

CONCEPTUAL REVIEW ARTICLE

Danish as a Window Onto Language Processing and Learning

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Abstract: It is often assumed that all languages are fundamentally the same. This assumption has been challenged by research in linguistic typology and language evolution, but questions of language learning and use have largely been left aside. Here we review recent work on Danish that provides new insights into these questions. Unlike closely related languages, Danish has an unusually reduced phonetic structure, which seemingly delays Danish-learning children in several aspects of their language acquisition. Adult language use appears to be affected as well, resulting, among other things, in an increased dependence on top-down information in comprehension. In this conceptual review, we build the argument that a causal relationship may exist between the sound structure of Danish and the peculiarities of its acquisition and use. We argue that a theory of language learning that accommodates the existing evidence from Danish must explicitly account for the interaction between learner-related factors and language-specific constraints.

Keywords Danish; language processing; language acquisition; phonetics; top-down information; learnability

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Introduction

Unlike the other North Germanic languages, Danish has since the Middle Ages developed a highly unusual sound structure subject to pervasive phonetic reduction (Basbøll, 2005). The result is a speech stream characterized by long, uninterrupted sequences of vocalic sounds, which has been claimed to be “a harder nut to crack perceptually than most languages which it otherwise is reasonable to compare it to” (Grønnum, 2003, p. 129).

Danish is not the only language with a highly unusual sound structure: For instance, Nuxalk and Tashlhiyt Berber have words that comprise only obstruents (Bagemihl, 1991; Dell & Elmedlaoui, 1985). However, what makes the phonetic idiosyncrasies of Danish particularly interesting is that Danish-learning children fall behind on some early linguistic milestones (e.g., Bleses et al., 2008a), compared to children learning other European and North American languages. Danish children are delayed even in relation to children learning Norwegian and Swedish, which are closely related to Danish both genetically and typologically (see Bleses & Trecca, 2016, for a review). Spoken Danish is also relatively difficult to understand for adults in these neighboring countries, despite the three languages being very similar in written form (Gooskens, van Heuven, van Bezooijen, & Pacilly, 2010), and most foreigners find Danish hard to learn as a second language (Jespersen & Hejrná, 2019; Normann Jørgensen, 2013).

Researchers have therefore speculated about whether the unusual traits of Danish phonetic structure may make the language intrinsically hard to understand and learn. Bleses and colleagues (Bleses & Basbøll, 2004; Bleses et al., 2008a; Bleses, Basbøll, & Vach, 2011) have suggested that the frequent reduction of obstruents to vocalic sounds in Danish speech may drastically reduce the salience of phonetic cues that listeners can use to extract linguistic units from the continuous sound stream. As a result, words become harder to segment from neighboring units. Moreover, because word endings are affected the most by reduction, inflectional morphemes may also be hard to identify in continuous speech. By reducing the availability of processing cues, the sound structure of Danish may ultimately hinder learning. However, only a few studies have addressed this issue directly, and some of the available literature either is published in Scandinavian languages or is still unpublished or published in hard-to-obtain books.

The hypothesis of a relation between phonetic reduction and learnability in Danish seems to be in line with recent theories of language acquisition as a type of skill acquisition, in which the child learns to process language through engaging in interactions with others (e.g., Chater & Christiansen, 2018). The

incremental nature of language processing, together with our limited memory for auditory sequences and the fleetingness of the language input, constrains language processing to be fundamentally a “now-or-never” task (Christiansen & Chater, 2016). The highly reduced speech in Danish appears to provide the listener with ambiguous low-level information that requires more effort to process, and which is more likely to become subject to possible interference from subsequent speech input. Such difficulties in processing may make the language intrinsically harder to learn.

However, the idea that some languages may be fundamentally harder to learn than others seems to be at odds with the often implicit presupposition that all languages are equally easy to learn and use (for reviews, see Newmeyer, 2003; Walkden, 2019). Some nativist-generativist theories of language acquisition claim that the conditions of language learning are uniform across languages because all languages are constrained by the same underlying structure (e.g., Holmberg, 2017; Ringe, 2013; Roberts, 2017). Some functional-cognitive approaches make a similar assumption—albeit implicitly—in arguing that languages are complex adaptive systems that evolve toward global optima of learnability and usability, where hard-to-learn properties are likely to be compensated by other easier-to-learn ones (e.g., Bybee, 2007; Christiansen & Dale, 2004; Kirby, Cornish, & Smith, 2008). Similarly, some emergentist theories (which view language acquisition as the product of the child’s domain-general learning capabilities and of the characteristics of the ambient language) implicitly assume that conceptual difficulty in language learning should be equal across languages, although with different language-internal distributions of simpler and more complex elements (e.g., MacWhinney, 2005; MacWhinney & Bates, 1989). In this theoretical landscape, the case of Danish seems puzzling and may shed new light on current theories of language learning and processing.

In this conceptual review, we discuss studies that suggest the existence of a psycholinguistic impact of phonetic reduction in Danish on higher levels of language learning and processing (including morphology and syntax) that makes the language intrinsically hard to process and learn. Our goal is twofold: First, we provide a comprehensive overview of the existing literature relating phonetic reduction to the acquisition of Danish.¹ After introducing Danish sound structure and its peculiarities, we present evidence of delayed acquisition in Danish-learning children and of the association between phonetic reduction and reduced processability in Danish speech. We then discuss how this evidence can provide new insights into topical discussions about language learning. We examine initial evidence that the language system of native

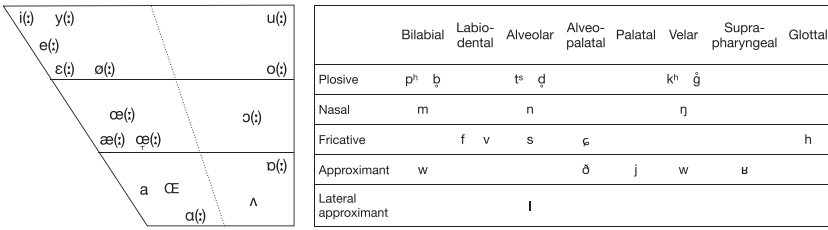


Figure 1 Danish full vowels, with length contrast (:) (left), and Danish consonants (right). Adapted from Grønnum (1998, pp. 99–100).

Danish speakers seems to adapt to the challenging sound structure of the language to facilitate processing. All the studies reviewed in these sections are then summarized in Table 1 (p. 5), together with relevant methodological information. We conclude by arguing that the case of Danish may impose important constraints on any comprehensive theory of language learning: The theory must explicitly explain the (causal) relationship between surface properties of the language and its intrinsic processability; it must allow for crosslinguistic peculiarities in adult language use to emerge as a result of language-specific challenges in early acquisition; and it must explicitly account for the possibility that some languages are inherently harder to learn than others.

Conceptual Review of the Literature

Phonetic reduction in Danish

Danish has a “complicated segmental phonology of reduction” (Bleses et al., 2008a, p. 623) resulting in high “phonetic opacity” (Bleses, Basbøll, & Vach, 2011, p. 1224). The vowel inventory is unusually large, with 10 different short vowel phonemes and 10 different long vowel phonemes. Short–long vowel pairs most often have the same vowel quality (e.g., *hylde* [ˈhyl̥] “shelf” vs. *hyle* [ˈhy:l̥] “to howl”). There are further phonemic distinctions due to *stød*, a glottal-stop-like or creaky voice suprasegmental feature that can apply to all long vowels (e.g., *køber* [ˈkʰø:ʔb̥ʌ] “(I) buy” vs. *køber* [ˈkʰø:b̥ʌ] “(a) buyer”; Grønnum, Vazquez-Larruscaín, & Basbøll, 2013), so that the vowel inventory comprises 30 phonologically distinct vowels. However, the 10 short vowels have 16 conditioned allophones, and the 10 long vowels have 13 conditioned allophones (see Figure 1). Considering the possible *stød* in each of the long vowels and two conditioned schwa allophones, the phonetic vowel inventory contains 44 monophthongal vowel sounds. In addition, there are 18 falling diphthongs and 31 rising

Table 1 Overview of the reviewed studies (in the order in which they appear in the text)

Study	Age group ^a	<i>n</i>	Method	Linguistic focus	Main finding
Bacquin and Zola Christensen (2013)	adults	446	Comprehension (self-reported)	Crosslinguistic intelligibility in Scandinavia	Better performance for Danish speakers on comprehension of Swedish than vice versa
Gooskens et al. (2010)	adults	42	Spoken sentence comprehension test	Crosslinguistic intelligibility in Scandinavia	Better performance for Danish speakers on recognition on Swedish cognate words than vice versa
Blom et al. (2018)	adults	9,015	Spoken sentence comprehension test	Comprehension of phonetically reduced linguistic units	Impaired comprehension of phonetically reduced words in semantically ambiguous, syntactically complex, and abstract sentences

(Continued)

Table 1 (Continued)

Study	Age group ^a	<i>n</i>	Method	Linguistic focus	Main finding
Pharao et al. (2017)	adults	32	Lexical decision task	Recognition of phonetically reduced words	Lower accuracy and longer reaction times in the recognition of segmentally reduced words presented in isolation
Kjærbaek et al. (2015)	Children (0;9–2;5)	2	Longitudinal corpus analysis (CHILDES)	Receptive/productive vocabulary	Delayed acquisition for Danish words with ambiguous syllabic counts (resulting from strings of vocoids)
Trecca et al. (2019)	adults	186	Artificial language learning paradigm	Word segmentation	Possible negative effect of weak syllable sonority markers on word segmentation
Hilton et al. (2011)	adults	64 ^b	Phonetic analyses of read-aloud speech data	Phonetic reduction in fluent speech	Higher omission of canonic syllables in Danish vs. Norwegian and Swedish

(Continued)

Table 1 (Continued)

Study	Age group ^a	<i>n</i>	Method	Linguistic focus	Main finding
Schüppert et al. (2012)	adults	19 ^b	Phonetic analyses of read-aloud speech data	Phonetic reduction in fluent speech	Higher omission of canonic syllables in Danish vs. Norwegian and Swedish
Clausen and Fox-Boyer (2017)	Children (2;6–4;11)	443	Picture-naming test	Phonological development	Faster acquisition of phones and clusters and faster resolution of phonological processes for Danish children
Bleses (1998)	Children (3;11–8;4)	358	Picture elicitation task	Inflectional morphology	Lower performance on past tense for Danish vs. Norwegian and Icelandic

(Continued)

Table 1 (Continued)

Study	Age group ^a	<i>n</i>	Method	Linguistic focus	Main finding
Blases, Basbøll, and Vach (2011)	Children (3;11–8;4)	445	Secondary analysis/corpus analysis	Inflectional morphology	Lower performance on past tense for Danish vs. Swedish; lower “segmentability” of past tense suffixes in Danish vs. Norwegian, Icelandic, and Swedish
Blases et al. (2008a, 2008b)	Children (0;8–3;2)	19,848	MB-CDI parental report	Receptive/productive vocabulary	Slower acquisition of receptive and productive vocabulary, slower vocabulary spurt, lower median phrase comprehension, delayed imitation and labeling for Danish (vs. other Western languages)

(Continued)

Table 1 (Continued)

Study	Age group ^a	<i>n</i>	Method	Linguistic focus	Main finding
Bleses, Basbøll, Lum et al. (2011)	Children (0;8–3;2)	19,848	MB-CDI parental report/secondary analysis	Receptive vocabulary	Negative correlation between vocoid–contoid ratio and rate of vocabulary acquisition
Trecca et al. (2020)	Children (1;10–2;1)	22	Looking-while-listening	Online language processing	Lower proportion of gazes to pictures named in highly vocalic sentences
Trecca et al. (2018)	Children (2;0–2;11)	36	Looking-while-listening	Online language processing	Worse performance on retention of novel object names learned in highly vocalic sentences
Bohn (2013)	parent–child dyads	51 ^b	Phonetic analyses of spontaneous speech data	Child-directed speech	No hyperarticulation and no slower speech rate in Danish child-directed speech

(Continued)

Table 1 (Continued)

Study	Age group ^a	<i>n</i>	Method	Linguistic focus	Main finding
Dideriksen (2016)	parent-child dyads	5 ^b	Phonetic analyses of spontaneous speech data	Child-directed speech	No hyperarticulation in Danish child-directed speech
Dideriksen and Fusaroli (2018)	parent-child dyads	23 ^b	Phonetic analyses of spontaneous speech data	Child-directed speech	No hyperarticulation in Danish child-directed speech
Ishkhanyan et al. (2019)	adults	66	Categorical perception (discrimination)	Categorical perception of phonetic contrasts	Increased reliance on pragmatic-contextual information when processing minimal-pair phonetic contrasts for Danish vs. Norwegian
Trecca et al. (2019a, 2019b)	adults	320	Sentence comprehension task (mouse tracking)	Sentence comprehension	Increased reliance on pragmatic-contextual information in spoken sentence processing for Danish vs. Norwegian

(Continued)

Table 1 (Continued)

Study	Age group ^a	<i>n</i>	Method	Linguistic focus	Main finding
Dideriksen et al. (2019)	adult dyads	77 ^b	Quantitative conversation analysis	Common ground in conversation (backchannel, repair, alignment)	Higher backchanneling and alignment and lower conversational repair for Danish vs. Norwegian
Stivers et al. (2009)	adults		Acoustic analyses of conversation data	Turn taking	Longer inter-turn pauses for Danish vs. other major European languages and indigenous languages
Højten and Nazzi (2016)	Children (1;7–1;9)	64	Interactive word-learning task	Phonological development	Better retention of vowel contrasts vs. consonant contrasts in nonce word learning in Danish

Note. MB-CDI = MacArthur-Bates Communicative Developmental Inventory.

^a Children's ages shown as (years;months).

^b Number of individuals or dyads who provided speech material for the analysis.

diphthongs, which can, however, be analyzed phonologically as vowel–consonant or consonant–vowel sequences (Grønnum, 1998).

Several consonants are subject to lenition and often full-blown vocalization (Rischel, 1970), both diachronically and synchronically (Schachtenhaufen, 2013; Schachtenhaufen & Højen, *[Manuscript in preparation]*). Lenition manifests itself through the loss of aspiration, as in the case of /p t k/, which are phonetically realized as the unaspirated/unvoiced [b d g°] in non-initial syllable position and often further reduced to [β r γ] in intervocalic position; and through the loss of closure, which turns phonetically defined consonants or *contoids* into (nonsyllabic) phonetically defined vowels or *vocoids*. For instance, /b v/ are often realized as [u] (e.g., *løbe* [ˈlø:uə] “to run”; *kniv* [ˈkʰniʊ̯] “knife”); /g/ is realized as either [u] or [ɪ] (e.g., (*at*) *koge* [ˈkʰɔ:uə] “(to) boil” and *kage* [ˈkʰæ:ɪə] “cake”); and /d r/ are mandatorily realized respectively as the nonlateral approximant [ð] (e.g., *mad* [ˈmað] “food”) and as the nonsyllabic vowel [ʌ] (e.g., *bær* [bæʌ] “berry”).

Lenition adds to the already large inventory of voiced segments and results in highly vocalic speech characterized by a high ratio of vocoids to contoids, in which long uninterrupted sequences of vowels (e.g., *her er jeg* [ˈhæ æ ˈjaʝ], “here am I”) are common. Contributing further to the opacity of Danish speech are the frequent deletion of semivowels (e.g., *tog* [tˢo:u̯] → [tˢo:ˀ], “took”) and the pervasive assimilation of schwas to neighboring sonorants, which causes the assimilating segments to become syllabic (e.g., *gade* [ˈgˢæ:ðə] → [ˈgˢæ:ðð], “street”). Moreover, Danish is characterized by prosodic peculiarities such as the absence of local signals to utterance function (e.g., no clear intonation falls or preboundary lengthenings at the end of utterances) and the absence of compulsory sentence accents (i.e., salient words are not prosodically marked; Grønnum, 2003), which add to the overall opacity of the language.

Taken individually, these phenomena are not unique to Danish (e.g., pervasive consonant lenition and schwa assimilation are common in Spanish and German, respectively). However, their combination seems to constitute a “uniquely dangerous cocktail” (Basbøll, 2009a) for processing and learning. The comparison with Norwegian and Swedish is particularly appropriate here because the three languages have very similar morphosyntax and overlapping vocabularies, and the three countries have a long common history, along with similar cultural and socioeconomic conditions. Together, the three languages thus afford a well-balanced natural experiment (of the kind proposed by Evans & Levinson, 2009) that supports the idea of Danish speech being particularly unclear. Danish is relatively hard to understand for speakers of Norwegian and

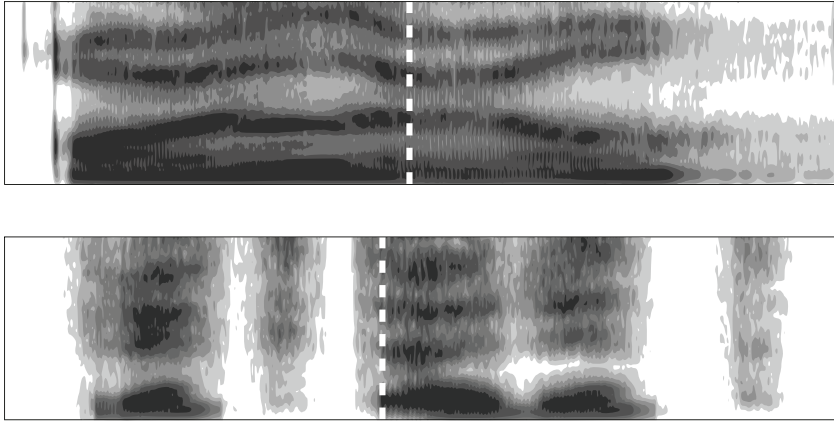


Figure 2 Spectrograms of the Danish and Norwegian cognates *røget ørred* (above) and *røkt ørret* (below) with white dotted lines indicating the approximate locations of word boundaries. Adapted from Trecca et al. (2018, p. 182).

Swedish, despite the three languages being very similar in written form (e.g., Bø, 1978; Gooskens & Kürschner, 2010; Maurud, 1976). Speakers of Swedish are particularly challenged in understanding Danish, as shown using both self-reported measures of mutual understanding (e.g., Bacquin & Zola Christensen, 2013) and language comprehension tasks (e.g., Gooskens et al., 2010).

There are no formal hypotheses in the literature about how phonetic opacity in Danish impedes processability and learnability. However, several ideas have been put forward in previous studies. One suggestion is that the long sequences of voiced segments with no clear acoustic intensity cues, which straddle syllable, morpheme, and word boundaries, lack clear acoustic-phonetic cues to word and/or morpheme segmentation (Bleses, Basbøll, Lum, & Vach, 2011; Bleses, Basbøll, & Vach, 2011; Bleses et al., 2008a). For instance, untrained listeners may find the eight adjacent vocoids—spanning three morpheme boundaries and one word boundary—in the Danish *røget ørred* [ˈʁʌjəð, ˈœʁʌð] “smoked trout” (Figure 2) particularly hard to segment into constituent units. This is possibly because the lack of obstruents results in a virtually continuous signal without salient spectral discontinuities (e.g., Liberman, Harris, Hoffman, & Griffith, 1957; Mattys & Jusczyk, 2001; Nazzi, Dille, Jusczyk, Shattuck-Hufnagel, & Jusczyk, 2005; Stevens, 1998).

There is also initial evidence that the frequent assimilation of unstressed vowels (schwa) affects comprehension (Blom, Ejstrup, & Hopmann, 2018)

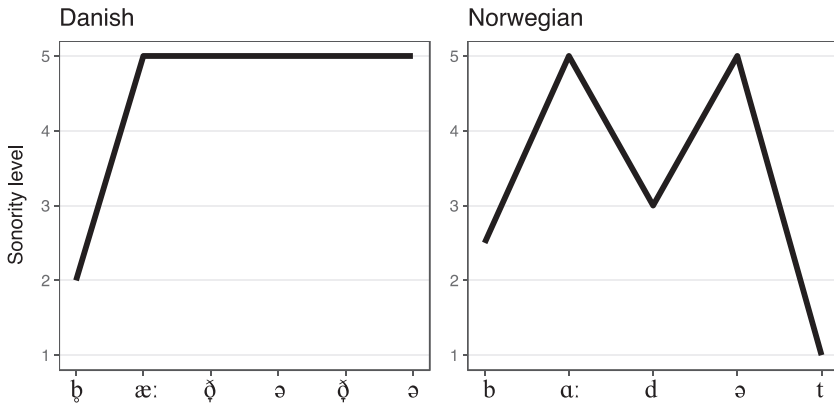


Figure 3 Stylized representation of segment sonority for the Danish *badede* (left) and the Norwegian *badet* (right). Adapted from Trecca et al. (2019, p. 162).

and that the lenition of intervocalic consonants impairs word recognition (Pharao, Ridder Malmstedt, & Veng, 2017) in spoken Danish. Processability may also be reduced because of the weaker sonority markers of syllable structure in Danish, which may affect the counting of syllables (Kjær-bæk, Thomsen, Lambertsen, & Basbøll, 2015; Trecca et al., 2019). Due to the high proportion of voiced segments, the difference in sonority between syllable nuclei (which are highly sonorous in most languages) and syllable onsets and codas (which have low sonority in most languages) is reduced. This factor seems to contribute to blurring the boundaries between syllables: For instance, the trisyllabic word *lærer* [lɛːɾɛ] “teachers” is most often reduced to the disyllabic [lɛːɾ] in casual speech (Schüppert, Hilton, Gooskens, & van Heuven, 2012); similarly, the pronunciation of the highly sonorous *badede* “bathed” (Figure 3) can vary from the trisyllabic [ˈbæːðəðə] to the virtually monosyllabic [ˈbæːðː] in casual speech (Bleses, Basbøll, & Vach, 2011). These processes are responsible for the fact that Danes tend not to articulate around 25% of all canonical syllables in fluent speech, thus resulting in more semantic information being conveyed per time unit in Danish compared to other Scandinavian languages (Hilton, Schüppert, & Gooskens, 2011; Schüppert et al., 2012).

In what follows, we will offer the *Danish opacity hypothesis* (DOH) as an explanation for the possible causal connection between phonetically reduced speech and intrinsically lower processability and learnability in Danish. We will review studies of Danish acquisition and processing that provide evidence

for the DOH, and we will offer possible explanations of the mechanisms resulting in the DOH in the Discussion section.

Note that the DOH only makes claims about the learnability of vocabulary and grammar as a function of phonetic opacity. This is because the challenges associated with Danish speech are not at the level of individual sounds (paradigmatically) but rather seem to be rooted in difficulties with segmenting continuous speech (syntagmatically). Thus, the DOH does not predict that the acquisition of Danish phonology (i.e., learning basic sound contrasts) should be delayed. Clausen and Fox-Boyer (2017) found that Danish children are even ahead in their development of productive phonology compared to learners from several other language groups: They master all individual phones early on and often resolve phonological processes before learners of other languages.

Early language acquisition of Danish

Inflectional Morphology

Early experimental evidence in support of the DOH comes from a cross-Scandinavian experimental study of past tense morphology acquisition (Bleses, 1998; Ragnarsdóttir, Simonsen, & Bleses, 1998). The researchers used a picture elicitation task to test 4-, 6-, and 8-year-old children learning Danish, Norwegian, or Icelandic on their knowledge of regular and irregular past tense forms. The prediction was that the phonetic opacity of the verb forms, quantified by the researchers to be highest for Danish, would affect performance negatively for the Danish group. Danish performance was indeed lower than Norwegian and Icelandic performance in all age groups (Figure 4). Phonetic opacity explained much of the crosslinguistic differences in performance even when morphological complexity and type–token frequency in speech corpora were controlled for.

Bleses, Basbøll, and Vach (2011, p. 1218) later updated these findings with data from a comparable group of Swedish children (Veres, 2004), who also outperformed Danish children on knowledge of past tense forms. The authors then combined these experimental findings with corpus data on the sonority of segments at morpheme boundaries to quantify the intrinsic processability of different past tense suffixes. They found that 29% of all word-internal morphological boundaries in Danish (vs. only 8% in Swedish and Norwegian) fall within vocalic sequences that have no sonority boundary cues. Similar results were found in a corpus analysis by Trecca et al. (2019), who showed that vocoid–vocoid diphones occur three times more often in Danish than in US English child-directed speech and that these diphones contain word boundaries more than twice as often in Danish as in US English. Moreover, the study by

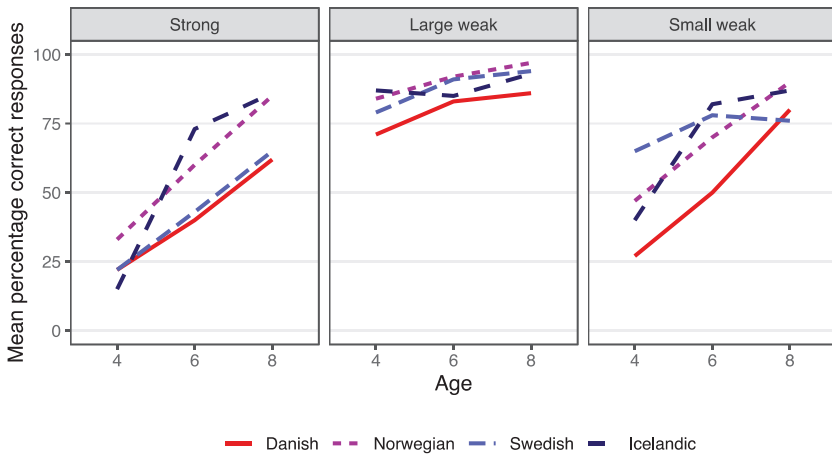


Figure 4 Mean percentage scores on a crosslinguistic picture elicitation task with past tense forms for children aged 4, 6, and 8 years. The three columns refer to the irregular past tense class [strong class, e.g., (*at*) *ligge/lå* “(to) lie/lay”] and the regular past tense classes [large weak class, e.g., (*at*) *bade/badede* “(to) bathe/bathed,” and small weak class, e.g., (*at*) *råbe/råbte* “(to) shout/shouted”]. Adapted from Bleses, Basbøll, & Vach (2011, p. 1218). [Color figure can be viewed at wileyonlinelibrary.com]

Bleses, Basbøll, and Vach (2011) showed that the frequency of phonetically reduced past tense forms in the children’s input (derived from the Odense Twin Corpus, Basbøll et al., 2002, and from the Danish Plunkett corpus in the CHILDES database, Plunkett, 1985, 1986) correlated negatively with the number of correctly inflected verbs in the experiment ($r = -.32, p < .001$).

Vocabulary

Evidence in support of the DOH is also found in studies of vocabulary development. Using the MacArthur-Bates Communicative Developmental Inventory: Words and Gesture parental report (Fenson et al., 2007), Bleses et al. (2008a) carried out a crosslinguistic comparison study of 8- to 15-month-old children (Figure 5). Compared to learners of 13 other languages, Danish children showed a smaller receptive vocabulary already at 9 months (Swedish children have an equally small vocabulary, but only until 12 months of age) and a shallow learning curve throughout. At 15 months, Danish children had a median vocabulary score of 90 words, which is substantially smaller than the median for Croatian children, who were at the top of the distribution. The vocabulary of Danish children was also smaller than that of Swedish children by around 60

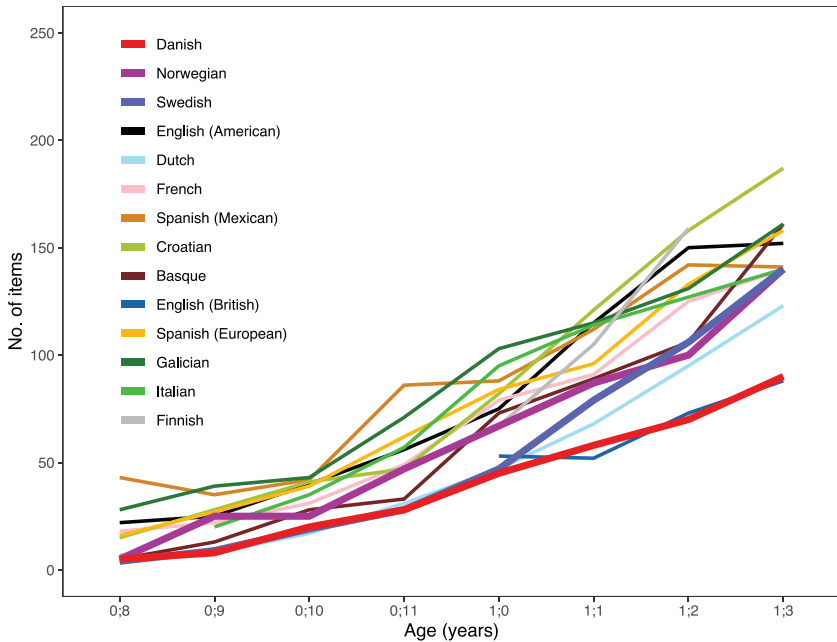


Figure 5 Crosslinguistic median vocabulary comprehension scores at 0;8 to 1;3 years in the MacArthur-Bates Communicative Developmental Inventory: Words and Gesture. Adapted from Bleses et al. (2008a, p. 634) with the addition of Norwegian data from Kristoffersen et al. (2012, 2013). Danish, Swedish, and Norwegian data are highlighted by thicker lines. [Color figure can be viewed at wileyonlinelibrary.com]

words at 15 months. Norwegian was not included in the original study, but data from a subsequent longitudinal study using the same parental report inventory (Kristoffersen, Simonsen, Eiesland, & Henriksen, 2012; see also Kristoffersen et al., 2013) showed Danish children also falling behind Norwegian children, who had a median receptive vocabulary score of 140 words at age 15 months.

Other interesting results emerged from Bleses et al. (2008a) study. All languages but Danish showed a sizable vocabulary spurt from age 11 to 12 months, whereas Danish children did not show a vocabulary spurt until around 15 months (Bleses et al., 2008b); median scores on phrase comprehension were also remarkably lower in Danish than in eight other languages (including Swedish) in the whole age range; Danish children had a lower frequency of imitation of words produced by adults and of labeling of objects compared to four other language groups, including Swedish; and they had among the lowest median vocabulary production scores in the

crosslinguistic distribution and were delayed in the acquisition of expressive vocabulary by up to 2 months.

Using the data from Bleses et al. (2008a), Bleses, Basbøll, Lum, and Vach (2011) correlated the vocoid–contoid ratio in seven of the 13 languages in the original study with their receptive vocabulary development rate in the whole age range (8–15 months). They found a strong negative correlation ($r = -.9$, $p = .006$) between vocoid–contoid ratio and vocabulary development rate. Danish, which had the highest vocoid–contoid ratio in the study (1.29), was associated with the slowest vocabulary learning rate.

Spoken Language Processing

Two recent experimental laboratory studies have used eye tracking to investigate the relationship between phonetic opacity, word segmentation, and acquisition delay. Trecca, Bleses, Højen, Madsen, and Christiansen (2020) used the looking-while-listening paradigm (as developed by Fernald, Zangl, Portillo, & Marchman, 2008) to examine how sequences of adjacent vocoids affect word segmentation in spoken Danish. Children aged 24 months were presented with pairs of familiar objects on a screen, while their eye movements were recorded as one of the two objects was named. The names of the target objects were either consonant-initial or vowel-initial and were preceded by carrier phrases that were either contoid-final or vocoid-final. The speed of gaze shifts to the target object was taken as a measure of segmentability of the object label from the carrier phrase. On average, children oriented faster to the target object when consonants or contoids were on both sides of the target word boundary (e.g., *Find bilen!* [²feŋ² 'b_oi:²ln] “Find the car!”), slower when vowels or vocoids occurred on one side or the other of the word boundary (e.g., *Find aben!* [²feŋ² 'ε:b_om] “Find the monkey!” or *Her er bilen!* [²he²Λ æ Λ 'bj:²ln] “Here is the car!”), and slowest when vowels or vocoids occurred on both sides (e.g., *Her er aben!* [²he²Λ æ Λ 'ε:b_om] “Here is the monkey!”; Figure 6). This result suggests that the presence of vocoids at word boundaries may reduce the acoustic-phonetic salience of the carrier phrase–target word boundary, thereby slowing down target object recognition.

Trecca, Bleses, Madsen, and Christiansen (2018) used a similar procedure to test the impact of vocoids on word learning. Danish children at 24–36 months of age were presented with two novel nonsense object–label pairings either unambiguously (one object on the screen) or ambiguously (one novel object and one familiar object). As in the previous study, the labels were embedded in contoid-final and vocoid-final carrier phrases, with each novel word consistently associated with the same carrier phrase throughout the

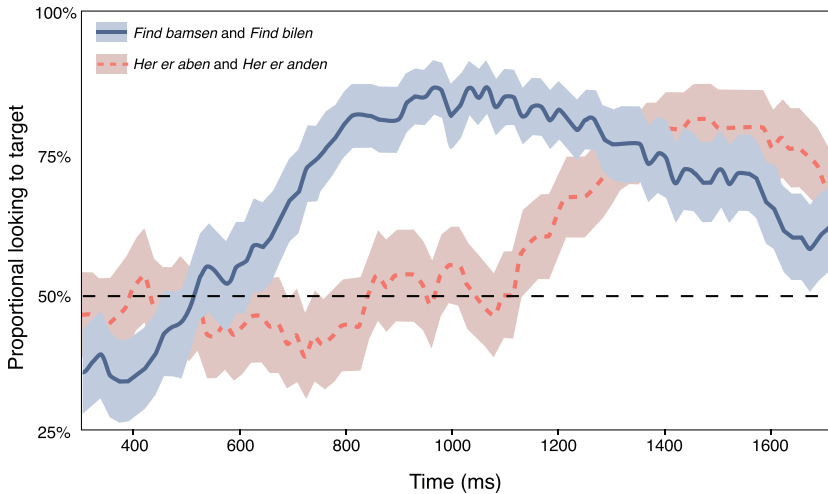


Figure 6 Processing time associated with sentences where contoids or consonants were on both sides of the carrier phrase–target word boundary (all sentences: *Find bamsen* and *Find bilen*, blue/solid line) and sentences where vocoids or vowels were on both sides of the carrier phrase–target word boundary (all sentences: *Her er aben* and *Her er anden*, red/dashed line). Shaded areas represent the standard error of the mean. Adapted from Trecca et al. (2020, p. 907). [Color figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

experiment for each child. After training, the children were tested on their ability to recall the correct object–label pairings. The results showed that looks at the target picture increased more reliably across time for the words that were learned in the contoid-final carrier phrase than for words learned in the vocoid-final carrier phrase. It is also of interest that the children’s performance was generally poor on the task of mapping novel labels onto novel objects in ambiguous naming situations, a skill that is well-developed in English-speaking children of the same age (e.g., Halberda, 2006): This adds to the evidence that Danish-speaking children generally fall behind with regards to a range of linguistic milestones.

Child-Directed Speech

Albeit peripheral to the DOH, there are a few peculiarities of Danish child-directed speech (CDS) that are worth noting, as they may exacerbate the issues described so far. Bohn (2013) analyzed Danish CDS data from native-speaking parent–child dyads in play situations in the laboratory. In contrast to what has been found in several other languages (e.g., American English, Cristià, 2010;

British English, Shute & Wheldall, 1995; German, Fernald & Simon, 1984), Danish CDS was not significantly slower than adult-directed speech (ADS). Moreover, not only did parents not hyperarticulate vowels when talking to their children (as they do in, e.g., American English, Russian, and Swedish, Kuhl et al., 1997; and in Australian English, Burnham, Kitamura, & Vollmer-Conna, 2002), but they even hypoarticulated in some cases. Recent spontaneous data from mother–child dyads in the home (Dideriksen, 2016; Dideriksen & Fusaroli, 2018) showed slower speech rates for CDS compared to ADS, conforming to the general crosslinguistic tendencies, but also a significantly reduced vowel space in CDS compared to ADS, as also found by Bohn (2013).

Possible Compensatory Cognitive Strategies

Bleses et al. (2008a) report data from the MacArthur-Bates Communicative Developmental Inventory: Words and Sentences parental report for 16–30-month-olds (Fenson et al., 2007) showing that Danish-learning children, though initially delayed, catch up with the average productive vocabulary size of 13 other European and North American languages around the age of 30 months. This upswing suggests two possible scenarios: (a) Danish children may catch up simply because of increased time and exposure to the language, possibly because the characteristics of Danish facilitate language acquisition in this age range; or (b) Danish children may learn compensatory strategies that are long-lasting and may carry over into adulthood.

Initial evidence from studies of adult Danish speakers seems to speak in favor of the development of compensatory mechanisms, such as increased reliance on top-down processing. These mechanisms may develop during childhood and leave a trace on the adult speech perception system. For instance, Ishkhanyan et al. (2019) tested adult native speakers of Danish and Norwegian on a categorical perception paradigm designed to measure contextual (top-down) biasing on phoneme identification. The onsets of the Danish and Norwegian cognate words *sendt* [ˈsɛnˀt] “sent”) and *tændt* [ˈtʰɛnˀt] “lit”) were manipulated to generate target words whose initial phoneme varied on a continuum between [s] and [tʰ].² These words were then embedded in sentences that were contextually biased towards either *sendt* (e.g., “sent/lit an e-mail”) or *tændt* (e.g., “sent/lit a candle”). Participants listened to sentences while the two target words appeared on screen, and were instructed to click on the word they heard. When the stimulus was phonemically ambiguous, Danes were significantly more inclined to click on the word that was semantically congruent with the context, compared to Norwegians. Furthermore, Danes were slower than Norwegians in making a choice whenever the context was incongruent,

indicating a stronger reliance on top-down processed contextual evidence to disambiguate the target word.

Trecca, Tylén, Fusaroli, Johansson, and Christiansen (2019a, 2019b) found a similar top-down reliance in sentence comprehension. Adult Danes and Norwegians listened to short stories consisting of a preamble (e.g., “the boy walked into the pet store”) and a main event (e.g., “the boy bought a goldfish for the girl”), after which they were shown four drawings depicting the characters in different who-did-what-to-whom scenarios (e.g., a boy giving a fish to a girl). They were then asked to click on the picture that matched the story. In some trials, agent and object were switched around, creating internal incongruencies in the stories. In these cases, Danes were more prone than Norwegians to disregard the actual input and rectify the story to a more expectation-driven interpretation based on contextual cues (e.g., when hearing the preamble “the goldfish walked into the pet store”, and the main event “the boy bought a goldfish for the girl,” the Danes would select the goldfish-gives-boy-to-girl image, in accordance with the preamble). When signal noise was added to the auditorily presented stories to make the bottom-up signal less informative, Norwegians also changed their processing strategy to rely more on contextual information. This is taken as additional evidence that crosslinguistic differences in processing strategy may indeed be contingent on the relative opaqueness of the acoustic input.

Dideriksen, Fusaroli, Tylén, Johansson, and Christiansen (2019; see also Dideriksen, Fusaroli, Tylén, Dingemanse, & Christiansen, 2019) hypothesized that this adaptation to a more cost-efficient reliance on top-down information would also manifest itself in the form of more solid pragmatic/semantic frames (common ground) in dialogue. The authors coded dialogue data from Danish and Norwegian dyads for occurrences of either backchannel (i.e., vocal tokens of understanding/agreement), alignment (i.e., reuse of lexical/syntactic/semantic forms), or repair (i.e., vocal tokens of communication issues). Danes showed a significantly and consistently higher degree of backchanneling and alignment, whereas conversational repair was more pervasive in Norwegian. This suggests that Danes may adapt to the pressure for more top-down-driven processing by building robust common ground with higher redundancy.

Evidence of a similar adaptation is reported by Stivers et al. (2009). In a study of spontaneous conversations in 10 language groups ranging from European, American, and Asian languages (such as English and Japanese) to indigenous languages (such as Tzeltal and Yéli Dnye), the authors observed that Danish dialogues had longer inter-turn pauses than dialogues in the other

languages, with a mean transition time of 469 milliseconds (vs., e.g., only 8 milliseconds in Japanese). When the upcoming turns were answers to questions, the transition time was almost twice as high (~800 milliseconds), and transition times for non-answer turns were also among the highest in the sample (~380 milliseconds). Answers to questions were associated with shorter transition times when eye contact was made with the interlocutor in all languages, except for Danish.

Together, these studies suggest that Danish may be processed differently from other languages even by adult speakers. The challenges associated with the acquisition of Danish in early childhood may carry over into adulthood by changing the processing system: Specifically, these changes may concern the relative weighting of bottom-up information (e.g., linguistic cues carried by the speech signal) and top-down information (e.g., expectations determined by contextual cues and previous cues; see e.g., Ferreira & Chantavarin, 2018).

Discussion

We have reviewed a series of studies suggesting that the opaque phonetic structure of Danish may tax the learner's language system to a higher degree than other closely related languages, delaying children's language acquisition (see Table 1 for an overview). Danish speakers may adapt to the opaque phonetic structure by developing compensatory processing strategies that can be observed in adult language use. Although evidence in support of the DOH is arguably still sparse, we propose that the findings presented in this review may have important implications for theories of language learning.

First, the reviewed evidence seems to suggest that theories of language learning in early childhood should explicitly make the connection between surface properties of different languages (e.g., various degrees of phonetic opacity) and degrees of inherent processability and learnability. We argue that this link is intrinsic to a view of language learning and use as determined, on the one hand, by processing constraints ingrained in the language system (e.g., the now-or-never bottleneck; Christiansen & Chater, 2016) and, on the other hand, by the burden that particular types of linguistic input place on the system (e.g., O'Grady, 2015). In this view of *processing determinism* (e.g., O'Grady, 2012), the course of development is predicted by processing pressures imposed by different properties of the ambient language on the language system. In the abovementioned now-or-never bottleneck, the cognitive system deals with these constraints by recoding the input in a quick and economic (i.e., compressed) way and integrating these representations into increasingly higher levels of linguistic analysis locally and incrementally (*chunk-and-pass*

processing). Languages that are harder to recode—for instance, because they suboptimally mark morpheme or word boundaries at the perceptual level, thus making word segmentation harder—impede the chunking and passing mechanisms, with possible cascading effects accumulating up through higher levels of linguistic representation. For example, delays at the word segmentation level may hold up detecting multiword combinations, which in turn might hamper phrase- and sentence-level processing, potentially resulting in partial failures of comprehension.

Second, the reviewed evidence suggests that challenges associated with the early acquisition process may be linked to idiosyncratic ways in which speakers use the language in adulthood. This may entail that dealing with difficult aspects of a language in the early stages of acquisition forces the language learner to adopt compensatory cognitive solutions that are long-term and language-specific: for instance, learning to put more weight on top-down pragmatic and contextual cues, as may be the case for Danish. The Danish data do not seem to speak in favor of a language-internal *structural* compensation: That is, different aspects of the language system do not seem to compensate for each other, such as morphosyntax compensating for phonological ambiguities (see e.g., Christiansen & Dale, 2004). Instead, the Danish data seem to point to compensation strategies developed within the *processing system*, such as changes in the relative weighting of bottom-up and top-down information. That is, the language processing system of the learner may be radically changed in the interaction with the ambient language as the system adjusts to it. For instance, Danish-learning children seem to adapt very early on to the highly vocalic content of their ambient language by exhibiting a “vocalic bias” in learning (i.e., better recall of minimal pairs contrasting by vowels, e.g., /dy:ʔl/–/du:ʔl/, than by consonants, e.g., /fan/–/san/), in contrast with the *consonantal bias* typically found in learners of other European languages (Højen & Nazzi, 2016). Thus, the development of processing strategies may be contingent on language-specific properties, such as the relative distribution of consonants and vowels (cf. Keidel, Jenison, Kluender, & Seidenberg, 2007), already at an early age and possibly persisting into adulthood.

We argue that current theories of language learning do not necessarily predict this possibility explicitly. In many generativist theories, much of the weight is put on the hard-wired linguistic knowledge of the learner, with processing and learning constraints being innate and the role of the ambient language being confined to helping the learner discover language-specific constraints (e.g., Berwick & Chomsky, 2008; Biberauer & Roberts, 2017). In functional approaches, the main explanatory burden is put on the learning

process itself, with the learner absorbing language patterns from the environment through domain-general processing mechanisms (e.g., categorization, chunking, and statistical learning) and generalizing to new situations (e.g., Ambridge & Lieven, 2015; Tomasello, 2015). Theories of associative learning concerned with the contingency and salience of cues to form–function mappings (e.g., Ellis, 2008; MacWhinney, 2005) acknowledge more explicitly than the aforementioned accounts the role of language-related factors in shaping the learner’s language system.

Last, we take the reviewed evidence to suggest that theories of language learning and use must allow for the fact that some languages may be intrinsically harder to process and learn than others, even when compared with genetically and typologically related languages. We believe that this demand is met by theoretical frameworks that consider different languages as unique products of cultural evolution that impose different degrees of constraints on processing and learning. For instance, functional approaches that consider language change as driven by the interaction of cultural, ecological, and cognitive factors (e.g., Christensen, Fusaroli, & Tylén, 2016; Christiansen, 2013; Evans & Levinson, 2009; Lupyan & Dale, 2010; Nölle, Staib, Fusaroli, & Tylén, 2018) fulfill this criterion by explicitly predicting the emergence of differences in processability and learnability over time. Because individual languages have different historical trajectories of cultural evolution (Dunn, Greenhill, Levinson, & Gray, 2011; Everett, 2016), some may, at least temporarily, end up in suboptimal local usage-based minima. Danish speech may have evolved an increasingly opaque structure—contrary to the predictions of most theories of language evolution (e.g., Beckner et al., 2009; Kirby, 2007)—and may currently be moving toward a local minimum of processability. For instance, there is evidence that Danish vowels have been diachronically moving closer to each other in the F1–F2 vowel space, gradually minimizing contrasts between, for instance, the phonemically distinctive vowel qualities [a] and [æ] (Basbøll, 2009b; Reinholt Petersen, 2008). However, there remain open empirical questions about whether Danish is indeed moving toward a local minimum of processability, what could be driving the change, and whether it will move away from the minimum.

Conclusion

The conditions of language learning and use are often assumed to be the same across languages, but the case of Danish would seem to cast doubt on this assumption. We have argued that the puzzling nature of Danish acquisition and use should inform discussions about whether all languages are cut from

the same *universal cloth* (e.g., Hornstein & Boeckx, 2009; Pinker, 1994), or whether even closely related languages are unique historical products of cultural evolution (e.g., Christiansen & Chater, 2008; Evans & Levinson, 2009). From a societal perspective, addressing the issues related to learning Danish has potential implications for (a) language pedagogy in daycare/school and L2 instruction, for instance, to improve general reading instruction in Denmark, where the percentage of readers at the top proficiency level is lower than the OECD average (OECD, 2010); and (b) the linguistic rehabilitation of brain-damaged patients and the development of strategies for reading instruction for children with dyslexia, two situations that may be particularly affected by the indistinctness of Danish speech (e.g., Elbro, Borstrøm, & Petersen, 1998). Unfortunately, the current empirical evidence is still sparse and unsystematic. Research is required into how the long sequences of voiced segments and the pervasive segment/syllable reduction impact speech processing, in order to provide a more nuanced understanding of the intrinsic processability of Danish speech. Moreover, empirical studies are needed to explicitly test the hypothesis that the structuring of the language system in early childhood that happens in order to compensate for the opacity of the ambient language carries over into adulthood and determines how the language is used by adult speakers. Fully understanding the puzzle of Danish will require a crosslinguistic and crossdisciplinary effort to empirically tackle these remaining questions. We hope that this review will spark new empirical research into the relationship between learner-related and language-specific factors in language learning and processing, not only in Danish but also in other, similarly intriguing languages.

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Notes

- 1 Note that this review is confined to research on phonetics, speech perception, and speech processing in Danish-learning preschool children and in adult speakers of Danish, thus it does not include children of school age. Issues related to literacy, orthographic depth, and reading are important for a complete account of how Danish is learned across the lifespan (e.g., orthographic depth hinders the performance of Danish-speaking 10–13-year-olds on a range of linguistic measures compared to Swedish children of the same age; van Daal & Waas, 2017), but we view these issues as adding an extra layer of difficulty on top of the much more fundamentally complex nature of Danish sound structure, which is the topic of this conceptual review.

- 2 It should be noted that the Danish [t^s] often lacks proper closure and can become similar to [s], making Danes necessarily more context-dependent in this particular instance.

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Appendix: Accessible Summary (also publicly available at <https://oasis-database.org>)

Can the Strange Pronunciation of Danish Teach Us Something About How We Understand and Learn Languages?

What This Research Was About and Why It Is Important

For decades, researchers have assumed that all languages are equally hard to understand and learn. This idea is challenged by recent research on Danish, which shows that Danish children are unusually slow at learning their native language, and that even adult Danes show peculiarities in everyday language use. Researchers have suggested that this may be due to the indistinct pronunciation of Danish—characterized by many vowels and few consonants—which may make the language intrinsically hard to understand and learn. The present article reviews the available literature on Danish to systematically assess this hypothesis. The literature review shows that Danish may indeed be harder to understand and learn than other closely related languages.

What the Researchers Did

- The researchers reviewed all the available literature that empirically links the unusually complex pronunciation of Danish to the observed peculiarities of language acquisition and use.

What the Researchers Found

- The pronunciation of Danish is unusually complex, even in relation to very closely related languages like Swedish and Norwegian, which are virtually identical to Danish in written form.
- Danish-learning children are delayed in the acquisition of vocabulary and morphology, compared to children learning other European and North-American languages.
- There is growing evidence that the seemingly “slurred” pronunciation of Danish—especially the long sequences of contiguous vowels without intervening consonants—negatively affects the comprehension of familiar words and the acquisition of new words.
- There is initial evidence that Danish-learning children may adapt to the difficult speech input by learning to rely more on contextual cues in communication, compared to speakers of other languages. It can be observed that adult Danish speakers are more context-dependent in understanding spoken language than speakers of a closely related language such as Norwegian.

Things to Consider

- The case of Danish seems to be at odds with the long-established view that all languages are equally hard to understand and learn since they are cut from the same “universal cloth.”
- Instead, the case of Danish speaks in favor of a view of different languages as unique historical products of cultural transmission that can differ in how easy or hard they are to understand and learn, even for native speakers.
- This result has significant implications for pre-school and primary school literacy education, and highlights the importance of effective reading instruction in Denmark, where the percentage of proficient readers is lower than in other comparable countries.

Materials, data, open access article: N/A

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