Vesna Cigan
University of Zagreb, Croatia

A PHONOLOGICAL DESCRIPTION OF TERMS IN GERMAN AND ENGLISH MECHANICAL ENGINEERING TEXTBOOKS

Abstract

Both phonology and phonetics contribute to a better understanding of how a language makes up syllables and words to serve as a means of communication. This paper aims at analysing and contrasting the terms in German and English mechanical engineering texts regarding their phonological features, similarities and differences. In this analysis, a lexical unit serves as a point of departure, but the syllable as a phonological unit has been used as a prime. Syllables exhibit a varying degree of complexity, ranging from a simple V syllable to a CCCVC syllable template. The prevailing syllable template in the analysed technical vocabulary was CVC, followed by the CV syllable template, as an absolute universal in world languages. Applying the notion of sonority to analyse consonantal sequences in onsets and codas, several language-specific violations of the Sonority Sequencing Principle (SSP) were found. Furthermore, special attention was given to the vowel and diphthong features that pointed to differences between the two languages. The findings of the sample analysis gave rise to the observation that language-specific phonological constraints are attested in the sample features.

Keywords: phonology, LSP, syllable, syllable template, consonantal sequences, phonological constraints.

1 Introduction

Investigating specific domain terms in respect of their phonological features, specificities, relationships between component parts, word and syllable internal organization, contingent dependences or constraints poses a highly interesting endeavour. A wide range of phenomena of human language has been described and documented in phonetics and phonology as they cover many aspects of language related to the human body and mind. Both of these linguistic disciplines are necessary and complementary to understand language as a means of human communication. Accordingly, the description of language uniqueness involves the notions of linearity and duality. The twofold structure of a speech stream provides meaningful signs composed of respective sounds that standing as separate individual sounds are meaningless. These sounds, termed phonemes, represent the secondary and lower level of the double articulation. The sequence of sounds in a string exhibits a distinctive value as well as the choice of a respective phoneme and allows the creation of a potentially infinitive number of meaningful sequences out of a number of meaningless elements (Martinet, 1982). The phonological level is part of the conceptual unit: the concept connects the word with its significance and with its form. The speaker's knowledge of the words and sounds of which they consist, allows him/her to combine different sounds into a meaningful unit (Jelaska, 2004). For example, the German word *Keil* (Eng. *wedge*) is composed of the sounds [k], [aɛ̯], and [l] which can also be combined to form another word *Leik* with a different meaning (Eng. cordage as the edging of a sail). Moreover, due to the qualitative contrast in sound when occurring in the same context, phonemes, as the smallest meaning-distinguishing elements, convey a distinct meaning, e.g. *Buch* – *Tuch*, *Heim* – *Keim*, *pig* – *dig*, *dark* – *park*.[1]

Since its very beginnings, phonological theory has undergone diverse theoretical development closely related to what scholars have focused their attention on. Among the various frameworks let us mention some of the major theoretical approaches. After founding the School of Phonology in the late 1950s, Chomsky and Halle (1968) published their monumental book *The Sound Pattern of English* that not only posited the basic paradigm of the standard generative phonology, but also gave rise to challenges to this work and further developments (Fudge, 1969; Kahn, 1976; Selkirk, 1980). Another very influential approach as "a modification of the theory of generative phonology", auto-segmental phonology, was proposed by John Goldsmith in his dissertation (1976). Hayes (1995) was concerned with stress as the linguistic manifestation of rhythmic structure, a notion of metrical phonology designed by Liberman (1975) and Liberman and Prince (1977). Other relevant theories or scholars are appropriately referred to in the following sections.

The phonological analysis draws upon the role and significance a syllable has for understanding speech perception and recognition of words. The ability to quickly syllabify words as a key to reading mastery is of equal importance. In this work, the auto-segmental phonology framework has mainly been adopted as the syllable "is one of the oldest constructs in the study of language, and most studies of phonology have found a place for the syllable within them" (Goldsmith, 2011, p. 164).

1 Examples by V.C.

2 Methodology

This paper aims at analysing and contrasting the terms in German and English mechanical engineering texts with regard to their phonological features, similarities and differences. When compiling the corpus to support the purpose, a set of standard design criteria was applied: text type, domain, time span, and medium.

The corpus includes a three-volume textbook on engineering mechanics in German and its translation into English. The original German version has been the bestselling educational textbook on mechanics for more than two decades with 12 editions having been published so far. The selected textbooks in German and English that constitute the corpus were published within a two-year period from 2009 to 2011 (Table 1). The addition of the English volumes to the source corpus enabled the compilation of parallel corpora[2] being roughly equal in size and containing a 200,000-word sample each. As the corpus may not represent all the texts in the target population in precisely the correct proportions (Sinclair, 2005) the selection of texts for this study provides a small-scale model of the linguistic material i.e. a particular type of text in two languages rather uniform in structure, however capturing enough of the language to support the notion of representativeness[3] and to provide a "cross-section" of the discourse (Teubert, 2005, p. 4). Built on the same design criteria and being both parallel corpora and corpora of specialised texts of equal size, the corpora serving the research objectives also qualify as snapshot corpora (McEnery & Hardie, 2012).

Table 1
Textbooks constituting the corpus

Language	Textbooks	Published	Number of word tokens
German	Technische Mechanik Band 1: Statik	2009	180,526
	Technische Mechanik Band 2: Elastostatik	2009	
	Technische Mechanik Band 3: Kinetik	2010	
English	Engineering Mechanics 1 Statics	2009	201,166
	Engineering Mechanics 2 Mechanics of Materials	2011	
	Engineering Mechanics 3 Dynamics	2011	

In order to extract the words from the designed corpora for a comparison, the tools for the frequency counts of the freeware software programme AntConc (Anthony, 2020) were used to create a word frequency list from each monolingual sub-corpus. The obtained lists of the words most frequently occurring in sub-corpora were then used for the manual selection of the words to constitute the sub-samples. In addition to the high frequency criterion, the selection of words was also influenced by the importance of these words being terms in a specific domain (Table 2). The compiled bilingual sample included specific domain terms

2 A parallel corpus, according to Teubert (1996), is a bilingual or multilingual corpus that contains an equal amount of texts originally written in languages A and B with their respective translations.

3 'A sample size of 20,000 words would yield samples that are large enough to be representative of a given variety (Oostdijk, 1991).

belonging to two categories (nouns 97%; adjectives 3%) and allowing for the analysis at several levels.

Table 2
Sample retrieved from sub-corpora

German

	Word	Frq.		Word	Frq.		Word	Frq.
1.	Kraft	530	19.	Gleichgewichts-bedingung	166	36.	Knoten	99
2.	Richtung	349				37.	Biegung	94
3.	Bewegung	340	20.	Lage	165	38.	Mechanik	94
4.	Moment	340	21.	Schnitt	146	39.	Zug	93
5.	Balken	287	22.	Arbeit	139	40.	Massenträgheits-moment	91
6.	statisch	297	23.	Stoß	139			
7.	Gleichung	273	24.	Länge	137	41.	Änderung	91
8.	Spannung	245	25.	Zeit	136	42.	Last	91
9.	Punkt	234	26.	Lager	135	43.	Gewicht	90
10.	Geschwindigkeit	217	27.	Schnittgröße	132	44.	Elastizität	83
11.	Schwingung	215	28.	Stabkraft	127	45.	Querschnitt	72
12.	Achse	188	29.	Beschleunigung	122	46.	Druck	81
13.	Fläche	185	30.	Gleichgewicht	122	47.	Ermittlung	81
14.	Koordinate	180	31.	Kinetik	119	48.	Abstand	79
15.	Stab	174	32.	Energie	108	49.	Belastung	64
16.	Verschiebung	171	33.	senkrecht	105	50.	Anwendung	58
17.	Ebene	169	34.	Bedingung	102			
18.	Winkel	169	35.	Schwerpunkt	102			

English

	Word	Frq.		Word	Frq.		Word	Frq.
1.	force	2191	19.	bar	359	37.	angular	221
2.	stress	902	20.	obtain	357	38.	displacement	220
3.	moment	891	21.	shear	354	39.	component	215
4.	equation	737	22.	constant	350	40.	principle	212
5.	system	722	23.	coordinate	350	41.	length	206
6.	mass	585	24.	axis	331	42.	inertia	187
7.	beam	549	25.	spring	330	43.	weight	182
8.	condition	548	26.	support	309	44.	virtual	178
9.	body	524	27.	resultant	297	45.	impact	177
10.	direction	522	28.	position	296	46.	value	176
11.	motion	522	29.	energy	292	47.	integration	173
12.	equilibrium	514	30.	plane	287	48.	reaction	172
13.	velocity	488	31.	angle	272	49.	momentum	171
14.	section	479	32.	yield	272	50.	strain	156
15.	determine	440	33.	rigid	259			
16.	solution	421	34.	rotation	247			
17.	load	381	35.	acceleration	237			
18.	vector	367	36.	friction	231			

After an inventory of 50 adequate lexical units per language had been compiled, the syllabification process was carried out to provide a scheme for a further detailed description of the word and syllable structures, in order to identify the prevailing syllable template and to identify the similarities and differences in the two languages under examination. When analysing the English sub-sample, the British pronunciation i.e. transcription system will be applied as rooted in the model of 'Received Pronunciation'.[4]

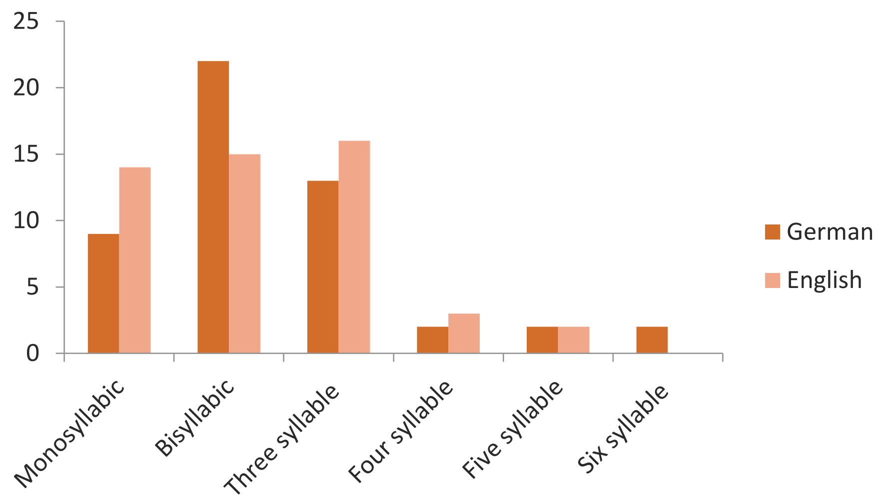
The approach to the syllabification process applied in the first stage of a multi-tier analysis is based on the Maximal Onset Principle (Kahn, 1976) stating that a syllable onset should be extended at the expense of the previous syllable coda. The syllable boundaries were placed to match the morphological boundaries. The contingent specific occurrences will be discussed in detail. In the second step, the analysis investigates the internal organization of the syllable, the identification of the frequent syllable template, phoneme sequence patterns and frequency of occurrence.

3 Results and discussion

3.1 Sample features

In this linguistic analysis a lexical unit serves as the point of departure, but the syllable as a phonological unit has been used as a prime. The selected words constituting of a sample of 100 lexical units contain a total of 237 syllables. When categorized by the number of syllables (Figure 1) they vary in length from one to six syllables. The English sub-sample contains more monosyllabic words (14 vs. 9) out of which one ends with a vowel (bar) and one with a diphthong (shear). Almost half of the German sub-sample is bi-syllabic and outnumbers those found in the English sample (22 vs. 15). It is interesting to note that the English sub-sample

Figure 1
Word frequencies according to syllabification



4 British Received Pronunciation (RP), traditionally defined as the standard speech used in London and south-eastern England, is one of the many forms (or accents) of standard speech throughout the English-speaking world (Enciclopaedia Britannica).

contains slightly more three syllable words (16 vs. 13). The longest word consisting of six syllables prevails in the German sub-sample, which is no surprise given that typologically German allows for the formation of long compounds (*Zusammensetzungen*).

3.2 Syllable structure

The attention in this chapter is focused on the nature of syllable internal organisation. Most linguists of phonology agree that a syllable is a sequence of phonemes as the smallest speech sounds distinguishing meaning and that a syllable is a unit of organization for a sequence of phonemes. A view that has also been accepted as evidence is that the syllable has a particular kind of internal structure (Goldsmith, 1990). The author shares the view of Kessler and Treiman (1997) that the main concern for syllables is whether the vowel is grouped with the prior consonant (called the onset), with the posterior consonant (the coda), or with neither. In many cases, determining the internal syllable boundaries can pose a problem. In German, syllable boundaries usually coincide with the morpheme boundaries, but a morpheme boundary can appear within a syllable and a syllable boundary within a morpheme, as the following examples demonstrate (intra-word morpheme boundaries are shown with "+") (Fuhrhop & Peters, 2013)[5]:

(1)	Morpheme boundaries	Syllable boundaries
	Atem	A.tem
	ruf+t	ruft
	ruf+en	ru.fen
	Be+ruf+ung	Be.ru.fung
	Richt+ung	Rich.tung

Much the same pattern is true of English as some morphological boundaries are critical to syllable establishment (Goldsmith, 2011). Specifically, there are quite a few cases which are morphologically complex, but behave as single units phonologically and the other way around. In such cases, according to Gussmann (2002), the morphological boundary of the word is invisible to phonology. A few examples will illustrate the possible divisions (2).

(2)	Morpheme boundaries	Syllable boundaries
	velocity	ve.lo.ci.ty
	valid+ity	va.li.di.ty
	perform+ance	per.form.ance or per.for.mance (rule about two consonants)
	diploma	di.plo.ma
	diploma+t	di.plo.mat
	Diplom (*Germ.*)	Di.plom
	Diplom+at (*Germ.*)	Di.plo.mat
		(word division variants: Di-plo-mat · Dip-lo-mat) (DWDS)

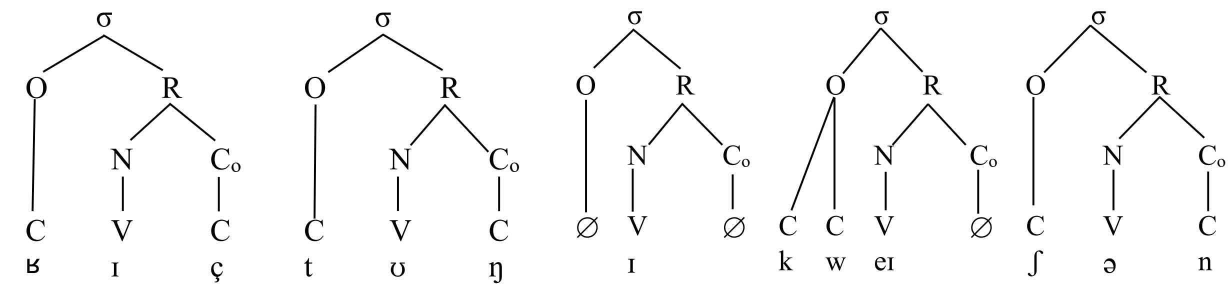
5 For more detailed rules cf. Wöllstein and Dudenredaktion (2016).

The general approach followed here is based on the onset-rime theory, a hierarchical model allowing both constituents to contain elements, in particular the vowel groups to form a constituent with the coda called the rime (Fudge, 1969; Goldsmith, 1990; Selkirk, 1982).

Applying the onset-rime model the representation of the internal organization of the syllable exhibits the following structures (3, 3a).

(3) Richtung CVC.CVC Rich.tung

(3a) equation C.VV̑.CVC e.qua.tion



σ = syllable; O = onset; R = rime; N = nucleus C_o = coda; C = consonant V = vowel
*The inverted breve ̑ (V̑) placed over a letter indicates the weaker element of a diphthong.

Among a total of 237 syllables, the most frequent syllable templates are CV and CVC with 134 occurrences, accounting for 56% of all syllables in the bilingual sample. The syllable templates identified in the bilingual lexical units are arranged in descending order of frequency and shown in Table 3.

Considering the fact that CV and CVC have been recognized as absolute universal syllable types in the majority of languages, the finding that prevailing syllable types in the German sub-sample are CV and CVC templates (n = 67; 55%) was expected and is in complete agreement with the observations valid for the German language as found in Fuhrhop and Peters (2013). The same trend was noticed in the English sub-sample which consistently contains 67 occurrences of CV and CVC syllable types accounting for 58% of the total of 115 syllables. It is worth noticing that Delattre and Olsen (1969) [6] reported in their analysis of syllables in four languages somewhat higher frequency of CV and CVC syllable occurrence in a 2000-sample of English and German, compared to our findings (63% vs. 56%). Furthermore, regarding the variety of syllable structures, 15 different types were identified in the German sub-sample and 14 in the English one, which is also consistent with the findings of Delattre and Olsen (1969).

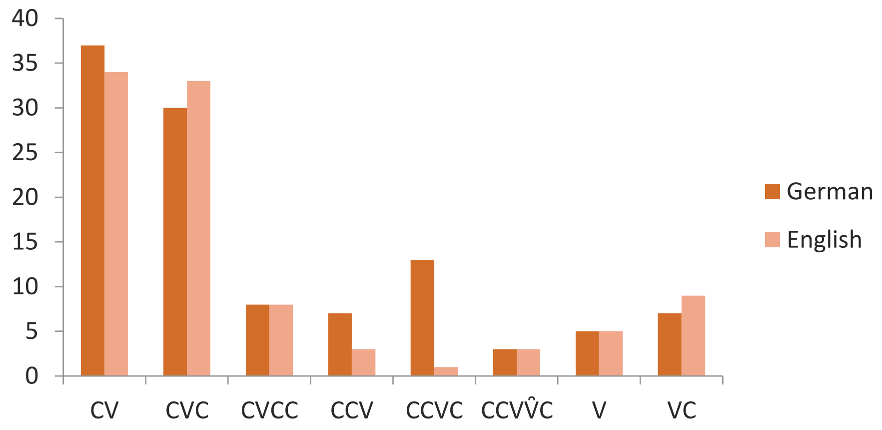
The percentage of CCVC syllable type (with consonants dominating the syllable) is higher in the German sub-sample (13 vs. 1), whereas more frequent syllable types in the English sub-sample are CVC (33 vs. 30) and VC (9 vs. 7) (Figure 2). The greater representation of the consonant clusters in the syllable types found in the German sub-sample and their lower representation in the syllable types in the English sub-sample indicate a cross-linguistic variation in syllable types.

6 The research included narrative and dramatic texts in English, French, German, and Spanish.

Table 3
Syllable-type inventory of the two sub-corpora

Syllable template (type)	German		English	
Total	122		115	
	Frequency	%	Frequency	%
CV	37	30.00	34	29.50
CVC	30	24.50	33	28.60
CVCC	8	6.50	8	6.90
CVCCC	3	2.40	0	0.00
CVV̂	1	0.80	10	8.60
CVV̂C	1	0.80	4	3.40
CVV̂CC	1	0.80	0	0
CCV	7	5.70	3	2.60
CCVC	13	10.60	1	0.80
CCVCC	3	2.40	1	0.80
CCVV̂	2	1.60	1	0.80
CCVV̂C	3	2.40	3	2.60
CCCVC	0	0	2	1.70
CCCVV̂C	0	0	1	0.80
V	5	4.00	5	4.30
VV̂C	1	0.80	0	0
VC	7	5.70	9	7.80

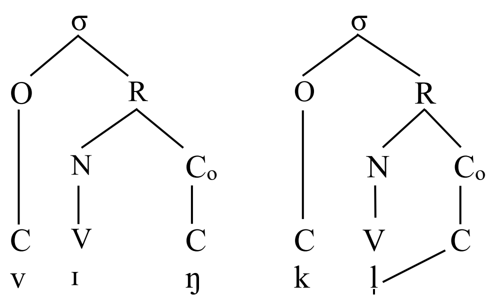
Figure 2
Most frequent syllable templates



In the process of identification of syllables, we make use of the Maximal Onset Principle in that the maximum consonants were assigned to the syllable onset at the expense of the preceding syllable coda or to the right-hand syllable, not the left, as far as possible (Roach, 2009) and as permitted by the phonological constraints of the two languages under examination. The analysis pointed to several words that involved some initial doubt on their proper syllabification.

When syllabifying the word *Winkel*, two vowels (/ɪ/ and /ə/) can be distinguished that indicate two CVC syllables. For the representation of phonemes in the second syllable two distinct phonetic transcriptions were found. According to the Langenscheidt digital dictionary (Langenscheidt), the second syllable has the vowel schwa /ə/ as the nucleus, phoneme /k/ in the onset and /l/ in the coda position – [ˈvɪŋkəl]. In the German pronunciation dictionary *Deutsches Aussprachewörterbuch* (Krech et al., 2009) and Langenscheidt paper dictionary *Großwörterbuch. Deutsch als Fremdsprache* (Götz et al., 2008), the second syllable is reduced to a two-consonant cluster – [ˈvɪŋkl̩] (4).

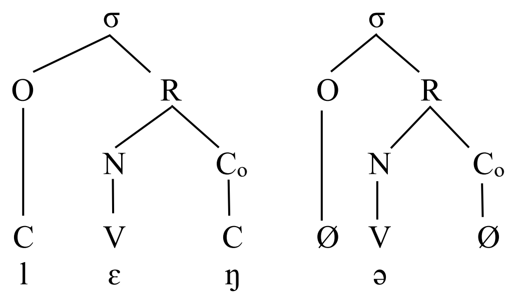
(4) Winkel IPA: [ˈvɪŋkl̩] 2s CVC.CVC



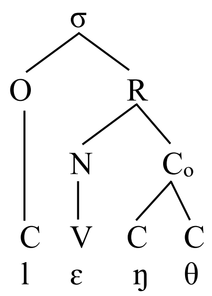
According to the pronunciation rules of German (Krech et al., 2009), the phoneme schwa /ə/ is unstressed and not pronounced in the suffix -el after plosives. Therefore, the phoneme /l̩/ following the velar plosive /k/ is syllabic because it acts as both a vowel and a consonant. The vocalic quality of the syllabic /l̩/ acts as a vowel for its own syllable, thus not necessarily implying the presence of V in the second, word-final syllable.

In the word *Länge* the string CVCV can only be syllabified CVC.V, not CV.CV, being incongruent with the morphological boundary (5). The velar nasal phoneme /η/ in German cannot appear word-initially i.e. in onsets, but only in codas. The same applies to English exemplified in the sub-corpus by an equivalent lexeme *length* (5a). In many words codas containing /η/ are strict codas. Only a small number of words permit ambi-syllabic /η/ (Hayes, 2009). The first syllable with a coda consonant /η/ is followed by another syllable as the final syllable in the word containing only a nucleus (vowel /ə/). In contrast, the word *length* is monosyllabic comprising a branching coda with the consonant /η/ followed by /θ/.

(5)
Länge IPA: [ˈlɛŋə] 2s CVC.V
Län-ge (DWDS)

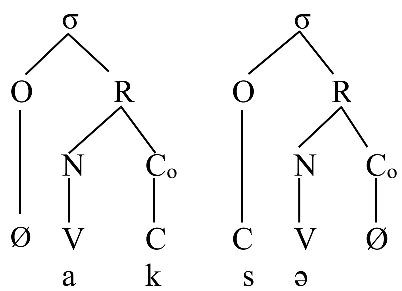


(5a)
length [lɛŋkθ]; BE [lɛŋθ] 1s CVCC

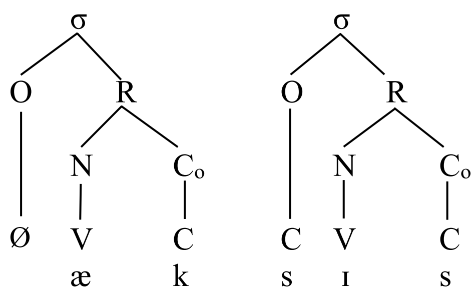


A word pair *Achse* and *axis* also posed some indeterminacy when syllabified. Should *Achse* be syllabified as [ˈak.sə] or [ˈaks.ə] ([ˈæk.sɪs] or [ˈæks.ɪs] respectively) in that the syllable boundary is shifted to the right i.e. the phoneme /s/ is shifted to the left forming a consonant cluster /ks/ in coda. Even more so since /ks/ is a syllabic coda cluster permitted in both German and English (e.g. text) and a phonotactic condition allows a vowel /ə/ to appear syllable-finally. By appealing to the Maximal Onset Principle *Achse* and *axis* should be syllabified as represented in (6) and (6a). Moreover, cross-linguistically onsets have priority over codas (Radford et al., 2009; Zec, 2007).

(6)
Achse IPA: [ˈaksə] 2s VC.CV



(6a)
axis [ˈæksɪs] 2s VC.CVC



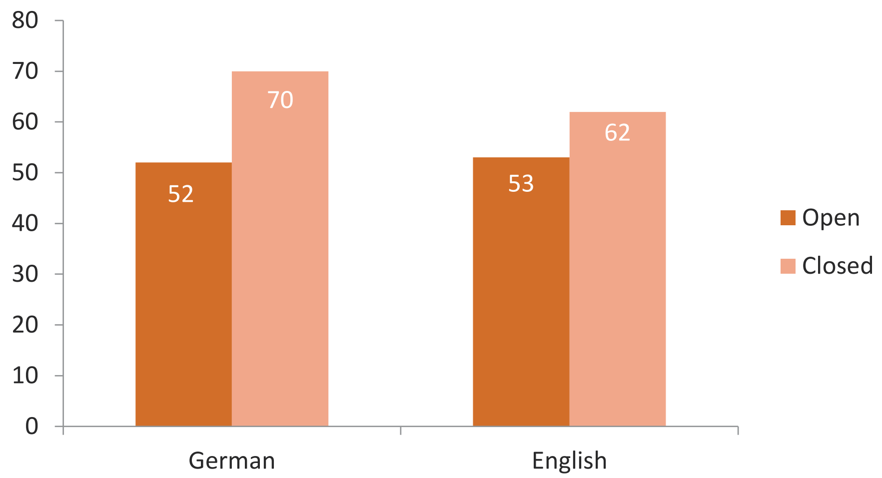
For a further examination of the nature of syllabic organisation, the notion of sequence in terms of both syllable sequence within a word and the sequence of syllable constituents should be taken into consideration. Within a word, syllables can appear initially, medially and finally (Table 4).

Table 4
Syllable position within a word

Words	No. of syllables	Monosyllabic	Word initial	Word medial	Word final
100	237	22 (9.2 %)	78 (32.9%)	59 (24.8%)	78 (32.9%)

Depending on the way constituents or segments are organized within a syllable, languages allow *open* or *closed* syllables and in the account of ‘quantity or amount of sound’, respectively sonority hierarchy[7], *light* and *heavy* syllables. German and English allow both *open* and *closed* syllables, that is, open being those without and closed being those with one or more final consonants. A syllable is 'heavy' if it contains a long vowel, or a diphthong, or a short vowel followed by a consonant. An open syllable which contains only a short vowel is 'light' (Durand, 1990, p. 201). The representation of syllables according to this typology is presented in Figure 3.

Figure 3
Open and closed syllable representation



The English sub-sample contains more monosyllabic words (13 vs. 9) out of which one ends with a vowel (*bar*) and one with a diphthong (shear). As closed syllables outnumber open syllables in the bilingual sample used, and the arrangement of syllable segments follows phonotactic patterns, the relationship of the individual segments (sounds) to each other will also receive some attention. The crucial aspects of syllable segment sequencing are governed by the sonority principle (Parker, 2011). Syllable segments can be distinguished according to the level of sonority or the sonority hierarchy by which vowels are more sonorous than consonants. Vowels tend to occur in the nucleus, whereas less sonorous sounds tend to occur in onsets and codas. In our 100-word sample, the phoneme /b/ occurring word-initially has the same frequency as the phoneme /ʃ/ with nine occurrences. Phonemes /s/ and /k/ have the same representation in the sample with eight occurrences. The phoneme /l/ is ranked fourth with six occurrences (Table 5).

7 For the purpose of this paper sonority is understood as an amount of acoustic energy produced by speech organs. Herein a detailed discussion on the various definitions and applications of the notion of sonority is not essential.

Table 5
Word-initial phonemes

Phoneme	/b/	/ʃ/	/s/	/k/	/l/
German	Balken Bedingung Belastung Beschleunigung Bewegung Biegung	Schnitt Schnittgröße Schwerpunkt Schwingung Spannung Stab Stabkraft Stoß	statisch	Kinetik Knoten Koordinate Kraft	Lage Lager Länge Last
English	bar beam body	shear	section solution spring strain stress support system	component condition constant coordinate	length load

At the syllable level a various degree of complexity has been noticed. The number of segments ranges from simplex, zero onset and zero coda, only the nucleus, to maximal syllables CVCCC and CCVV̂C in German and maximal syllables CCCVC and CCCVV̂C in English. The longest consonant cluster contains three consonants and appears both word-initially, /str-/ in English (*stress*), and word-finally /ηkt/ in German (*Punkt*). The combinations of consonant clusters prevail in the German sub-sample. Syllable-initial clusters with two consonants are six times as frequent in German as in English (Table 6). These findings are consistent with those of Delattre and Olsen (1969) whose analysis of syllables in four languages showed that consonant load is greatest in German and somewhat less in English. A more detailed analysis of consonant clusters will be given in the following text.

Table 6
Distribution of consonant clusters

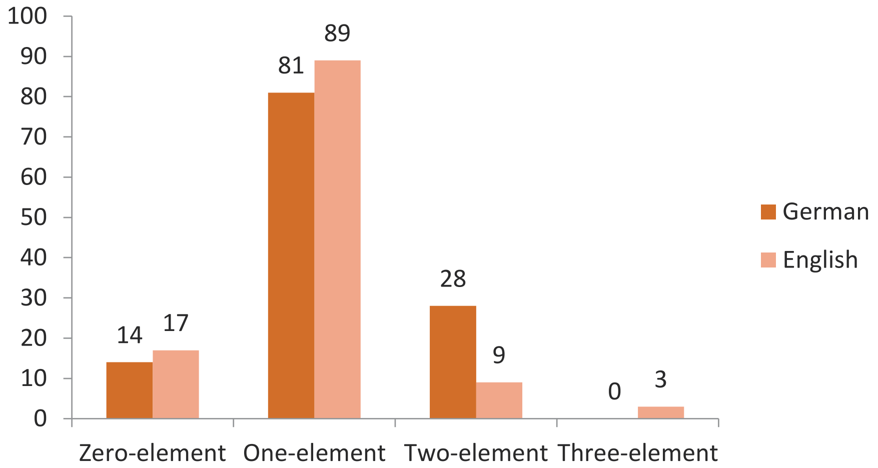
Consonant cluster	word-initial (onset)		word-medial		word-final	
	German	English	German	English	German	English
CC	19	3	9	7	8	8
CCC	0	3 /str/ /spr/	0	0	2 /ηkt/	0

3.2.1 Syllable onsets and codas

3.2.1.1 Onsets

To constitute a syllable, a single vowel serving as a nucleus will suffice. However, in order to form a meaningful unit that will be recognized by a person as denoting a specific thing or a concept, other segments or a sequence of sounds are needed. Consonants may either precede (termed onset) or follow the nucleus (termed coda). Languages may impose restrictions as to the number of onset consonants, their sequence and a minimum sonority distance. The pho-no-tactics of German and English allow complex consonant clusters in both the syllable onset and the coda. The German and English sub-samples are found to have zero-, one-, two- and three-member onsets and codas with different occurrences (Figures 4 and 5, Table 7).

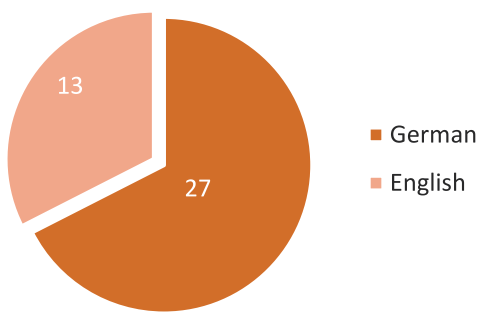
Figure 4
Onset types



The English sub-sample exhibits a higher frequency of onset-less syllables (17 vs. 14) and a somewhat higher frequency of simple non-branching onsets (represented by a single consonant). Onset CC cluster occurrence is higher in the German sub-sample, whereas onset CCC cluster was found only in the English sub-sample (*spring*, *strain*, *stress*), although German permits three-element onsets (*Beanspruchung, Ursprung*)[8]. Delattre and Olsen (1969) found only one syllable with onset CCC cluster in the German sub-sample and four in the English sub-sample.

Analysed at the word level, 33 words in the English sub-sample start with a one-element onset but only 23 in the German sub-sample. In contrast, the rate of branching onsets is higher at the beginning of the German words (17 vs. 13) (Figure 5).

Figure 5
Branching onsets



8 Examples that are manually extracted from the corpus.

Only a one word-initial cluster with three consonants /str-/ is found in English (*spring*, *strain*, *stress*)[9] and only a one word-final cluster of three consonants /ηkt/ in German (*Punkt*) (Table 7).

Table 7
Frequency of onset clusters [CC] and [CCC]

	BO	CC-onset		CCC-onset	
	Total	word-initial	word-internal	word-initial	word-internal
German	28	19	9	0	0
English	12	3	6	3	0

The CC onset clusters in German occur word-initially, including the /ʃl/ consonant sequence in the word *Beschleunigung* as a noun derived from the verb *beschleunigen,* also a new word formed using the derivational affix *be*-. The same applies to *displacement*, a word formed by derivational affixes *dis*- and *–ment.* Three onset consonant clusters out of nine – /fr/ /pl/ and /pr/ – are found in English in the word-initial position (Table 8).

Table 8
Branching onset phoneme sequences

German

Phoneme sequence	Position	Word
/dr/	word-initial	Druck
/fl/	word-initial	Fläche
/gl/	word-initial	Gleichung Gleichgewicht
/kr/	word-initial	Kraft, Knoten
/kv/	word-initial	Querschnitt
/st/	word-initial	statisch
/ʃl/	word-initial	Beschleunigung
/ʃn/	word-initial	Schnitt
/ʃp/	word-initial	Spannung
/ʃt/	word-initial	Stab, Stoß
/ʃv/	word-initial	Schwerpunkt Schwingung
/ts/	word-initial	Zeit, Zug

English

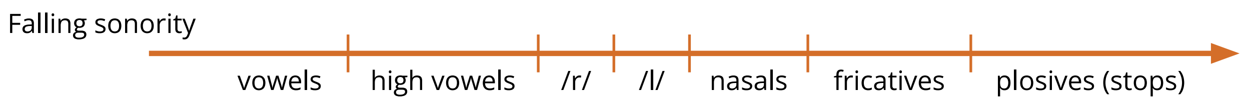
Phoneme sequence	Position	Word
/br/	word-internal	equilibrium
/gj/	word-internal	angular
/gr/	word-internal	integration
/kw/	word-internal	equation equilibrium
/st/	word-internal	constant
/tʃ/	word-internal	virtual
/fr/	word-initial	friction
/pl/	word-initial	plane displacement
/pr/	word-initial	principle

When analysing a consonantal sequence within a syllable, the notion of sonority should also be taken into account as its major function is to organize the segments within syllables (Parker, 2011). The sonority values of adjacent segments are diverse in that vowels as more

9 According to Roach (2009), the number of possible CCC clusters in English is quite small (*stream*, *square*).

sonorous elements occur in the nucleus acting as a sonority peak, while less sonorous elements appear in onsets and codas. So far, scholars have developed a number of scales to indicate segment sonority values, all of them ranging from vowels exhibiting the highest level of sonority to those with the lowest sonority (Selkirk, 1982; Steriade, 1982; Wright, 2004; Zec, 2007; Parker, 2012). There is a general tendency that a syllable has only one peak of sonority and segments are organized according to sonority sequencing restrictions around the peak in that the more sonorous segments are closer to the peak and the less sonorous ones are more distant from it. Put another way, the onset consonant clusters must rise in sonority toward the nucleus, while coda clusters fall in sonority (Hooper, 1976; Steriade, 1982; Selkirk, 1984). This principle is known in literature as the Sonority Sequencing Principle (SSP) or Sonority Sequencing Generalisation (SSG). The sonority scale suggested by Wiese (1988; 2011) (7) was adopted as the appropriate scale for German because it can predict the phonotactic within a German syllable relatively accurately (Meibauer et al., 2015). The scale in (7) is readily comparable to the typical five-category sonority scale *vowel > glide > liquid > nasal > obstruent* to be applied when explaining the occurrences in the English sub-sample (8).

(7) Sonority scale (Wiese, 1998)



[translated and adapted by V. Cigan]

(8) Modal sonority hierarchy (Clements, 1990; Kenstowicz, 1994; Smolensky, 1995)

natural class:	vowels	>	glides	>	liquids	>	nasals	>	obstruents
abbreviation:	V		G		L		N		O
sonority index (SI)	5		4		3		2		1

According to SSP in a bi-consonantal onset cluster, the second consonant should be more sonorous than the first one (Zec, 2007). It should also be noted that SSP serves as a universal sonority hierarchy[10] applied to explain the phonotactic constraints or language-specific requirements. To represent the consonantal sequences more accurately, the hierarchy in (8) should be more finely nuanced so that the obstruents are subdivided into fricatives and stops (9).

(9) Adapted sonority hierarchy

vowels	>	glides	>	liquids	>	nasals	>	obstruents	
								fricatives	stops
V		G		L		N		F	S
6		5		4		3		2	1

10 With due exceptions, e.g. Noelliste (2019) argues that a universal hierarchy cannot account for the Bavarian German data.

The most frequent phoneme beginning a word and constituting a branching onset in the German sub-sample is the voiceless fricative /ʃ/ followed by the voiceless stops /p/ and /t/ (e.g. *Spannung*, *Stab*), liquid /l/ (e.g. *Beschleunigung*), nasal /n/ (e.g. *Schnitt*) and the voiced fricative /v/ (e.g. *Schwingung*). The word i.e. the syllable-initial cluster in *Spannung* contains the voiceless fricative /ʃ/ in C_1 position and the voiceless stop /p/ in C_2 position which belongs to one of the exception groups to the SSP. In addition, clusters F + S i.e. /s/ + stop clusters are common in Germanic languages such as in the English words *stop* or *school* (Parker, 2008) although fricatives are more sonorous than stops. The second syllable in *Spannung* is a well-formed syllable as it follows the SSP pattern (10). Another example of the SSP violation is the onset cluster [st] in the German word *statisch*. In English the violations occur in the syllable-initial CC clusters of /sp/, /st/ and /sk/, where the stops (/p/, /t/, /k/) are the least sonorous and are closer to the syllable peak. It should also be noted that /s/ is more sonorous than the stops occupying the first slot in the onset or being the pre-initial consonant of (/p/, /t/, /k/) in two-consonant clusters as Roach (2009) calls it. /s/ is exceptional in that it is the only English phoneme involved in SSP violations (Sherwin, 1999). Cross-linguistically, certain violations are more common than others (Morelli, 2003). As reported by Parker (2011) and McMahon (2020), the most frequent exceptions to the SSP involve /s/, in English followed by a plosive as in *spill*, *still* and *skill.*

(10) *Spannung*

	2	1	6		3	6	3
	/ʃ	p	a	.	n	ʊ	ŋ/

Additional phonotactic constraint in respect of the adjacent onset and coda segments is the minimal sonority distance parameter according to which consonants stand at a certain distance from each other within the sonority hierarchy and differ from each other in sonority to a degree determined language-specifically (Steriade, 1982). According to Parker (2011), the sonority distance can be calculated by using the formula $b - a \geq x$ where a = Sonority Index of C_1 and b = Sonority Index of C_2. Given the sonority hierarchy in (10), the onset segments /g/ and /l/ forming the cluster S (C_1) + L (C_2) or the onset cluster [kr] belonging to the same sonority classes have a sonority distance of 3 points (11). The same pattern is found in the English word plane – [*pl*]*ane.*

(11) Sonority distance of [gl]

b (liquid, C_2) – *a* (voiced stop, C_1)

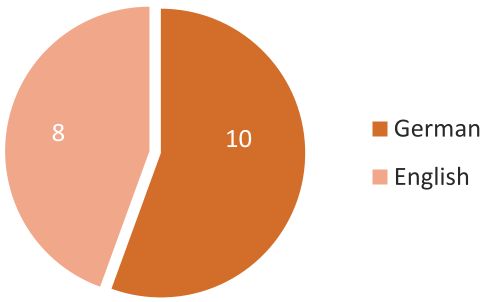
↳ 4 – ↳ 1 = 3

It is also noteworthy that in German the sequences of the consonants with the same sonority value are permissible only if they follow sonority sequencing restrictions. For example, the segment sequence fricative + fricative is only allowed if the voiceless palato-alveolar fricative /ʃ/ is followed by the labial fricative /v/ (*Schwingung*). The reverse sequence [vʃ] is not allowed.

3.2.1.2 Codas

In contrast to onsets, sample syllables tend to contain codas much less frequently, in particular branching coda (Figure 6), which is in accordance with a general observation that fewer consonants and consonant sequences are permitted in codas than in onsets (Goldsmith, 2011). In the German sub-sample, a branching coda occurs both word-initially and word-finally, whereas in the English sub-sample only in the word-final position (Table 9).

Figure 6
Branching coda



According to the sonority effects, a consonant sequence within a coda (after a nucleus) should display falling sonority so as to comply with the SSP. Almost all coda consonant clusters exhibit a decrease in sonority e.g. fricative + stop cluster or nasal + stop cluster, as fricatives and nasals have a higher sonority value than stops.

Table 9
Branching coda consonant sequences

German

Consonant sequence	Position	Word
[çt] F+S	word-final syllable-final	Gewicht Gleichgewicht senkrecht
[ft] F+S	word-final syllable-final	Kraft
[ŋk] N+S	word-internal syllable-final	senkrecht
[ŋkt] N+S+S	word-final syllable-final	Punkt Schwerpunkt
[nt] N+S	word-final syllable-final	Abstand

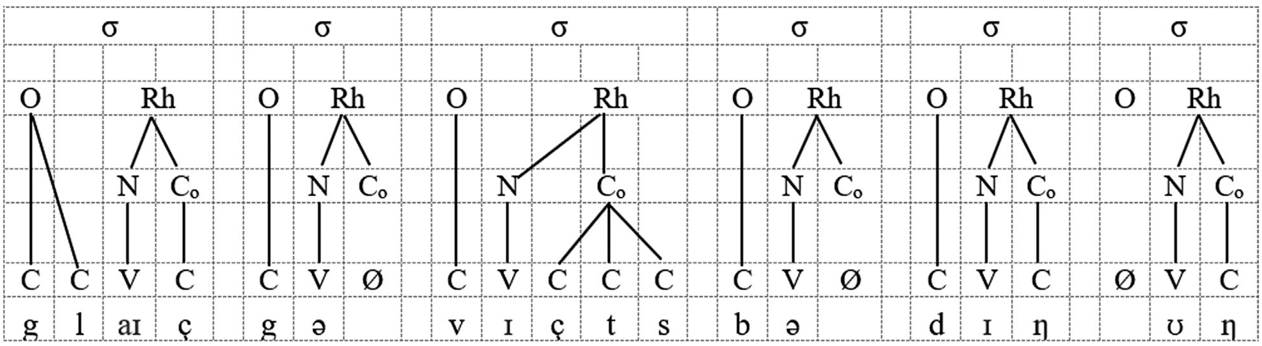
English

Consonant sequence	Position	Word
[nt] N+S	word-final syllable-final	moment component constant displacement
[kt] S+S	word-final syllable-final	impact
[ŋθ] N+F	word-final syllable-final	length
[ld] L+S	word-final syllable-final	yield

Although consonant segments in order to be considered well-formed must be separated by at least one interval in the sonority hierarchy, one cluster contains segments of the same sonority value – [kt], also a segment of [ŋkt]. Sequences of segments with the same degree of sonority are only partly permitted inasmuch as the second segment in that cluster is /t/.

German is known for its morphological productivity, in particular compounding, and accordingly, its extensive use of compounds. Long compounds extracted from the German sub-sample exemplify not just results of a productive word formation process in action in a technical text, but also the phonotactics of German that allows complex consonant clusters both in the onset and the coda. In compounds ending in *-heit*, *-ion*, *-ität* (loan suffixes), *-keit*, *-schaft* and *-ung*[11] the linking element *-s-* occurs primarily due to phonological factors, in particular when the stem ends in a consonant (Wegener, 2003). According to the sonority hierarchy, *-s-* can follow all sounds in the same syllable (except s-sounds) (Fuhrhop, 1996) and produce rather complex coda structure, as clearly observable in (12).

(12) Gleichgewichtsbedingung; 6 syllables; CCVV̂C.CV.CVCCC.CV.CVC.VC



3.3 Vowels and diphthongs

3.3.1 Vowels

The distribution of sounds within a word allows for language-specific patterns. In particular, among many, the most important difference between a vowel and a consonant according to Roach (2009) is the way of their distributions. In the simplest structures, monosyllabic words, a unit is constituted only by a vowel. As there are no words without a vowel, the vocalic nucleus is an indispensable constituent of the syllable (Gussmann, 2002). The vocalic nucleus can, but must not, either be preceded or followed by a single consonant or a slot of consonants.

In our 100-word sample vowels /e:/ and /ə/ in German and /ə/, /ɪ/ and /i:/ in English form a syllable by themselves as a sole constituent. The most frequent is the short central vowel /ə/ with 23 occurrences in the German and 40 occurrences in the English sub-sample (Table 10). This result could have been expected bearing in mind that schwa is by far the most frequently occurring vowel in West Germanic languages such as German, English, and Dutch (Delattre, 1965).

11 Aronoff and Fuhrhop (2002, p. 464) classify these suffixes as closing suffixes as they are not open for further word-formation so that linking elements "reopen closed stems again for further morphological processes".

Table 10
Frequency of vowels

Vowel Ger.	Example	Frequency
ə	Ebene	23
ʊ	Punkt	17
ɪ	Winkel	19
a	Achse	13
ɛ	Länge	10
a:	statisch	6
e:	Kinetik	5
i:	Verschiebung	2
o	Moment	2
o:	Stoß	2
ɐ	Lager	2
ɛ:	Elastizität	1

Vowel Eng.	Example	Frequency
ə	velocity	40
ɪ	impact	22
æ	static	7
e	pressure	7
i	energy	4
i:	beam	3
ɔ:	force	3
ɒ	body	3
a:	bar	1
ʌ	resultant	1
ɛ	stress	1
ɜː	virtual	1
u:	solution	1

Due to schwa high frequency and unique linguistic status, its representation in the sample used deserves a more detailed analysis. There are several approaches to the determination of schwa features. Some scholars characterize it as lacking fundamental phonological features (van Oostendorp, 2000), others point to its lower position on the sonority hierarchy being the only noteworthy difference to other vowels. Kager (1989) and Féry (1995) view schwa as "weightless" or non-moraic. Roach (2009) observes that schwa is different from the other vowels in several important ways. In quality it is mid (i.e. halfway between close and open) and non-peripheral but rather central (i.e. halfway between front and back). In respect of tension, it is generally described as lax since it is not articulated with much energy and makes no special demands on the articulators.

The syllabification process revealed four positions of schwa in the respective sample. It occurs in a word-final syllable, word-initial syllable, in word prefixes and a word-internal position (Table 11). The languages under consideration differ in three positions: no words in the German sub-sample are attested to have the vowel /ə/ in a word-initial syllable neither in a word-internal position, and no words in the English sub-sample are found to have schwa in word prefixes. A greater variety in the schwa vowel distribution is noticed in the English sub-sample occurring in word-initial syllables, word-final syllables and in word-internal positions.

A greater number of syllables having a vowel /ə/ within a syllable followed by no coda (14 vs. 9) was found in the English sub-sample. Consistent with its major feature, schwa occurs in the unstressed position mainly after the chief stress in a word-final syllable. In German, the majority of word-final syllables end in a vowel [e] having no coda. Two closed, unstressed syllables with the phoneme /ə/ and a coda are found in *Bal.ken* and *Win.kel*. The vowel /ə/ is here epenthetic and not obligatory as it is not pronounced in the suffixes *–el* and *–en* after plosives and as /l̩/ and /n̩/ serve as syllable nuclei. Wiese (1996) claims, though, that schwa in

German is generally epenthetic. Due to its vocalic quality /l/ in English also acts as a vowel in its syllable. Accordingly, /l/ in *angle* blends with /g/ and schwa need not be epenthesized. The same was shown in Browman and Goldstein (1992) who state that a schwa can be replaced by a syllabic consonant. Roach (2000, p. 80) maintains that using a schwa in certain cases “would sound strange (or at best over-careful)”.

Table 11
Representation of schwa in the bilingual sample

	German	English
/ə/ in word-final syllables	Ach.se E.be.ne Flä.che Ko.or.di.na.te La.ge Läng.e Schnitt.grö.ße Bal.ken Win.kel	ac.ce.le.ra.tion con.di.tion di.rec.tion e.qua.tion fric.tion in.te.gra.tion lo.ca.tion mo.tion po.si.tion re.ac.tion ro.ta.tion sec.tion so.lu.tion vi.bra.tion i.ner.tia con.stant dis.place.ment mo.ment com.po.nent sys.tem e.qui.li.bri.um mo.men.tum an.gle pre.ssure vec.tor an.gu.lar prin.ci.ple vir.tu.al
/ə/ in word prefixes	Be.ding.ung Be.las.tung be.rech.nen Be.schleu.ni.gung Be.we.gung Ge.schwin.dig.keit Ge.wicht (Gleichgewicht, Gleichgewichtsbedingung)	

	German	English
/ə/ in word-initial syllables		ac.ce.le.ra.tion com.po.nent con.di.tion mo.men.tum ob.tain po.si.tion so.lu.tion su.pport ve.lo.ci.ty
/ə/ in word-internal position	Än.de.rung E.be.ne	ac.ce.le.ra.tion an.gu.lar prin.ci.ple ve.lo.ci.ty

The schwa vowel in the English word-final syllable *–tion*, a noun-forming suffix can be pronounced with /ʃən/ or without schwa /ʃn̩/. According to Wells (1965), words usually pronounced with a syllabic consonant are often pronounced with schwa plus a consonant when greater clarity is needed. Today, in contrast to Received Pronunciation[12], syllables in many words are not reduced to syllabic consonants but are commonly pronounced more fully. Pronunciations with the schwa vowel are increasingly present among younger speakers. The reintroduction of vowels can be seen as one of the ways in which pronunciation has been brought closer to the spelling (Lindsey, 2019).

In addition to the schwa vowel /ə/ as the prototypical vowel of the unstressed position, German has a second schwa vowel /ɐ/ or a-schwa, also occurring in unstressed syllables and constituting a minimal pair i.e. making meaningful contrasts as in (12). The two schwa vowels as occupants of the unstressed positions are also regarded as reduced vowels characterized by centrality but under the significant co-articulatory influence of the context.

(12) bitte [b'ɪtə] bitter [b'ɪtɐ]
Lage [l'a:gə] Lager [l'a:gɐ]

The primary function of the vowel schwa is to occupy a syllable nucleus and to ensure a certain number of syllables. Moreover, being in contrast with full vowels it contributes to the differentiation of words and their forms (13).

(13) gerannt [gəʁ'ant] Garant [gaʁ'ant]
Motte [m'ɔtə] Motto [m'ɔto:]
Bein [bae̯n] Beine [bae̯nə]

According to Flemming (2009, p. 16), there are "two quite distinct types of a schwa vowel" in American English in particular, a word-medial schwa variable in quality, and mid central word-final schwa, which is more stable. In their study, Flemming and Johnson (2007) found significant phonetic differences between schwa vowels in word-final positions (*china*, *comma*)

12 For example, the inflectional endings *–ed*, *-es* when pronounced with a vowel, predominantly contain [ɪ] in RP, although in other varieties of English schwa may be the preferred option (Gussmann, 2002).

and schwa vowels in other positions (*suppose*, *probable*), word-final schwa vowels having twice as long duration as non-final schwa vowels. When investigating the contextual variability, Flemming's analysis (2009) pointed to a cause-effect relationship between the high variability and surrounding context. Applying this line of studies, it is possible to notice the difference of schwa quality in *per.pen.di.cu.lar* and *per.pen.di.cu.lar*. Furthermore, in contrast to German, schwa in English word-final syllables with an empty coda is greater in length (*Fläche*, *Lage* vs. *pressure*, *perpendicular*).

In terms of length, an important property of vowels, the German sub-sample has as many long vowels as English (German: /aː/, /eː/, /iː/ and /oː/; English: /aː/, /ɜː/, /iː/ and /ɔː/). They share vowels /aː/ and /iː/ but differ in respect of the occurrences of the German long half-close front unrounded vowel /eː/ (*Ebene*) and the long half-close back rounded vowel/oː/ (*Stoß*) in comparison to the English long central between half-close and half-open unrounded vowel /ɜː/ (*work*) and the long half-open back rounded vowel /ɔː/ (*force*).

3.3.2 Diphthongs

For the purpose of description of diphthongs in the two sub-samples, diphthongs are defined as sequences of two vowels realized within one syllable and constituting phonetic units with a significant change in sound quality (Fuhrhop & Peters, 2013). If two vowels occur in one syllable, only one vowel forms the syllable peak and the other is unsyllabic (Meibauer et al., 2015). Furthermore, diphthongs need to be distinguished from the sequences of two vowels (Russ, 2010).

In concordance with the phonological literature (Gimson, 1970; O'Connor, 1973; Jones, 1975; Hall, 2011), the English sub-sample comprises more diphthongs than the German sub-sample (Table 12). The prevailing diphthong is [eɪ] occurring in nine words. It is interesting to notice that the diphthongs [eɪ] and [aɪ] are represented in spelling by the letters <a> and <i> that are pronounced in the same way when spelled individually. Equally represented diphthongs in the German sub-sample are [aɪ̯] and [ai] with three occurrences. The phonemic diphthong[13] [ai] is represented by two writing diphthongs <ei> and <ai>, out of which <ei> occurs significantly more frequently and <ai> is not found in the German sub-sample. The corresponding English diphthong of [aɪ̯] is [aɪ] found in di.rec.tion, and vi.bra.tion. The two diphthongs differ in that the English one starts further back than the German one i.e. is not too fronted.

Table 12
Representation of diphthongs in the two sub-samples

Diphthong	German	Diphthong	English
aɪ̯	Glei.chung Gleich.ge.wicht Ar.beit	əʊ̯	motion lo.ca.tion
ai	Ge.schwin.dig.keit Ma.ssen.träg.heits.mo.ment Zeit	aɪ	di.rec.tion vi.bra.tion

13 Fuhrhop and Peters (2013) distinguish writing and phonemic diphthongs (*Schreib-* und *Sprechdiphtonge*).

Diphthong	German	Diphthong	English
ɔɪ̯	Be.schleu.ni.gung	əʊ̑	com.po.nent co.or.di.nate mo.ment ro.ta.tion
		ɔɪ	point
		eə	a.re.a
ɛɐ̯	Ver.schie.bung	eɪ	ac.ce.le.ra.tion co.or.di.nate dis.place.ment e.qua.tion in.te.gra.tion plane ro.ta.tion strain weight
		oʊ	load

4 Conclusion

This paper aims at analysing and contrasting the terms in German and English mechanical engineering texts regarding their phonological features, similarities and differences. Starting the analysis at the word level, the English sub-sample is found to contain more monosyllabic words and slightly more three-syllable words, whereas bi-syllabic words in German sub-sample outnumber those in English. Accounting for 56% of syllables, the most frequent syllable templates are CV and CVC, highly common types for many languages. More words in the English sub-sample start with a one-element onset, whereas the rate of branching onsets is higher at the beginning of the German words. The most frequent phonemes occurring word-initially are /b/ in the German and /ʃ/ in the English sub-sample.

Furthermore, a prevailing two-consonant cluster is found in the German sub-sample occurring three times as frequently as in the English one. The languages under consideration differ in the position of onset CC-clusters in that in English these clusters are also found word-internally. Based on the presented data there are language-specific restrictions as to which consonants can occur together both in onset and coda. Accordingly, sonority sequencing restrictions are confirmed as a language specific constraint. Although allowed in both languages, the first C in the three-consonantal cluster in English is /s/, whereas German allows more options for the first slot – in addition to [sp, st, sk] attested combinations are also [ʃp, ʃt, ʃl]. A further difference between two languages lies in the position of the schwa vowel within a word and its varying length.

Although this survey has given only a snapshot of two languages for specific purposes, it has also shown that even a small body of specific domain text can serve as a good research sample in that it exhibits language-specific properties attested to be valid for the languages under scrutiny. Moreover, it has also revealed which and to what extant general language phonological features are represented in texts in special language domains.

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