The syntactic complexity in tracheoesophageal speech

A pilot study about complexity of grammar in verbal communication after total laryngectomy

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Content

Abstract

Background: Studies about the language and speech of patients after total laryngectomy (TL) have investigated the vocal quality and intelligibility and the language network in the brains of these patients. The language structure of such patients has never been analyzed before.
Aims and research question: The aims of this study are to discover if alaryngeal speech is a constraint affecting linguistic complexity and to generate hypotheses about the syntactic complexity in speech of persons who underwent TL and use tracheoesophageal speech (TES) as speech rehabilitation method. The main research question is: Does the syntactic complexity of speech change after TL?
Method: Speech data from eight TES-patients and eight healthy controls (HCs), gathered from interviews and dialogs, are used. The syntactic complexity is measured at the level of the C-unit, clause, and noun phrase by calculating the mean length of the units and percentages of simple and complex units.
Results: The results show that the syntactic complexity of the TES-patients seems to be low overall, but differs between the TES-patients, which could possibly be due to different levels of intelligibility and maybe due to the different number of years using TES or the age at TL. The HCs seems to have a more complex syntax than the TES-patients, which could be due to the fact that HCs have a longer maximum phonation time than TES-patients.
Conclusion: It can be concluded that the syntactic complexity of speech does change (even though it seems not by much) after TL. Alaryngeal speech is a constraint affecting linguistic complexity. Factors that could influence syntactic complexity in speech are: intelligibility, number of years using TES as speech method, age at TL, and maximum phonation time.

1. Introduction

This is a pilot study about the use and complexity of grammar in verbal communication after total laryngectomy (TL). An overview of different views about linguistic complexity and how this is measured in previous studies in different linguistic fields is given in section 1.1. In the next section, section 1.2, information about TL and speech after TL is given. In the last section of the introduction, section 1.3, the motivation for this study, the research questions, and the measures used in this study to investigate grammatical complexity are given.

1.1 Linguistic complexity

Researchers are interested in the differences in complexity across different languages, language varieties, or contexts of use. But what is linguistic complexity? What factors can affect complexity? And how can you measure linguistic complexity? In general, there is not one accepted definition or metric of complexity (Mitchell, 2009).

Miestamo (2008) points out that there are two different approaches to linguistic complexity: the absolute approach (also called objective or structural approach) and the relative approach (also called subjective or user-oriented approach). The absolute approach defines linguistic complexity as "the more parts a system has, the more complex it is," and the relative approach defines it as "the more costly or difficult a linguistic phenomenon is, the more complex it is" (see also Dahl, 2004).

Linguistic complexity can be affected by different factors. These factors could reduce the complexity and are, therefore, also called constraints. These constraints include cognitive load, situations of language contact, bilingual language activation (see e.g., Kruger & van Rooy, 2016; Kuiken & Vedder, 2019), language disorders (see e.g., Armstrong et al., 2011; Zwitserlood et al., 2015), and speech disorders (see e.g., Howell & Au-Yeung, 2007; Richels et al., 2010).

Previous research about linguistic complexity has been done at a global or local level. Researching complexity at a global level means that researchers are investigating the complexity of a language or dialect. Local linguistic complexity is measured at a specific linguistic domain. Measuring complexities in different subdomains of linguistics is seen as a more doable task than measuring the global linguistic complexity (Miestamo, 2008). These subdomains are: phonological, morphological, syntactic, semantic and lexical, and pragmatic complexity (Kortmann & Szmrecsanyi, 2012:9).

There are different fields of linguistics with different linguistic approaches in which researchers try to measure linguistic complexity. These fields include typological linguistics (a functional approach), theoretical linguistics (a theoretical approach), and second-language (L2) acquisition and language and speech pathology (applied approaches; see Housen et al., 2019:4; Kortmann & Szmrecsanyi, 2012). In typological linguistics, researchers compare different languages. Typological linguists explore a certain language (variety) or language family to obtain all the features of that language (variety) or language family and compare it to the other languages of the world that are spoken now or were spoken in the past. Theoretical linguists believe that humans have a universal invariant mechanism for language underlying the language they actually speak. So, theoretical linguists examine the nature of human language and the underlying principles of language in general. In L2 research, linguists focus on the performance of a second language. These researchers investigate how certain characteristics, like the person's first language or language aptitude, or certain teaching methods influence the performance of the second language. Researchers in language and speech pathology investigate the language or speech of persons with a language or speech disorder due to brain damage or damage in the vocal tract or auditory system. These researchers usually measure and examine the performance of a first language. Linguistic complexity is measured differently among these different linguistic fields (see sections 1.1.1 till 1.1.4).

1.1.1 Complexity in typological linguistics

Typological linguistics has been interested in measuring the complexity of entire grammars of languages and comparing the grammatical complexity of different languages. Researchers in this field of linguistics have made a range of global and local complexity measures. For example, McWhorter (2001, 2007) assessed the global complexity of grammars by focusing on overspecification (difference of number of semantic markings), structural elaboration (number of rules required to generate surface forms), and irregularity (the number of irregularities in a grammar; McWhorter, 2007:21-35). However, other typologists say that it is more relevant to measure and compare the local linguistic complexity at different subdomains or subsystems, such as the case system or tense system (see Miestamo, 2008; Sinnemäki, 2011). Typologists are typically interested in the complexity of the phonology and morphology of languages (Housen et al., 2019; e.g., Bane, 2008; McWhorter, 2007; Shosted, 2006).

Shosted (2006) proposed to measure linguistic complexity by counting the occurrences of 'indicators of complexity' in a given language. These indicators are structural units like phonemes, tones, and inflectional markings. After counting these units, the complexity scores for the phonology (e.g., the size of a phoneme inventory and number of phonological alternations) and morphology (e.g., the size of a syllable inventory and number of inflectional categories) can be obtained. Many of these 'indicators of complexity' and other descriptive or typological complexity measures are documented in the online archive *The world atlas of language structures* (WALS; Dryer & Haspelmath, 2013).

Some typologists point out that these complexity measures are descriptive and intuitive (Dahl, 2004). The question is how to decide which linguistic properties should be admitted into the set of complexity indicators, and which complexity indicators are weighing more than others. This question requires answers which are not intuitively obvious. Therefore, an alternative approach looks at independently motivated notions of complexity, and attempts to apply these notions to linguistic systems. For example, Bane (2008) used the notion of Kolmogorov's complexity (Kolmogorov, 1965) to measure the morphological complexity of linguistic systems. Kolmogorov complexity says that an object is more complex than another as it takes longer to describe. Based on this notion, he posed that "we can measure a language's morphological complexity as the proportion of the lexicon's total description length that is due to the description lengths of the affixes and signatures" (Bane, 2008:73).

Biber (1988; as mentioned by Kruger & van Rooy, 2016) proposed a multidimensional register analysis with a total of 67 linguistic features to measure variability to understand how language registers are different. Many of the differences on these features turned out to be related to complexity of various kinds. Kruger and van Rooy (2016) used the linguistic features of four of the six dimensions of language from Biber (1988; as mentioned by Kruger & van Rooy, 2016) to investigated the differences in language structures and language complexity between texts written by British English native speakers (monolingual language activation), texts in a second language (L2) variety of English (East African English) (bilingual language activation), and texts in translated English (situation of language contact). These features included mean word length, type/token ratio, pronouns, nouns, nominalizations, adverbials (for time and place), stranded prepositions, causative adverbial subordinators, private verbs, *be* as main verb, *that* deletion ratio, direct *wh*-questions, independent clause coordination, phrasal coordination, sentence relatives, pied-piping relative clauses, and *wh*-relative clauses (in subject and object position). These features are about the morphology and syntax of languages or language varieties. One of the findings of Kruger and van Rooy (2016) was that bilingual language activation and situations of language contact increase the cognitive load what leads to less complex language.

1.1.2 Complexity in theoretical linguistics

Contrary to typological linguistics, in formal theoretical linguistics, especially generative linguistics, researchers try to capture linguistic complexity mostly with syntactic complexity measures. There are many different syntactic complexity measures available, such as the Immediate Constituent-to-Word Ratio (IC-to-word ratio; Hawkins, 2004). Hawkins (2004) proposed a complexity measure, based on the linguistic efficiency principle Minimize Domains, which he called the Immediate Constituent-to-Word Ratio. This measure calculates the number of words that need to be parsed to recognize the immediate constituents (ICs) of a phrase. For example, in the sentence '*John* $_{VP}$[*went* $_{PP1}$[*to London*] $_{PP2}$[*in the late afternoon*]], there are three ICs in the verb phrase (V, PP1, and PP2) and four words ('*went to London in*') that need to be parsed in order to recognize the ICs, so the IC-to-Word ratio is 3/4 = 75%. The higher this ratio, the lower the complexity (Hawkins, 2004:32-33).

Other examples of syntactic complexity measures in theoretical linguistics are the Mean Dependency Distance (Liu, 2008) and the Derivational Complexity Metric (Jakubowicz, 2003, 2011). Liu (2008) measured the syntactic complexity with a dependency distance metric based on the Distance-Based Theory of Linguistic Complexity of Gibson (2000). Words depend on other words in a sentence, for example a determiner depends on a noun and an object noun depends on a verb. The dependency distance is the distance in words between the dependent and the governor (the word the dependent is connected to). The Mean Dependency Distance (MDD) is calculated by dividing the sum of all dependency distances in a sentence (or sample) by the number of words minus one. The higher the MDD, the more complex a sentence is. The Derivational Complexity Metric of Jakubowicz (2003, 2011) includes two clauses: 1) "Merging α_i n times gives rise to a less complex derivation than merging α_i (n + 1) times"; 2) "Internal Merge of α gives rise to a less complex derivation than Internal Merge of $\alpha + \beta$" (Jakubowicz, 2011:340). This means that the more a linguistic element can be merged, the more complex the sentence is (see also the Derivational Complexity Hypothesis in Jakubowicz & Nash, 2001). So, in formal generative linguistics there is no generally accepted metric for quantifying and comparing the complexity of different grammars.

Besides generative linguistics there is a strand of research about the evolution of language. Sampson (1980; as described by Hendrikse & van Zweel, 2010) demonstrated the evolutionary advantage of hierarchically structured information. He proposed a parable of two watchmakers, Tempus and Hora, and applied this to the evolution of language. The structure of Tempus' watches is linear (all parts are in a linear sequence) and the structure of Hora's watches are hierarchical (some parts are subordinated). Hierarchical systems are more stable than linear systems. Looking from this perspective to language, it seems that language complexities are equal, because language in general is a hierarchical and, therefore, a stable system. But, other linguists, for example Biber (1988; as mentioned by Kruger & van Rooy, 2016), show that not all complexities are equal. To him, phrasal complexity is harder on the mind, since it entails density, whereas clausal complexity allows for sequential processing without requiring such complex integration of dense units of information.

1.1.3 Complexity in second-language research

Within second-language (L2) research there is also no consensus about how to measure linguistic complexity (Housen et al., 2019). Different researchers use different complexity measures, but some measures are more commonly used than others. Ortega (2003) gives an overview of the most used syntactic complexity measures in L2 writing. She included 21 studies in her research and concluded that the following six syntactic measures were used mostly to measure written complexity: mean length of sentence (MLS), mean length of T-unit (MLTU), and mean length of clause (MLC), as measures of the production at clausal or phrasal level; mean number of T-units per sentence (TU/S) which reflects the amount of coordination; and the mean number of clauses per T-unit (C/TU) and of dependent clauses per clause (DC/C) as measures of the amount of subordination. A T-unit is a minimal terminable unit, which consists of one independent clause and any dependent clauses connected to it (Hunt, 1965).

There are also other syntactic complexity measures used in L2 research. Kuiken and Vedder (2019) explored the syntactic complexity in written texts of L2 learners and native writers of Dutch, Italian, and Spanish. They measured the overall complexity by counting the number of clauses per T-unit and the number of dependent clauses per clause, but they also looked at coordination, subordination and phrasal complexity. The complexity of coordination and subordination was, respectively, measured by averaging the number of coordination type (coordination between T-units, withing a T-unit, or between constituents) and of subcoordination type (complement, adverbial, or relative clauses) per 100 words. The phrasal complexity was measured by the number of post-modifying noun phrases per 100 words and the mean length of the post-modifying noun phrases. They found that the most proficient learners of Italian L2 produced more coordinate and subordinate clauses and longer post-modifying noun phrases than the least proficient learners (however, this was not found in Dutch L2 and Spanish L2).

Besides syntactic complexity measures, morphological complexity is also measured in many L2 studies. For example, de Clercq and Housen (2019) measured the morphological complexity of oral texts of Dutch students learning French or English and found a more continuous increase of morphological complexity in French L2 than in English L2 and concluded that morphological complexity is an essential component in measuring the linguistic complexity in L2 acquisition. They used the measures: Types/Family (T/F) ratio from Horst and Collins (2006), Inflectional Diversity (ID) from Malvern et al. (2004), and the Morphological Complexity Index (MCI) from Pallotti (2015; see also Brezina & Pallotti, 2019). To calculate the T/F ratio, you count the number of morphologically different word forms and divide this by the number of word families used in the data set (for example, *work*, *works*, *working*, and *worker* are four types of one word family). ID is the difference between the number of different words in lemmatized texts and the number of different words in unlemmatized texts (for example, in unlemmatized texts *work*, works, and *working* are three types, but in lemmatized texts only the lemma *work* is counted). Lemmas are different from word families in that lemmas only include inflectional variants of the same word class (so, for example, *work* and *worker* are within one word family, but are two lemmas). To calculate the MCI, the number of verb exponents are counted per text (for example, *works*, *walks*, and *runs* are instances of the same verb exponent '-s', so are counted as one). So, morphological complexity can be measured by counting different words, word families, lemmas or the different affixes which express different grammatical categories and functions.

Some researchers look at both syntactic and morphological complexity. For example, Spoelman and Verspoor (2010) measured the linguistic complexity at word, noun phrase (NP), and sentence level. Their longitudinal case study focuses on intra-individual variability in accuracy rates and complexity measures in written texts of a Dutch student learning Finnish. The results show that the interaction of the different complexity measures changes over time and that no relationship was found between accuracy and complexity measures over time. The complexity measures they used are: number of morphemes per word, word complexity ratio (the difference between the average sentence length in morphemes and the average sentence length in words), number of words per NP, NP complexity ratio (average NP length in words), number of simple, compound, complex, and compound-complex sentences, and sentence complexity ratio (average number of dependent clauses). Verspoor and Sauter (2000:36-44) define a compound sentence as a sentence with a coordinating conjunction, a complex sentence as a sentence with one or more dependent clauses, and a compound-complex sentence as a compound sentence with one or more dependent clauses or a complex sentence with two or more dependent clauses joined by a coordinating conjunction. Droop and Verhoeven (1998) measured the complexity of written texts to know if the text was written at a high or low linguistic complexity level. They analyzed linguistic complexity by counting the mean length of sentences, words, and syllables and looked at the complexity of verbal groups and noun compounds.

1.1.4 Complexity in language and speech pathology

Whereas L2 research mostly measures the complexity of written texts, research in language and speech pathology measures the complexity of oral communication. For example, Armstrong et al. (2011) studied (among other things) the linguistic productivity and complexity in oral communication (monologues and dialogues) of two aphasia patients and two healthy controls. They segmented the discourse samples in communication units (C-units). A C-unit is one main clause with one or more subordinate clauses in oral language (Loban, 1976:20-21), so it is like a T-unit (which is used for written language; Hunt, 1965) but used for oral language production. The measures they used were: number of C-units, mean length of C-units (in words and clauses), type/token ratio (TTR; as measure for semantic diversity), number of abandoned C-units, and number of omissions/errors. They also measured the percentage of words in mazes. Mazes are words which to not contribute meaning to the ongoing language flow, and the amount of mazes indicates the degree of linguistic uncertainty of the speaker (Loban, 1976:22). This study distinguished repetitions, revisions, false starts and filled pauses. Each measure was calculated for each speaker. Armstrong et al. (2011) found that the healthy controls produced longer C-units in both contexts (and, therefore, have a higher linguistic complexity) than the aphasia patients, and the aphasia patients produced more words in mazes, abandoned C-units, and omitted words/errors (and, therefore, have a higher linguistic certainty) than the healthy controls.

There are a few more studies in language pathology research in which the researchers measure linguistic complexity as an outcome measure (e.g., Jakubowicz, 2011; Savage & Donovan, 2017; Zwitserlood et al., 2015). Savage and Donovan (2017) researched the linguistic complexity in oral communication (dialogues) of aphasia patients. They used the measures: mean length of utterance (in words), type/token ratio, number of different words, percentage of simple utterances (utterances containing a noun phrase and verb phrase with or without an additional phrase), percentage of complex utterances (utterances containing clauses with a coordinate or subordinate conjunction or containing embedded clauses), and propositional idea density (the number of ideas conveyed by the speaker divided by the total word count of that speaker). Zwitserlood et al. (2015) researched the development of morphosyntactic accuracy and grammatical complexity in Dutch school-age children with specific language impairment (SLI) in comparison with typically developing peer and language-matched children and found that children with SLI have delayed developmental trajectories. They measured the grammatical complexity with these measures: mean length of T-units (in words), number of complex sentences divided by total number of T-units, number of subordinate clauses divided by total number of T-units, and number of relative clauses divided by total number of T-units (they used the term 'T-unit' instead of 'C-unit', which has the same definition as 'T-unit' but is used for oral language according to Loban (1976:20-21), see previous alinea). A complex sentence in this study is a sentence containing a subordinate, infinitival and/or reduced clauses, and/or with a coordination conjunction. Jakubowicz (2011) measured the derivational complexity of French children who have a typically developing language or SLI. She measured this with the theoretical complexity measure: the Derivational Complexity Metric (see section 1.1.2 and Jakubowicz, 2003).

There are also some studies with participants who stutter in which the linguistic complexity of utterances was measured (e.g., Al-Tamimi et al., 2013; Howell & Au-Yeung, 2007). Howell and Au-Yeung (2007) investigated whether phonetic complexity affected the number of stutters in the spontaneous speech of Spanish children (ageing 6 till 18 years) and adults (18 plus) who stutter. They found that phonetic complexity affects the stutter rate of content words in the speech of the older children (aged 11 till 18) and of the adults. They measured the phonetic complexity of the speech of their participants by using Jakielski's (1998)[1] Index of Phonetic Complexity (IPC). The participants get a point: 1) if a consonant (C), the participant produces, is a dorsal; 2) if a C is a fricative, affricate or liquid; 3) if the C in a coda and the C in the following onset of a syllable differ in place of articulation;

[1] Only the abstract was available; information about the Index of Phonetic Complexity is retrieved from Howell and Au-Yeung (2007).

4) if the participant produces a C-cluster; 5) if the C's in a C-cluster differ in place of articulation; 6) if a vowel (V) is a rhotic; 7) if a word ends with a C; and 8) if a word consists of three or more syllables. The more point a participant gets, the more complex his/her speech was. There are more studies done in which the IPC is used to measure the phonetic complexity in oral language. For example, Al-Tamimi et al. (2013) researched the phonetic complexity of Jordanian Arabic speakers who stutter and used an adaptation of the IPC for the Arabic language.

Besides phonetic complexity, utterance/syntactic complexity is used in studies with participants who stutter (e.g., Richels et al., 2010; Ryan, 2000). Richels et al. (2010) measured the complexity at the level of utterances. They investigate the relation between utterance complexity and position and the stutter rate on function words in conversational interactions of pre-school-aged children who stutter. They called an utterance grammatically complex if it contained two or more clauses connected with a coordinate or subordinate conjunction, one main clause with an embedded or dependent clause, a noun phrase modified by a clause, or two or more verb phrases. They found that children did not stutter more frequently on function words in complex utterances than in simple utterances, but stuttering was more likely to occur with increasing sentence length. Ryan (2000) researched the speaking rate, conversational speech acts, interruption, and linguistic complexity of pre-school children who stutter or not stutter and their mothers. To measure the linguistic complexity, he used the Developmental Sentence Score (DSS) of Lee (1974; as described by Hughes et al., 1992): the participants get a score between 1 and 8 for each of the following categories: 1) indefinite pronouns and noun modifiers, 2) personal pronouns, 3) main verbs, 4) secondary verbs, 5) negatives, 6) conjunctions, 7) *wh*-question, and 8) interrogative reversals. The DSS is the average score for one sample. He found that children who stutter demonstrate a slightly lower DSS score than children who do not stutter, and that sentences with stuttering and/or normal disfluency obtained a higher DSS scores (so, a higher linguistic complexity) than fluent sentences. So, stuttering is more likely to occur in syntactically complex and longer sentences.

To summarize, there are many different ways to measure linguistic complexity. The kind of measures used in theoretical linguistic and typological linguistic differ a lot, but in L2 research and research in language and speech pathology occur measures that look more alike. Linguistic complexity can be measured at the level of sounds, words, phrases, clauses, and T-units/C-units/sentences. Most of the found measures include counting of certain elements, such as sounds, syllables, and (mostly) words. Many researchers also compare less complex and more complex sentences or clauses (by using their own definition of a complex sentence/clause).

1.2 Total laryngectomy

Total laryngectomy (TL) is a surgical procedure in which the complete larynx (voice box) is removed. The reason that people have to undergo such a surgery is, in most cases, because of an advanced larynx or hypopharynx carcinoma. When the cancer cannot be treated with chemotherapy or when the cancer came back after the chemotherapy, the physician and the patient consider about removing the larynx (Hilgers & van As, 2008). The most important risk factors for larynx and hypopharynx cancer are alcohol and smoking (Trigg et al., 2000).

Cancer has, generally speaking, no symptoms, but larynx or hypopharynx cancer could be noticeable. The symptom a patient with a glottic carcinoma could have is hoarseness, and the symptoms a patient with a supraglottic larynx carcinoma could have are: pain in the throat, difficulty with swallowing, globus sensation (feeling a lump in the back of the throat), halitosis (a bad breath), and pain irradiation to the ear. When the tumor obstructs the larynx, the patient could become short of breath (Timmermans et al., 2012).

In the Netherlands (where this study is held) the incidence (in 2020) of larynx and hypopharynx cancer is 658 and 181 and the prevalence (2016-2020) of these forms of cancer is 2572 and 549, respectively. More men than women develop these forms of cancer (Integraal Kankercentrum Nederland, n.d.). Worldwide, there has been more than 100.000 laryngectomies (Atos, n.d.). In the

Netherlands, there are around 150 people per year who undergo a TL (Timmermans et al., 2012). About 20 of these people are treated in the Nederlands Cancer Institute the Antoni van Leeuwenhoek (AvL) in Amsterdam.

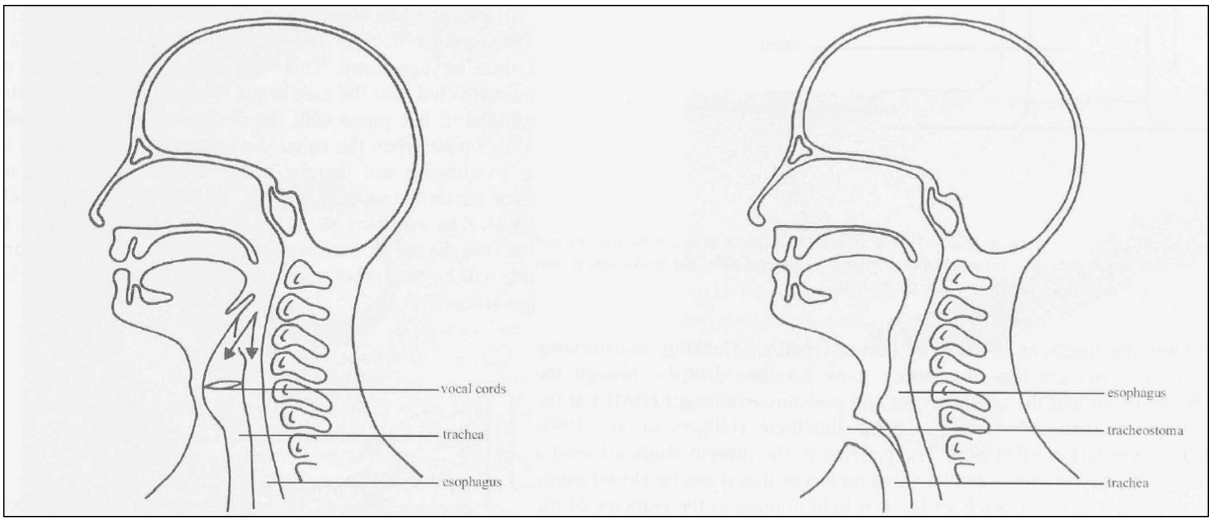


Figure 1: Anatomical situation before (left) and after (right) total laryngectomy (van As, 2001).

Total laryngectomy is not without consequences. After TL, the trachea will be attached to the skin at the front side of the neck, this results in a tracheostoma (see Figure 1). The patient breaths through this tracheostoma and is no longer able to choke, because the windpipe and the esophagus are permanently separated. The patient is also no longer able to smell, because the air cannot go through the nose anymore, and to speak normally, because the patient has no vocal cords anymore. Another consequence of not being able to breathe through the nose is that the air cannot be warmed up, moisturized, and filtered from dust and other air pollutants. This causes the patient to cough up phlegm more often, and causes airway infections and tiredness; (van Dam et al., 1999; Hilgers & van As, 2008; Timmermans et al., 2012). After TL patients also have to learn how to swallow again (Zenga et al., 2018). Many patients get social and psychological problems due to this surgical operation (Timmermans et al., 2012). Due to these consequences of TL the quality of life for these patients reduces (MacLean et al., 2009a, 2009b; Perry et al., 2015).

Fortunately, there are tools and techniques to reduce the severity of some complaints after TL and increases the quality of life, such as a heat and moisture exchanger and a technique to learn patients to smell again (see Hilgers & Ackerstaff, 2000; Timmermans et al., 2012). There are also different methods of speech rehabilitation what also increased the quality of life of these patients (Souza et al., 2020; Ţiple et al., 2016). These different methods of alaryngeal speech rehabilitation are discussed in section 1.2.1 and an overview of the studies about the speech and language after TL is given in section 1.2.2.

1.2.1 Speech rehabilitation

The first laryngectomy was executed in 1873 by Billroth, and Gussenbauer described in 1874 how the patient was rehabilitated (see Bień et al., 2008; Hilgers & van As, 2008). This patient got an artificial larynx consisting of a trachea cannula that stuck out of the tracheostoma, and a tube with a reed-like device inside. By closing the trachea cannula, the air from the lungs could pass this device what causes a sound. So, by doing this, the patient was able to speak. However, this method was quickly no longer used due to significant complications in the healing process of the wound and because of the earlier discovery of the esophageal speech (Hilgers & van As, 2008).

Patients who do not have had a vocal reconstructive surgery, can learn esophageal speech (ES). This method requires coordinated effort of the tongue and pharyngeal muscular system to force air into the esophagus. This air must then be pushed through a narrowing of the esophagus what causes the esophagus to vibrate and to create a sound (which sounds like a burp). With this sound and by articulation in the mouth, the patient is able to speak (Chen et al., 2001; Zenga et al., 2018). This technique is hard to learn and takes several months to master. Only 25-70% of the patients can acquire this speech rehabilitation method successfully (Chen et al., 2001). A disadvantage is that the air volume for every utterance is only 80 mL what causes a short phonation time of one to two seconds (normal phonation time is 20 seconds). It also demands great effort and causes many frustrations. Advantages of this method are that it is cheap and that the tracheostoma does not have to be closed (Timmermans et al., 2012). Although ES is not frequently used (anymore), it remains an important method of speech rehabilitation after TL, particularly when other methods of speech rehabilitation are too expensive for the patient (Zenga et al., 2018).

When esophageal speech or speech via a voice prothesis do not work for a patient, the electrolarynx (EL) could provide a temporary or permanent solution for the patient to speak (see Figure 2). The EL is also useful in emergencies or as a backup (de Vetter, 2008; Timmermans et al., 2012). The EL is a handheld device containing a vibrating plate or membrane, which will vibrate and make a monotone mechanical sound when you press the button. To communicate with electrolaryngeal speech (ELS), the patient has to hold the EL against his or her throat, floor of the mouth, or cheek and press the button and articulate with the mouth (de Vetter, 2008; Timmermans et al., 2012; Zenga et al., 2018). ELS demands a lot of practice, good physical conditions, enough motivation and sharp articulation (de Vetter, 2008). More research about and developments of the electrolarynx are needed to ease the use of the electrolarynx in patients with poor manual dexterity and to improve the ability to speak with varied intonations (Kaye et al., 2017).

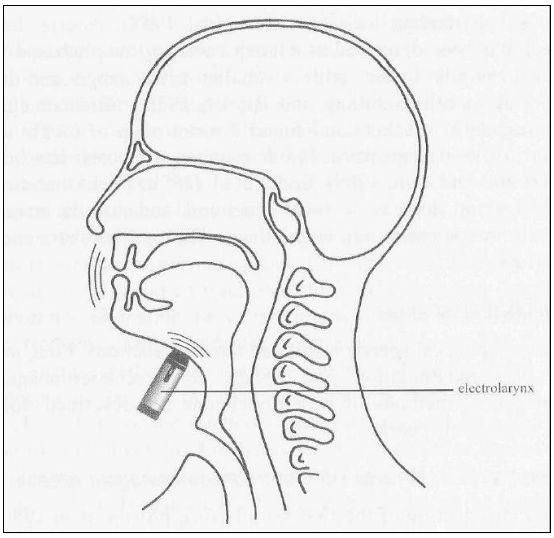


Figure 2: Voicing after total laryngectomy using an electrolarynx (van As, 2001).

The third method of speech rehabilitation is with a voice prothesis. This kind of speech is called tracheoesophageal speech (TES) and is mostly used after TL. The voice prothesis is placed in the tracheostoma between the larynx and the esophagus and has a one-way valve mechanism to prevent aspiration of moisture and food to the larynx (see Figure 3). There are two types of prothesis: an indwelling and non-indwelling prothesis. A non-indwelling prothesis can be removed and replaced by the patients themselves, but the non-indwelling prothesis must be removed and replaced by a medical specialist (Hilgers & van As, 2008; for more about the different protheses and application of the protheses, see Chen et al., 2001; Hilgers & van As, 2008). To speak, the patient has to press on the tracheostoma button what causes the exhaled air to flow via the prothesis in the neopharynx (the wall of the esophagus and throat) and creates a sound. A disadvantage is that the patient always needs his hand and points to his handicap, but, fortunately, since a few years there are automatic speech valves, so the patient could speak without using his hand (Timmermans et al., 2012). So, there are three different methods of (alaryngeal) speech rehabilitation, but TES is the most preferred and the most frequently used one.

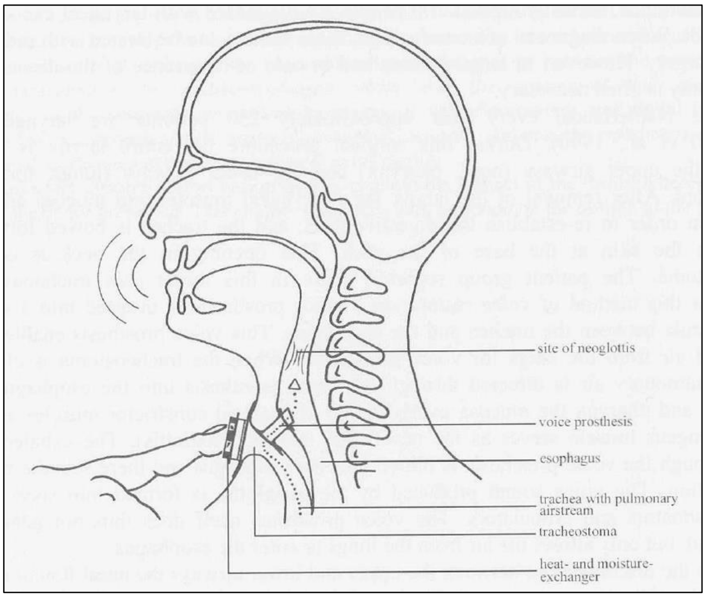


Figure 3: Voicing after total laryngectomy using a voice prothesis (van As, 2001)*.*

1.2.2 Speech and language after total laryngectomy

One of the reasons TES is the most frequently used speech rehabilitation methods is because it has a better vocal quality and intelligibility than the other methods. Van Sluis et al. (2018) did a systematic review of the literature about perceptual, acoustic, and patient-reported outcomes for ES, ELS, TES, and healthy speech. They included 26 articles from which they gathered perceptual outcomes, acoustic outcomes, and patient-reported outcomes. They found that TES has better acoustic outcomes for F0, maximum phonation time and intensity than ES, and that TES has a better perceived voice quality and intelligibility compared with ES and ELS. The outcomes on the patient-reports showed no differences between ES, ELS, and TES. So, TES has a better vocal quality and intelligibility than ES and ELS (see also Xi, 2010), but, as this study emphasizes, its vocal quality is still deviant from and it is still less intelligible than healthy laryngeal speech (van Sluis et al., 2018; see also Smith & Calhoun, 1994).

Van As (2001) researched the voice quality of TES by a perceptual evaluation and an acoustic analysis, and investigated the relationship between the perceptual and acoustic findings with the neoglottic characteristics of patients with TES. In each study around 40 persons with TES participated. The perceptual evaluation was done by native listeners and trained speech-language pathologists after listening to a read-aloud text done by the participants at 20 semantic bipolar seven-points scales (for example, deviant-normal, weak-powerful, slow-quick, rough-not rough, and unintelligible-intelligible). The trained raters also judged the overall voice quality as good, reasonable, or poor. The acoustical analysis was done with PRAAT. Three sustained vowels /a/ at a comfortable pitch and loudness were recorded per participant. With video-fluorscopy and highspeed imaging the anatomical and morphological characteristics of the neoglottis were established. Some of her conclusions were that there are large differences in the patients' voice quality and neoglottic characteristics, that the findings of the perceptual evaluation and the findings of the acoustical analysis correlate, and that the voice quality of TES correlates with the characteristics of the neoglottis. So, there is not only a difference in voice quality between the three different speech methods, ES, ELS, and TES, but also within the group of patients with TES (see also Jongmans et al., 2006). Further research is needed to improve the surgical techniques that can positively influence the neoglottis of the patients and thereby the vocal quality of TES (van As, 2001).

There are two fMRI studies done about the language network in the brains of patients after TL. The goal of the first study of Liu et al. (2010)[2] was to assess the existence of plasticity of language networks of TL-patients with a stable long-term rebuilt pronunciation. The sixteen TL-patients and seventeen healthy persons had to read neutral Chinese bi-words out loud. The researchers found that there are differences between the activated voxels in several parts of the brain between the patients and the healthy persons. They concluded that functions of some linguistic pathways and connections have been enhanced and that changes in plasticity happen in the right parietal cortex of TL-patients with long-term rebuilt pronunciation. The goal of the study of Wypych et al. (2020) was to analyze the cortical presentation of some language functions in TL-patients. The eighteen TL-patients treated with electrolarynx speech and eighteen healthy persons had to do four tasks in which they had to speak or read words in mind. The researchers found differences in the activation of several parts of the brain between the TL-patients and healthy persons. They concluded that there is an altered cortical activation in response to language tasks in TL-patients in comparison with healthy persons. So, besides the voice quality and intelligibility of speech, language networks and language representations in the brain change after TL, but does the overt language structures of patients after TL also change?

1.3 This study

The current study is considered as a pilot study and is focused on the use and complexity of the syntactic structures in spoken language of persons who underwent TL and use tracheoesophageal speech as speech rehabilitation method (TES-patients). The reason for this study is that the language structure of such patients has (to our knowledge) never been analyzed before. Knowing how complex the syntax of these patients is, may add suggestions of language therapy after TL. The syntactic structures were chosen to investigate, because it was thought that the decreased air volume and maximum phonation time of such persons (see van Sluis et al., 2018) would most likely affects the syntactic structures and not the morphology or phonology. The aims of this study are to discover if alaryngeal speech is a constraint which affects linguistic complexity and to generate hypotheses about the syntactic complexity of persons who underwent a TL. The main research question for this study is:

Does the syntactic complexity of speech change after total laryngectomy?

This research is divided into two parts: a descriptive part in which the syntax of TES-patients is described and a comparative part in which the syntactic complexity of TES-patients is compared with that of healthy control persons. The descriptive part will focus on the first sub-question and the comparative part on the second sub-question:

1. How complex is the syntax of semi-spontaneous speech of patients who underwent a total laryngectomy and use tracheoesophageal speech?

[2] Only the abstract was available in English. This article is written in Chinese, which is a language not know by the author of this paper, so the information about this study is based on the abstract only.

2. Are there differences in the syntactic complexity of speech between TES-patients and healthy controls?

Since no other study has researched the syntax of the speech of TES-patients, the measures were taken from studies investigating the syntax of patients with a language disorder or from studies investigating the syntax of a second language (see section 1.1.3 and 1.1.4). The measures are based on the measures in these kinds of studies, because they are targeting online processing (in the case of studies about languages disorders) or targeting the overall performance of language (in the case of second language research). Some of these measures were adjusted by the researcher to make the measures more suitable for the data used in this study. The syntactic complexity measures that are used in this study are at three levels, namely at the level of the C-unit, clause, and noun phrase (NP). The term 'C(ommunication)-unit' (and not 'T-unit') is used, because the data is spoken (and not written) language.

- At the level of the C-unit:
  - C-unit complexity ratio 1 (mean length of C-units in words)
  - C-unit complexity ratio 2 (mean length of C-units in clauses)
  - Percentage of simple and complex C-units
- At the level of the clause:
  - Clause complexity ratio (mean length of clauses in words)
  - Percentage of unreduced and reduced clauses
- At the level of the NP:
  - NP complexity ratio (mean length of noun phrases in words)
  - Percentage of simple, compound, and complex NPs

Besides these measures, the percentage of words in mazes (this study includes abandoned clauses, false starts, repetitions, and interjections as mazes) is also calculated and excluded in the further analysis. Mazes occur maybe because of not carefully planning an utterance or changing a concept, or they occur to fill up pauses. The amount of mazes indicates the degree of linguistic uncertainty of the speaker (Loban, 1976:22). The higher the amount of mazes, the more certain or careful a speaker would be in planning an utterance.

2. Method

2.1 Participants and material

For this study interviews with patients who underwent TL and are using tracheoesophageal speech (TES-patients) and unscripted dialogs between healthy controls (HCs) were analyzed. These interviews and dialogs were already conducted and transcribed.

The interviews with the TES-patients were conducted in 2017 and 2018 at the participants' homes to examine women's perspective on life after TL (van Sluis et al., 2020). These interviews are about the medical history of the patients and the patients' lives after TL. Each interview lasted around the 90 minutes. The data used for this study were around the 1000 words per TES-patient, which were gathered from the first, the middle, and the last part of the interview to get a representative dataset of the whole interview. (The patient may have to get used to the situation and interviewer and could get more tired at the end. This may influence their language use. Therefore, these three parts of the interview are used in this study.) The Institutional Review Board (IRB) has approved that this data may be reused for this study (this study is registered under the code IRBd20-367).

The dialogs between HCs were recorded in 2008 at the University of Amsterdam in a quiet room and used in the study of van Son et al. (2008). The recordings and transcriptions are taken from the

IFA Dialog Video Corpus (Nederlandse Taalunie, 2007; van Son et al., 2008). The participants (which were acquaintances of each other) were instructed to speak freely, so the dialogs are about different topics (e.g., the holidays, good restaurants, and hobbies). Of each dialog only 15 minutes were annotated. The data used for this study were around the 1000 words per HC, which were gathered from the beginning of the transcriptions.

For this study, data from eight TES-patients and eight HCs were used. All participants were female and spoke Dutch as their first language. The TES-patients were between the 60 and 76 years old at the time of the interview and had a TL 1 to 31 years before the time of the interview. Seven TES-patients had a good intelligibility and were able to speak in fluent sentences, and one had a poor intelligibility and was limited in her verbal communication. They had different levels of education (van Sluis et al., 2020). The features of the TES-patients are given in Table 1. The eight eldest female HCs were chosen from the corpus to get a HC-group which matches as much as possible with the TES-group. The HCs were between the 31 and 62 years old at the time of the interview and do not have speech or language problems. Almost all HCs finished the university or were still studying at a university. One of them (HC4) was a phonetician and one (HC5) was a speech therapist. The features of the HC-participants are given in Table 2.

Table 1: Participants who underwent total laryngectomy and use TES as type of speech (van Sluis et al., 2020).

TES-patient	Gender	Age at TL (in years)	Age at time interview (in years)	Intelligibility	Highest education
1	Female	67	68	Good	Secondary education
2	Female	71	74	Poor	University
3	Female	54	67	Good	Higher vocational education
4	Female	47	65	Good	Higher vocational education
5	Female	69	74	Good	Vocational education
6	Female	52	76	Good	Lower education
7	Female	29	60	Good	Secondary education
8	Female	47	62	Good	Vocational education

Note. TL = total laryngectomy; TES = tracheoesophageal speech.

Table 2: Healthy controls (van Son et al., 2008).

HC	Gender	Age at time interview (in years)	Highest education
1	Female	62	Vocational education
2	Female	32	University
3	Female	55	University
4	Female	62	University
5	Female	59	University
6	Female	43	University
7	Female	34	University
8	Female	31	University

Note. HC = healthy control.

2.2 Procedure and measures

The dataset consisted of around the 1000 words per participant. To make the dataset ready for analyzing, the mazes (abandoned clauses, false starts, repetitions, and interjections) were marked, and the words were split into utterances, C-units, clauses, prepositional phrases (PPs), and noun phrases (NPs). This is done by NO (the author of this paper) and controlled by BvR (advisor and second independent researcher). Abandoned clauses are clauses which are not finished because, for example, the conversation partner interrupts the participant, the participant wanted to say something or used a gesture to convey the message (see Example 1). False starts are parts of an utterance the participant later reformulates (see Example 2). A repetition is a word or are words which are spoken for the second (or third) time (see Example 3). Interjections are words which express a feeling or emotion, like affirmation (e.g., *ja* 'yes' and *juist* 'right'), denial (e.g., *nee* 'no'), uncertainty (e.g., *nou* 'yeah' and *denk ik* 'I think'), and anxiety (e.g., *oh* 'oh' and *verhip* 'shoot'). Words like 'uh' may be analyzed as an interjection but are not counted as an interjection in this study. They are left out of the whole analysis, because these 'uh's were not all written down in the transcriptions of the interviews. The abandoned clauses, false starts, repetitions, interjections and the words in these mazes were counted and excluded in the further analysis (like Armstrong et al. (2011) did), because they can be caused by interruptions of the conversation partner and/or do not add complexity to or take complexity away from the syntactic structures.

1) *Want dan ga je knijpen,* ***om het af te****.*
   'Because then you squeeze, **to**.'
2) ***Het is*** *er is een soort van blokkade.*
   '**It is** there is a kind of blockade.'
3) *Maar er kwam* ***er kwam*** *hier een man.*
   'But there came **there came** a man here.'

An utterance is an answer on a question, a clause is a group of words consisting of at least a subject and predicate, and a C-unit is a main clause with zero, one or more subordinate clauses (Loban, 1976). In Dutch a main clause has a subject-verb[3]-object (SVO) or VSO word order (see Example 4) and a subordinate clause starts with a subordinator and has a SOV or OSV word order (see Example 5 and 6). Subordinators are for example relative pronouns (e.g. *die* 'who', welke 'which'), question words (e.g., *wanneer* 'when', *waar* 'where', and *hoe* 'how'), *dat* 'that' and *of* 'if' (which indicate indirect speech/thought), *omdat* 'because' (which indicates a reason), and *als* 'if' (which indicates a condition or assumption). A PP is a part of a clause consisting of a pre- or circumposition (e.g., *in* 'in(side)', *op* 'on, at', *van* 'of, from', and *van … af* 'from') and an NP and, generally, expresses a time, place, or direction (see Example 7). An NP is a part of a clause consisting of one or more nominals with or without nominal modifiers (which can be determiners, adjectives, and adverbs, a modifying PP, or a relative clause, see Example 8, 9, and 10 respectively).

4) *En toen hebben ze een biopsie genomen. Want ik had een dikke klier.*[4]
   V S O S V O
   'And then they did a biopsy. Because I had a big gland.'
5) *Ik zeg dan niks, omdat ik dan geen ruzie wil.*
   S V O S O V
   'I say nothing, because I do not want a fight.'
6) *En dan moest je 's ochtends vertellen, welke vis je wilde eten.*
   V S O S V
   'And then in the morning you had to tell, which fish you wanted to eat.'
7) $_{\text{PP}}$[*in* $_{\text{NP}}$[*Leiden*]][5]
   '$_{\text{PP}}$[in $_{\text{NP}}$[Leiden]].'
8) $_{\text{NP}}$[*Ik*] *had niet* $_{\text{NP}}$[*zo'n fijne huisarts*].
   '$_{\text{NP}}$[I] did not have $_{\text{NP}}$[such a nice GP].'

[3] The finite verb. In Dutch it is called the *persoonsvorm*.
[4] The beginning of a C-unit is marked with a capital letter and the end with a dot. Clauses are separated by a comma.
[5] NPs and PPs are marked with square brackets.

9) $_{NP}$[*de andere kant* $_{PP}$[*van* $_{NP}$[*het eiland*]]]
‘$_{NP}$[the other side $_{PP}$[of $_{NP}$[the island]]]’
10) $_{NP}$[*die stemprothese,* $_{NP}$[*die*] *steeds maar dicht zat*]
‘$_{NP}$[that voice prothesis, $_{NP}$[which] was closed constantly]’

When the dataset was split, features from the dataset were gathered and put in tables. These features were the number of occurrences of the different units in the dataset per participant and per group, namely the number of utterances, C-units, clauses, NPs, and PPs, and the number of words which occurred in the NPs. After counting these units, two C-unit complexity ratios (mean length of C-units in words and clauses; based on Armstrong et al., 2011; Kuiken & Vedder, 2019; Ortega, 2003; Savage & Donovan, 2017; Spoelman & Verspoor, 2010; Verspoor & Sauter, 2000; Zwitserlood et al., 2015), a clause complexity ratio (mean length of clauses in words; based on Ortega, 2003) and an NP complexity ratio (mean length of NPs in words; based on Spoelman & Verspoor, 2010) were calculated per participant and per group.

The other features which are gathered from the dataset were the percentage of the different types of C-units, clauses and NPs per participant and group (based on Savage & Donovan, 2017; Spoelman & Verspoor, 2010). Every C-unit is labeled as ‘simple’ or ‘complex’. A simple C-unit (see Example 11) is a C-unit that consists of only a main clause and a complex C-unit is a C-unit that consists of a main clause with one or more subordinate clauses. When a C-unit is labeled as complex, it is also further specified how many subordinate clauses the C-unit consists of (see Example 12-14). Every clause is labeled as ‘unreduced’ (a ‘normal’ clause, meaning a group of words consisting of at least a subject and predicate; see Example 15) or ‘reduced’. A reduced clause can be an ellipsis (see Example 16) or a telegram style clause (see Example 17). Ellipses are grammatically recoverable clauses, which are dependent on the immediately preceding context. Telegram style is a reduction which may be due to spoken language and may likely be enhanced by speech limitations (e.g., omitting of subject or finite verb). Every NP is labeled as ‘simple’, ‘compound’, or ‘complex’. A simple NP is an NP which consists of a pronoun or anaphoric determiner, or of a single noun with or without a determiner (see Example 18 and 19 respectively). A compound NP is an NP consisting of coordinating nouns or NPs (see Example 20 and 21 respectively) and a complex NP is an NP consisting of one or more nouns with nominal modifiers. These nominal modifiers can be: determiners, adjectives, and adverbs (see Example 22); modifying nouns or NPs (see Example 23); modifying PPs (see Example 24); or relative clauses (see Example 25).

11) [simple C-unit] *Ik kan dat goed inschatten.*
‘I can estimate that well.’
12) [complex1 C-unit] *En ik zie, dat er niets staat*.
‘And I see, that there is nothing.’
13) [complex2 C-unit] *Want ik merk, dat het beter gaat, en dat ze me verstaan dus.*
‘Because I notice, that it goes better, and that they understand me.’
14) [complex3+ C-unit] *Het is natuurlijk niet de eerste keer, dat ze dingen beloven, waar zij ook niks aan hebben, waar wij helemaal niet over gaan, waar ze niks aan kunnen veranderen.*
‘It is of course not the first time, that they promise things, which means nothing, which we do not decide, which they cannot change.’
15) [unreduced clauses] *Ik heb nog nooit een plan gemaakt, dat uitgerold kan worden.*
‘I have never made a plan, which can be unrolled.’
16) [ellipsis] *(Want Erik is ook nog een groot vogelliefhebber.) En ik inmiddels ook*.
‘(Because Erik is also a great bird fan.) And in a meanwhile I too.’
17) [telegram style] *En chemo zeven weken.*
‘And chemo seven weeks.’

18) [simple NPs] *ik*; *die*
'I'; 'who'/'this'

19) [simple NPs] *dingen*; *de kijkoperatie*; *zestien juni*; *wij allemaal*
'things'; 'the exploratory surgery'; 'June sixteen'; 'we all'

20) [compound NP] *bami of nasi*
'noodles or rice'

21) [compound NP] *die palmbomen en die azuurblauwe zee*
'those palm trees and that azure blue sea'

22) [complex NPs] *zo'n fijne huisarts; drie of vier gulden*
'such a nice GP'; 'three or four guilder'

23) [complex NPs] *hotel De Goudfazant; een paar keer*
'hotel The Golden Pheasant'; 'a few times'

24) [complex NP] *kip met kerrie en rijst*
'chicken with curry and rice'

25) [complex NP] *de dame, die daar was geweest*
'the lady, who has been there'

The data collection and analysis are done by NO and controlled by BvR. A more elaboration on the procedure, criteria, and definitions used in this study is given in Appendix A.

2.3 Design and statistics

The current study concerns a pilot and descriptive study to get a first impression of the complexity of language structures of TES-patients. In the first part of the results (section 3.1) the outcomes of the TES-patients' speech are described only by descriptive statistics (means, ranges, standard deviations, and *Z*-scores). In the second part of the results (section 3.2) these outcomes are compared with the outcomes of the speech of the healthy controls.

To compare the outcomes of the TES-patients and of the HCs, the non-parametric Mann-Whitney U test is used. This test is used for independent samples which are likely to be not normal distributed (Field, 2013:213-228), which is the case in this study. The data in this study are from two different groups of participants (so, from two independent samples) and the variables are percentages or ratios (e.g., number of words per C-unit) which are probably not normal distributed.

3. Results

3.1 TES-patients

This section presents the analysis of the syntactic complexity of TES-patients. First the mazes are discussed in section 3.1.1, then the C-units in section 3.1.2, the clauses in section 3.1.3, and the noun phrases in section 3.1.4.

3.1.1 Mazes

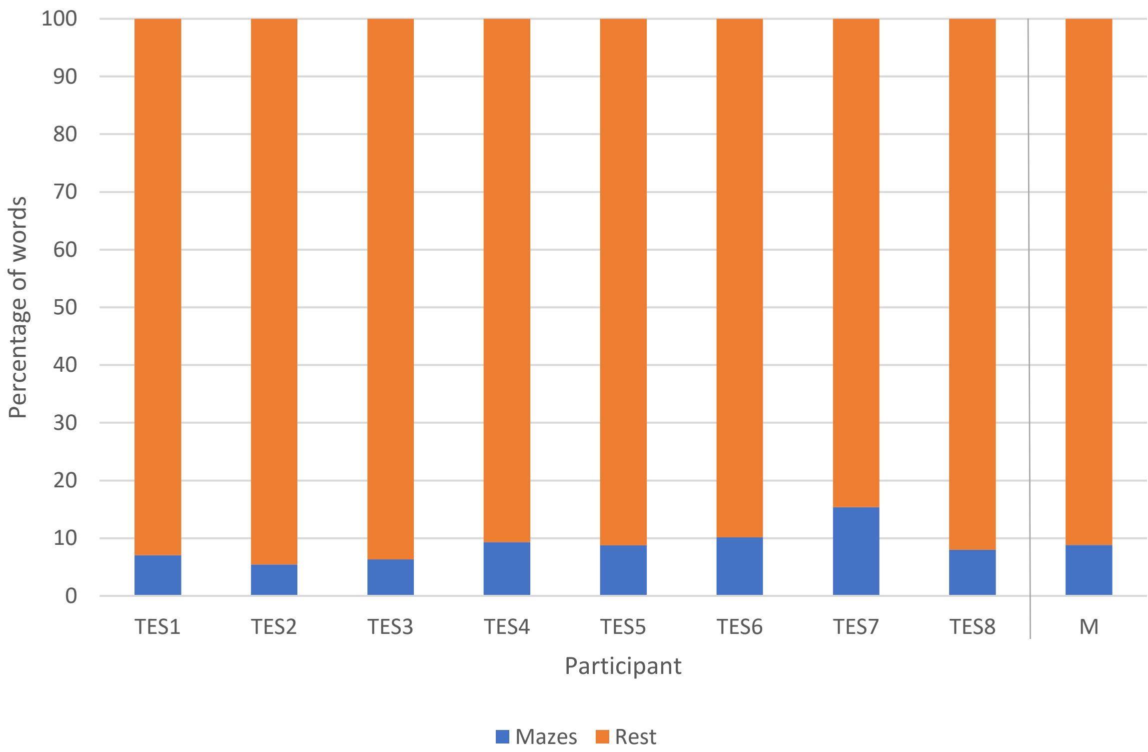
Four kinds of mazes are seen in the speech of TES-patients and therefore counted. These mazes are abandoned clauses (AbanCl), false starts (FS), repetitions (Rep), and interjections (Int). The number of the different mazes and the number of words which occurred in these mazes are given per TES-patient in Table 3. The means and standard deviations of these measures are also given. The mean number of abandoned clauses is 5 (*SD*=3; *range*=1-10) and the mean number of words in all abandoned clauses is 15 (*SD*=11; *range*=3-30) per TES-patient. This means that on average an abandoned clause consists of three words. The mean number of false starts is 8 (*SD*=4; *range*=3-13) and the mean number of words in false starts is 19 (*SD*=12; *range*=4-34), so on average a false start consists of two words. Not every TES-patient uttered repetitions. The mean number of repetitions is 2 (*SD*=3; *range*=0-8) and the mean number of words in repetitions is 4 (*SD*=4; *range*=0-11), so a repetition mostly consists of one or two words. The mean number of interjections per TES-patient is 49 (*SD*=19; *range*=33-88) and the mean number of words in interjections is 51 (*SD*=19; *range*=36-93), so an interjection consists mostly of only one word. This means that most of the words in mazes were interjections and that there are just a few repetitions in the speech of TES-patients.

The percentage of words in mazes ranges from about 5% to 15%, and on average 9% (*SD*=3.1) of the words spoken by a TES-patient are words in mazes. This is shown in Table 3 and Figure 4. As the mean and standard deviation shows, there is a reasonably amount of variation in the percentage of words in mazes in the speech of TES-patients. TES-patient 7 deviates the most from the mean percentage of words in mazes (*Z*=2.1).

Table 3: Outcomes on mazes in speech of TES-patients.

TES-patient	Total #words	AbanCl		FS		Rep		Int		Total words in mazes	
		#	#words	#	#words	#	#words	#	#words	#	%
1	1010	3	7	11	23	0	0	39	41	71	7.0
2	1013	1	3	4	4	2	3	43	45	55	5.4
3	1000	4	7	3	8	2	3	44	45	63	6.3
4	1021	10	29	5	13	3	5	42	48	95	9.3
5	1013	6	22	10	29	1	2	33	36	89	8.8
6	1002	9	30	13	32	3	4	36	36	102	10.2
7	1015	6	18	13	34	8	11	88	93	156	15.4
8	1003	3	3	7	10	0	0	66	67	80	8.0
M(SD)	1010(7)	5(3)	15(11)	8(4)	19(12)	2(3)	4(4)	49(19)	51(19)	89(31)	8.8(3.1)

Note. TES = tracheoesophageal speech; AbanCl = abandonded clauses; FS = false starts; Rep = repetitions; Int = interjections; # = number of; #words = number of words in; % = percentage of; M = mean; SD = standard deviation.



Note. TES = tracheoesophageal speech; M = mean; mazes = abandoned clauses, false starts, repetitions, and interjections.

Figure 4: Percentage of words in mazes in speech of TES-patients.

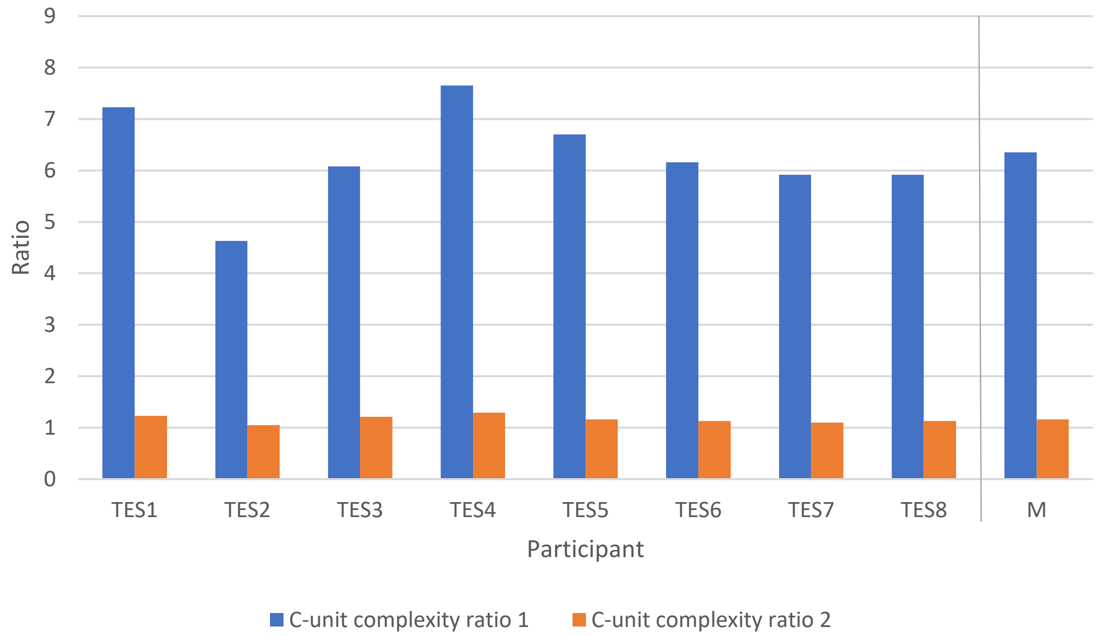
3.1.2 C-units

Table 4 shows the number of words (excluding the words in mazes), C-units, and clauses and the C-unit complexity ratios per TES-patient (which is also shown in Figure 5). The means and standard deviations of these measures are also given. On average, a C-unit in the speech of a TES-patient consists of six or seven words and there is a standard deviation of almost one word per C-unit and a maximum variation of three words between the TES-patients (complexity ratio 1: *M*=6.35; *SD*=.91; *range*=4.63-7.65). TES-patient 2 deviates the most from the mean number of words per C-unit, but this is not a very large deviation from the mean (*Z*=-1.9). Most of the C-units in the speech of TES-patients consist of only one clause (complexity ratio 2: *M*=1.16; *SD*=.08; *range*=1.05-1.29).

Table 4: C-unit complexity ratios of TES-patients.

TES-patient	#words	#C-units	#clauses	C-unit complexity ratios	
				1	2
1	939	130	160	7.23	1.23
2	958	207	218	4.63	1.05
3	937	154	187	6.08	1.21
4	926	121	156	7.65	1.29
5	924	138	160	6.70	1.16
6	900	146	165	6.16	1.13
7	859	134	148	6.41	1.10
8	923	156	177	5.92	1.13
M(SD)	921(30)	148(27)	171(22)	6.35(0.91)	1.16(0.08)

Note. TES = tracheoesophageal speech; # = number of; 1 = number of words per C-unit; 2 = number of clauses per C-unit; M = mean; SD = standard deviation.



Note. TES = tracheoesophageal speech; M = mean; C-unit complexity ratio 1 = number of words per C-unit; C-unit complexity ratio 2 = number of clauses per C-unit.

Figure 5: C-unit complexity ratios of TES-patients.

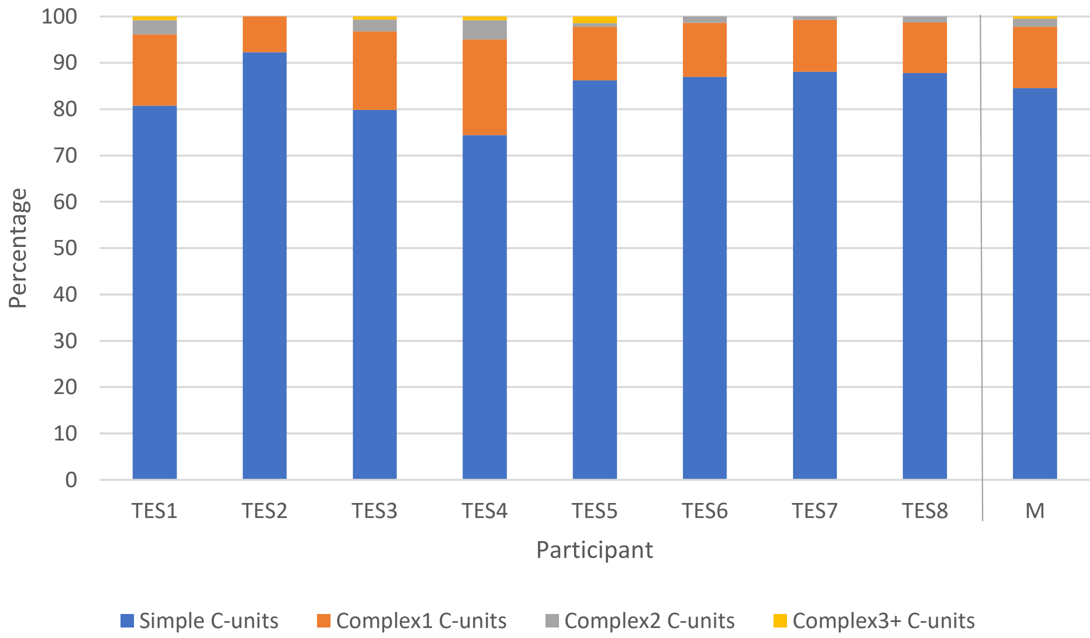
The C-units are divided in four types: simple (only a main clause), complex1 (main clause with one subordinate clause), complex2 (main clause with two subordinate clauses), and complex3+ (main clause with three or more subordinate clauses). Table 5 shows the number and percentages (which are also shown in Figure 6) of simple and complex C-units. The mean (and standard deviation and range) of the percentage of simple C-units in the speech of TES-patients is 85% (*SD*=5.7; *range*=74.4-92.3), that of complex1 C-units is 13% (*SD*=4.1; *range*=7.7-20.7), that of complex2 C-units is 1.7% (*SD*=1.4; *range*=0-4.1), and that of complex3+ C-units is 0.5% (*SD*=.5; *range*=0-1.4). This means that most C-units spoken by TES-patients are just simple C-units, that some C-units consist of one subordinate clause and just a few of two or more subordinate clauses.

There is not a lot of variation in the percentages of the different types of C-units in the speech of TES-patients (SDs are between 0.5 and 5.7; see Table 5). TES-patient 2 and TES-patient 4 deviate the most from the mean percentage of simple C-units, but these are still not very large deviations from the mean (*Z*=1.4 and *Z*=-1.8, respectively).

Table 5: Types of C-units in speech of TES-patients.

TES-patient	Total #C-units	Simple C-units		Complex1 C-units		Complex2 C-units		Complex3+ C-units	
		#	%	#	%	#	%	#	%
1	130	105	80.8	20	15.4	4	3.1	1	0.8
2	207	191	92.3	16	7.7	0	0.0	0	0.0
3	154	123	79.9	26	16.9	4	2.6	1	0.6
4	121	90	74.4	25	20.7	5	4.1	1	0.8
5	138	119	86.2	16	11.6	1	0.7	2	1.4
6	146	127	87.0	17	11.6	2	1.4	0	0.0
7	134	118	88.1	15	11.2	1	0.7	0	0.0
8	156	137	87.8	17	10.9	2	1.3	0	0.0
M(SD)	148(27)	126(30)	84.5(5.7)	19(4)	13.2(4.1)	2(1)	1.7(1.4)	1(1)	0.5(0.5)

Note. TES = tracheoesophageal speech; simple = only main clause; complex1 = main clause and one subordinate clause; complex2 = main clause and two subordinate clauses; complex3+ = main clause and three or more subordinate clauses; # = number of; % = percentage of; M = mean; SD = standard deviation.



Note. TES = tracheoesophageal speech; M = mean; simple = only main clause; complex1 = main clause and one subordinate clause; complex2 = main clause and two subordinate clauses; complex3+ = main clause and three or more subordinate clauses

Figure 6: Types of C-units in speech of TES-patients.

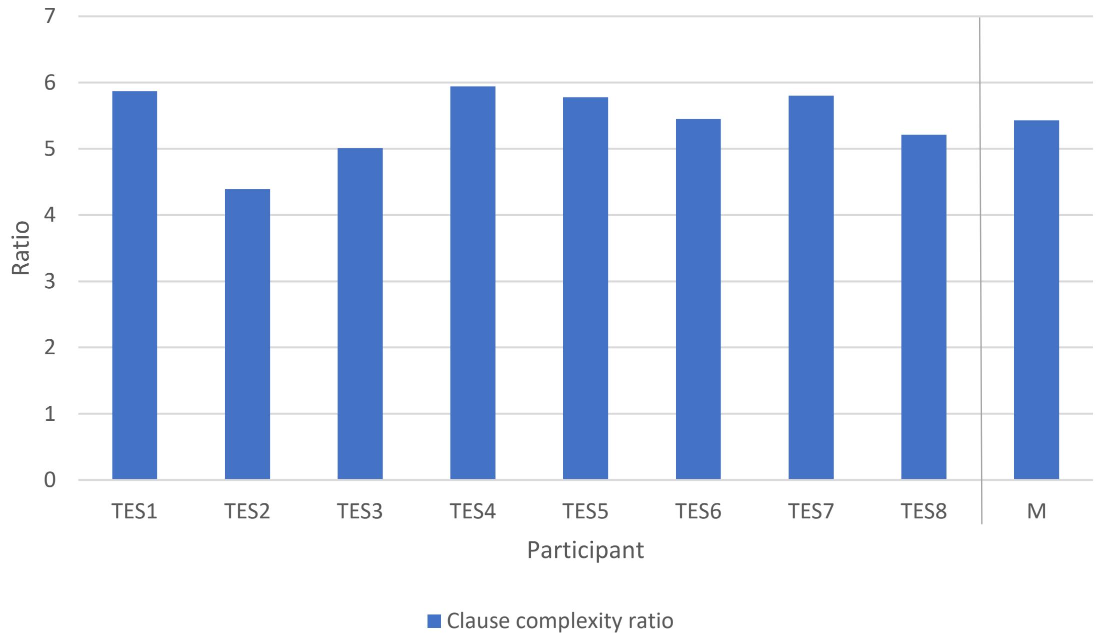
3.1.3 Clauses

Table 6 shows the number of words (excluding the words in mazes) and clauses and the clause complexity ratios (which is also shown in Figure 7) per TES-patient. The means and standard deviations of these measures are also given. Most clauses in the speech of TES-patients consist of four, five or six words and there is a standard deviation of just half a word per clause (complexity ratio: *M*=5.43; *SD*=.53; *range*=4.39-5.94). TES-patient 2 deviates the most from the mean number of words per clause, but this is not a very large deviation from the mean (*Z*=-2.0).

Table 6: Clause complexity ratio of TES-patients.

TES-patient	#words	#clauses	Clause complexity ratio
1	939	160	5.87
2	958	218	4.39
3	937	187	5.01
4	926	156	5.94
5	924	160	5.78
6	900	165	5.45
7	859	148	5.80
8	923	177	5.21
M(SD)	921(30)	171(22)	5.43(0.53)

Note. TES = tracheoesophageal speech; # = number of; clause complexity ratio = number of words per clause; M = mean; SD = standard deviation.



Note. TES = tracheoesophageal speech; M = mean; clause complexity ratio = number of words per clause.

Figure 7: Clause complexity ratio of TES-patients.

The clauses are divided in two types: unreduced and reduced[6] (an ellipsis or telegram style clause). Table 7 shows the number and percentages (which are also shown in Figure 8) of unreduced and reduced clauses. The mean (and standard deviation and range of the) percentage of unreduced clauses in the speech of TES-patients is 87% (*SD*=8.3; *range*=68.8-94.7), and that of reduced clauses is 13% (*SD*=8.3; *range*=5.3-31.2). This means that most clauses spoken by TES-patients are unreduced clauses, and that some clauses are reduced.

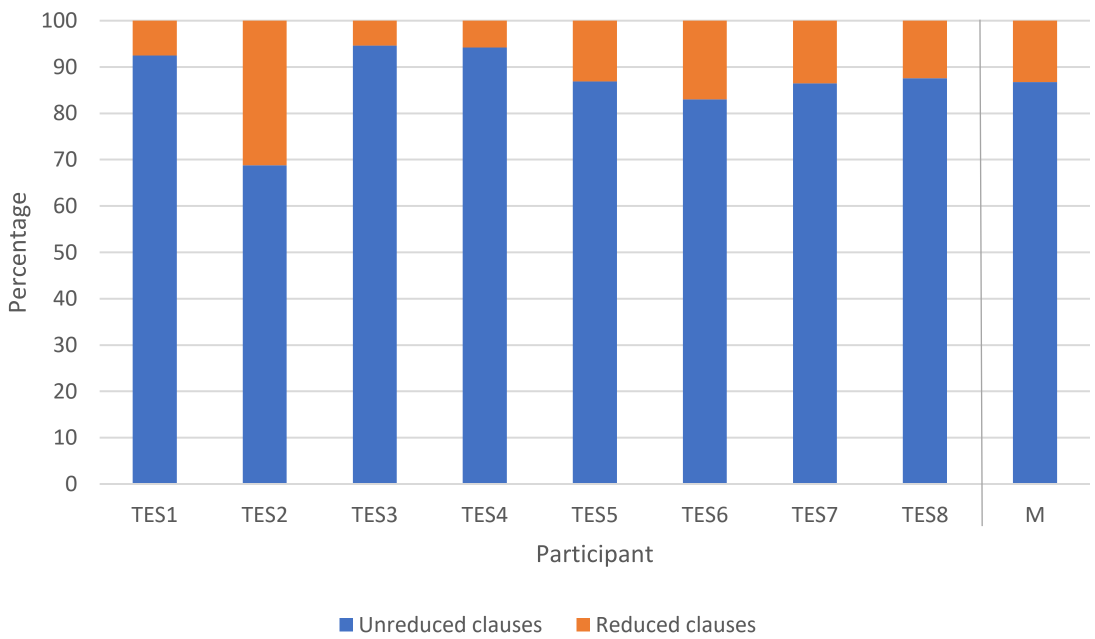
There is not a lot of variation in the percentages of the different types of clauses in the speech of TES-patients (SDs are 8.3; see Table 7), but there is one TES-patient, TES-patient 2, who deviates a lot from the mean percentage of reduced clauses (*Z*=2.2).

[6] Ellipses and telegram style clause are treated as one type of clause (reduced clauses), because there were just a few ellipses found in the speech of the participants (*M*=2 (1.3%), *SD*=2 (1.0%), *range*=0-4 (0%-2.5%)).

Table 7: Types of clauses in speech of TES-patients.

TES-patient	**Total #clauses**	**Unreduced clauses**		**Reduced clauses**	
		#	**%**	**#**	**%**
1	160	148	92.5	12	7.5
2	218	150	68.8	68	31.2
3	187	177	94.7	10	5.3
4	156	147	94.2	9	5.8
5	160	139	86.9	21	13.1
6	165	137	83.0	28	17.0
7	148	128	86.5	20	13.5
8	177	155	87.6	22	12.4
M(SD)	171(22)	148(15)	86.8(8.3)	24(19)	13.2(8.3)

Note. TES = tracheoesophageal speech; unreduced = 'normal' = a group of words consisting of at least a subject and predicate; reduced = ellipsis or telegram style; # = number of; % = percentage of; M = mean; SD = standard deviation.



Note. TES = tracheoesophageal speech; M = mean; unreduced = 'normal' = a group of words consisting of at least a subject and predicate; reduced = ellipsis or telegram style.

Figure 8: Types of clauses in speech of TES-patients.

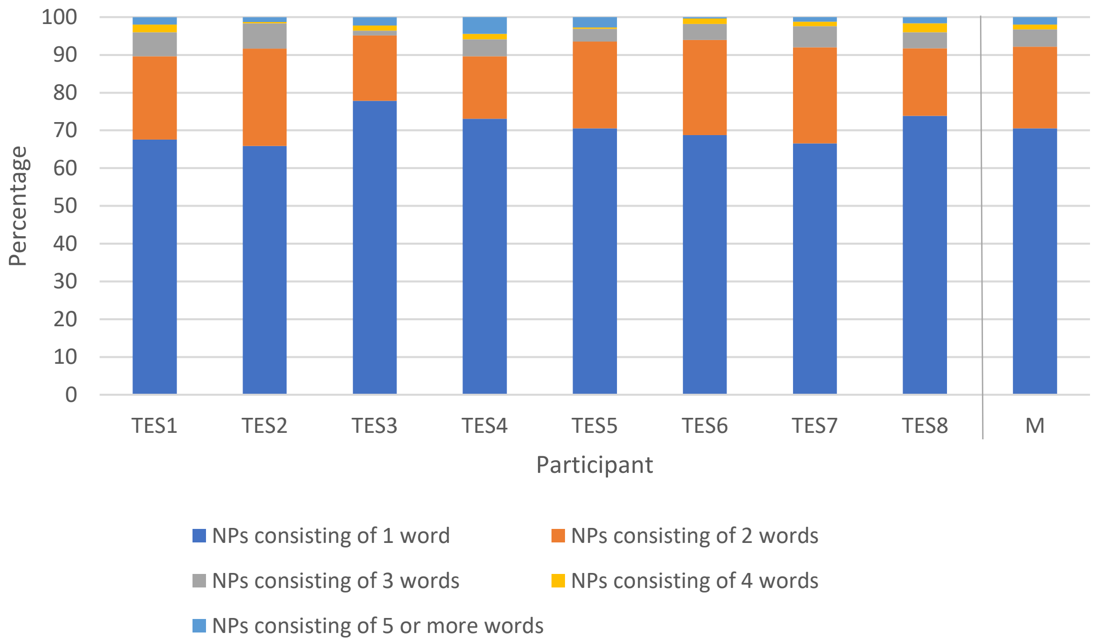
3.1.4 NPs

Table 8 shows the number of NPs (excluding the NPs in mazes), the frequency of the lengths of NPs in words (which is also shown in Figure 9), total number of words in NPs and the NP complexity ratio (which is also shown in Figure 10) per TES-patient. The means and standard deviations of these measures are also given. On average 71% of the NPs consists of one word (*SD*=4.1; *range*=65.9-77.8), 22% of two words (*SD*=3.8; *range*=16.6-25.7), 5% of three words (*SD*=1.7; *range*=1.3-6.8), 1% of four words (*SD*=.7; *range*=.3-2.3), and 2% of five or more words (*SD*=1.2; *range*=.4-4.4; see Table 8 and Figure 9). This means that most NPs consist of only one word or two words, and just a few NPs of three or more words. There is not a lot of variation between the TES-patients. This is also shown by the NP complexity ratio (*M*=1.45; *SD*=.07; *range*=1.35-1.59; see Table 8 and Figure 10). TES-patient 4 deviates the most from the mean number of words per NP, but this is still not a very large deviation from the mean (*Z*=2.0).

Table 8: Frequency of lengths of NPs and NP complexity ratio of TES-patients.

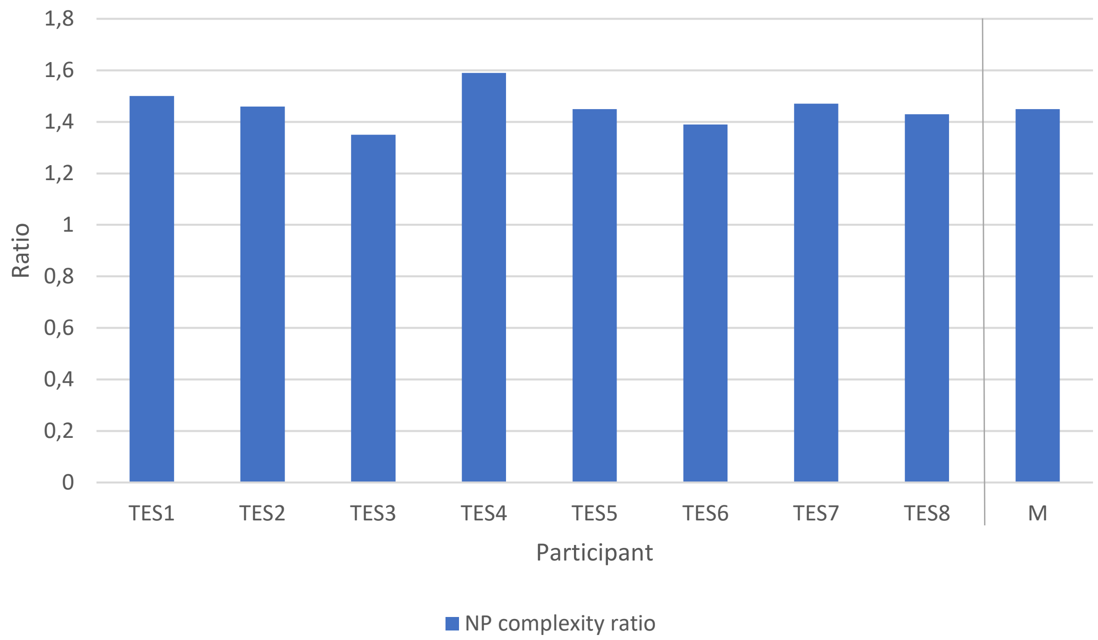
TES-patient	Total #NPs	Length of NPs in words 1 #	1 %	2 #	2 %	3 #	3 %	4 #	4 %	5+ #	5+ %	#words in NPs	NP complexity ratio
1	299	202	67.6	66	22.1	19	6.4	6	2.0	6	2.0	448	1.50
2	311	205	65.9	80	25.7	21	6.8	1	0.3	4	1.3	454	1.46
3	311	242	77.8	54	17.4	4	1.3	4	1.3	7	2.3	420	1.35
4	271	198	73.1	45	16.6	12	4.4	4	1.5	12	4.4	431	1.59
5	292	206	70.5	67	22.9	10	3.4	1	0.3	8	2.7	423	1.45
6	282	194	68.8	71	25.2	12	4.3	4	1.4	1	0.4	393	1.39
7	251	167	66.5	64	25.5	14	5.6	3	1.2	3	1.2	368	1.47
8	302	223	73.8	54	17.9	13	4.3	7	2.3	5	1.7	432	1.43
M (SD)	290 (21)	205 (22)	70.5 (4.1)	63 (11)	21.7 (3.8)	13 (5)	4.5 (1.7)	4 (2)	1.3 (0.7)	6 (3)	2.0 (1.2)	421 (28)	1.45 (0.07)

Note. TES = tracheoesophageal speech; NP = noun phrase; # = number of; % = percentage of; NP complexity ratio = number of words per noun phrase; M = mean; SD = standard deviation.



Note. TES = tracheoesophageal speech; NP = noun phrase; M = mean.

Figure 9: Percentages of NPs with 1, 2, 3, 4, or 5 or more words in speech of TES-patients.



Note. TES = tracheoesophageal speech; NP = noun phrase; M = mean; NP complexity ratio = number of words per noun phrase.

Figure 10: NP complexity ratio of TES-patients.

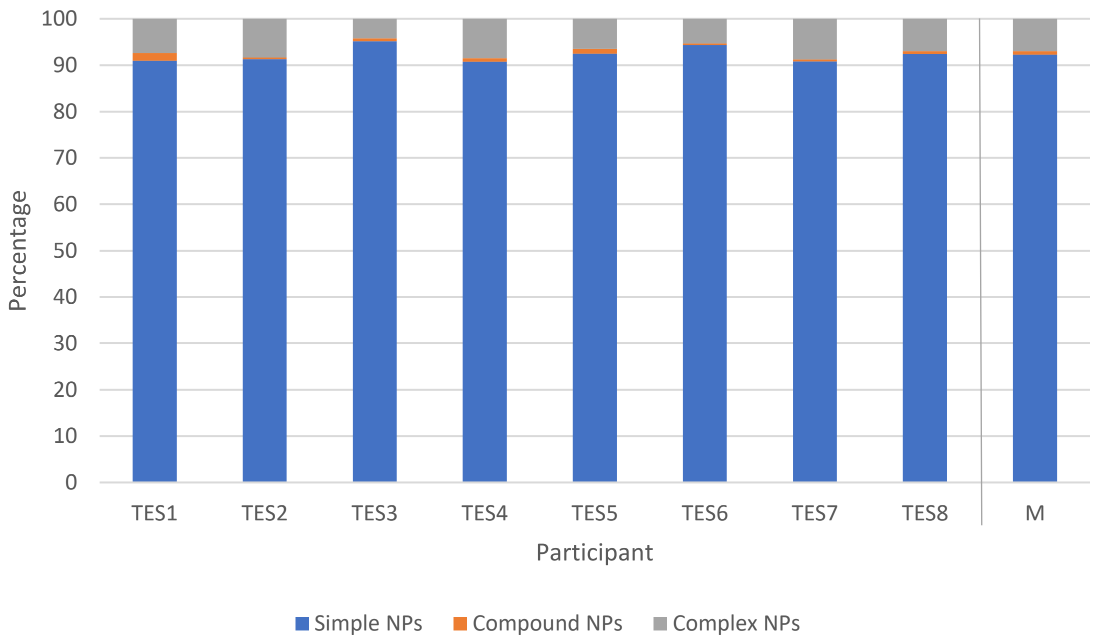
The NPs are divided in three types: simple (a (pro)noun and/or determiners), compound (coordinating nouns or NPs) and complex (noun(s) with nominal modifiers). Table 9 shows the number and percentages (which are also shown in Figure 11) of the different types of NPs. The mean (and standard deviation and range of the) percentage of simple NPs in the speech of TES-patients is 92% (*SD*=1.7; *range*=90.8-95.2), that of compound NPs is 0.7% (*SD*=.4; *range*=.3-1.7), and that of complex NPs is 7% (*SD*=1.6; *range*=4.2-8.8). This means that most NPs spoken by TES-patients are simple NPs, and that some NPs are complex and just a few are compound NPs.

There is not a lot of variation in the percentages of the different types of NPs in the speech of TES-patients (SDs are between 0.4 and 1.7; see Table 9). TES-patient 3 deviates the most from the mean percentage of simple NPs, but this is still not a very large deviation from the mean (*Z*=1.7).

Table 9: Types of NPs in speech of TES-patients.

TES-patient	**Total #NPs**	**Simple NPs**		**Compound NPs**		**Complex NPs**	
		#	**%**	**#**	**%**	**#**	**%**
1	299	272	91.0	5	1.7	22	7.4
2	311	284	91.3	1	0.3	26	8.4
3	311	296	95.2	2	0.6	13	4.2
4	271	246	90.8	2	0.7	23	8.5
5	292	270	92.5	3	1.0	19	6.5
6	282	266	94.3	1	0.4	15	5.3
7	251	228	90.8	1	0.4	22	8.8
8	302	279	92.4	2	0.7	21	7.0
M(SD)	290(21)	268(22)	92.3(1.7)	2(1)	0.7(0.4)	20(4)	7.0(1.6)

Note. TES = tracheoesophageal speech; NP = noun phrase; simple = pronoun, anaphoric determiner, or single noun (+ determiner); compound = coordinating nouns or noun phrases; complex = one or more nouns with nominal modifiers; # = number of; % = percentage of; M = mean; SD = standard deviation.



Note. TES = tracheoesophageal speech; NP = noun phrase; M = mean; simple = pronoun, anaphoric determiner, or single noun (+ determiner); compound = coordinating nouns or noun phrases; complex = one or more nouns with nominal modifiers.

Figure 11: Types of NPs in speech of TES-patients.

3.2 TES-patients compared with HCs

This section describes the outcomes on the TES-patients' speech in comparison with the outcomes on the speech of the HCs. This section follows the same structure as section 3.1, meaning that section 3.2.1 describes the mazes, 3.2.2 the C-units, 3.2.3 the clauses, and 3.2.4 the noun phrases. The last section, section 3.2.5 gives an overview of the differences and agreements between the TES-patients and HCs.

3.2.1 Mazes

There are four kinds of mazes, namely, abandoned clauses (AbanCl), false starts (FS), repetitions (Rep), and interjections (Int). The number of the different mazes and the number of words which occurred in these mazes are given per TES-patient and per HC in Table 10. The means and standard deviations of these measures are also given. On average the HCs uttered a few more clauses which they abandoned (*M*=7; *SD*=3; *range*=4-15) than the TES-patients (*M*=5; *SD*=3; range=1-10). The mean lengths of abandoned clauses are the same for the TES-patients (15/5=3) and HCs (22/7≈3 words per abandoned clause). On average the HCs made twice as many false starts (*M*=16; *SD*=4; *range*=11-23) than the TES-patients (*M*=8; *SD*=4; *range*=3-13). The mean lengths of false starts are the same for the TES-patients (19/8=2) and HCs (34/16≈2 words per false start). The HC group varies more in the number of repetitions and made on average much more repetitions (*M*=21; *SD*=10; *range*=7-33) than the TES-patients (*M*=2; *SD*=3; *range*=0-8). The mean lengths of repetitions are the same for the TES-patients (4/2=2) and HCs (31/21≈2 words per repetition). The HC group varies more in the number of interjections and made on average much more interjections (*M*=72; *SD*=27; *range*=39-122) than the TES-patients (*M*=49; *SD*=19; *range*=33-88). An interjection consists mostly of only one word. The largest difference between the TES-patients and HCs is in the number of false starts and repetitions.

The HCs uttered twice as many words in mazes (*M*=16.1%; *SD*=3.0; *range*=13.6-22.3) than the TES-patients did (*M*=8.8%; *SD*=3.1; *range*=5.4-15.4), as shown in Table 10 and Figure 12. A Mann-Whitney U test showed that the TES-patients and HCs differ significantly from each other in the percentage of words in mazes (*U*=10.0, *Z*=-2.3, *p*<.01).

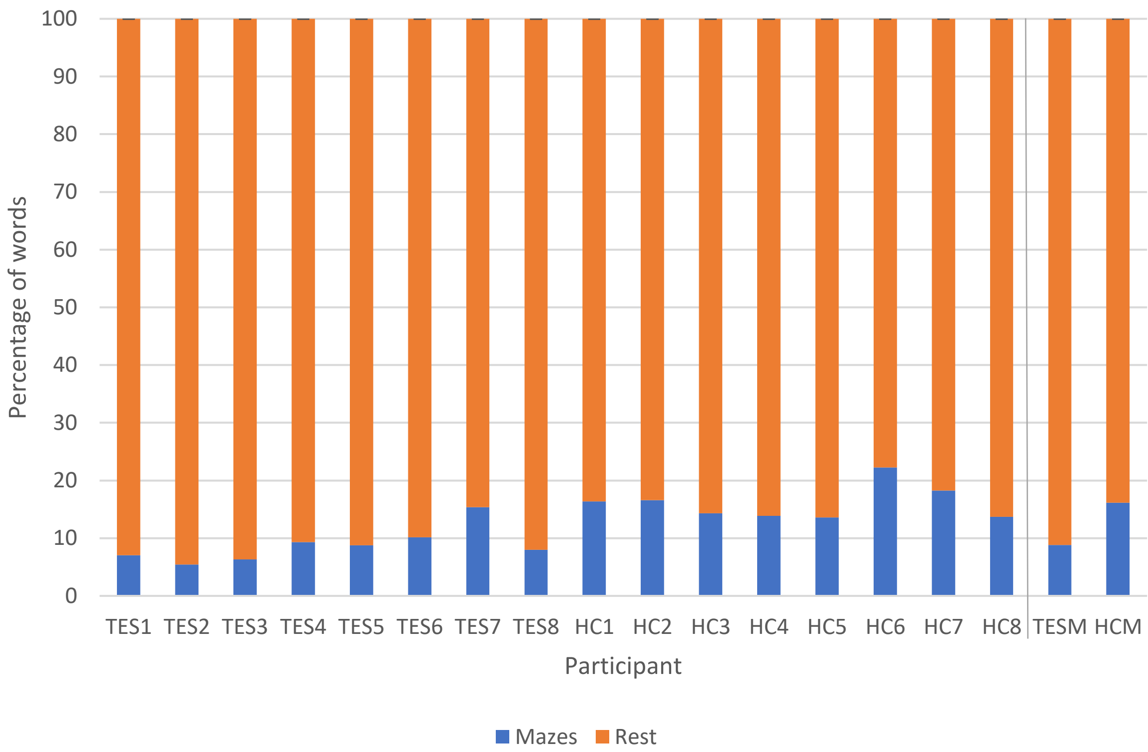
As the standard deviations show (in Table 10), both groups have a same amount of variation in the percentage of words in mazes (see also Figure 12).

Table 10: Outcomes on mazes in speech of TES-patients and HCs.[7]

Part.	**Total #words**	**AbanCl**		**FS**		**Rep**		**Int**		**Total words in mazes**	
		#	**#words**	**#**	**#words**	**#**	**#words**	**#**	**#words**	**#**	**%**
TES1	1010	3	7	11	23	0	0	39	41	71	7.0
TES2	1013	1	3	4	4	2	3	43	45	55	5.4
TES3	1000	4	7	3	8	2	3	44	45	63	6.3
TES4	1021	10	29	5	13	3	5	42	48	95	9.3
TES5	1013	6	22	10	29	1	2	33	36	89	8.8
TES6	1002	9	30	13	32	3	4	36	36	102	10.2
TES7	1015	6	18	13	34	8	11	88	93	156	15.4
TES8	1003	3	3	7	10	0	0	66	67	80	8.0
HC1	1038	15	51	11	28	32	52	39	39	170	16.4
HC2	1012	5	11	17	35	32	40	79	82	168	16.6
HC3	1019	5	14	15	30	13	17	76	85	146	14.3
HC4	1040	8	20	14	27	24	46	48	51	144	13.8
HC5	1013	4	16	11	20	7	7	89	95	138	13.6
HC6	1051	6	12	23	49	33	44	122	129	234	22.3
HC7	1052	7	24	20	61	16	25	72	82	192	18.3
HC8	1001	6	26	13	25	14	20	49	66	137	13.7
TESM(SD)	1010(7)	5(3)	15(11)	8(4)	19(12)	2(3)	4(4)	49(19)	51(19)	89(31)	8.8(3.1)
HCM(SD)	1028(19)	7(3)	22(13)	16(4)	34(14)	21(10)	31(16)	72(27)	79(28)	166(33)	16.1(3.0)

Note. TES = tracheoesophageal speech; HC = healthy control; AbanCl = abandonded clauses; FS = false starts; Rep = repetitions; Int = interjections; # = number of; #words = number of words in; % = percentage of; M = mean; SD = standard deviation.

[7] The data of TES-patients are copied from Table 3.



Note. TES = tracheoesophageal speech; HC = healthy control; M = mean; mazes = abandonded clauses, false starts, repetitions, and interjections.

Figure 12: Percentage of words in mazes in speech of TES-patients and HCs.[8]

3.2.2 C-units

Table 11 shows the number of words (excluding the words in mazes), C-units, and clauses and the C-unit complexity ratios (which is also shown in Figure 13) per TES-patient and HCs. The means and standard deviations of these measures are also given. On average, a C-unit in the speech of HCs consists of (almost) one word more (complexity ratio 1: *M*=7.50; *SD*=.76; *range*=6.83-9.27) than a C-unit in the speech of TES-patients (complexity ratio 1: *M*=6.35; *SD*=.91; *range*=4.63-7.65). A Mann-Whitney U test showed that the TES-patients and HCs differ significantly from each other in the number of words per C-unit (*U*=10.0, *Z*=-2.3, *p*<.05).

Most C-units consist of only one clause for both groups of participants (complexity ratio 2 of the TES-patients: *M*=1.16; *SD*=.08; *range*=1.05-1.29; complexity ratio 2 of the HCs: *M*=1.23; *SD*=.09; *range*=1.12-1.37). A Mann-Whitney U test showed that the TES-patients and HCs do not differ significantly from each other in the number of clauses per C-unit (*U*=20.0, *Z*=-1.3, *p*=.23).

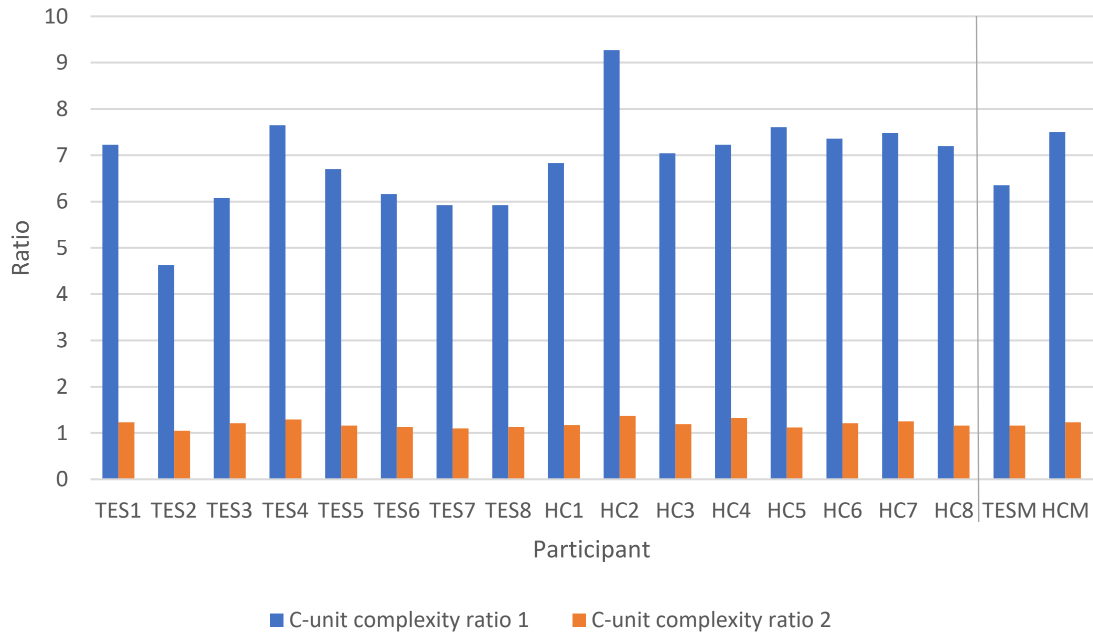
As the standard deviations show (in Table 11), both groups have a same amount of variation in the number of words and clauses per C-unit (see also Figure 13).

[8] The data of TES-patients are copied from Figure 4.

Table 11: C-unit complexity ratios of TES-patients and HCs.[9]

Part.	#words	#C-units	#clauses	C-unit complexity ratios	
				1	**2**
TES1	939	130	160	7.23	1.23
TES2	958	207	218	4.63	1.05
TES3	937	154	187	6.08	1.21
TES4	926	121	156	7.65	1.29
TES5	924	138	160	6.70	1.16
TES6	900	146	165	6.16	1.13
TES7	859	134	148	6.41	1.10
TES8	923	156	177	5.92	1.13
HC1	868	127	149	6.83	1.17
HC2	844	91	125	9.27	1.37
HC3	873	124	148	7.04	1.19
HC4	896	124	164	7.23	1.32
HC5	875	115	129	7.61	1.12
HC6	817	111	134	7.36	1.21
HC7	860	115	144	7.48	1.25
HC8	864	120	139	7.20	1.16
TESM(SD)	921(30)	148(27)	171(22)	6.35(0.91)	1.16(0.08)
HCM(SD)	862(23)	116(11)	142(13)	7.50(0.76)	1.23(0.09)

Note. TES = tracheoesophageal speech; HC = healthy control; # = number of; 1 = number of words per C-unit; 2 = number of clauses per C-unit; M = mean; SD = standard deviation.



Note. TES = tracheoesophageal speech; HC = healthy control; M = mean; C-unit complexity ratio 1 = number of words per C-unit; C-unit complexity ratio 2 = number of clauses per C-unit.

Figure 13: C-unit complexity ratios of TES-patients and HCs.[10]

[9] The data of TES-patients are copied from Table 4.
[10] The data of TES-patients are copied from Figure 5.

The C-units are divided in four types: simple (only a main clause), complex1 (main clause with one subordinate clause), complex2 (main clause with two subordinate clauses), and complex3+ (main clause with three or more subordinate clauses). Table 12 shows the number and percentages (which are also shown in Figure 14) of simple and complex C-units per TES-patient and HC. The TES-patients uttered more simple C-units (*M*=85%; *SD*=5.7; *range*=74.4-92.3) than the HCs (*M*=81%; *SD*=5.8; *range*=70.3-88.7), and therefore the HCs uttered more complex C-units (complex1: *M*=15%; *SD*=3.3; *range*=10.4-20.9; complex2: *M*=2.9%; *SD*=2.0; *range*=.8-6.6; complex3+: *M*=.9%; *SD*=1.1; *range*=0-2.4) than the TES-patients (complex1: *M*=13%; *SD*=4.1; *range*=7.7-20.7; complex2: *M*=1.7%; *SD*=1.4; *range*=0-4.1; complex3+: *M*=.5%; *SD*=.5; *range*=0-1.4), but these differences are not very large. A Mann-Whitney U test showed that the TES-patients and HCs do not differ significantly from each other in the percentage of simple C-units (*U*=22.0, *Z*=-1.1, *p*=.33), complex1 C-units (*U*=22.0, *Z*=-1.1, *p*=.33), complex2 C-units (*U*=19.0, *Z*=-1.4, *p*=.20), and complex3+ C-units (*U*=25.0, *Z*=-0.8, *p*=.51).

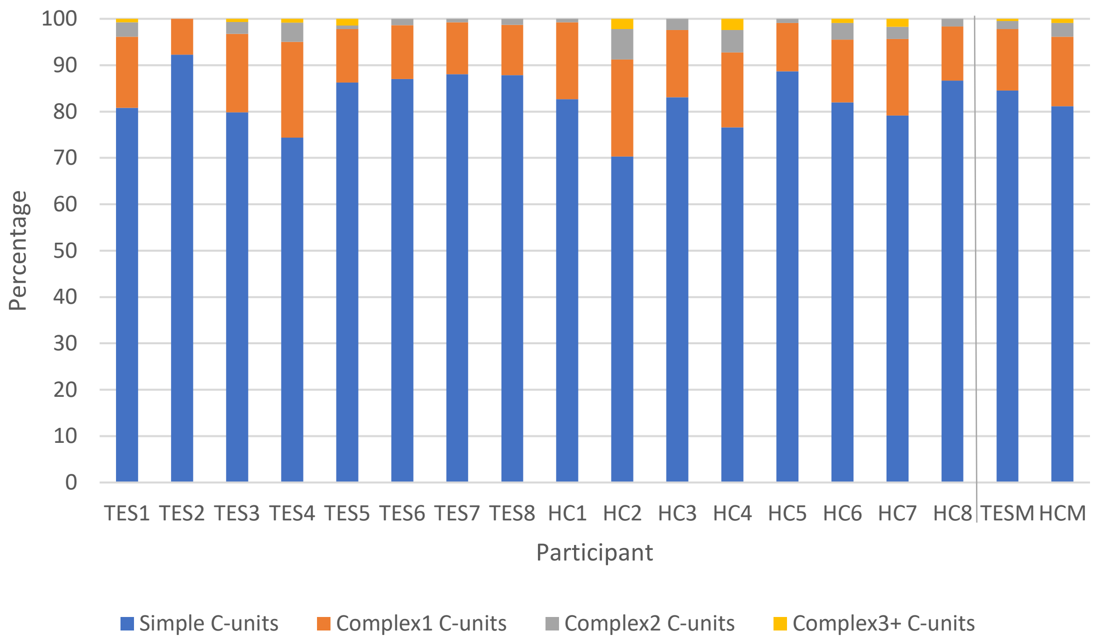
There is not a lot of variation in the percentages of the different types of C-units within both groups of participants (SDs of the TES-patients are between 5.7 and 0.5 and the SDs of the HCs are between 5.8 and 1.1; see Table 12 and Figure 14).

Table 12: Types of C-units in speech of TES-patients and HCs.[11]

Part.	**Total #C-units**	**Simple C-units**		**Complex1 C-units**		**Complex2 C-units**		**Complex3+ C-units**	
		#	**%**	**#**	**%**	**#**	**%**	**#**	**%**
TES1	130	105	80.8	20	15.4	4	3.1	1	0.8
TES2	207	191	92.3	16	7.7	0	0.0	0	0.0
TES3	154	123	79.9	26	16.9	4	2.6	1	0.6
TES4	121	90	74.4	25	20.7	5	4.1	1	0.8
TES5	138	119	86.2	16	11.6	1	0.7	2	1.4
TES6	146	127	87.0	17	11.6	2	1.4	0	0.0
TES7	134	118	88.1	15	11.2	1	0.7	0	0.0
TES8	156	137	87.8	17	10.9	2	1.3	0	0.0
HC1	127	105	82.7	21	16.5	1	0.8	0	0.0
HC2	91	64	70.3	19	20.9	6	6.6	2	2.2
HC3	124	103	83.1	18	14.5	3	2.4	0	0.0
HC4	124	95	76.6	20	16.1	6	4.8	3	2.4
HC5	115	102	88.7	12	10.4	1	0.9	0	0.0
HC6	111	91	82.0	15	13.5	4	3.6	1	0.9
HC7	115	91	79.1	19	16.5	3	2.6	2	1.7
HC8	120	104	86.7	14	11.7	2	1.7	0	0.0
TESM(SD)	148(27)	126(30)	84.5(5.7)	19(4)	13.2(4.1)	2(2)	1.7(1.4)	1(1)	0.5(0.5)
HCM(SD)	116(11)	94(14)	81.1(5.8)	17(3)	15.0(3.3)	3(2)	2.9(2.0)	1(1)	0.9(1.1)

Note. TES = tracheoesophageal speech; HC = healthy control; simple = only main clause; complex1 = main clause and one subordinate clause; complex2 = main clause and two subordinate clauses; complex3+ = main clause and three or more subordinate clauses; # = number of; % = percentage of; M = mean; SD = standard deviation.

[11] The data of TES-patients are copied from Table 5.



Note. TES = tracheoesophageal speech; HC = healthy control; M = mean; simple = only main clause; complex1 = main clause and one subordinate clause; complex2 = main clause and two subordinate clauses; complex3+ = main clause and three or more subordinate clauses.

Figure 14: Types of C-units in speech of TES-patients and HCs.[12]

3.2.3 Clauses

Table 13 shows the number of words (excluding the words in mazes) and clauses and the clause complexity ratios (which is also shown in Figure 15) per TES-patient and HC. The means and standard deviations of these measures are also given. On average, a clause in the speech of HCs consists of (almost) one word more (complexity ratio: *M*=6.13; *SD*=.45; *range*=5.46-6.78) than a clause in the speech of TES-patients (complexity ratio: *M*=5.43; *SD*=.53; *range*=4.39-5.94). A Mann-Whitney U test showed that the TES-patients and HCs differ significantly from each other in the number of words per clause (*U*=7.0, *Z*=-2.6, *p*<.01).

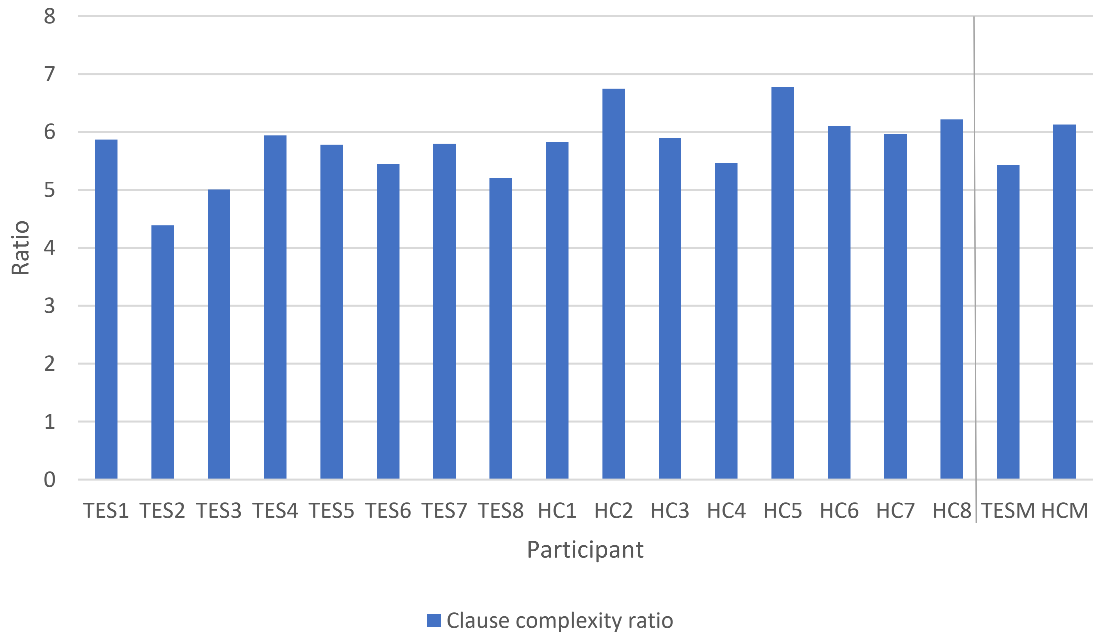
As the standard deviations show (in Table 13), both groups have a same amount of variation in the number of words per clause (see also Figure 15).

[12] The data of TES-patients are copied from Figure 6.

Table 13: Clause complexity ratio of TES-patients and HCs.[13]

Participant	#words	#clauses	Clause complexity ratio
TES1	939	160	5.87
TES2	958	218	4.39
TES3	937	187	5.01
TES4	926	156	5.94
TES5	924	160	5.78
TES6	900	165	5.45
TES7	859	148	5.80
TES8	923	177	5.21
HC1	868	149	5.83
HC2	844	125	6.75
HC3	873	148	5.90
HC4	896	164	5.46
HC5	875	129	6.78
HC6	817	134	6.10
HC7	860	144	5.97
HC8	864	139	6.22
TESM(SD)	921(30)	171(22)	5.43(0.53)
HCM(SD)	862(23)	142(13)	6.13(0.45)

Note. TES = tracheoesophageal speech; HC = healthy control; # = number of; clause complexity ratio = number of words per clause; M = mean; SD = standard deviation.



Note. TES = tracheoesophageal speech; HC = healthy control; M = mean; clause complexity ratio = number of words per clause.

Figure 15: Clause complexity ratio of TES-patients and HCs.[14]

[13] The data of TES-patients are copied from Table 6.
[14] The data of TES-patients are copied from Figure 7.

The clauses are divided in two types: unreduced and reduced[15] (an ellipsis or telegram style clause). Table 14 shows the number and percentages (which are also shown in Figure 16) of unreduced and reduced clauses per TES-patient and HC. The TES-patients uttered more unreduced clauses (*M*=87%; *SD*=8.3; *range*=68.8-94.7) than the HCs (*M*=85%; *SD*=4.5; *range*=77.7-93.6), and therefore the HCs uttered more reduced clauses (*M*=15%; *SD*=4.5; *range*=6.4-22.3) than the TES-patients (*M*=13%; *SD*=8.3; *range*=5.3-31.2), but this difference is very small. A Mann-Whitney U test showed that the TES-patients and HCs do not differ significantly from each other in the percentage of unreduced and reduced clauses (*U*=21.0, *Z*=-1.2, *p*=.28).

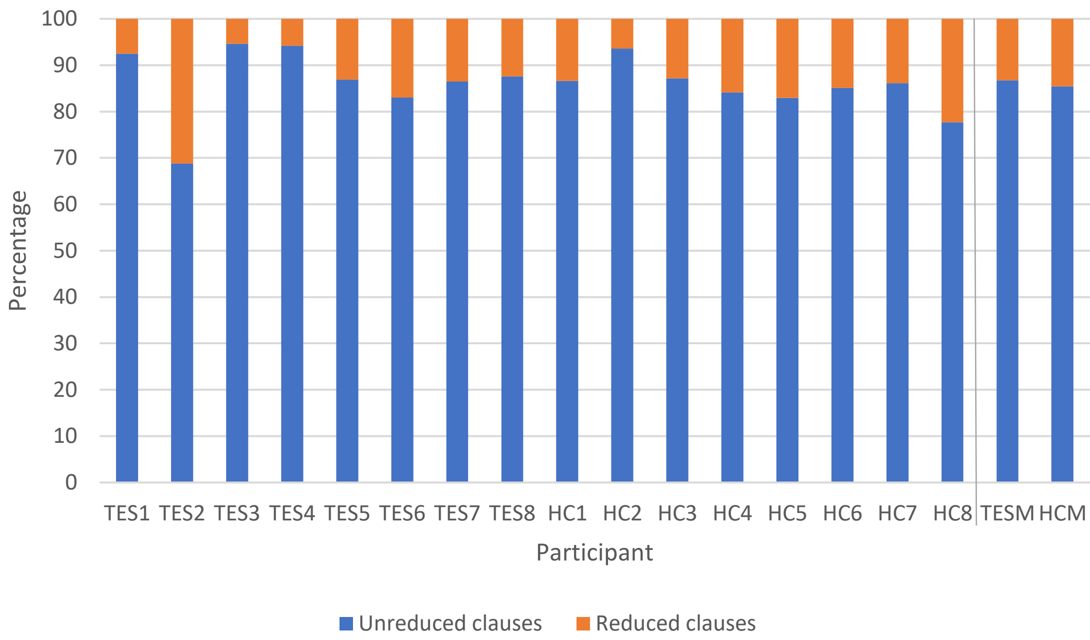
There is not a lot of variation in the percentages of the different types of clauses withing both groups of participants, but the TES-patient group varies more than the HC group (SDs of the TES-patients are 8.3 and the SDs of the HCs are 4.5; see Table 14 and Figure 16).

Table 14: Types of clauses in speech of TES-patients and HCs.[16]

Participant	**Total #clauses**	**Unreduced clauses**		**Reduced clauses**	
		#	**%**	**#**	**%**
TES1	160	148	92.5	12	7.5
TES2	218	150	68.8	68	31.2
TES3	187	177	94.7	10	5.3
TES4	156	147	94.2	9	5.8
TES5	160	139	86.9	21	13.1
TES6	165	137	83.0	28	17.0
TES7	148	128	86.5	20	13.5
TES8	177	155	87.6	22	12.4
HC1	149	129	86.6	20	13.4
HC2	125	117	93.6	8	6.4
HC3	148	129	87.2	19	12.8
HC4	164	138	84.1	26	15.9
HC5	129	107	82.9	22	17.1
HC6	134	114	85.1	20	14.9
HC7	144	124	86.1	20	13.9
HC8	139	108	77.7	31	22.3
TESM(SD)	171(22)	148(15)	86.8(8.3)	24(19)	13.2(8.3)
HCM(SD)	142(13)	121(11)	85.4(4.5)	21(6.6)	14.6(4.5)

Note. TES = tracheoesophageal speech; HC = healthy control; unreduced = a group of words consisting of at least a subject and predicate; reduced = ellipsis or telegram style; # = number of; % = percentage of; M = mean; SD = standard deviation.

[15] Ellipses and telegram style clause are treated as one type of clause (reduced clauses), because there were just a few ellipses found in the speech of the participants (TES-patients: *M*=2 (1.3%), *SD*=2 (1.0%), *range*=0-4 (0%-2.5%); HCs: *M*=3 (2.3%), *SD*=1 (1.0%), *range*=2-6 (1.6%-4.3%)).
[16] The data of TES-patients are copied from Table 7.



Note. TES = tracheoesophageal speech; HC = healthy control; M = mean; unreduced = a group of words consisting of at least a subject and predicate; reduced = ellipsis or telegram style.

Figure 16: Types of clauses in speech of TES-patients and HCs.[17]

3.2.4 NPs

Table 15 shows the number of NPs (excluding the NPs in mazes), the frequency of the lengths of NPs in words (which is also shown in Figure 17), total number of words in NPs and the NP complexity ratios (which is also shown in Figure 18) per TES-patient and HC. The means and standard deviations of these measures are also given. The mean (and standard deviation and range of the) frequency of the lengths of NPs of the TES-patients and HCs are, in order of increasing number of words per NP, respectively, 71% (*SD*=4.1; *range*=65.9-77.8) and 63% (*SD*=3.6; *range*=56.5-66.2; NPs consisting of one word), 22% (*SD*=3.8; *range*=16.6-25.7) and 24% (*SD*=3.4; *range*=18.8-29.1; NPs consisting of two words), 5% (*SD*=1.7; *range*=1.3-6.8) and 7% (*SD*=1.9; *range*=4.8-10.0; NPs consisting of three words), 1% (*SD*=.7; *range*=.3-2.3) and 2% (*SD*=1.0; *range*=.8-3.4; NPs consisting of four words), and 2% (*SD*=1.2; *range*=.4-4.4) and 5% (*SD*=1.1; *range*=3.6-6.6; NPs consisting of five or more words; see Table 15 and Figure 17). This means that the TES-patients uttered more NPs which consist of one word than the HCs, and that the HCs uttered more NPs which consist of more than one word than the TES-patients (see Table 15 and Figure 18). There is not a lot of variation within both groups of participants.

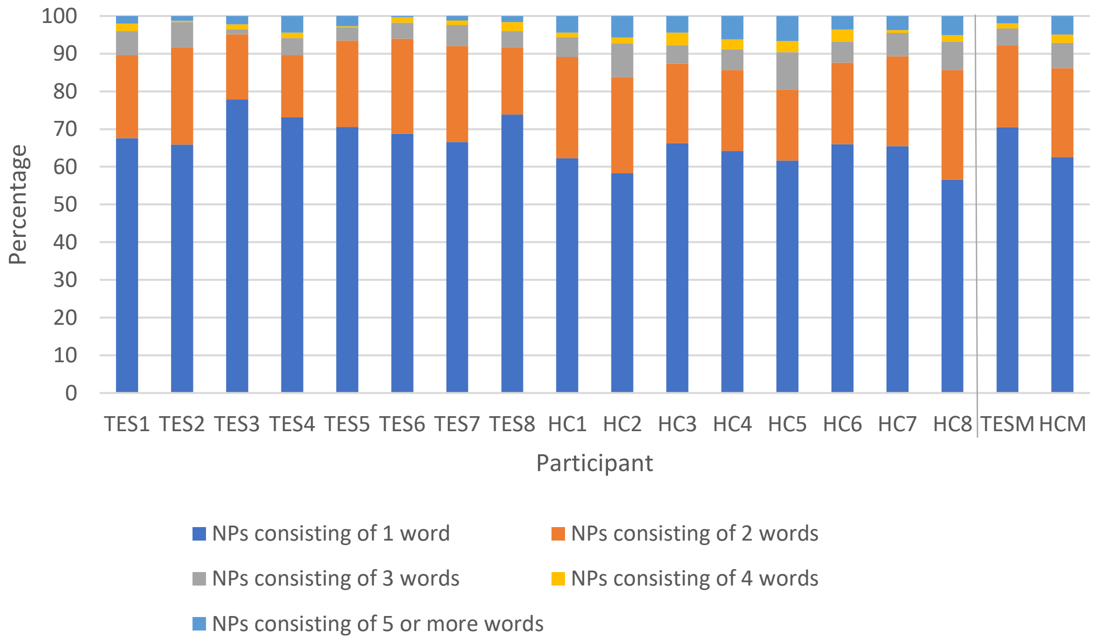
The NP complexity ratio also shows that the HCs uttered more NPs which consist of more than one word (*M*=1.71; *SD*=.09; *range*=1.57-1.85) in comparison with the TES-patients (*M*=1.45; *SD*=.07; *range*=1.35-1.59; see Table 15 and Figure 18). On average, five out of seven NPs spoken by HCs consists of two words (while the other NPs consists of one word), and four out of nine NPs spoken by TES-patients consists of two words (while the other NPs consists of one word). A Mann-Whitney U test showed that the TES-patients and HCs differ significantly from each other in the number of words per NP (*U*=1.0, *Z*=-3.3, $p<.01$).

[17] The data of TES-patients are copied from Figure 8.

Table 15: Frequency of lengths of NPs and NP complexity ratio of TES-patients and HCs.[18]

Part.	Total #NPs	NPs consisting of … word(s)										#words in NPs	NP complexity ratio
		1		2		3		4		5+			
		#	%	#	%	#	%	#	%	#	%		
TES1	299	202	67.6	66	22.1	19	6.4	6	2.0	6	2.0	448	1.50
TES2	311	205	65.9	80	25.7	21	6.8	1	0.3	4	1.3	454	1.46
TES3	311	242	77.8	54	17.4	4	1.3	4	1.3	7	2.3	420	1.35
TES4	271	198	73.1	45	16.6	12	4.4	4	1.5	12	4.4	431	1.59
TES5	292	206	70.5	67	22.9	10	3.4	1	0.3	8	2.7	423	1.45
TES6	282	194	68.8	71	25.2	12	4.3	4	1.4	1	0.4	393	1.39
TES7	251	167	66.5	64	25.5	14	5.6	3	1.2	3	1.2	368	1.47
TES8	302	223	73.8	54	17.9	13	4.3	7	2.3	5	1.7	432	1.43
HC1	249	155	62.2	67	26.9	13	5.2	3	1.2	11	4.4	411	1.65
HC2	247	144	58.3	63	25.5	22	8.9	4	1.6	14	5.7	439	1.78
HC3	293	194	66.2	62	21.2	14	4.8	10	3.4	13	4.4	497	1.70
HC4	307	197	64.2	66	21.5	17	5.5	8	2.6	19	6.2	525	1.71
HC5	271	167	61.6	51	18.8	27	10.0	8	3.0	18	6.6	500	1.85
HC6	250	165	66.0	54	21.6	14	5.6	8	3.2	9	3.6	422	1.69
HC7	243	159	65.4	58	23.9	15	6.2	2	0.8	9	3.7	381	1.57
HC8	237	134	56.5	69	29.1	18	7.6	4	1.7	12	5.1	421	1.78
TESM (SD)	290 (21)	205 (22)	70.5 (4.1)	63 (11)	21.7 (3.8)	13 (5)	4.5 (1.7)	4 (2)	1.3 (0.7)	6 (3)	2.0 (1.2)	421 (28)	1.45 (0.07)
HCM (SD)	262 (26)	164 (22)	62.6 (3.6)	61 (6)	23.6 (3.4)	18 (5)	6.7 (1.9)	6 (3)	2.2 (1.0)	13 (4)	5.0 (1.1)	450 (51)	1.71 (0.09)

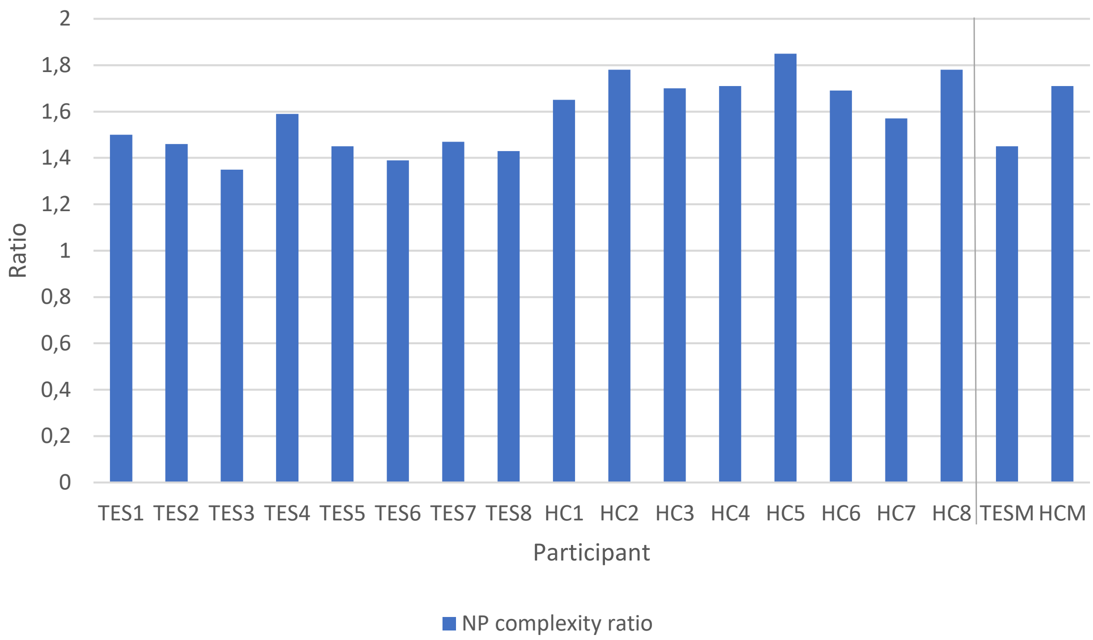
Note. TES = tracheoesophageal speech; HC = healthy control; NP = noun phrase; # = number of; % = percentage of; NP complexity ratio = number of words per noun phrase; M = mean; SD = standard deviation.



Note. TES = tracheoesophageal speech; HC = healthy control; NP = noun phrase; M = mean.

Figure 17: Percentages of NPs with 1, 2, 3, 4, or 5 or more words in speech of TES-patients and HCs.[19]

[18] The data of TES-patients are copied from Table 8.
[19] The data of TES-patients are copied from Figure 9.



Note. TES = tracheoesophageal speech; HC = healthy control; NP = noun phrase; M = mean; NP complexity ratio = number of words per noun phrase.

Figure 18: NP complexity ratio of TES-patients and HCs.[20]

The NPs are divided in three types: simple (a (pro)noun and/or determiners), compound (coordinating nouns or NPs) and complex (noun(s) with nominal modifiers). Table 16 shows the number and percentages (which are also shown in Figure 19) of the different types of NPs per TES-patient and HC. The TES-patients uttered more simple NPs (*M*=92%; *SD*=1.7; *range*=90.8-95.2) than the HCs (*M*=86%; *SD*=4.1; *range*=79.3-92.6), and the HCs uttered more compound NPs (*M*=1.5%; *SD*=.6; *range*=.7-2.1) and complex NPs (*M*=13%; *SD*=4.5; *range*=5.3-19.9) than the TES-patients (compound NPs: *M*=.7%; *SD*=.4; *range*=.3-1.7; complex NPs; *M*=7%; *SD*=1.6; *range*=4.2-8.8). A Mann-Whitney U test showed that the TES-patients and HCs differ significantly from each other in the percentage of simple NPs (*U*=6.0, *Z*=-2.7, *p*<.01), compound NPs (*U*=8.5, *Z*=-2.5, *p*=.01), and complex NPs (*U*=6.0, *Z*=-2.7, *p*<.01).

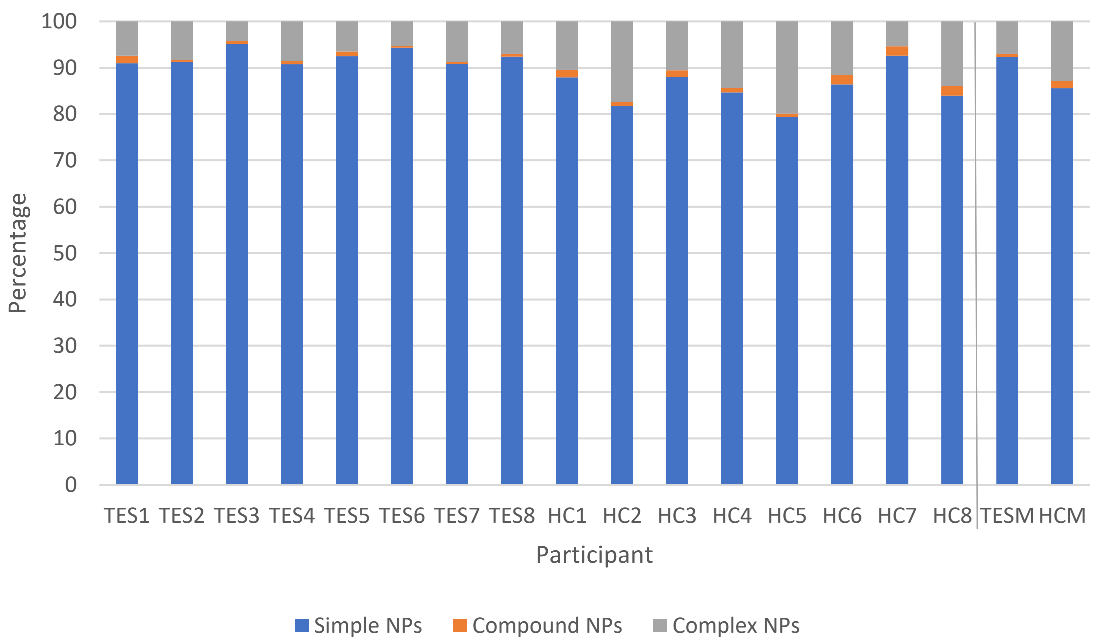
There is not a lot of variation in the percentages of the different types of NPs within both groups of participants, but the HC group varies more than the TES-patient group (SDs of the TES-patients are between 0.4 and 1.7 and the SDs of the HCs are between 0.6 and 4.5; see Table 16 and Figure 19).

[20] The data of TES-patients are copied from Figure 10.

Table 16: Types of NPs in speech of TES-patients and HCs.[21]

Part.	**Total #NPs**	**Simple NPs**		**Compound NPs**		**Complex NPs**	
		#	**%**	**#**	**%**	**#**	**%**
TES1	299	272	91.0	5	1.7	22	7.4
TES2	311	284	91.3	1	0.3	26	8.4
TES3	311	296	95.2	2	0.6	13	4.2
TES4	271	246	90.8	2	0.7	23	8.5
TES5	292	270	92.5	3	1.0	19	6.5
TES6	282	266	94.3	1	0.4	15	5.3
TES7	251	228	90.8	1	0.4	22	8.8
TES8	302	279	92.4	2	0.7	21	7.0
HC1	249	219	88.0	4	1.6	26	10.4
HC2	247	202	81.8	2	0.8	43	17.4
HC3	293	258	88.1	4	1.4	31	10.6
HC4	307	260	84.7	3	1.0	44	14.3
HC5	271	215	79.3	2	0.7	54	19.9
HC6	250	216	86.4	5	2.0	29	11.6
HC7	243	225	92.6	5	2.1	13	5.3
HC8	237	199	84.0	5	2.1	33	13.9
TESM(SD)	290(21)	268(22)	92.3(1.7)	2(1)	0.7(0.4)	20(4)	7.0(1.6)
HCM(SD)	262(26)	224(23)	85.6(4.1)	4(1)	1.5(0.6)	34(13)	12.9(4.5)

Note. TES = tracheoesophageal speech; HC = healthy control; NP = noun phrase; simple = pronoun, anaphoric determiner, or single noun (+ determiner); compound = coordinating nouns or noun phrases; complex = one or more nouns with nominal modifiers; # = number of; % = percentage of; M = mean; SD = standard deviation.



Note. TES = tracheoesophageal speech; HC = healthy control; NP = noun phrase; M = mean; simple = pronoun, anaphoric determiner, or single noun (+ determiner); compound = coordinating nouns or noun phrases; complex = one or more nouns with nominal modifiers.

Figure 19: Types of NPs in speech of TES-patients and HCs.[22]

[21] The data of TES-patients are copied from Table 9.
[22] The data of TES-patients are copied from Figure 11.

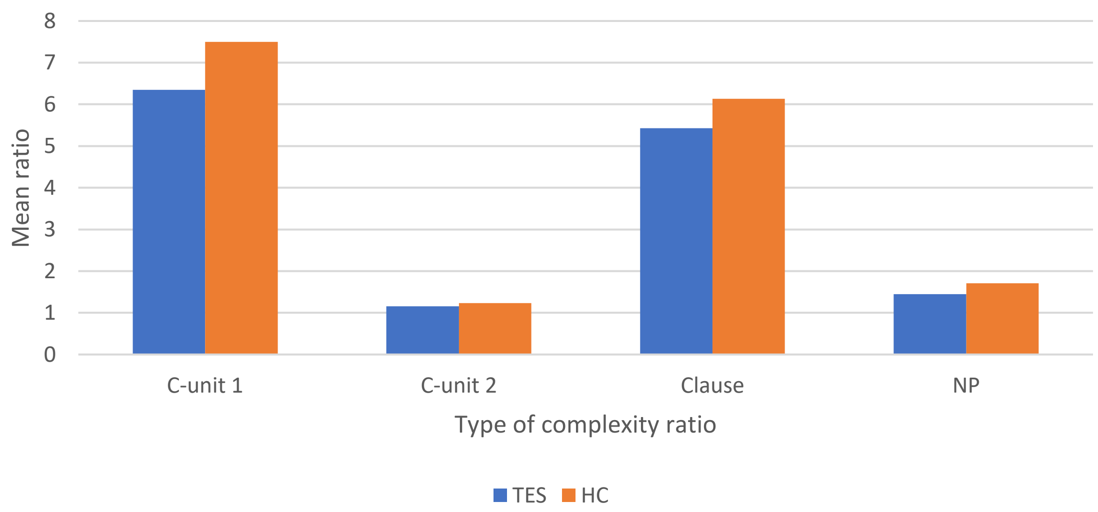
3.2.5 Overview

Table 17 and Figures 20 and 21 give an overview of the data discussed in sections 3.2.1 till 3.2.4.

Table 17: Means and standard deviations of complexity ratios and percentage of types of units of TES-patients and HCs.[23]

Measure		TESM(SD)	HCM(SD)
%mazes		8.8(3.1)*	16.1(3.0)
C-unit complexity ratio 1 (words/C-unit)		6.35(0.91)*	7.50(0.76)
C-unit complexity ratio 2 (clauses/C-unit)		1.16(0.08)	1.23(0.09)
Types of C-units	%Simple	84.5(5.7)	81.1(5.8)
	%Complex1	13.2(4.1)	15.0(3.3)
	%Complex2	1.7(1.4)	2.9(2.0)
	%Complex3+	0.5(0.5)	0.9(1.1)
Clause complexity ratio		5.43(0.53)*	6.13(0.45)
Types of clauses	%Unreduced	86.8(8.3)	85.4(4.5)
	%Reduced	13.2(8.3)	14.6(4.5)
NP complexity ratio (words/NP)		1.45(0.07)*	1.71(0.09)
Types of NPs	%Simple	92.3(1.7)*	85.6(4.1)
	%Compound	0.7(0.4)*	1.5(0.6)
	%Complex	7.0(1.6)*	13.0(4.5)

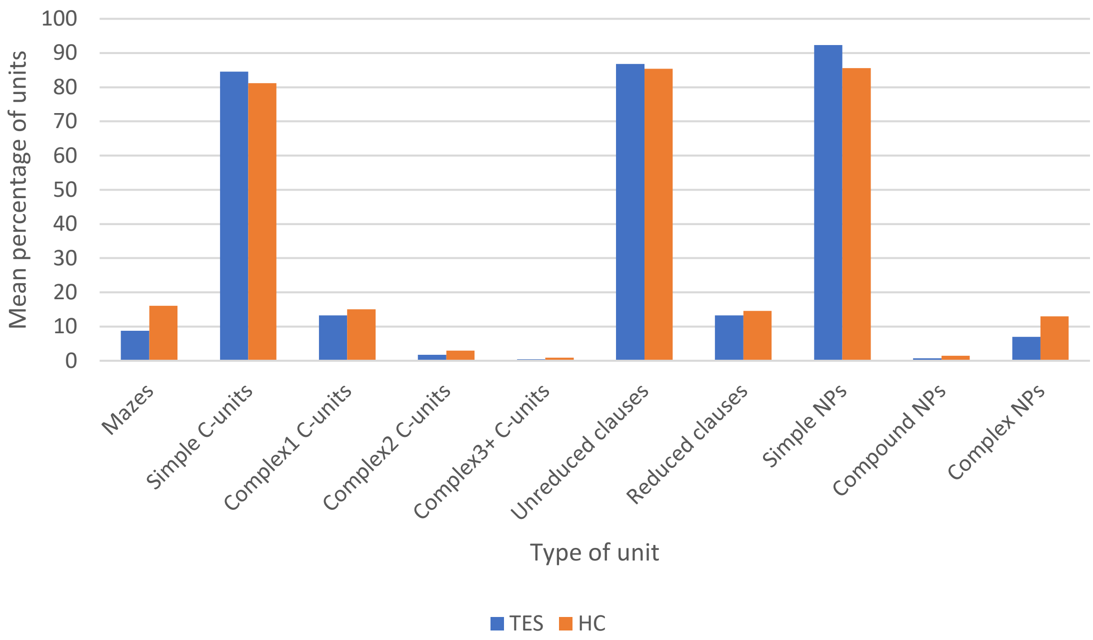
Note. *=significantly different from the HC group (Mann-Whitney U test); TES = tracheoesophageal speech; HC = healthy control; M = mean; SD = standard deviation; % = percentage of; mazes = abandoned clauses, false starts, repetitions, and interjections; simple C-unit = only main clause; complex1 = main clause and one subordinate clause; complex2 = main clause and two subordinate clauses; complex3+ = main clause and three or more subordinate clauses; unreduced = a group of words consisting of at least a subject and predicate; reduced = ellipsis or telegram style; NP = noun phrase; simple = pronoun, anaphoric determiner, or single noun (+ determiner); compound = coordinating nouns or noun phrases; complex = one or more nouns with nominal modifiers.



Note. TES = tracheoesophageal speech; HC = healthy control; M = mean; C-unit complexity ratio 1 = number of words per C-unit; C-unit complexity ratio 2 = number of clauses per C-unit; clause complexity ratio = number of words per clause; NP complexity ratio = number of words per noun phrase.

Figure 20: Mean complexity ratios of TES-patients and HCs.[24]

[23] These data are copied from Table 10-16.
[24] These data are copied from Figure 13, 15, and 18.



Note. TES = tracheoesophageal speech; HC = healthy control; M = mean; mazes = abandoned clauses, false starts, repetitions, and interjections; simple C-unit = only main clause; complex1 = main clause and one subordinate clause; complex2 = main clause and two subordinate clauses; complex3+ = main clause and three or more subordinate clauses; unreduced = a group of words consisting of at least a subject and predicate; reduced = ellipsis or telegram style; NP = noun phrase; simple NP = pronoun, anaphoric determiner, or single noun (+ determiner); compound = coordinating nouns or noun phrases; complex = one or more nouns with nominal modifiers.

Figure 21: Mean percentages of types of units of TES-patients and HCs.[25]

4. Discussion

4.1 Answering the research questions

The aims of this study were to discover if alaryngeal speech is a constraint affecting linguistic complexity and to generate hypotheses about the syntactic complexity of persons who underwent a total laryngectomy (TL). The research questions (one main and two sub questions) used to achieve these aims were:

Does the syntactic complexity of speech change after total laryngectomy?

1. **How complex is the syntax of semi-spontaneous speech of patients who underwent a total laryngectomy and use tracheoesophageal speech?**
2. **Are there differences in the syntactic complexity of speech between TES-patients and healthy controls?**

The results on the first sub question are discussed in section 4.1.1 and the results on the second one and on the main research question are discussed in section 4.1.2.

[25] These data are copied from Figure 12, 14, 16, and 19.

4.1.1 The syntax of TES-patients

To answer the first sub question of this study, spoken text by persons who underwent TL and therefore used tracheoesophageal speech (TES-patients) were analyzed. The speech was analyzed on mazes, C-units, clauses, and noun phrases (NPs).

The amount of mazes indicates the degree of linguistic uncertainty of the speaker (Loban, 1976:22). The results on the mazes show that most of the words in mazes are interjections and that there are just a few repetitions in the speech of TES-patients. The TES-patients do vary reasonably in the amount of words in mazes. This suggests that some TES-patients seems to be a bit more certain and careful in planning an utterance, since words are costly.

The longer a C-unit and the more complex C-units a person utters, the more complex the syntax of that person's speech is. The results at the level of the C-unit show that a C-unit has a length of six or seven words with a deviation of almost one word between the TES-patients. Most C-units have a length of only one clause. Analyzing the different types of C-units, it appears that most C-units spoken by TES-patients are simple C-units, so only consist of a main clause. Some C-units consist of a main clause with one subordinate clause and just a few C-units consist of a main clause with two or more subordinate clauses. There is not a lot of variation in the amount of the different types of C-units between the TES-patients. So, the syntax at the level of C-units seems not very complex, but the length of C-units in words differs between the TES-patients.

The shorter a clause and the more reduced clauses a person utters, the less complex the syntax of that person's speech is. The results at the level of the clause show that most clauses have a length of four, five or six words with a deviation of half a word between the TES-patients. Analyzing the different types of clauses, it appears that most clauses spoken by TES-patients are unreduced (normal) clauses and that only some clauses are reduced. There is not a lot of variation in the amount of the different types of clauses between the TES-patients. So, the syntax at the level of clauses seems not very complex.

The longer an NP and the more compound and complex NPs a person utters, the more complex the syntax of that person's speech is. The results at the level of the NP show that most NPs have a length of only one word or two words, and just a few of three or more words. There is not a lot of variation in the length of NPs between the TES-patients. Analyzing the different types of NPs, it appears that most NPs spoken by TES-patients are simple NPs, some are complex, and just a few are compound NPs. There is not a lot of variation in the amount of the different types of NPs between TES-patients. So, the syntax at the level of NPs seems not very complex.

One TES-patient stands out of the outcomes on the measures. TES-patient 2 differs (more than the other TES-patients) from the mean of many measures. This TES-patient uttered shorter C-units and clauses than the other TES-patients, and made more simple C-units and reduced clauses than the other TES-patients. So, it seems that this TES-patient has a less complex syntax than the other TES-patients. This TES-patient is the only one with a poor intelligibility (see Table 1 in the method section), so a poor intelligibility possibly affects the syntactic complexity.

A few other TES-patients also differ (more than the other TES-patient) from the mean of some measures. TES-patient 3 differs the most from the mean percentage of simple NPs, in such that she uttered the most simple NPs, so she has a simpler syntax at the level of the NP than the other TES-patients. No reason or factor is found to explain the outcomes on TES-patient 3, but comorbidity could possibly be the reason. A TES-patient could have other disorders or diseases (like asthma, COPD, diabetes, or obesity) which could, besides using TES, affect the syntactic complexity.

TES-patient 4 differs the most from the mean percentage of simple C-units and in the NP complexity ratio, in such that she uttered the lowest amount of simple C-units, so the highest amount of complex C-units, and the longest NPs. So, TES-patient 4 has a more complex syntax at the level of C-units and NPs than the other TES-patients. This may be due to the fact that this TES-patient use TES for quite some years (18 years) or because the TL was executed at an age below the age of 50 (namely, at the age of 47; see Table 1 in the method section). The many years of using TES could cause familiarization with TES which causes the language to be more complex than after just a few years of using TES. The lower the age of the patients at TL, the more adaptation and the better the healing of the wound (since young people recover faster from a surgery than elderly people) which causes the language to be more complex than having TL at an old age.

There are two other TES-patients (TES6 and TES7) who uses TES for a longer time than TES-patient 4 and two (TES7 and TES8) who got the TL also at an age below the age of 50. These TES-patients do not seem to have a more complex syntax than the other TES-patients, which may be due to the fact that they have a lower educational level (lower, secondary, or vocational education) than TES-patient 4 (who has a higher vocational education; see Table 1 in the method section). TES-patient 3 also has a high education level (higher vocational education), but, as discussed above, has a simpler syntax at the level of the NP than the other TES-patients (and the other complexity ratios are also not high, see Figure 5 and 7). TES-patient 1 has a low education level (secondary education), but has high scores on the complexity ratios and percentage of unreduced clauses (see Figure 5, 7, 8, and 10). So, the level of highest education does not seem to be a factor for syntactic complexity in speech of TES-patients.

TES-patient 7 differs the most from the mean percentage of words in mazes, in such that she uttered the most (words in) mazes. This could be a sign of familiarization with the TES method, since the TL of this TES-patient 7 has been carried out many years (31 years) before the data used in this study was collected (see Table 1 in the method section) and, therefore, is not (anymore) as careful in planning an utterance than the other TES-patients.

To summarize, the syntactic complexity of the TES-patients seems to be low overall, but differs between the TES-patients. The differences between the TES-patient could possibly be due to different levels of intelligibility and maybe due to the different number of years using TES as the speech method or the age at TL. The education level does not seem to be a reason for the differences in the syntactic complexity between the TES-patients.

4.1.2 The syntax of TES-patients in comparison with HCs

To answer the second sub question of this study, spoken text by persons who underwent TL and therefore used tracheoesophageal speech (TES-patients) were compared with that of healthy control persons (HCs). The two groups were compared at the levels of mazes, C-units, clauses, and noun phrases (NPs).

The results show that the TES-patients and HCs differ from each other in the percentage of words in mazes. The HCs uttered twice as many words in mazes than the TES-patients did. The largest difference is in the number of false starts and repetitions. Both groups have the same amount of variation in the percentage of words in mazes. So, the TES-patients seem to be more certain and careful in planning an utterance or fill up less pauses with interjections than HCs. This could also be a sign of feeling less freely and comfortable in speaking, since the HCs spoke with close acquaintances and the TES-patients with unknown persons.

The results at the level of the C-unit show that the TES-patients and HCs differ from each other in the length of C-units in words. The HCs uttered C-units of about one word longer than the TES-patients did. There are no differences in the length of C-units in number of clauses and both groups have the same amount of variation in the lengths of C-units. The TES-patients and HCs do also not differ in the percentages of simple and complex C-units and there is not a lot of variation in the percentages of the different types of C-units in both groups of participants. So, HCs have a little bit more complex syntax at the level of C-units than TES-patients.

The results at the level of the clause show that the TES-patients and HCs differ from each other in the length of clauses. The HCs uttered clauses of almost one word longer than the TES-patients did. Both groups have a same amount of variation in the length of clauses. The TES-patients and HCs do not differ in the percentages of unreduced and reduced clauses and there is not a lot of variation in the percentages of the different types of clauses in both groups of participants, but the TES-patient group varies more than the HC group. So, HCs have a little bit more complex syntax at the level of clauses than TES-patients.

The results at the level of the NP show that the TES-patients and HCs differ from each other in the length of NPs. The HCs uttered longer NPs than the TES-patients did. There is not a lot of variation in the lengths of NPs within both groups of participants. The TES-patients and HCs also differ from each other in the percentage of simple, compound, and complex NPs. There is not a lot of variation in the percentages of the different types of NPs in both groups of participants, but the HC group varies more than the TES-patient group. So, HCs have a more complex syntax at the level of NPs than TES-patients.

To summarize, there are differences found between TES-patients and HCs. The HCs seem to have a more complex syntax than TES-patients at the levels of C-units, clauses, and NPs. The HCs utter longer C-units, clauses, and NP, which could be due to the fact that HCs have a larger air volume and a longer maximum phonation time than TES-patients (van Sluis et al., 2018). HCs have a longer breath than TES-patients, which causes them to be able to utter longer C-units than TES-patients. The TES-patients seem to be more certain and careful in planning an utterance or fill up less pauses with interjections than HCs (or they are feeling less freely and comfortable in speaking, due to no familiarity with the conversation partner).

So, does the syntactic complexity of speech change after TL? The short answer is: yes, but it seems not much. The HCs seems to have a more complex syntax at all the analyzed levels than the TES-patients, but more research is needed (see section 4.3). The next section (section 4.2) discusses the achievement of the aims of this study.

4.2 Achieving the aims

4.2.1 New constraint?

Previous studies showed that there are various factors or constraints which affect linguistic complexity. These constraints are cognitive load, situations of language contact, bilingual language activation (see e.g., Kruger & van Rooy, 2016; Kuiken & Vedder, 2019), language disorders (see e.g., Armstrong et al., 2011; Zwitserlood et al., 2015), and speech disorders (see e.g., Howell & Au-Yeung, 2007; Richels et al., 2010). The first aim of this study was to discover if alaryngeal speech is a constraint affecting linguistic complexity. The results show that the syntactic complexity of speech changes after TL (see section 4.1), so we may indeed add alaryngeal speech as another constraint for linguistic complexity.

But what causes alaryngeal speech to be less complex than laryngeal (normal) speech? The second aim of this study was to generate hypotheses about the syntactic complexity of persons who underwent a TL. These hypotheses are discussed in the following section.

4.2.2 Hypotheses to test in further research

The outcomes on the first research question show that the syntactic complexity differs between the TES-patient which has possibly to do with the intelligibility of the speech and maybe with the different number of years using TES as the speech method. One TES-patient, who was the only one with a poor intelligibility, had a lower syntactic complexity than the other TES-patients. One TES-patient, who was one of three TES-patients who used TES as the speech method for the longest time or had TL at an age below the age of 50, had a higher syntactic complexity than the other TES-patients at some levels of syntax.

Three hypotheses may be generated based on the outcomes on the first research question. These hypotheses are the following:

1. The syntax in the speech of TES-patients who have a poor intelligibility is less complex, than the syntax in the speech of TES-patients who have a good intelligibility (so, the less intelligible the person's speech is, the less complex the syntax in their speech is).

2. The syntax in the speech of TES-patients who used TES for a short time is less complex, than the syntax in the speech of TES-patients who used TES for a longer time (so, the less years a person uses TES as the speech method, the less complex the syntax in their speech is).

3. The syntax in the speech of TES-patients who had TL at an old age (above the age of 50) is less complex, than the syntax in the speech of TES-patients who had TL at a younger age (below the age of 50; so, the older a person was at TL, the less complex the syntax in their speech is).

To test the first hypothesis, outcomes on syntactic complexity have to be compared with the intelligibility of the TES-patients. The outcomes on the intelligibility may be the clarity of the sounds they make or the understandability of the message they want to convey. To test the second and third hypotheses, outcomes on syntactic complexity have to be compared with the number of years using TES as the speech method and with the age at which TL was executed. Based on the outcomes of this study, the first hypothesis is more plausible than the other two and, therefore, may be the first and most interesting one to be investigated in further research.

The outcomes on the second research question (and the main research question) show that the syntactic complexity of the TES-patients differs to some extend from that of the HCs, so the syntactic complexity seems changed a bit after a TL. Since TES-patients have a smaller air volume and a shorter maximum phonation time than healthy persons (van Sluis et al., 2018), and since the air volume and maximum phonation differ between TES-patients (van As, 2001), the following hypothesis is generated:

4. The syntax in the speech of TES-patients who have a short maximum phonation time is less complex, than the syntax in the speech of TES-patients who have a longer maximum phonation time (so, the shorter the maximum phonation time of a person's speech is, the less complex the syntax in their speech is).

To test this hypothesis, outcomes on syntactic complexity (especially on the complexity ratios used in this study) have to be compared with the maximum phonation time of TES-patients (and/or healthy persons). It would also be interesting to compare the syntactic complexity with the length of an 'breath-unit' (the words spoken in one breath) instead of maximum phonation time of a vowel.

So, based on the outcomes of this study, four hypotheses could be tested in future studies. This is a pilot study to get a first impression of the use and complexity of grammar in verbal communication after TL. The outcomes of this study are, therefore, used to generate hypotheses about the complexity of the grammar of TES-patients. Because of being a pilot study, this study has (besides some strengths) some limitations which have to be improved in further research.

4.3 Strengths, limitations, and further research

The participants in this study were a group of TES-patients and a group of healthy controls. Including a control group is a strength of this study. Both groups matched in number of participants (eight participants per group) and gender (all participants were female). A control group was important to include in this study, because then the outcomes of the TES-patients could be compared to outcomes of people who had not undergone TL. The speech of the control group was analyzed to get an impression of the complexity of 'normal', laryngeal speech as the baseline of this study.

Another strength is that the (syntactic) complexity was measured at three different levels of syntax (and not just at one level), namely the C-unit, the clause, and the noun phrase. Per level, even two different kinds of measures were used (the length of the units and percentages of simple and complex units) to get more information about the complexity of the syntax in the speech of the participants.

Furthermore, a second independent researcher advised the researcher about the criteria for the units and labels and controlled the data analysis done by the researcher. The results of a study are more valid when the analysis is controlled by a second researcher than when there was no second researcher involved. The involvement of a second independent researcher/advisor causes this study to be more valid than without it.

The speech data of the TES-patients were taken from interviews and that of the HCs from dialogs, so the data of the comparing groups of participants were not of the same kind of speech. This is a pilot study to get a first impression of the syntactic complexity of TES-patients, so this research is done with data which was already available. The data used in this study was not collected especially for this study. This might have affected the outcomes on this study. In further research, data should be collected especially for testing the research questions of the study, and the datasets of the different groups of participants (if two or more groups are being compared) have to be of the same kind to get a higher validity.

The speech data in this study was unscripted. In future studies the researcher could choose to have more scripted data to be able to compare the language structures between the participants better. A more scripted task causes the participants to use language structures which are more alike. By using scripted task, you can, therefore, better compare the language structures in the speech of the participants. Tasks the participants could do, are, for example, answering questions about a story they have read, describing pictures, or telling a short story about an event in their lives.

This study had only eight participants per group which were all female. For a pilot study, this could be enough to get a first impression of the tested variables. In further research, the group of participants should consist of more participants and of an equal number of man and woman to get a higher reliability of the outcomes.

Also, the groups of participants did not match in age, conversation partner, and setting. The TES-patients were older than the HCs; the TES-patients spoke with unknown persons, while the HCs spoke with acquaintances; and the interview was at the TES-patients' homes and the dialogs between the HCs were recorded in a quiet room at a university. Besides matching gender and number of participants per group, the participants should be matched in age, have the same (kind of) conversation partner (recommended is the researchers themselves or the partner of the participant), and be in the same setting. It is important to match the groups of participants in as many ways as possible.

The statistical test which was used in this study was a non-parametrical test, because the data were percentages which are not normal distributed. In further research, parametrical tests should be used, to get a better and more reliable outcomes. This means that the data should meet the assumptions for parametrical tests (see Field, 2013:164-176).

In future research, this study may be repeated with inclusion of participants who use esophageal speech (ES) and electrolarynx speech (ELS). ES and ELS are, like TES, alaryngeal speeches. So, to get a better view of the whole population who uses alaryngeal speech, further research should include TES-, ES-, and ELS-patients. Then, comparison between the different kind of alaryngeal speeches could also be done.

Another outcome which would be interesting to look at is the propositional idea density. The propositional idea density is the number of ideas conveyed by the speaker divided by the total word count of that speaker (Savage & Donovan, 2017). With this measure the efficiency of the language of alaryngeal speech could be investigated. It would be interesting to see if patients with alaryngeal speech convey the same number of ideas as HCs even though they use less words than HCs. If this is the case, then the patients use their language more efficient. But if this is not the case, these patients should probably get language therapy to increase their language efficiency and, therefore, to improve their communication.

Lastly, another interesting suggestion for further research is investigating syntactic complexity in comparison with phonetic complexity. The results of this study showed that TES-patients have a less complex syntax than the healthy controls. TES-patients might avoid certain words with sounds which are hard to pronounce because of TL and their current speech method, what causes syntactic normalization. Syntactic normalization might have an impact on the syntactic complexity. Further research may investigate which sounds are hard to pronounce for patients with alaryngeal speech, and then investigate if this affects their language and linguistic complexity. If this is the case, these patients can be better informed before their TL about what their language would become and which words would be harder to pronounce after TL.

5. Conclusion

After analyzing the syntax of persons who underwent a total laryngectomy (TL) and are therefore using tracheoesophageal speech (TES-patients), and comparing the syntax of these persons with healthy control persons (HCs), it can be concluded that the syntactic complexity of speech does change (even though it seems not by much) after TL. This pilot study showed that alaryngeal speech is a constraint affecting linguistic complexity, but further research is needed to investigate what causes alaryngeal speech to be less complex than laryngeal (‘normal’) speech, so hypotheses about the syntactic complexity in the speech of TES-patients are generated. Factors that could be a reason for a lower syntactic complexity in speech are: poor intelligibility, a short time using TES as speech method, old age at TL, or a short maximum phonation time.

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Appendix A: Data collection and analysis with definitions, criteria, and examples.

Step 1: Making dataset ready for analysis:

a. *Marking the mazes:*

Mazes are abandoned clauses, false starts, repetitions, and interjections. Here are the definitions with of these terms with examples (the mazes are bold):

Abandoned clause = A clause which is not finished.

- Examples:
    - *Want dan ga je knijpen, om het af te.*
      'Because then you squeeze, to.'
    - *Het is heel duidelijk herkenbaar, dat een politie.*
      'It is clearly recognizable, that a police.'
    - *En het beste is.*
      'And the best is.'
    - *Dus ik ga hem maar eens even.*
      'So I will […] him.'
    - *En dat was een.*
      'And that was a.'

False start = Part of an utterance the participant later reformulates.

- Examples:
    - *Het is er is een soort van blokkade*
      'It is there is a sort of blockade'
    - *Want ik kende ik had deze kinderen nog nooit gezien*
      'Because I knew I had not yet seen these children'
    - *Die kun je kun je die gewoon gebruiken*
      'These you can you can just use these'
    - *En op m'n fiets op m'n bromfiets gister*
      'And on my bike on my motorbike yesterday'
    - *Omdat je het geld van de van het stadsdeel moet uitgeven*
      'Because you have to spend the money of the of the city area'

Repetition = The word or words which are spoken for the second (or more) time(s).

- Examples:
    - *Maar er kwam er kwam hier een man*
      'But there came there came here a man'
    - *In het begin vond ik het wel heel erg heel erg*
      'In the beginning I found it very bad very bad'
    - *Dan dan dan knettert het motortje*
      'Then then then the motor sputters'
    - *Hij hij kan hij kan op sommige plekken behoorlijk kronkelen*
      'He he may he may coil at some places'

Interjection = Expression of a feeling or emotion, like affirmation, denial, uncertainty, anxiety, joy, etc.

- Examples:
    - *ja ja / goed he / juist*
      'yes yes / good right / right'

- nou / *maar goed*
  'well / but okay'
- *enzo* / *of zo*
  'etc / or so'
- *verhip*
  'shoot'
- *zeg maar* / eerlijk gezegd
  'so to speak / to be honest'
- *denk ik* / *geloof ik*
  'I think / I believe'
  (like in sentences like this one: *Het is denk ik ook heel oud* 'It is I think very old too')

b. Splitting the text:

The texts spoken by the participants had to be split into utterances, clauses, C-units, noun phrases (NPs), and preposition phrases (PPs). Here are the definitions and criteria used for splitting the texts with examples.

Utterance = A response to a prompt.

1. All the words spoken by interviewee until the next question is asked by the interviewer.
2. If interviewer gives backchannels (e.g., *ja* 'yes' or *oké* 'okay') the utterance of the interviewee continues.

Clause = Group of words consisting of at least a subject and predicate.

1. A clause starts with a subject, coordinator, subordinator, finite verb, or an adverbial.
- See examples of C-units.
2. A clause could be in telegram style (without (finite) verb or subject) or could be an ellipsis.
- See examples in step 2b.
3. A comparative phrase is a coordinate phrase within the same clause (*dan* 'than' and *als* 'even as / like' are coordinators).
- Examples:
  - *Ze hebben dezelfde kleur als een politieautootje*
    'They have the same color as a police car'
  - *Blijkbaar is er meer mis met hondenbezitters dan met honden*
    'Apparently there is something more wrong with dog owners than with dogs'

C-unit = A main clause with zero, one or more subordinate clauses (Loban, 1976).

1. A main clause which has an SVO or VSO word order, and zero, one or more subordinate clauses which starts with a subordinator and has an SOV or OSV word order.
- Examples of main clause with relative clause:
  - *Ik werd gek van die stemprothese, die steeds maar dicht zat.*[28]
    'I became crazy because of this voice prothesis, that was closed again and again.'
  - *Maar die kinderen -die hier wonen- komen ook.*
    'But those children -who live here- also come.'
  - *Dat was toch buslijn 199, waar we ons zorgen over moesten maken.*
    'It was bus line 199, we had to worry about.'
- Examples of main clause with adverbial clause:
  - *Ik zeg dan niks, omdat ik dan geen ruzie wil.*
    'Then I say nothing, because I do not want a fight.'
  - *En -als ze me dan zien in werkelijkheid- dan zijn ze opeens heel aardig.*
    'And -when they actually see me- then suddenly they are very nice.'

[28] The beginning of a C-unit is marked with a capital letter and the end with a dot. Clauses are separated by a comma; embedded clauses are in between hyphens.

  - *En nu sta ik op, wanneer ik wil.*
    'And now I get up, when I want it.'
- Examples of main (reporting) clause with reported clause (indirect speech/thought):
  - *Mijn schoonheidsspecialiste zegt, dat het heel goed is.*
    'My beautician says, that it is very good.'
  - *Ik weet niet, of je het gemerkt hebt.*
    'I do not know, if you have noticed it.'
- Examples of main clause with interrogative complement clause:
  - *Ik wist niet, hoe ik het moest doen.*
    'I did not know, how I had to do it.'
  - *Eerst moet hij dan maar vertellen, waarom die houten stukjes in die betonnen rand niet goed zijn.*
    'First he must tell, why those wooden pieces inside that concrete edge are not okay.'
- For more examples see step 2b.

2. In the absence of a subordinator a new C-unit starts.
- Examples:
  - *Toen zei ze. U heeft een carcinoom.*
    'Then she said. You have a carcinoma.'
  - *Ik bedoel. Het hele leven is toch voor en nadelen.*
    'I mean. This whole life is with advantages and disadvantages.'
  - *En nou dat is hier. In het flevoziekenhuis ben ik geopereerd.*
    'And that is here. In the flevohospital I had the surgery.'
  - *Ik had vooral een nachtzuster. Die vond het fijn.*
    'Mainly I had a night nurse. She liked it.'

3. In the presence of a subordinator, but without the right word order, a new C-unit starts.
- Example of a word order after subordinator which is not SOV/OSV but SVO/VSO (=main clause word order).
  - *Er was mij geen keuze gegeven. Of ik moest me laten opereren.*
    'I had no choice. Whether I should be operated.'

4. In the presence of a coordinator a new C-unit starts (except if the following phrase is a coordinate phrase).
- Examples:
  - *Dat was allemaal goed. Maar er bleef zo veel slijm. En toen hebben ze een biopsie genomen. Want ik had een dikke klier.*
    'That was all good. But so much phlegm got stuck. And then they did a biopsy. Because I had a large gland.'
  - *Hij doet de boodschappen. Of hij doet het woord.*
    'He does the groceries. Or he does the talking.'
  - *Als de tv aanstaat of de radio, verstaat hij me nooit.*
    'When the TV or radio is on, he never understands me.'

5. When a NP is dislocated (to the left or right), it is not a separate C-unit.
- Examples:
  - *Het was een oude die stemprothese.*
    'It was an old one that voice prothesis.'
  - *Maar het strottenklepje pas na drie maanden heeft hij het eruit gehaald.*
    'But the throat valve even after three months he took it out.'
  - *Hondsdraf ken je dat.*
    'Ground ivy do you know that.'

NP = Part of a clause; consists of nominals (and nominal modifiers).

1. An NP consists of a pronoun or anaphoric demonstrative.

- Examples:
    - $_{NP}$[*ik*][29] ‘I’
    - $_{NP}$[*mij*] ‘me’
    - $_{NP}$[*het*] ‘it’
    - $_{NP}$[*die*] ‘that / who’
    - $_{NP}$[*wat*] ‘what’
    - $_{NP}$[*zich*] ‘…self / …selves’
    - $_{NP}$[*zelf*] ‘…self / …selves’
    - $_{NP}$[*iets*] ‘something/anything’

2. An NP consists of one or more nouns with or without nominal modifiers (=determiners, adjectives/adverbs, other NP, PP, or relative clause).

- Examples of an NP with a noun and a determiner, adjective, and/or adverb:
    - $_{NP}$[*keelklachten*]
      ‘throat complaints’
    - $_{NP}$[*de huisarts*]
      ‘the general practioner’
    - $_{NP}$[*die stemprothese*]
      ‘that voice prothesis’
    - $_{NP}$[*zes zeven weken*]
      ‘six seven weeks’
    - $_{NP}$[*zo’n fijne huisarts*]
      ‘such a nice GP’
    - $_{NP}$[*iets heel anders*]
      ‘something very different’
- Examples of an NP with coordination of nouns or NPs:
    - $_{NP}$[*toeters en bellen*]
      ‘bells and whistles’
    - $_{NP}$[*de weer en wind*]
      ‘the wind and wheather’
    - $_{NP}$[$_{NP}$[*mij*] *en* $_{NP}$[*mijn jongste zoon*]]
      ‘me and my youngest son’
    - $_{NP}$[$_{NP}$[*achttien euro*] *of* $_{NP}$[*zoiets*]]
      ‘eighteen euro or something like that’
    - $_{NP}$[$_{NP}$[*geen auto*] *zelfs niet* $_{NP}$[*een*] *en ook* $_{NP}$[*geen fietser*]]
      ‘no car even not one and also no cyclist’
    - $_{NP}$[$_{NP}$[*een vingervormig blad*] $_{NP}$[*lange steel*]]
      ‘a finger-shaped leaf long stem’
- Examples of an NP with a head noun/NP and a modifying noun/NP:
    - $_{NP}$[*21 december* $_{NP}$[*drie jaar terug*]]
      ‘December 21 three years ago’
    - $_{NP}$[$_{NP}$[*hotel*] $_{NP}$[*De Goudfazant*]]
      ‘hotel The Golden Peasant’
    - $_{NP}$[$_{NP}$[*een weekendje*] $_{NP}$[*Center Parcs*]]
      ‘a weekend Center Parcs’
    - $_{NP}$[$_{NP}$[*het woord*] $_{NP}$[*carcinoom*]]
      ‘the word carcinoom’
    - $_{NP}$[*wij allemaal*]
      ‘we all’
    - $_{NP}$[$_{NP}$[*Een soort*] $_{NP}$[*eend*]]
      ‘a kind of duck’

[29] NPs are marked with square brackets.

  - $_{NP}$[$_{NP}$[*een beetje*] $_{NP}$[*een idee*]]
    'a small idea' (lit. 'a bit an idea')
  - $_{NP}$[$_{NP}$[*een paar*] $_{NP}$[*keer*]]
    'a few times'
  - $_{NP}$[$_{NP}$[*iets*] $_{NP}$[*geluid*]]
    'soft/little sound' (lit. 'something/a little bit sound')
- Examples of an NP with modifying PP:
  - $_{NP}$[*de andere kant* $_{PP}$[*van* $_{NP}$[*het* eiland]]]
    'the other side of the island'
  - $_{NP}$[*een rustige plek* $_{PP}$[*met* $_{NP}$[*computers*]]]
    'a quite place with computers'
  - $_{NP}$[*de helft* $_{PP}$[van $_{NP}$[*de burgers*]]]
    'half of the citizens'
  - $_{NP}$[*een schaaltje* $_{PP}$[*met* $_{NP}$[*vier schaaltjes* $_{PP}$[*met* $_{NP}$[*sausjes*]]]]]
    'a bowl with four bowls with sauces'
- Examples of an NP with relative clause:
  - $_{NP}$[*die stemprothese, die steeds maar dicht zat*]
    'that voice prothesis, that was closed again and again'
  - $_{NP}$[*de dame*, *die daar was geweest*]
    'the lady, who has been there'

3. *Er* is never a NP or PP (*er* replaces an NP/PP, it is analyzed as an adverb or part of a pronominal adverb)

- Examples:
  - *Want er zijn dus zitplekken*.
    'Because there are sitting areas.'
  - *Dan doe ik er ook zoete sambal op*.
    'Then I add also sweet sambal to it.'
  - *Op alle deuren heeft ze gezet, wat er in zit*.
    'At all the doors she wrote, what is inside.'

PP = Part of a clause; consists of a pre- or circumposition and NP; generally, expresses a time, place, or direction.

1. Consists of a pre- or circumposition and an NP.

- Examples of an PP starting with a preposition:
  - $_{PP}$[*van* $_{NP}$[*Sinterklaas*]][30]
    'from Santa Clause'
  - $_{PP}$[*in* $_{NP}$[*Leiden*]]
    'in Leiden'
- Examples of an PP consisting of a circumposition:
  - $_{PP}$[*van* $_{NP}$[*het bed*] *af*]
    'off the bed'
  - $_{PP}$[*naar* $_{NP}$[je] *toe*]
    'to/at you'

2. In the absence of a pre- or circumposition, it is not a PP, but just an NP.

- Example of a seemingly omitted preposition:
  - *En dan* $_{NP}$[*zo'n veld*] *hadden* $_{NP}$[*ze*] $_{NP}$[*hooi*] *gemaakt*.
    'And then such field they made hay.'
- Examples of no preposition, but a particle after NP:
  - *Dan moet je zeker* $_{NP}$[*de trap*] *op*
    'Then you certainly have to ascend/go up the stairs.'

[30] PPs are, like NPs, marked with square brackets.

  - *Ik had* $_{NP}$[*zoiets*] <u>*van*</u>. (+direct speech/thought)
    'I thought something like.'
  - *En ik wou bijna* $_{NP}$[*de keukendeur*] <u>*uit*</u> *lopen*.
    'And I almost walked out of the kitchen door.'
- Example of a preposition used as adverbial adposition:
  - *Toen hadden we* $_{NP}$[*wind*] <u>*tegen*</u>.
    'Then we had the wind against us.'

<u>Step 2: Gathering features from the dataset.</u>

a. *Counting the units and calculating means and standard deviations:*

The following units were counted and the number of words within these units were counted (see the examples). After this was done, the means and standard deviations were calculated.

Total words:
- Notes:
  - Total number of words with inclusion of abandoned clauses, interjections, false starts, and repetitions.
  - This number is around the 1000 words per participant (the utterance consisting of the 1000th word is entirely used in the analysis).

Abandoned clauses:
- Notes:
  - Every abandoned clause is counted.
  - The number of words in abandoned clauses are also counted.
- Examples:
  - *Want dan ga je knijpen, <u>om het af te</u>.* = 1 (4 words)
    'Because then you squeeze, <u>to</u>.'
  - *En dat was een.* = 1 (4 words)
    'And that was a.'

Interjections:
- Notes:
  - Every interjection is counted.
  - If an interjection is repeated every repetition is counted.
  - The number of words in interjections are also counted.
- Examples:
  - *Ja oké* = 2 (2 words)
    'Yes alright'
  - *Ja ja ja* = 3 (3 words)
    'Yes yes yes'
  - *Zeg maar* = 1 (2 words)
    'so to speak'

False starts:
- Notes:
  - Every false start is counted.
  - The number of words in false starts are also counted.
- Examples:
  - <u>*Het is*</u> *er is een soort van blokkade* = 1 (2 words)
    '<u>It is</u> there is a sort of blockade'
  - *Zoals <u>dat</u> <u>die</u> <u>op die bank</u> op die bankjes* = 3 (5 words)
    'Like <u>that</u> <u>those</u> <u>at that bench</u> at those benches'

Repetitions:

- Notes:
  - Every repetition is counted.
  - One repetition can consist of more than one word.
  - Multiple repetitions (of the same words) can follow each other.
  - The number of words in repetitions are also counted.
- Examples:
  - *Er kwam er kwam* = 1 (2 words)
    'There came there came'
  - *Met met met* = 2 (2 words)
    'With with with'
  - *Hij hij kan hij kan* = 2 (3 words)
    'He he can he can'

Words:

- Notes:
  - Total number of words with exclusion of abandoned clauses, interjections, false starts, and repetitions.

C-units:

- Notes:
  - With exclusion of abandoned clauses, interjections, false starts, and repetitions.
  - The end of a C-unit is marked with a dot.
  - Number of C-units is number of dots (.).
- Examples:
  - *Dat was allemaal goed. Maar er bleef zo veel slijm. En toen hebben ze een biopsie genomen. Want ik had een dikke klier.* = 4
    'That was all good. But so much phlegm got stuck. And then they did a biopsy. Because I had a large gland.'

Clauses:

- Notes:
  - With exclusion of abandoned clauses, interjections, false starts, and repetitions.
  - Clauses are separated by a comma; embedded clauses are in between hyphens.
  - Number of clauses is number of dots (.), number of commas (,) and number of hyphens (-) divided by two.
- Examples:
  - *Maar die kinderen -die hier wonen- komen ook.* = 1+0+2/1 = 2
    'But those children -who live here- came too.'
  - *Als ik wist, dat zij kwamen, scheurde ik gewoon dat uit.* = 1+2+0/2 = 3
    'If I knew, that they were coming, I just riped that out.'
  - *Ik denk, dat het de mensen -die dit in de brievenbus krijgen- uitdaagt, om meteen te luisteren.* = 1+2+2/2 = 3
    'I think, that it provokes the people, who receive this in the postbox, to listen immediately.'

NPs:

- Notes:
  - With exclusion of abandoned clauses, interjections, false starts, and repetitions.
  - NPs are marked with square brackets.
  - Number of NPs is number of $_{NP}$[.
- Examples:
  - $_{NP}$[*Wat*] *moet* $_{NP}$[*je*] $_{PP}$[*als* $_{NP}$[$_{NP}$[*raadslid*] *dan wel* $_{NP}$[*raadsvoorzitter*]]] $_{PP}$[*met* $_{NP}$[*zulke burgers* $_{PP}$[*met* $_{NP}$[*probleempjes*]]]]. = 7
    'What should you do as councillor or chairman of the council with such citizens with troubles.'

- *Ken* $_{NP}$[*jij*] $_{NP}$[$_{NP}$[*het merk*] $_{NP}$[*Cavasole schoencreme*]]. = 4
  'Do you know the brand Cavasole shoe-polish.'

Words in NPs:

- Notes:
  - With exclusion of abandoned clauses, interjections, false starts, and repetitions.
  - If a word occurs in two NPs, it is counted twice.
  - First, the number of words in NP is counted per NP (1=NP which consists of one word; 2=NP which consists of two words; 3=NP which consists of three words; etc.); secondly, the frequencies of the number of words per NP is made (i.e., NPs with only one word occur 202 time, NPs with two words occur 66 times, etc.), and then the total number of words in NPs is calculated.

b. *Labeling the units, counting frequencies of the labels, and calculating percentages, means, and standard deviations:*

The following units were labeled (with a sign representing the type of unit) and the number of occurrences of each label/sign were counted. After this was done, the means and standard deviations were calculated.

<u>C-units:</u>

1. **Simple C-unit (ø[31]) = Only a main clause.**

- Examples:
  - *En ik passeer hem.*
    'And I pass him.'
  - *Ik denk.*
    'I think.'
  - *Dit hier gaat helemaal verkeerd.*
    'This here goes completely wrong.'
  - *Ik krijg een hele vette bon en een berisping.*
    'I get a very hefty fine and a reprimand.'

2. **Complex1 C-unit (!) = Consists of one subordinate clause.**

- Examples:
  - *En ik zie, dat er niets staat.*
    'And I see, that there is nothing.'
  - *Als ik door bleef rijden, dan knal ik op hem.*
    'If I would have driven on, then I would have bumped into him.'
  - *En de dame -die daar was geweest- die had het daar zo heerlijk gevonden.*
    'And the lady -who has been there- she enjoyed it very much.'

3. **Complex2 C-unit (@) = Consists of two (coordinating) subordinate clauses.**

- Examples:
  - *Als ik wist, dat zij kwamen, scheurde ik gewoon dat uit.*
    'If I knew, that they were coming, I just riped that out.'
  - *Want ik merk, dat het beter gaat, en dat ze me verstaan dus.*
    'Because I notice, that it gets better, and that they understand me.'

4. **Complex 3 C-unit (#) = Consists of three or more (coordinating) subordinate clauses.**

- Examples:
  - *Maar het feit, dat mensen je ook niet zo goed verstaan, of niet weten, waarover ze het met jou moeten hebben.*
    'But the fact, that people do not understand you very well, or not know, about what they should talk with you.'

[31] This sign means that this type of unit is not labeled.

- *Ik denk, dat het de mensen -die dit in de brievenbus krijgen- uitdaagt, om meteen te luisteren.*
  'I think, that it provokes the people, who receive this in the postbox, to listen immediately.'
- *Weet je, wat er gebeurt, als je lof laat uitgroeien, wat voor plant je dan krijgt.*
  'Do you know, what happens, if you let chicory grow, which plant you get.'

5. Complex 4 C-unit ($) = Consists of four (coordinating) subordinate clauses.

- Examples:
  - *Het is natuurlijk niet de eerste keer, dat ze dingen beloven, waar zij ook niks aan hebben, waar wij helemaal niet over gaan, waar ze niks aan kunnen veranderen.*
    'It is of course not the first time, that they promise things, that won't help them, that we do not decide, that we cannot change.'
  - *Ik weet ook niet, waarom dat dan is, waarom hij dat dan wil weten, of dat ik dat weet, of dat ie gewoon denkt van.*
    'I also do not know, why that is, why he wants to know that, or that I know that, or that he just thinks that.'

<u>Clauses:</u>

1. Unreduced clause (ø) = Group of words consisting of at least a subject and predicate.

- Examples:
  - *Ik had niet zo'n fijne huisarts*
    'I had not such a nice GP'
  - *Die meewerkte*
    'who cooperates'
  - *Die zei*
    'who says'
  - *Je moet eerst maar een stoppen met roken*
    'You should stop smoking first'

2. Reduced clause: telegram style (*) = A reduction (without verb or subject) which may be due to spoken language and may likely be enhanced by speech limitations.

- Examples:
  - *En chemo zeven weken*
    'And chemo seven weeks'
  - *Iedere dag naar Amsterdam*
    'Every day to Amsteram'
  - *Over fietsen gesproken*
    'Speaking about cycling'
  - *Tien uur geroepen*
    'Ten hours calling'
  - *Zeker niet tegen een politieagent*
    'Certainly not to a policeman'
  - *Heel leuk*
    'Very nice'
  - *Verschilt*
    'Differs'
  - *Was een mooi gebied*
    'Was a nice area'

3. Reduced clause: ellipsis (() = Grammatically recoverable clause, which is dependent on the immediately preceding context.

- Examples:
  - *Want Erik is ook nog een groot vogelliefhebber. <u>En ik inmiddels ook</u>.*
    'Because Erik was a great bird fan. And meanwhile so am I.'

- *Ik had de L al wel thuisgebracht. Maar de C nog niet.*
  'I had recognized the L. But not yet the C.'
- *Dan moet je diep in de aarde wroeten. En echt alles keurig eruit pikken.*
  'Then you have to dig deep in the ground. And pluck everything nicely out of it.'
- *Als weer zo'n muterende operatie zou komen. Of iets, waardoor moeilijker ga praten.*
  'If there will be again such a mutating surgery. Or something, that would make it harder to speak.'
- *En dan was hij minder bitter, net als onze lof.*
  'And then he had a less bitter taste, just like our chicory.'

NPs:

1. **Simple NP (ø) = NP consisting of a pronoun or anaphoric determiner; NP consisting of one noun (and determiner).**

- Examples:
  - *Ik* 'I'
  - *Die* 'that/who'
  - *Dingen* 'things'
  - *de kijkoperatie* 'the exploratory surgery'
  - *de eerste week* 'the first week'
  - *zestien juni* 'June sixteen'
  - *iedere dag* 'every day'
  - *veel staar* 'much cataract'
  - *wij allemaal* 'we all'
  - *hetzelfde idee* 'same idea'
  - *drie of vier gulden* 'three or four guilder'
  - *mijn zoon* 'my son'

2. **Compound NP (&) = NP consisting of two (or more) coordinating head nouns or NPs.**

- **Examples:**
  - *bami of nasi*
    'noodles or rice'
  - *juni of juli*
    'June or July'
  - *die palmbomen en die azuurblauwe zee*
    'those palm trees and that azure blue sea'
  - *een bioptie en een slikopname*
    'a biopsy and a swallowing test'
  - *mij en mijn jongste zoon*
    'me and my youngest son'
  - *een dag of tien*
    'a day or ten'

3. **Complex NP (^) = NP consisting of a noun (and determiner) with nominal modifiers (adjective, adverb, and/or modifying noun); NP consisting of a noun or noun phrase with modifying N or NP; NP consisting of an NP modified by an PP; NP consisting of a relative clause.**

- Examples:
  - *zo'n fijne huisarts*
    'such a nice GP'
  - *een half jaar*
    'half a year'
  - *totaal geen moeite*
    'totally no difficulty'
  - *heel veel verpleegers*
    'many nurses'
  - *hotel De Goudfazant*
    'hotel The Golden Pheasant'
  - *een paar keer*
    'a few times'
  - *een beetje gebarentaal*
    'a little bit of sign language'
  - *Bakje koffie*
    'cup of coffee'
  - *kip met kerrie en rijst*
    'chicken with curry and rice'
  - *de andere kant van het eiland*
    'the other side of the island'
  - *de dame, die daar was geweest*
    'the lady, who has been there'
  - *het ergste, wat er is*
    'the worst, what can happen'

Step 3: Analyzing the data per participant and per group:

Outcomes:

- Mazes:
  - Percentage of words in mazes
- C-units:
  - Number of words per C-unit (C-unit complexity ratio 1)
  - Number of clauses per C-unit (C-unit complexity ratio 2)
  - Percentage of simple C-units
  - Percentage of complex1 C-units
  - Percentage of complex2 C-units
  - Percentage of complex3+ C-units
- Clauses:
  - Number of words per clause (clause complexity ratio)
  - Percentage of unreduced clauses
  - Percentage of reduced clauses
- NPs:
  - Number of words per NP (NP complexity ratio)
  - Percentage of simple NPs
  - Percentage of compound NPs
  - Percentage of complex NPs

Statistics:

- Mean
- Standard deviation
- Ranges
- Mann-Whitney U test (to compare the groups of participants)

Sources used during data collection and analysis:

Online dictionary (https://www.vandale.nl)
Website of Onze Taal (https://onzetaal.nl)
Some webpages of the website of Taalportaal (https://taalportaal.org)

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Some webpages of the website of ANS (https://e-ans.ivdnt.org)

- Algemene Nederlandse Spraakkunst. (2021, April). Naamwoordelijke constituenten met een complexe kern. https://e-ans.ivdnt.org/topics/pid/ans1407lingtopic
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- Algemene Nederlandse Spraakkunst. (2021, April). Voornaamwoordelijke bijwoorden. https://e-ans.ivdnt.org/topics/pid/topic-15741673051642495

Other source:

- Beliën, M.L. (2008). Constructions, constraints, and construal: Adpositions in Dutch. LOT. https://research.vu.nl/ws/portalfiles/portal/42180200/abstract+dutch.pdf