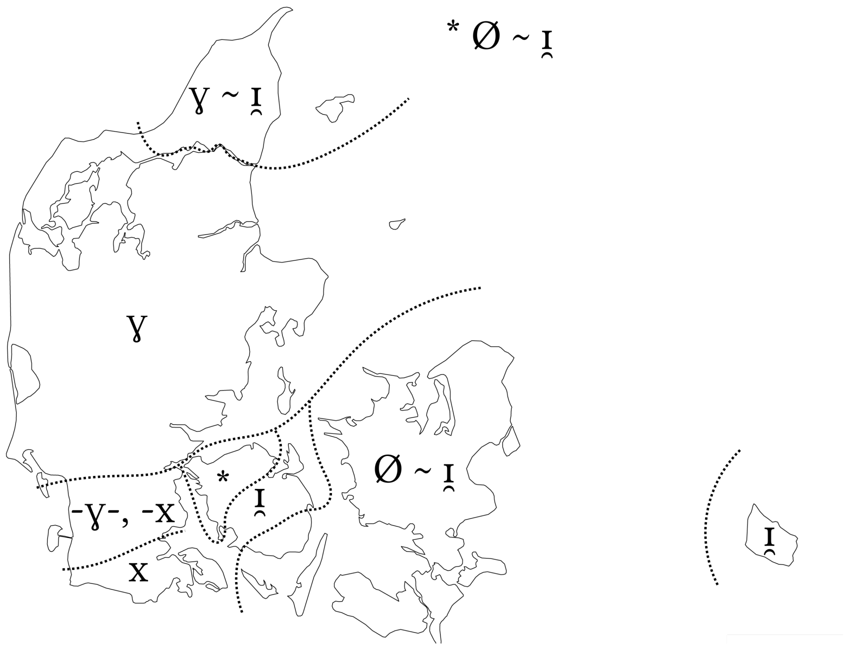


Figure 2.4: *Map showing varying outcomes of /k/ weakening after front vowels in traditional varieties of Danish. Adapted from Bennike and Kristensen (1898–1912: map 52) in slightly simplified form.*

Early descriptions of Danish phonetics sometimes described stød as a full glottal closure (e.g. Sweet 1874: 97, who describes it as "the sound produced in coughing"). In Modern Standard Danish, stød is better described as laryngealization rather than full glottal closure (e.g. Fischer-Jørgensen 1987, 1989), although full glottal closure may well be found in other varieties (e.g. Sørensen 2012). In several regional varieties, particularly in northern Jutland, stød is realized as a so-called 'parasitic plosive' (*klusilspring*), i.e. a dorsal stop, the precise place of articulation of which is determined by the preceding vowel. Parasitic plosives were first described by Nielsen (1947), and have been discussed several times since (Andersen 1955; Søndergaard 1970; Nielsen 1978; Ejskjær 1990, 2006; see Liberman 2006 for an argument that parasitic plosives are not related to stød). Andersen

(1972) argued that parasitic plosives are 'reduction diphthongs', i.e. vowels which undergo a change in the feature [±vocalic]. These vowels originally underwent syllable-finally devoicing (due to stød), and later developed secondary articulatory characteristics like friction or complete closure.[35] Mortensen (2012) analyzes this as a case of high vowel devoicing.

On the topic of stød, recall from Section 2.2.1 that some Western Jutlandic varieties have 'vestjysk stød', i.e. preglottalization of obstruents, as the modern reflex of Old Danish geminates (Skautrup 1928; Ringgaard 1960, 1974; Ejskjær 1967, 1990). In some varieties, preglottalization even co-occurs with parasitic plosives.

Overall, as should be clear from this brief overview, regional differences in the phonological development of stops are quite well-described. The situation is different for phonetic variation. The Danish dialectological tradition has largely been couched within the structuralist tradition of glossematics, which is explicitly not interested in phonetic substance (Hjelmslev 1943).

There has, however, been some interest in the variable realization of /t/. /t/-affrication (as discussed in 2.3.4) is known to be regionally delimited, although there is no consensus in the literature about which varieties lack affrication. Brink and Lund (1975: 353) describe it as missing from "all the country's dialects" (translation mine).[36] A distinctly non-affricated variant of /t/ is known colloquially as 'dry t'. Dry t is mentioned in an encyclopedia article on aspirated stops (Petersen 2009b), which associates the variant with northern Jutland; cp. the corresponding article on affricates, which makes reference to /t/ in Modern Standard Danish (Petersen 2009a). Petersen et al. (2021: 156ff.) describes non-affricated /t/ as a feature of western rather than northern Jutland. Grønnum (2005: 51) describes it as a feature of a "high and formal style" (translation mine); affrication *is* a relatively recent development, so non-affricated /t/ is conservative in a sense, but recall from Section 2.3.4 that affrication was already exceptionless in Copenhagen Danish by the early 1950s (Brink and Lund 1975). When descrip-

[35]Indeed, in recordings of these varieties, seemingly free variation is often heard between parasitic palatal and velar fricatives and parasitic plosives.

[36]This is a dubious claim, especially since Standard Copenhagen Danish is of course also a dialect.

tions of relevant regional varieties mention articulation of /t/, they simply say that it is fronted relative to Standard Danish (Nielsen 1984), or retracted relative to Standard Danish (Espegaard 1995), respectively. I published a small-scale study on the phonetics of /t/ throughout the Jutland peninsula, showing that lack of affrication is found to varying extents throughout the area (Puggaard 2018a; see also Puggaard 2018b). This study also found an interesting interaction between VOT and affrication; more noisy stop releases were found to be more common in varieties that also had relatively long VOT.

I return to regional variation in stops in Chapter 6, where I focus mostly on phonetic differences, which are certainly the most understudied. Using a large legacy corpus called *Dialektsamlingen* 'the dialect collection' (DS 1971–1976; see Section 6.2.2), I shed light on regional differences in VOT and affrication patterns in stops, and discuss the variable patterns of closure voicing in the data. I focus particularly on the varieties of Jutland, which show relatively limited influence from Copenhagen Danish in the corpus recordings.

2.5.4 Summary

In spite of the relatively unified account of stops given before this section, variation actually abounds. The unaspirated stops /b g/ commonly reduce in spontaneous speech, and /d/ is often lost in clusters. A palatalized variety of /t/ is widespread in Copenhagen's multiethnolect, signaling complex social meaning. Other regional varieties than Modern Standard Danish have been subject to sometimes very different patterns of diachronic change, leading in turn to very different stop gradation patterns. Stød sometimes interacts with stops in complex ways in regional varieties. /t/-affrication, which is salient in Standard Copenhagen Danish, is not found throughout the entire speech community, although it remains unclear precisely where it is found and where it is not.