The use of co-speech gestures in patients after total laryngectomy using tracheoesophageal speech

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1. Abstract

Background: Patients after total laryngectomy (TL) lose their natural voice and are assigned to voice restoration and rehabilitation. One of the methods to help restore the voice is tracheoesophageal speech. Various studies have investigated speech outcomes after TL. To our knowledge, no research has yet been done on non-verbal communication after TL in patients using tracheoesophageal speech.
Aim/research question: The aim of this current study is to investigate non-verbal communication by exploring the use of co-speech gestures in patients after TL using tracheoesophageal speech. The main research question of this current study will be: How are co-speech gestures used by patients after total laryngectomy using tracheoesophageal speech?
Method: To answer this question, annotation of gesture types, functions and timing places of interviews of eight laryngectomized female patients has been performed. Additionally, time sampling of the interviews is done. This time sampling is also applied to a group of healthy controls that have been included.
Results: The results show that the gesture type 'beats' is used in the highest frequency by the TL patients. Furthermore, the gesture function 'other' and timing place 'other' are used the most. The results of the annotation show resemblance with the results of the time sampling. The healthy controls show a different distribution of co-speech gestures than the TL patients.
Conclusion: Most of the used gestures in TL patients have no semantic content (beats). Due to the fact that 'other' was the most used category in both the gesture functions and the timing places, it shows that the used classification of gestures is not fully sufficient for the mapping of co-speech gestures in TL patients. However, the results show that TL patients in this study do make an effort to use co-speech gestures. Further research is necessary to conclude if the use is significant more than in a healthy population. However, this current study does mark a starting point concerning research within this domain.

Keywords: Total laryngectomy, non-verbal, communication, co-speech, gesture, annotation

2. Introduction

Over more than a century ago, in the year 1873, the first total laryngectomy (TL) was performed (Hoffmann, 2021). TL is a surgical procedure of the removal of the larynx and has been of essence in the medical world ever since. The procedure provides people with advanced laryngeal and hypopharyngeal cancer a greater chance at life. In the past century, a great amount of research has been done on TL and consequently the procedure has improved over the years (Ceachir, Hainarosie, & Zainea, 2014). The procedure causes, due to the removal of the larynx, the loss of the patients' natural voice. However, speech restoration and rehabilitation provide a chance for patients after a TL to eventually still be able to speak. The three main modalities are esophageal speech, electrolarynx speech and tracheoesophageal speech. Various studies have performed acoustic analyses and have investigated speech outcomes of TL patients. At this moment, it is unclear what happens when it comes to research about non-verbal communication after TL. Very little is known about this subject. To fully comprehend a speaker's intention in everyday communication, information is integrated from multiple sources, including verbal and non-verbal communication. The latter is expected to be of importance in patients after TL because speech and gesture seem to be closely entwined (McNeill, 1992) and TL patients have a poorer intelligibility. In the literature, there are different views concerning the relationship between speech and gesture. McNeill, a leading researcher in the field of gesture, states that speech and gesture are part of the same self-organizing process whereas other views, for example the trade-off hypothesis (described in: de Ruiter, Bangerter, and Dings (2012)) or the lexical retrieval hypothesis (described in: Wagner, Malisz, and Kopp (2014)), consist of the idea that the production of gesture can have an influence on speech production and vice versa. The literature seems to be divided on the exact relationship between speech and gesture. However, it does become clear within the existing views that the two are intertwined. Nonetheless, the use of gesture within patients after TL using tracheoesophageal speech has (to our knowledge) not been investigated yet. This study investigates specifically co-speech gestures (movements that are produced alongside speech and illustrate the concepts conveyed in speech (Cartmill & Goldin-Meadow, 2016)) and not only gestures in general. This study aims to explore those gestures that are in connection with the speech of the TL patients. Due to the alaryngeal speech (speech without use of the glottis) of the patients, it is interesting to investigate if this alaryngeal speech can have a possible influence on the use of gestures in the patients. The aim is to explore the use of co-speech gestures in TL patients. The research question in this pilot study is, therefore, formulated as:

- How are co-speech gestures used by patients after total laryngectomy using tracheoesophageal speech?

The following sub-questions have been formulated:

- What types of co-speech gestures do patients after total laryngectomy use?
- What is the function of co-speech gestures usage by patients after total laryngectomy?

Besides the mapping of the use of co-speech gestures in TL patients this current study also included healthy controls to be able to compare the outcomes of the TL patients with a healthy population. For this reason, the following sub-question has been added:

- How are co-speech gestures used by healthy controls?

To eventually be able to answer these questions, different steps have been taken. First of all, a relevant theoretical framework was obtained to discuss the existing literature concerning gesture and TL. Within this framework, different views concerning the topic of (co-speech) gesture were highlighted and different classification systems were discussed. Furthermore, a theoretical background of TL and its clinical implications was provided with more details of the surgical procedure, the voice rehabilitation and speech outcomes. After that, the methods are thoroughly discussed and the results have been set out and visualized. The results are interpreted in the discussion section and eventually the conclusion is formulated. The current study is considered as an exploratory pilot study and therefore, no hypotheses have been tested.

3. Theoretical framework

3.1 Gesture

In this section, the existing literature about the concept of gesture in general (section 3.1.1), co-speech gesture (section 3.1.2), and the relationship between gesture and speech (section 3.1.3) will be discussed. Furthermore, the classification of gestures will be discussed and those classifications that are most widely used in literature will be emphasized (section 3.1.4).

3.1.1 What is gesture?

When in co-presence, humans communicate about their feelings, thoughts, intentions, and plans by way of bodily movements (Kendon, 2004). These movements can convey information about the level of engagement and the nature of their intentions and attitudes (Kendon, 2004). Other than that, these bodily movements can also function as a process of discourse; as a part of transferring information (Kendon, 2004). Kendon (2004) described a 'gesture' as a visible action of any body part, when used as an utterance or as part of an utterance. In which 'utterance' refers to any ensemble of an action that counts as an attempt to transfer information of some sort. Church, Kelly, and Wakefield (2016) described that gestures in the broadest conceptualization have been defined as any action with the hands, arms, fingers, face, or even the whole body that is used to transfer information to one another (Crais, Watson, & Baranek, 2009). Speakers may use gestures as if they are the functional equivalents of lexical elements in spoken language, alternating them with spoken elements within a sentence.

From a functional point of view gestures can, therefore, according to Kendon (1997), be regarded as 'part of language'; gestures and speech function together as a composite multi-modal expression to convey the communicator´s intended message.

When it comes to bodily movements, or 'gestural behaviour', it is important to make a distinction between gestures that hearing people use spontaneously during a conversation (gesticulation) and formal sign languages that deaf people use as their sole linguistic communication system. Sign languages are different from gesture as they display the same underlying structural features as spoken languages (Cartmill & Goldin-Meadow, 2016). Sign languages are total conventionalized language systems consisting of all linguistic properties and are, by definition, used as a replacement for speech (de Beer, Hogrefe, Hielscher-Fastabend, & de Ruiter, 2020). The current study is concerned with gesticulation and not sign language. From this point on, this current study will, therefore, only use 'gesture' in reference to gesticulation.

In the literature, a few studies examine the use of gestures in healthy people. Cohen (1977) investigated the use of hand gestures in different communicative settings. The participants (24 male junior communication students[1]) were either seated in a face-to-face setting (FTF), they gave their directions to the experimenter over an intercom (INT) or were instructed to record themselves (ALONE). The results showed that the participants seated in FTF used a mean of 5.61 gestures in 90 seconds and that the use of hand gestures decreased from FTF to INT to ALONE. Hence, the presence of a visible interlocutor has an influence on the use of hand gestures. This outcome was also found in an earlier study by Cohen and Harrison (1973). They found a mean amount of 8.65 hand gestures per task. However, they did not specify the duration of the task which makes it hard to compare the outcomes with other studies. When looking at gender differences in gesture use, not many studies have looked into this. One study by Kavakli and Chen (2014)[2] investigated gender differences in gesture-based interaction by comparing the use of different gesture types in describing different objects. In their study, 8 males and 10 females with an age range of 25-30 years old were included. The participants were encouraged to use both hands and as many gestures as possible while describing the objects. The results showed that females seem to be more diverse in their gesture use compared to males. The frequency of the used gestures was higher in females (2.39) than in the males (1.78) but the total duration of the description was also longer in females (444 sec) than in males (384 sec).

[1] In Cohen's (1977) study no age of the participants was mentioned. Their age was estimated at 21-23 years due to the fact that they were junior students.

[2] This study was presented during CENTRIC 2014, The Seventh International Conference on Advances in Human-oriented and Personalized Mechanisms, Technologies and Services, held in Nice, France

Because of the fact that the speaking duration of the females and males were not equal, the comparison between the two genders is less valuable.

3.1.2 Co-speech gesture

When focusing on gesticulation as a form of non-verbal communication, it is important to distinguish movements related to communication (e.g., co-speech gestures) and movements that are not (e.g., yawning). Cartmill and Goldin-Meadow (2016) described co-speech gestures as movements that are produced next to speech and that illustrate (most of the time) the concepts that are conveyed in speech. To distinguish the co-speech gestures from other movements, Church et al. (2016) described four steps that a researcher will proceed to code co-speech gestures. These steps are formulated as followed:

Step 1: Differentiate co-speech gesture from other behaviors
Step 2: Isolate the gesture word, morpheme, and utterance
Step 3: Describe the form and meaning of the co-speech gesture
Step 4: Analyze co-speech gesture to address a particular research question

Focusing on step 1, according to Church et al. (2016) little research has yet been conducted to determine how gesture coders actually distinguish gestures from other movements. In their study they formulated several criteria that co-speech gestures should satisfy:

(i) The hand or body movement occurs in a close temporal connection with speech;
(ii) The hand or body movement occurs when the speaker is actively engaged with another in communication;
(iii) The hand or body movement is semantically or pragmatically related to the speech content it accompanies;
(iv) The hand or body movement is not a direct functional act on the self, another person, or an object.

Movements that satisfy all four criteria would be classified according to Church et al. (2016) as co-speech gesture.

3.1.3 The relation between speech and gesture

Due to the fact that this current study is concerned with co-speech gestures it is important to first establish the relationship between speech and gesture in general. In this section, literature concerning gesture in general will be discussed.

Speech and gesture seem to be closely entwined. More than 90% of all gestures take place in the presence of speech (McNeill, 1992). The close relation between gesture and speech emerges early in life and is strengthened as children learn language (Cartmill & Goldin-Meadow, 2016). The relationship between speech and gesture has been widely defined in the literature (Alibali, Kita, & Young, 2000; Butterworth & Beattie, 1978; Cartmill & Goldin-Meadow, 2016; Church et al., 2016; de Beer et al., 2020; de Ruiter et al., 2012; Kendon, 1997, 2004; Kita, 2000; Özyürek, 2012; So, Kita, & Goldin-Meadow, 2009; van Nispen, van de Sandt-Koenderman, Sekine, Krahmer, & Rose, 2017; Wagner et al., 2014). It has long been established that gestures are inherently related to the process of speaking. An intriguing question that has evoked many studies is what the exact relation between gesture and speech is. Many answers to this question have been suggested. In this section, the most widely defined hypotheses and ideas concerning this matter will be discussed.

A well-known idea about the relationship between speech and gesture is that gesture reflects what is meant to convey in speech. In line with this view, So et al. (2009) discovered that speakers' gestures were parallel to speech when they were asked to describe scenes to an experimenter. They concluded that gesture goes hand in hand with speech. This view is also defined as the Hand-in-hand hypothesis. Opposed to this hypothesis, the view that gesture and speech have a trade-off relation (known as the trade-off hypothesis) exists. This hypothesis includes that gesture and speech complement each other in transporting information. Furthermore, this trade-off hypothesis in the speech-gesture relationship claims that (a) when gesturing gets harder, speakers will rely relatively more on speech, and (b) when speaking gets harder, speakers will rely relatively more on gestures (de Ruiter et al., 2012). de Ruiter et al. (2012) found that the hand-in-hand hypothesis was more supported by their results than the trade-off hypothesis. They concluded that gesture and speech tend to express similar types of information. Besides these two hypotheses, there are a number of different hypotheses that describe interactions between gesture and speech at different stages of the production process. Numerous researchers suggested that gestures play a direct role in speech production through priming the lexical retrieval of words (Krauss & Hadar, 1999; in Wagner et al., 2014). This idea is also formulated as the lexical-retrieval hypothesis. According to Wagner et al. (2014), this hypothesis is based on different studies that argue that (a) gesturing occurs during hesitation pauses or in pauses before words indicating problems with lexical retrieval (Butterworth & Beattie, 1978; Dittmann & Llewellyn, 1969) and (b) that the inability to gesture can cause verbal disfluencies. However, the implications of the lexical-retrieval hypothesis are often contrasted with the information packaging hypothesis. This hypothesis is based on the idea that gestures are important for the conceptual packaging of information before it is coded into speech (Kita, 2000). This view assumes that gesture plays a role in the conceptualization of information for speaking. Alibali et al. (2000) investigated the Lexical-retrieval and the information packaging hypothesis in 5-year-old children, using two tasks that required comparable lexical access, but different information packaging. Based on their results, they argued that the role of gesture in speech production goes beyond lexical retrieval. They claim that the use of gesture helps to organize spatial information for verbalization, and in that way, gesture plays a part in conceptualizing the message to be verbalized. Another account, the Growth Point theory of McNeill (1992), allows for more interaction between speech and gesture. In this theory, McNeill describes speech and gesture as inseparable parts of the same self-organizing process. According to him a growth point is a package that has both linguistic categorical and imagistic components and that these components are irreducibly. It addresses the concept that there is a specific starting point for a unitary thought.

Another perspective on the relationship between speech and gesture is the existence of gesture and prosody similarities. In the literature, interactions between gesture and prosody have been found and have been termed audiovisual prosody. Wagner et al. (2014) described the idea that gesture and prosody are linked both temporally (by some degree of synchrony) and structurally (by similarity in strength or shape) and that they can reinforce each other. They even concluded that the temporal coordination between prosody and gesture seems stronger than between gesture and speech in general. They discuss several studies which support the link between prosody and gesture. In a study by Parrell, Goldstein, Lee, and Byrd (2014) where speakers completed a motor task of co-speech tapping, it appeared that speakers could not de-synchronize the tapping and the empathic stress. This strong link between speech and prosody also received support by Esteve-Gibert and Prieto (2014). They found a temporal coordination between speech prosody and gesture in the babbling phase, with onsets of the gestures coinciding with onsets of prominent syllables.

A clinical group in which gestural use have been frequently studied are people with aphasia. Aphasia is a language disorder caused by damage to parts of the brain, located in the left hemisphere, that are connected to language (NIDCD, 2017). Speech of people with aphasia occurs mostly in two types: fluent and nonfluent speech with respectively the most common types Wernicke's aphasia and Broca's aphasia (NIDCD, 2017). A study by de Beer et al. (2020) on gesture use in people with aphasia concluded that people with aphasia compensate for their verbal deficiencies by using gestures. They also concluded that theories about the relationship between speech and gesture in people without language impairments are not immediately applicable for people with aphasia. Another study, by van Nispen et al. (2017) which studied the types of gestures produced by people with aphasia suggests as well that a big part of the gestures produced by people with aphasia convey information essential for understanding their communication. Thus, the role of gestures in communication in people with aphasia is rather important. This demonstrates that a change in the process of language production can have an impact on the use of gesture. However, this does not provide information about the role of gesture in patients that have undergone a change of their way of producing speech. In people with aphasia, the cause of the problems with speech is located in the brain (by brain damage) and in people after TL the cause is located in the throat (by removal of the larynx).

The different views in the studies mentioned above differ in how they perceive the relationship between speech and gesture and where in the process of language production that relationship has an effect. What is established, within these views and some other views that left unmentioned, is that there is at least some sort of relation between speech and gesture. It is, however, important to note that causes and effects in gesture and speech production are still not well understood and that the literature is divided on this topic.

3.1.4 Classification of gestures

Across the existing studies of gesture use, there are different ways of categorizing gestures, which leads to different classification systems. They range from a focus on interest in the meaning and function of gestures to a focus on the form of the gesture alone and ignoring the gesture's relation to the verbal utterance (Bressem, Ladewig, & Müller, 2013). The gestural movements of the hands and arms are presumably the most studied gestures. However, some research has also been done on head gestures (Altorfer et al., 2000; Kousidis, Malisz, Wagner, & Schlangen, 2013; McClave, 2000). Many head movements that co-occur with speech seem to have a pattern. Nonetheless, because of their variability and multidimensionality, it is challenging to identify characteristic parameters, which contribute to classifiable patterns of head movements (Altorfer et al., 2000; Kousidis et al., 2013). According to a study by McClave (2000) in which microanalysis of videotaped conversations took place, head gestures have been shown, just as manual gestures, to have semantic, discourse, and interactive functions.

Literature shows that most annotation systems of gestures take into account form as well as function (Wagner et al., 2014). A widely used and described classification is the classification by McNeill (1992). The gesture types within this classification are described by Cartmill and Goldin-Meadow (2016) as types of co-speech gestures. In this classification, McNeill (1992) characterizes and classifies the gestures with respect to their semantic function consisting of the four main following types of gestures:

- *(i)* *Iconic gestures*
- *(ii)* *Metaphoric gestures*
- *(iii)* *Deictic gestures*
- *(iv)* *Beats*

According to McNeill (1992), a gesture is *iconic* if it carries a close relationship to the semantic content of the segments of the accompanied speech and resembles a concrete object, action or event. The gesture displays aspects of the same scene that is presented in the speech. An example of an iconic gesture is the act of waving accompanying the utterance 'He waved at me back'. This example[3] is visualized in Box 1 below:

1) [waving]
'He waved at me back'

Box 1: Example of an iconic gesture. Note. [waving] = waving with the hand

Metaphoric gestures are described by McNeill to be similar to iconic gestures in the way that they are closely related to the semantic speech content. The difference is that metaphoric gestures present an image of an abstract concept. An example of a metaphoric gesture is to gesture the shape of a big object with your hands while uttering 'I got some big ideas' where in 'big' is the abstract concept. This example is visualized in Box 2 below:

2) [big]
'I got some big ideas'

Box 2: Example of a metaphoric gesture. Note. [big] = a gesture that indicates the adjective 'big'.

McNeill describes *deictic* gestures as pointing movements, which are mostly performed with a pointing finger or the hand, whilst any body part can be used, including the head. Deictic gestures do not always have to refer to concrete entities. Often, they refer to a part in the space where the gesture takes place (also known as gesture space). The meaning of the gesture depends then on the referential value of this region. An example of a deictic gesture is pointing to your stomach when at the same time uttering 'When I had surgery here'. In this example 'here' refers to a concrete entity namely the stomach. In Box 3 below, this example is visualized:

3) [_P:stomach]
'When I had surgery here'

Box 3: Example of a deictic gesture. Note. [_P:stomach] = pointing to the stomach

McNeill describes *beats* as movements that do not present an observable meaning. Beats can be identified by their prototypical movements. They have typically (not always) two movement components, they lack a specific gesture space, and are made wherever the hands are located at that time. Beat gestures can be distinguished from the other types by the fact that they carry no semantic content and have in most of the times no referent to refer to. Lucero, Zaharchuk, and Casasanto (2014)

[3] In every example, the upper line reflects the gesture that is made during the utterance and its duration. The second line visualizes the utterance.

even suggested in their study that beat gestures might have an effect on word retrieval because beats are motor actions and not because they are gestures, per se. They state in their results that beat gestures can help speakers produce low-frequency words. An example of a beat gesture accompanying a gesture is visualized below in Box 4:

4)	[hand:beat movements]
	'The music was so loud, it went <u>on and on and on</u>'

Box 4: Example of a beat gesture. Note. [hand:beat movements] = the hand making beat movements

In addition to these four categories, or as McNeill prefers to call it dimensions, he also talks about the following two:

1) *Emblems*
2) *Butterworths*

McNeill describes an *emblem* as a widely known type of gesture that shows cultural specificity. Emblems are not as structured as a language but are part of social communication. Emblems have names or standard paraphrases, are learned as specific symbols, are culturally specific, and can be used as if they were spoken words(McNeill, 1992). Cartmill and Goldin-Meadow (2016) describe emblems not as co-speech gestures because emblems can convey their meanings in the absence of speech. However, in some cases emblems can function as co-speech gestures because they do occur in presence of speech (based on the conditions for a co-speech gesture by Church et al. (2016)) . An example of an emblem is the shrug. A shrug can represent either being indifferent about something or not knowing the answer to a question. A relatively apparent example of an emblem is nodding your head when you mean to say 'yes' (when the nodding is synchronous to 'yes', the emblem functions as a co-speech gesture). This example is visualized in Box 5 below:

5)	[nod. head]
	'Yes, I would like that'

Box 5: Example of an emblem. Note. [nod.head] = nodding with the head

A *Butterworth* is described by McNeill as a gesture that accompanies a speech failure. He named this gesture after Brian Butterworth who studied the use of gestures and argued that a lot of gestures occur in response to speech failures. McNeill states that he does not agree with the view that speech failures are a necessity for the occurrence of gesture but he assumes that gestures that occur as part of an effort to recall or find a word exists. A Butterworth can function as a co-speech gesture when the Butterworth occurs in presence of the speech that it is connected to (based on the conditions for a co-speech gesture by Church et al. (2016)). An example of a Butterworth is the act of hand grasping while trying to recall a word. This example is visualized in Box 6 below:

6) [hand.grasp] *'Ooh, what was her name again? I think I forgot'*

Box 6: Example of a Butterworth. Note. [hand.grasp] = the hand making grasping movements with the fingers

This classification of McNeill, named above, is based on a continuum that he created, named Kendon's continuum, based on the ideas of Adam Kendon, and visualized as followed:

Gesticulation → Language-like-Gestures (or co-speech gestures) → Pantomimes → Emblems → Sign languages

In this continuum he described a *pantomime* as a gesture or sequence of gestures carrying a narrative line without accompanying speech. He described that from left to right 1) the obligatory presence of speech declines, 2) the presence of linguistic properties increases, and 3) characteristic gestures are replaced by socially regulated signs. He states that Kendon's continuum is relevant to sort out gestures of inherently different kinds. They bear different logical and behavioural relations to speech and it is important to take this into account. It is important to note that emblems are displayed as a different category than co-speech gestures. In most of the time an emblem does occur independent of speech. However, as mentioned earlier, an emblem can function as a co-speech gesture if the emblem is connected to the speech it accompanies (see Box 5 for an example).

Later, McNeill (2005) revises Kendon's continuum and argues for a complex of four different continua, each based on analytically different dimensions along which types the gestures in Kendon's continuum can be differentiated. He based them on the relationship to speech, to linguistic properties, to conventions and the character of semiosis (Wagner et al., 2014). These four continua show that the different kind of gestures can be arranged in different kinds of ways on the base of their different logical and behavioural relations to speech.

In addition to the classification of the gestures based on their semantic content, the semantic relation between gesture and speech can also be defined by the degree to which gesture conveys information that is not found in speech. These relations can be seen as functions of the concerned gestures. The following three functions of gestures in relation to speech are widely used and described by Cartmill and Goldin-Meadow (2016):

(i) *Complementary*
(ii) *Supplementary*

(iii) *Disambiguating*

A *complementary* gesture is described by Cartmill and Goldin-meadow as to reinforce the size, shape, movement, path, or location of what is expressed in the speech. An example of a complementary gesture is to express the act of writing when saying 'Then I wrote'. In that way you gesture the same thing that is named in the speech, so the gesture will complement the speech it accompanies. Cartmill and Goldin-Meadow described a *supplementary* gesture as to add information about the size, shape, movements, path, or location that is not expressed in speech. An example of a supplementary gesture is to make a gesture indicating the length of the hair and saying 'When my hair was this long'. In that way the gesture adds information and, therefore, supplements the speech it accompanies. A *disambiguating* gesture is described by Cartmill and Goldin-meadow as to specify the referent of an underspecified speech act. An example of a disambiguating gesture is pointing to a chair in the room saying 'I sat over there'. This sentence is an ambiguous sentence as 'over there' can still be everywhere. With the accompanying gesture the sentence loses its ambiguity.

These three different functions are useful to envision the range of relations that gesture can hold to speech. However, attributing a single gesture-speech relation to a particular communicative act can be problematic (Cartmill & Goldin-Meadow, 2016). It is, therefore, important to note that the three different functions are not mutually exclusive. A gesture can complement or disambiguate speech while at the same time adding information that is not expressed in speech (Cartmill & Goldin-Meadow, 2016). So is the example of the supplementary gesture above. This gesture is a disambiguating gesture at the same time as 'this' is also ambiguous.

In studies in which annotation takes place, the used classification is converted into tiers. The choice of an adequate annotation schema is, however, likely to depend on the characteristics of the concerned study. This involves the research question, research field, the intended type of analysis, the available material, and annotation resources (Wagner et al., 2014)

3.2 Total Laryngectomy

In this section, the surgical procedure named total laryngectomy will be elaborated. First, the implications for this procedure, and its incidence and risk factors (section 3.2.1) will be discussed. Then, more details about the surgery will be provided (section 3.2.2). After that, mental health concerning TL will briefly be discussed (section 3.2.3). Thereafter, different options of voice rehabilitation will be explored (section 3.2.4) and speech outcomes will be discussed (section 3.2.5).

3.2.1 Laryngeal and hypopharyngeal cancer: incidence and risk factors

Total laryngectomy (TL) is a surgical procedure performed in patients with advanced-stage laryngeal or hypopharyngeal cancer. Laryngeal cancer is a disease in which malignant cancer cells form in the tissues of the voice box (larynx) (NCI, 2019). Hypophraryngeal cancer is a uncommon form of throat cancer and develops in the bottom part of the throat (hypopharynx) behind the larynx (ClevelandClinic, 2021). Worldwide, almost 200,000 newly laryngeal cancer cases are diagnosed per year (Hoffmann, 2021). It is more common in men than women, with a ratio of 7:1 (Hoffmann, 2021). According to Hoffmann (2021), the most prominent risk factors associated with laryngeal cancer are smoking tobacco and the consumption of alcohol. The consumption of both seems to have a synergistic effect (Hoffmann, 2021). Also, viral infections, reflux, environmental influences, and genetic factors can play a role. The same risk factors are found in hypopharyngeal cancer but this type of cancer is, with an incidence of about 1/100,000, considerably less common than laryngeal cancer (Hoffmann, 2021)

3.2.2 The surgical procedure

During surgery, the entire larynx and vocal folds are removed, causing the airway to be interrupted. For this reason the surgeon creates a tracheal stoma where the respiration will be performed through (Ceachir et al., 2014). When zooming in on the complications that may arise preoperative, perioperative and postoperative they can be divided into general surgical risks, specific complications, and negative psychosocial consequences (Hoffmann, 2021). The latter will be discussed in the section below.

3.2.3 Psychosocial factors and Quality of Life

Focusing on psychosocial consequences, different views can be found in the literature. According to Vilaseca, Chen, and Backscheider (2006), long-term Quality of Life is not decreased after TL, when measured with general health instruments and compared with healthy individuals. However, impairment in physical scales is found when questionnaires specified to the disease or subscale scores are included. Various studies showed that psychosocial quality of life does decrease dramatically after TL. Keszte et al. (2013) concluded that healthcare professionals should take the mental health of laryngectomized patients more into account during consultations. Babin, Beynier, Le Gall, and Hitier (2009) suggest that there is a significant increase in feelings of solitude after TL. Tang and Sinclair (2015) stated that effective voice rehabilitation is crucial to prevent potential psychosocial consequences. In the section below, this subject will be discussed.

3.2.4 Voice rehabilitation

Patients after TL lose their natural voice and are assigned to voice rehabilitation. It is known that most of the patients after TL have trouble with adjusting to their new form of speech. A study by Lundström and Hammarberg (2011) in which patients after laryngectomy were asked to score the severity of their handicap in speaking, showed that 86% of the speakers perceived a moderate to severe voice handicap. The loss of the natural voice is a limiting factor in social relationships, tending to push individuals into social withdrawal (Tang & Sinclair, 2015). For these reasons, successful treatment of laryngeal cancer cannot be measured by survival rates alone (Tang & Sinclair, 2015). Rapid and effective recovery of voice and speech is, therefore, one of the main concerns of TL post-operative rehabilitation and is crucial to prevent potential psychosocial and economic consequences (Blom, 2000)[4].

Currently, there are three different methods to help restore the voice: esophageal speech, electrolarynx speech and tracheoesophageal speech.

Esophageal speech is produced by insufflation of air into the esophagus, essentially by swallowing air. This method is sometimes chosen because it can restore the voice with minimal surgical intervention (Tang & Sinclair, 2015). However, esophageal speech is more difficult than the other two methods to learn to use (Tang & Sinclair, 2015). Only about 25% - 70% of the TL patients that attempt to learn esophageal speech (following speech therapy) are successful (Chen, Tang, & Chang, 2001). In a more recent study of Neto et al. (2017), even lower success rates between 24% and 32% were reported.

The second method is the use of an electrolarynx. This contains a handheld device that produces vibrations in the oral cavity or pharyngeal mucosa (Tang & Sinclair, 2015). Benefits of using the electrolarynx are the lack of need for further surgical procedures (compared with tracheoesophageal speech) and ease of learning (compared with esophageal speech) (Tang & Sinclair, 2015). Disadvantages of this method include the mechanical sound of the produced voice, which causes much greater patient-perceived vocal handicap compared with tracheoesophageal speech. (Clements, Rassekh, Seikaly, Hokanson, & Calhoun, 1997; Koike, Kobayashi, Hirose, & Hara, 2002).

The last method is tracheoesophageal speech and is considered as the golden standard for voice rehabilitation after TL (Tang & Sinclair, 2015). To perform tracheoesophageal speech, a puncture is done in the back of the wall of the trachea and a voice prosthesis is placed. This puncture, also referred to as tracheoesophageal puncture (TEP), allows a patient to channel air from the lungs if he or she occludes the stoma in the neck. The air goes from the lungs through the puncture site and eventually all way up through the mouth (Tang & Sinclair, 2015). The airflow brings the pharyngeal esophageal segment (PE-segment) in vibration, which allows the patient to produce a rough and breathy sound. On the stoma in the neck, a heat moisture exchanger (HME) filter is placed (NHS, 2018). This device aids the moistening and filtering of the breath (NHS, 2018). There are various HME filters available. Most of these filters have the disadvantage of occupying one hand during speaking and of emphasizing the patient's disability, but there also exist HME-filters that do function without hands (Hilgers & Ackerstaff, 2006). The TEP can be performed at the time of the TL (primary puncture) or later afterwards (secondary puncture) (Brook & Goodman, 2020). Advantages of placing primary TEP are no

[4] Only the abstract was available. This study was cited in Tang and Sinclair (2015).

need for an additional surgical procedure and the faster start with speech rehabilitation after TL (Brook & Goodman, 2020). However, primary TEP is associated with increased risks after the TL like fistula formation, local infection, stomal stenosis (=narrowing), and leakage at the puncture site (Neto et al., 2017). The fact that Tang and Sinclair (2015) consider tracheoesophageal speech as the golden standard does need some nuance. A disadvantage of tracheoesophageal speech is that it requires constant care and maintenance (Brook & Goodman, 2020). The TEP needs daily cleaning and caring and the prosthesis needs to be replaced at regular intervals (Brook & Goodman, 2020). Not all patients have access to this constant care and tracheoesophageal speech can for that reason not in all situations be considered as the golden standard. However, when the patient has access to good healthcare, research (Tang & Sinclair, 2015; van Sluis et al., 2018) has shown that tracheoesophageal speech is superior to both the electrolarynx and esophageal speech. In their study, van Sluis et al. (2018), concluded that tracheoesophageal speech seems to be most pleasant and comprehensible in perceptual evaluations followed by esophageal speech. Electrolarynx speech was found to be the least pleasant and comprehensible speech method. However, despite the good prognosis of tracheoesophageal speech, the access to a speech therapist in the preoperative, perioperative, and postoperative settings is essential for proper tracheoesophageal speech management (Tang & Sinclair, 2015). Results considering long-term use in the review of Ramírez et al. (2001) reviewing 350 patients show successful results of TEP in 70% of the patients included. They concluded that long-term maintenance of the TEP in perfect use is possible.

3.2.5 Speech outcomes of tracheoesophageal speech

As mentioned above, tracheoesophageal speech is considered, when having access to good healthcare, as the best method for speech rehabilitation. The success rate of tracheoesophageal speech following TL varies between 70-95%. (Tusaliu, Tita, Tuas, Ranete, & Goanta, 2020). Factors such as size and location of the tumour, the extent of remaining pharyngeal mucosa after resection, the presence of underlying health conditions, and patient's ability to individually operate and properly maintain the prosthesis may influence eventually the successful voice restoration (Tusaliu et al., 2020). According to the study of van Sluis et al. (2018), tracheoesophageal speech is perceptually rated with a significantly better voice quality and intelligibility than esophageal speech and electrolarynx speech. Speakers who use tracheoesophageal speech can say about eight words per breath, or four words fewer than normal healthy speakers and they prolong phonation less long than normal speakers with an average of about sixteen seconds (Pindzola & Cain, 1989). On top of that, the phonation in tracheoesophageal speech seems to be less consistent. This can be physiologically explained by the fact that turbulences are more important at the PE-segment for tracheoesophageal speakers than at the glottis for healthy speakers (Drugman, Rijckaert, Janssens, & Remacle, 2015). Some tracheoesophageal speakers have trouble in regulating the airflow originated from the trachea which causes the airflow to go completely through the tracheoesophageal prosthesis when speaking. As a consequence of that, a certain airflow comes out of the tracheostoma which not only leads to less loud speech, but also to the impression of a more noisy signal, especially in the high frequencies (Drugman et al., 2015). According to the study of van Sluis et al. (2018), tracheoesophageal speakers do have significantly better outcomes for fundamental frequency, maximum phonation time, and intensity compared to electrolarynx speakers.

4. The present study

4.1 Rationale & research questions

As discussed in the theoretical framework above, gesture is an important part of the non-verbal communication, and in the literature, it is a widely defined and described subject. There exist many different theories about the relationship between speech and gesture. Some studies state that they are parallel to each other (de Ruiter et al., 2012; So et al., 2009) and others state that the gesture can affect the process of speech (Alibali et al., 2000; Butterworth & Beattie, 1978; Dittmann & Llewellyn, 1969). When it comes to research about communication after TL, little is known about this subject. There has been a considerable amount of research on acoustic analyses and voice restoration after TL in the literature (see also section 3.2.4). Nonetheless, to our knowledge, no research has yet been done on the use of co-speech gestures in people after a TL. As described in section 3.1.3, speech and gesture are entangled and various different hypotheses about the relationship between speech and gesture can be found in the literature. According to McNeill (1992) more than 90% of all gestures take place in the presence of speech. Gesticulation seems, therefore, to play an important role in natural communication. As discussed in section 3.2.5, TL patients can produce fewer words than healthy people produce and have a phonation that is shorter than healthy people have. Consequently, the speech of TL patients is less loud and more noisy. The possible effects of this affected speech on the use of co-speech gestures are still unexamined.

In summary, since natural speech is no longer possible in patients after TL and speech and gesture seem to be interrelated, and this domain has never been studied, it is interesting to investigate whether patients after TL use co-speech gestures. And if so, how they use it. The current study is considered as an exploratory study and strives to eventually receive an answer on the latter. The research question in this pilot study is therefore formulated as:

- How are co-speech gestures used by patients after total laryngectomy using tracheoesophageal speech?

The following sub-questions have been formulated:

- What types of co-speech gestures do patients after total laryngectomy use?

- What is the function of co-speech gestures usage by patients after total laryngectomy?

In order to get an impression of how co-speech gestures are used in healthy persons the following question has also been formulated:

- How are co-speech gestures used by healthy controls?

The importance of including this last question lies in being able to test (a part of) the used method in a healthy population. The aim of the study is to investigate how patients after TL use co-speech gestures. However, including healthy control participants is important to explore how co-speech gestures are used in healthy subjects when using (a part of) the same method. Nevertheless, it is important to know how healthy people use co-speech gestures, viewed, according to this particular method, in order to know how much value can be given to the findings of the gesture usage of TL patients.

In the following sections, the used methods will be described in detail, the results will be critically evaluated and eventually a conclusion is drawn based on the results and the earlier discussed literature.

5. Method

5.1 Materials

5.1.1 Interviews of TL patients

For this study, recordings of interviews of eight laryngectomized patients that were included in a qualitative descriptive study focusing on women's experiences following TL by (van Sluis, Kornman, van der Molen, van den Brekel, & Yaron, 2020) are used. The re-use of this data has been approved by the institutional review board (IRB) of AVL (code: IRBd20-367). The interviews were conducted in the participants' homes and include conversations between the concerning patient and a speech therapist. During the interviews, questions are asked by the speech therapist. These questions concerned subjects as the diagnosis, the experiences, and the present life of the concerning patient. The language production of the patients is, therefore, semi-spontaneous. Each interview lasted about 90 minutes. The angle from which the interviews are recorded differed per subject. In any case, the head and the arms were visible. In total, five minutes of each interview were used for annotation. This amounts to a total of 40 minutes (5 minutes x 8 patients) that have been annotated. These five minutes are five separate minutes throughout the interview that have been considered to contain a sufficient amount of gestures (+/- 10) judged by watching certain parts of the recording. In addition, ten randomly chosen samples have been observed during time sampling. To determine these ten samples the Random Number generator by Google has been used. For a detailed description of how to use this method, look into section 5.3 and Appendix A.

For the annotation the program ELAN (2020) was used. Two tiers were created based on section 3.1.4:

(i) Gesture type (I/M/D/Be/E/Bu)

(ii) Gesture function (C/S/D/O) (-/+/?)

The tier 'Gesture type' is based on the classification by McNeill (1992) and can have the value of *Iconic (I), Metaphoric (M), Deictic (D), Beats (Be), Emblems (E),* and *Butterworths (Bu)*. The tier 'Gesture function' is based on classification by Cartmill and Goldin-Meadow (2016) and can have the value of *Complementary (C), Supplementary (S), Disambiguating (D),* and *Other (O)* where in *Other* represents the gestures that seem to reflect a different function than C, S, or D. This category is added to ensure that no data was lost during annotation. It is, however, important to note that the three different functions are not mutually exclusive. A gesture can complement or disambiguate speech while at the same time adding information that is not expressed in speech

The stated criteria that a co-speech gesture should meet, as discussed in section 3.1.2, are used in this present study, but with some nuance. Church et al. (2016) stated that a co-speech gesture must occur in a close temporal connection with the speech. In this present study, gestures that occurred within 3 seconds before or within 3 seconds after the words the gestures refer to are included and counted as co-speech gestures as long as they are connected to the surrounding speech.

The criteria for a co-speech gesture of Church et al. (2016) are, therefore, adjusted to the following form:

(i) The hand or body movement occurs in a close temporal connection with the **surrounding** speech;

(ii) The hand or body movement occurs when the speaker is actively engaged with another in communication;

(iii) The hand or body movement is semantically or pragmatically related to the speech content it accompanies or **surrounds**;

(iv) The hand or body movement is not a direct functional act on the self, another person, or an object.

For this reason, different timing places of the gestures have been taken into account. The gesture can be used *simultaneous* (=) to the word/phrase it refers to, or *before* (-) or *after* (+) the word/phrase it refers to. These timing places can provide useful information about the use of co-speech gestures. When it is unclear if the gesture refers to a word/phrase in the nearby speech or there is no referring word/phrase in the nearby speech the category *other* (?) is used.

5.1.2 Interviews of healthy controls

To get an impression of co-speech gesture use in the healthy participants, interviews of 4 participants in a podcast have been used. This podcast, created by Kaj Gorgels, named 'effe relativeren' (Gorgels, 2020a, 2020b, 2020c, 2021) includes conversations between Kaj and his guests. This podcast is chosen because it captures a natural setting in which the interviews have been conducted. A podcast is deliberately chosen over a talk show in order to minimize the influence of side factors, for example media training. Media training could affect the spontaneity of movements and could have an effect on the use of gestures. The podcast is recorded in a way that both Kaj and his guest were on screen. The guests wore headphones and spook through a microphone (see Figure 1). They also had complete freedom of moment. The angle from which the interviews are recorded differed between a zoomed-out shot (see Figure 1) and a zoomed-in shot (see Figure 2) but during every interview, the hands were always visible. In every interview, Kaj asked his guests about topics that play a role in the guest's life. This can include personal life, work, goals, etcetera. The language production of the participants is, therefore, semi-spontaneous. Throughout every interview, ten randomly chosen samples are observed per participant in exactly the same way as in the TL patients. This equates to a total of 40 time samples (10 x 4 patients). However, within this group, only the gesture types are observed. To determine these ten time samples in every interview, the Random Number generator by Google has been used. For a detailed description of how to use this method look into section 3.3 and Appendix A.

Figure 1: screenshot of a zoomed-in shot of one of the interviews from the podcast 'Effe relativeren' by Kaj Gorgels. His guest is making a beat gesture while talking.

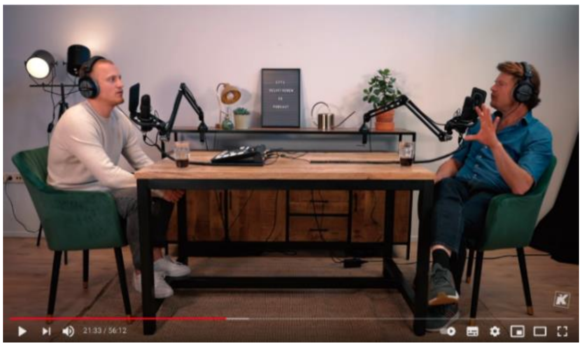

Figure 2: screenshot of a zoomed-out shot of the interviews from the podcast 'Effe relativeren' by Kaj Gorgels (seated on the left). His guest (seated on the right) is making a beat gesture while talking.

5.2 Participants

5.2.1 Clinical group

Eight Dutch-speaking women were included in this study. These women are all TL patients and were included in a qualitative descriptive study focusing on women's experiences following TL by van Sluis et al. (2020). The interviews used in this study were recorded for the purpose of the mentioned study. The inclusion criteria were: female; the TL was at least one year ago; and they did not have recurrent disease. The demographics are visible in Table 1 below. The mean age at the time of the TL was 54.5 years (SD = 14.18). The mean age at the time of the interview was 68.25 (SD = 5.92). The mean time after TL at the time of the interview was 13.75 years (SD = 10.54). Their educational attainment was diverse and ranged from secondary education to university. All participants had a voice prosthesis and a stoma with an HME-filter that requires assistance of one hand and used tracheoesophageal speech. Seven participants were able to speak in fluent sentences; one participant (patient 2) was limited in her verbal communication and had a poor intelligibility according to van Sluis et al. (2020). From now on, this group is referred to as 'TL patients'.

Table 1: Table showing the demographics of the included TL patients.

Patient	*Gender*	*Indication TL*	*Age at TL (years)*	*Age at time of interview (years)*	*Type of speech*	*Intelligibility*	*Highest education*
1	F	Salvage	67	68	TES	Good	Secondary education
2	F	Dysfunctional larynx	71	74	TES	Poor	University
3	F	Salvage	54	67	TES	Good	Higher vocational education
4	F	Primary	47	65	TES	Good	Higher vocational education
5	F	Dysfunctional larynx	69	74	TES	Good	Vocational education
6	F	Dysfunctional larynx	52	76	TES	Good	Lower education
7	F	Salvage	29	60	TES	Good	Secondary education
8	F	Primary	47	62	TES	Good	Vocational education

Note. F = Female; TL = Total laryngectomy; TES = Tracheoesophageal speech

5.2.2 Healthy controls

A control group was included in the current study. Within this control group, four participants (2 men, 2 women) were included. The demographics are visible in Table 2 below. The age at the time of the interview has a range of 24-49 years (Mean=37; SD=13.34). Three participants have completed higher vocational education and one participant secondary education. All included participants speak Dutch as their native language. They are all public figures in the Netherlands and sometimes appear there on television. They had no condition that could prevent the use of their natural voice and had a clear intelligibility. From now on, this group is referred to as 'healthy controls'.

Table 2: Table showing the demographics of the included healthy controls.

Participant	Gender	Age at time of interview	Intelligibility	Highest education
1	M	49	Good	Secondary education
2	M	48	Good	Higher vocational education
3	F	27	Good	Higher vocational education
4	F	24	Good	Higher vocational education

Note. M= Male; F= Female

5.3 Procedure

In this section, the procedure will be described. This procedure was performed by one researcher (FH) and consisted of three different parts. These three parts included the annotation (section 5.3.1), the time sampling (section 5.3.2) and the analysis (section 5.3.3). Figure 3 and Figure 4 show the procedure respectively of the TL patients and the healthy controls.

5.3.1 Annotation procedure

First, the annotation of the interviews of the TL patients has been performed. As described in section 5.1, five separate minutes throughout every interview have been annotated. First, the right minutes for the annotation were chosen. The first minute was excluded in every interview to give the patient time to settle in. The decision for the right minutes was based on whether it was the patient's turn and if gesticulation took place. This judgement was purely based on observation (+/- 10 gestures/min). Furthermore, these five minutes were ideally chosen and were not arbitrary. The annotation started with the first minute of the first patient moving on to the first minute of the second patient and eventually ending with the fifth minute of the last patient. This order of working was chosen to prevent unnoticed slight changes in working style to have an influence on the judgement of particular patients.

5.3.2 Time sampling

After the annotation of the total duration of five minutes per patient (a total of 40 minutes) was finished, ten randomly chosen samples throughout the interviews were included to see whether gestures took place throughout the whole interview and in which quantity. Unlike the deliberately chosen minutes for the annotation, these samples are arbitrary and are, therefore, more representative of the gesture use throughout the interviews. To generate the random samples the Random Number Generator by Google was used. This generator generates random numbers which are converted by the researcher (FH) to points of time. In Appendix A, there is an extensive description of how the random generated numbers from the generator are converted to specific times in the video. From every random generated point of time, the following 1.5 seconds was checked on gesture use. If the start of the gesture took place within these 1.5 seconds (the sample), it is included.

In case of the healthy controls, no annotation has been performed. Only the time sampling has been done on this group. This choice was made due to later integration of this group and lack of time. However, to include this time sampling in the healthy control group, provides data that can be compared to the time sampling of the TL patients. The time sampling was done in the same way as in the TL patients but with 40 samples instead of 80. This choice is also made due to later integration of this group and lack of time. For a step-by-step detailed description of the procedure of the annotation and time sampling look into the Protocol for Annotating gestures in Appendix A.

5.3.3 Analysis

After the annotation of the interviews of the TL patients was finished, the data is converted to Excel and in SPSS. Subsequently, the frequencies, means, and standard deviations have been obtained of the used gesture types, functions, and timing places. The data of the time sampling is also converted to Excel and in SPSS and the frequencies, means, standard deviations of the used gesture types of both groups and gesture functions of the TL patients have been obtained. The results are displayed visually in graphs and descriptive statistics took place.

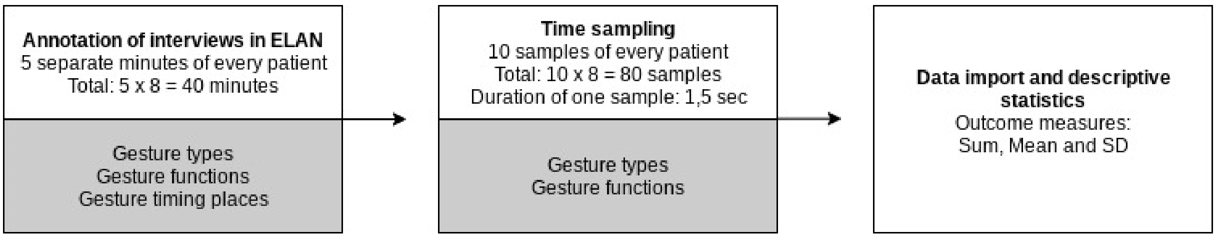

Figure 3: Figure showing the chronological order of the procedure in TL patients. Note. Sec = seconds; SD = standard deviation

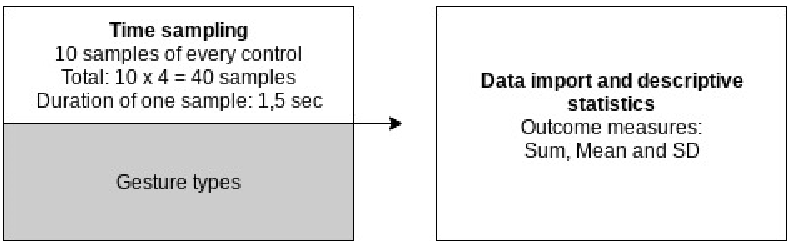

Figure 4: Figure showing the chronological order of the procedure in healthy controls. Note. Sec = seconds; SD = standard deviation

6. Results

In this section, the results will be outlined and visualized. In Appendix B, the complete results of the time sampling of each individual patient of both groups are displayed. The individual results of the annotation of the TL patients with the frequencies, means and standard deviations, can be found in Table 3 and 4. In Table 3, the individual results of the observed co-speech gestures can be found. In Table 4, the individual results of the gestures that occurred without speech can be found.

6.1 Annotation of the interviews

6.1.1 General measure outcomes

To analyze the dataset and to be able to quantify the outcomes, different measures have been used. In total, all the included patients taken together have used a total of 609 co-speech gestures. The total mean of the co-speech gestures is the use of 76.13 co-speech gestures per patient (SD=14.42). This equates the mean of 15.23 co-speech gestures used per minute per patient. This means that, on average, a co-speech gesture is used by the TL patients every 3.94 seconds.

In addition, 60 gestures occurred without surrounding speech referring to (and for this reason have not be classified as co-speech gestures). These gestures and their frequencies are visible in Table 4. These gestures occurred only in the gesture types 'iconic', 'deictic', and 'emblems'. The gestures only had the gesture functions 'supplementary' or 'other' and only occurred with the timing place 'other'. Of the gesture type 'emblems', 20 gestures consist of nodding of the head and 5 consist of shaking of the head.

Table 3: Table showing the total frequencies, means and SD's of all co-speech gestures used by TL patients.

Patient		1	2	3	4	5	6	7	8	**Total**	Mean	SD
Gesture type	Iconic	22	14	12	8	25	16	23	16	**136**	17	5,88
	Metaphoric	0	0	4	1	0	0	0	1	**6**	0,75	1,39
	Deictic	10	16	11	23	8	14	13	10	**105**	13,13	4,73
	Beats	20	27	44	42	33	24	28	54	**272**	34	11,63
	Emblems	10	3	7	10	12	4	23	17	**86**	10,75	6,67
	Butterworths	1	0	0	1	2	0	0	0	**4**	0,5	0,76
	Total	**63**	**60**	**78**	**85**	**80**	**58**	**87**	**98**	**609**	**76,13**	**14,42**
Gesture function	Complementary	33	22	27	28	35	18	34	37	**234**	29,25	6,71
	Supplementary	8	9	1	13	8	12	13	6	**70**	8,75	4,06
	Disambiguating	4	5	10	8	3	7	4	3	**44**	5,5	2,56
	Other	22	29	50	44	37	28	40	55	**305**	38,13	11,41
Timing place	Simultaneous (=)	26	26	28	33	37	25	42	30	**247**	30,88	6,06
	Before (-)	12	3	1	3	6	3	3	12	**43**	5,38	4,31
	After (+)	2	0	1	1	0	1	0	1	**6**	0,75	0,71
	Other (?)	23	31	48	48	37	29	42	55	**313**	39,12	11.03

Note. SD = standard deviation

Table 4: Table showing the total frequencies, means and SD's of all gestures that occurred without accompanying speech used by TL patients.

Patient		1	2	3	4	5	6	7	8	Total	Mean	SD
Gesture type	Iconic	1	4	5	0	1	1	3	1	**16**	2	1,77
	Metaphoric	0	0	0	0	0	0	0	0	**0**	0	0
	Deictic	1	3	2	1	0	0	0	0	**7**	0,88	1,13
	Beats	0	0	0	0	0	0	0	0	**0**	0	0
	Emblems	2	8	5	2	2	2	11	5	**37**	4,63	3,46
	Butterworths	0	0	0	0	0	0	0	0	**0**	0	0
	***Total*:**	**4**	**15**	**12**	**3**	**3**	**3**	**14**	**6**	**60**	**7,50**	**5,26**
Gesture function	Complementary	0	0	0	0	0	0	0	0	**0**	0	0
	Supplementary	2	3	7	1	2	1	4	1	**21**	2,63	2,07
	Disambiguating	0	0	0	0	0	0	0	0	**0**	0	0
	Other	2	12	5	2	1	2	10	5	**39**	4,88	4,09
Timing place	Simultaneous (=)	0	0	0	0	0	0	0	0	**0**	0	0
	Before (-)	0	0	0	0	0	0	0	0	**0**	0	0
	After (+)	0	0	0	0	0	0	0	0	**0**	0	0
	Other (?)	4	15	12	3	3	3	14	6	**60**	7,5	5,26

Note. SD= standard deviation

6.1.2 Gesture type

Looking at the results of the different gesture types (I/M/D/Be/E/Bu) based on the annotation, the type 'beats' was used 45% of the time (N=272), 'iconic' was used 22% of the time (N=136), 'deictic' was used 17% of the time (N=105) and 'emblems' were used 14% of the time (N=86). Further, 'metaphoric' gesture types were used 1% of the time (N=6) and 'Butterworths' were used 1% of the time (N=4). For a visualization of the ratio of the obtained outcomes, see Figure 5.

The different types of gestures occurred among the patients in different forms. To give an impression of how the different types of gestures appeared, quotes of different patients are visualized in Box 7 - 12 below.

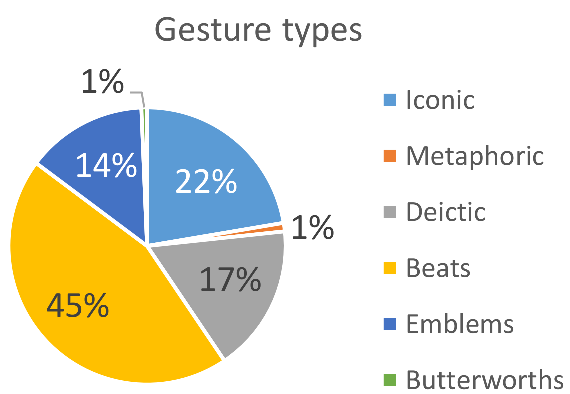

Figure 5: Pie chart showing the ratio in percentages of the use of different gesture types within the annotation. Note. The percentages in this figure are rounded. See table 3 for the exact frequencies.

7) **Iconic**

INT: [DUTCH] *'Wat deed u in de tijd dat u niet kon praten?'*

[ENG] *'What did you do during the time you could not talk?'*

[Writing gesture]

PAT: [DUTCH] *'Schrijven'*

[ENG] *'Writing'*

Box 7: Example of how an iconic gesture occurred. Note. INT = Interviewer; [ENG] = English; PAT = Patient

8) **Metaphoric**

[Holds hand by heart]

PAT: [DUTCH] *'…dan ben je bezig met medische zaken, niet met gevoelige…'*

[ENG] *'…then you are busy with medical matters, not sensitive ones…'*

Box 8: Example of how a metaphoric gesture occurred. Note. PAT = Patient; [ENG] = English

9) **Deictic**

[Points:neck]

PAT: [DUTCH] *'…, dat ik hier minder slijm heb'*

[ENG] *'…, that I have less mucus here'*

Box 9: Example of how a deictic gesture occurred. Note. [Points:neck] = Points to neck; PAT = Patient; [ENG] = English

10) **Beat**

[Moves hand frtl]

PAT: [DUTCH] *'…en een mannenstem is al zwaarder'*

[ENG] *'…and a male's voice is already deeper'*

Box 10: Example of how a beat gesture occurred. Note. Frtl = from left to right; PAT = patient; [ENG] = English

11) **Emblem**

INT: [DUTCH] *'…dat je een heel nieuw stukje van jezelf hebt ontdekt eigenlijk?'*

[ENG] *'…that you have, in fact, discovered a whole new part of yourself?'*

[Nod.head]

PAT: [DUTCH] *'Ja, ja'*

[ENG] *'yes, yes'*

Box 11: Example of how an emblem occurred. Note. INT= Interviewer; [ENG] = English, [nod.head] = nodding with the head; PAT= patient; [ENG] = English

12) **Butterworth**
[mov;fing]
PAT: [DUTCH] *'Toen kwam ik twee, drie dagen erna bij eeeh dokter [naam dokter]'*
[ENG] *'Then, two, three days later I went to see eeeh doctor [name of doctor]'*

Box 12: Example of how a Butterworth occurred. Note. [mov:fing] = moving fingers; PAT = patient; [ENG] = English

6.1.3 Gesture function

The different functions (C/S/D/O) assigned to the gestures are visible in Figure 6. In total, 653 gesture functions have been used. 44 gestures occurred with both the function 'supplementary' and the function 'disambiguating'. As seen in this figure, the function 'other' occurs 46% of the time (N=305), the function 'complementary' 36% of the time (N=234), function 'supplementary' in 11% of the time (N=70) and function 'Deictic' 7% of the time (N=44). An example of how a complementary gesture occurred throughout the patients is visible in box 7 above. Box 9 shows a gesture with as well a supplementary function as a disambiguating function as the gesture accompanying 'here' adds new information and specifies the referent. The function 'other' is annotated together with a beat gesture in most of the cases (N=272).

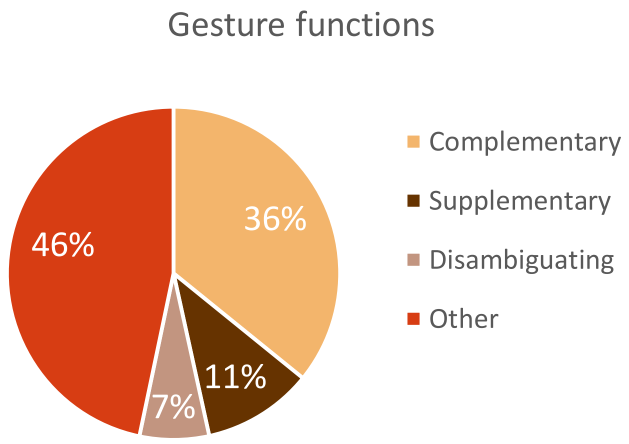

Figure 6: Pie chart showing the ratio in percentages of the use of different gesture functions within the annotation. Note. The percentages in this figure are rounded. See table 3 for the exact frequencies.

6.1.4 Gesture timing

The different timing places (-/+/=/?) of the used gestures are visible in Figure 7. As seen in this figure, the timing place 'other' referred to with '?' occurred 51% of the time (N=313), timing place 'simultaneous' referred to with '=' occurred 41% of the time (N=247), timing place 'before' referred to with '-' occurred 7% of the time (N=43) and timing place 'after' referred to with '+' occurred 1% of the time (N=6). The timing place 'before' (-) is visible in Box 7 above, as the gesture occurs before the utterance. The timing place 'simultaneous' (=) is visible in Box 8 – 12 as these lines show gestures that are timed together with the accompanying utterance. In Box 13 below, an utterance of how the timing places 'after' (+) is seen in the included patients have been set out.

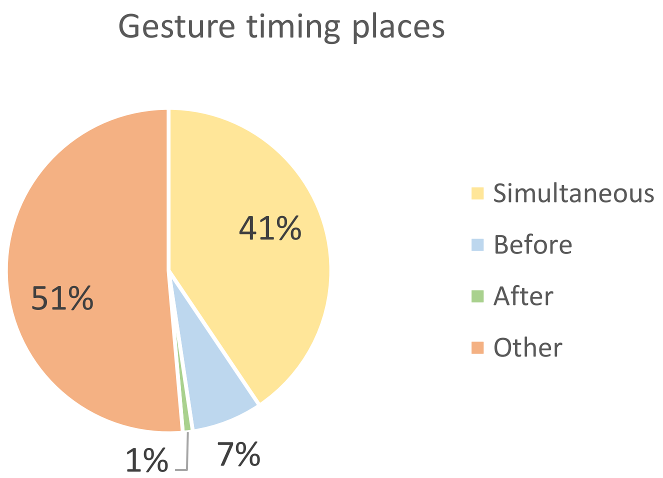

Figure 7: Pie chart showing the ratio in percentages of the use of different gesture timing places within the annotation. Note. The percentages in this figure are rounded. See table 3 for the exact frequencies

13) **After (+)** [finger:nose] PAT: [DUTCH] *'… je kan niet meer snuiten'* [ENG] '… you can not sneeze anymore'

Box 13: Example of how the timing place after (+) occurred. Note. [finger:nose] = finger on one side of the nose; PAT = patient, [ENG] = English

6.2 Time samples

6.2.1 General measure outcomes

In total, 80 time samples (10 x 8 interviews) of the TL patients have been taken into observation. The individual results of the time sampling of the TL patients and healthy controls are visible in Appendix B in respectively Table B1 and B2. Of the 80 time samples, co-speech gestures have been used at 46 times. This amounts to a percentage of 57.5% of all the included time samples. Throughout the interviews of the healthy controls, 40 time samples (10 x 4 interviews) have been observed. Of these 40 samples, co-speech gestures have been used at 22 times. This amounts to a percentage of 55% of all the included time samples.

6.2.2 Gesture type

<u>TL patients</u>

The different gesture types seen within the time sampling in the TL patients are visible in Figure 8. As seen in this figure, the gesture type 'beats' occurred 41% of the time (N=19), 'emblems' occurred 21% of the time (N=10), and 'iconic' and 'deictic' occurred both 19% of the time (respectively N=9 and N=8). The types 'metaphoric' and 'Butterworths' did not occur.

The differences in ratio percentages of use of the different gesture types in the TL patients between the annotation and the time sampling are visualized in Figure 10.

Healthy controls

The different gesture types seen within the time sampling in the control group are visible in Figure 9. As seen in this figure, the gesture type 'beats' occurred 82% of the time (N=18), and 'emblems' (N=2) and 'iconic' (N=2) occurred both 9% of the time. The other types 'deictic', 'metaphoric' and 'Butterworths' did not occur.

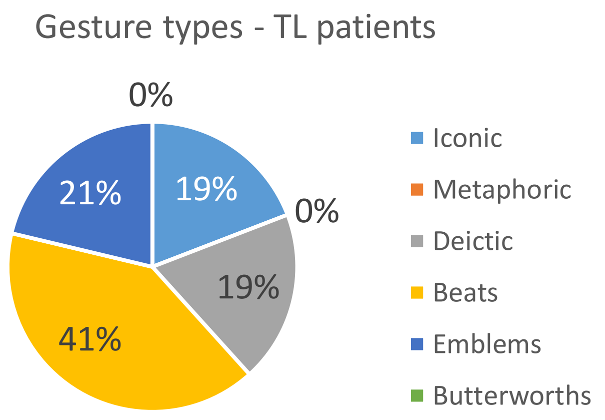

Figure 8: Pie chart showing the ratio in percentages of the use of different gesture types seen within the time sampling in the clinical group. Note. The percentages in this figure are rounded. See table B1 in Appendix B for the exact frequencies

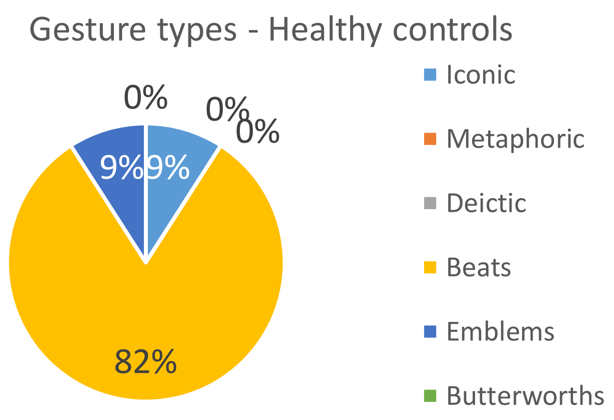

Figure 9: Pie chart showing the ratio in percentages of the use of different gesture types seen within the time sampling in the control group. Note. The percentages in this figure are rounded. See table B2 in Appendix B for the exact frequencies.

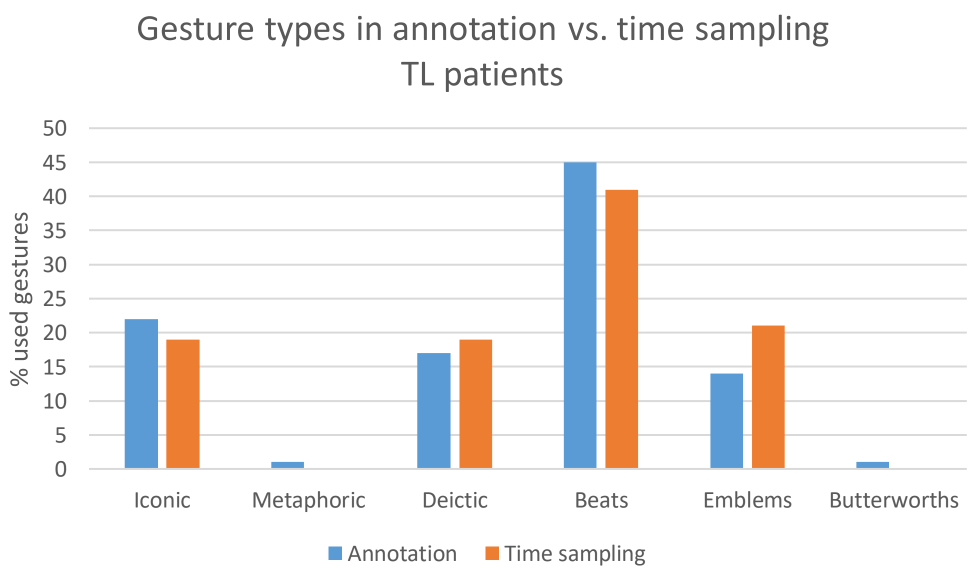

Figure 10: Bar chart showing the differences in ratio percentages of the use of different gesture types within the annotation compared to the time sampling of the TL patients

6.2.3 Gesture function

The gesture functions that occurred within the time sampling of the TL patients are visible in Figure 11. In total, 49 gesture functions have been used. 3 gestures occurred with both the function 'supplementary' as the function 'disambiguating'. As seen in this figure, 'other' occurs 47% of the time (N=23), 'complementary' occurs 35% of the time (N=17), 'supplementary' occurs 12% of the time (N=6), and 'disambiguating' occurs 6% of the time (N=3). The differences in ratio percentages of use of the different gesture functions in the TL patients between the annotation and the time sampling are visualized in Figure 12.

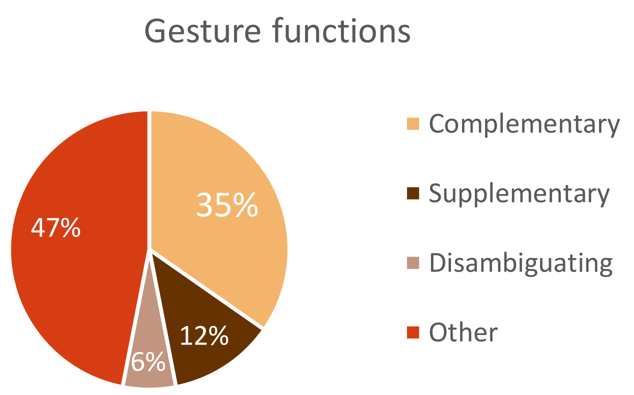

Figure 11: Pie chart showing the ratio in percentages of the use of different gesture functions seen within the time samples in the TL patients. Note. The frequencies in this figure are rounded. See table B1 in Appendix B for the exact frequencies

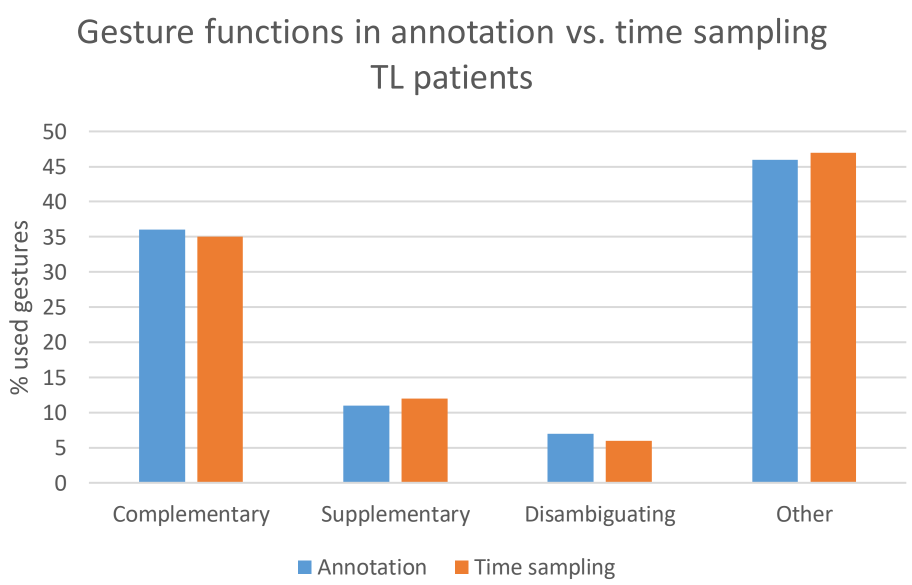

Figure 12: Bar chart showing the differences in ratio percentages of the use of different gesture functions within the annotation compared to the time sampling of the TL patients.

7. Discussion

The current study was done to gain insight in the use of co-speech gestures in patients after TL. Because this domain was still unexamined, this study is considered as a pilot study and, therefore, exploratory. The research question was, for this reason, broadly formulated:

- How are co-speech gestures used by patients after total laryngectomy using tracheoesophageal speech?

In order to answer this question, the following sub-questions have been formulated:

- What types of co-speech gestures do patients after total laryngectomy use?
- What is the function of co-speech gestures usage by patients after total laryngectomy?

And to be able to compare the outcomes of the TL group with a healthy control group the following question is added:

- How are co-speech gestures used by healthy controls?

To answer these questions, interviews of eight TL patients have been annotated on gesture type, gesture function and gesture timing place with use of the program ELAN. To be able to classify the gesture types and functions, classifications of McNeill (1992) and Cartmill and Goldin-Meadow (2016) have been used. In addition, time sampling has been performed to see how often the types and functions appeared throughout the interviews. This sampling is also done on a group of four healthy controls for the gesture types. Eventually the frequencies, means and SD's have been interpreted and visualized in graphs. Since this is a pilot study, no hypotheses were formulated and, therefore, no hypotheses were tested. The current study concerns an exploratory pilot study and the statistics were descriptive. As no statistical tests have been performed, the interpretation of the results remains speculative. However, the results will be discussed and related, if possible, to the literature that is highlighted in the theoretical framework (section 3).

7.1 Gesture use

The results show that 609 co-speech gestures were used by the eight included TL patients taken together. This amounts to an average of 15.23 co-speech gestures per minute per patient. This means that, on average, a co-speech gesture is used every 3.94 seconds by a TL patient. As mentioned in the theoretical framework, results of a study by Cohen (1977), show that healthy participants used 5.61 gestures per 90 seconds which means that a gesture was used by the healthy participants every 16.04 seconds. When this result is compared to the result of this present study, TL patients included in this study seem to make more co-speech gestures than the healthy participants included in Cohen's study. However, Cohen focused in his study only on gestures of the hand where in this study all gestures of different body parts are included and Cohen's research did not investigate co-speech gestures exclusively. Furthermore, the students included in his study were at a different age (estimated around 21-23) and were all male. The comparison is, therefore, not proportional. Furthermore, the difference in number of gestures used, is not statistically tested.

In addition to the 609 co-speech gestures that have been used, 60 gestures that occurred separately from speech are seen in the TL patients. These gestures were not classified as co-speech gestures since they did not meet the first and third criterion that a co-speech gesture should met, discussed in section 3.1.2 and adjusted for this study in section 3.1.1:

(i) The hand or body movement occurs in a close temporal connection with the **surrounding** speech;

(iii) The hand or body movement is semantically or pragmatically related to the speech content it accompanies or **surrounds**

Since these gestures did not have a close temporal connection with the surrounding speech, they could not be semantically or pragmatically related to it.

The 40 minutes that have been annotated in the present study have been selected and were ideally chosen. For this last reason time sampling has been added to this study. Of the 80 samples that have been observed in the TL patients, co-speech gestures have been used at 46 times. This amounts to a percentage of 57.5% of all the included samples. Throughout the interviews of the healthy controls, 40 samples have been observed. Of these 40 samples, co-speech gestures have been used at 22 times. This amounts to a percentage of 55% of all the included samples. This difference in percentage seems to be a small difference. However, no judgement can be made about this difference, because no statistical tests can be performed due to the absence of a hypothesis and the small study population.

The first sub question concerned the types of co-speech gestures used in TL patients. When focusing on the ratio in which the different gesture types have been used in the TL patients, noted during the annotation, it is clear that the gesture type 'beats' is used with the highest frequency (N=272) in 45% of the time. However, as seen in Table 3, the gesture type 'beats' also occurred with the highest SD (SD=11.63) of the different gesture types. This means that the total number of used beat gestures by the individual TL patients deviates an average of 11.63 gestures from the mean of 34 beat gestures. Thus, the total use of beat gestures differed the most of all gesture types between the patients. It is in this case important to note that indicating the beginning and ending of a beat gesture was at some moments complex. Beat gestures are very rhythmic and have a less clear beginning and ending, because one beat can merge into another without this being noticeable. This may have created some margin in the total number of used beat gestures and, therefore, has had a possible influence on the ratio of the different gesture types.

What is striking about the distribution of the different gesture types is that the frequencies of the types 'Butterworths' (N=4) and 'metaphoric' (N=6) are almost negligible. One explanation of the little use of metaphoric gestures could be the specificity that this category holds. An Iconic gesture can accompany almost every utterance. A requirement of the use of a metaphoric gesture is that the utterance contains a metaphorical expression, which is less common than utterances that are literary. Furthermore, McNeill (1992) described Butterworths as gestures that accompany speech failure. According to him, Butterworths occur as part of an effort to recall or find a word. When we connect this idea to the result of this study that 'Butterworths' only were used four times, it could be argued that the TL patients in this study do not seem to have difficulty to find or recall the right word. However, it is too short sighted to claim this idea. The fact that the patients do not seem to use 'Butterworths' very often, is not concluding about the occurrence of speech failures in the patients in general. They might have another way to express speech failure or do not express speech failure by the way of gesture at all.

Since patient 2 was the only patient with poor intelligibility and most limitations in speech, it is surprising that this patient does not show most co-speech gesture use (Table 3). One explanation for this could be the fact that this patient was so limited in her speech that more gestures occurred without speech in comparison to the other patients. This idea is also not convincingly reflected in the results, visualized in Table 4 in where patient 2 does make the most without speech occurring-gestures (N=15) but with a small difference (N=1; patient 7 uses a total of 14 gestures without accompanying speech). Another explanation could be the possibility of lack of speech in general caused by limitations in the speech of this patient. When she speaks less, this automatically affects the possible use of co-speech gestures.

In order to see how the different gesture types and functions occur across all interviews, time sampling was added to this study. This sampling added value to this study in the way that the occurrence of the different types and functions could be viewed in arbitrary, and not ideally chosen, samples. In this analysis, the healthy controls from the podcast have been included for the gesture types. This is, in addition to the results of the time sampling of the TL patients, discussed below.

Focusing on the used gesture types of TL patients within the time samples it is noticeable that the frequencies in which the gesture types occur are comparable to those of the annotated gestures. The distribution of the different types appears to be roughly the same as the results of the annotation (see Figure 10). The gesture type 'beats' did occur in the highest frequency (N= 19) 41% of the time. However, the second most used gesture type is not 'iconic' (N=9) like in the results of the annotations, but 'emblems' (N=10). However, this difference is only one gesture. The gesture types 'metaphoric' and 'Butterworths' did not occur. The fact that the proportions show similarities with the results of the annotation shows that the time sampling is a potential accurate model for the annotation of the used interviews in this study and that the results of the time samples are more or less representative for the whole recording.

The second sub question concerned the function of the co-speech gesture usage in TL patients. Looking at the different gesture functions, the gesture function 'other' is used in the highest frequency (N=305). This function is added by the researcher (FH) to the existing classification of types by Cartmill and Goldin-Meadow (2016) as a category for those gestures that one of the other functions could not cover. A majority of the used gestures did not meet the criteria of any of the 3 different functions 'complementary', 'supplementary' or 'disambiguating'. The fact that 'other' occurs in the highest frequency could indicate that the used classification of gesture types was unfortunately insufficient for this present study, because the majority of the gesture functions did not fit within the used classification.

The second most occurring gesture function was 'complementary' (N=234; 36% of the time) This function was described by Cartmill and Goldin-Meadow (2016) as to reinforce what is expressed in the speech. Besides the gestures with the function 'other' that could not be classified in one of the categories, TL patients in this study tend to use most of the left-over gestures to reinforce what they convey in their speech. This result can possibly be associated with the results of the study by Drugman et al. (2015), discussed in section 3.2.5. In their study, they described that the speech of TL patients using tracheoesophageal speech is not only less loud but also more noisy. The included TL patients in this study could be using complementary gestures, because they have less loud and noisier speech and complementary gestures serve to strengthen or reinforce the message conveyed in their speech. However, to be able to accept this hypothesis for TL patients in general, further research into this subject is necessary.

When we look at the different timing places that have been used we found that 'other' (?) is used in the highest frequency (N=313) followed by 'simultaneous' (=) (N=247). The timing place 'other' (?) especially occurs when the referent of the gesture is unclear or the gesture does not appear to have a referent. Considering the fact that beat gestures do not have a specific referent and that they are used in the highest frequency (N=272) of the gesture types, this result is not surprising.

A hypothesis that can be associated by the result that 'simultaneous' is the second most occurring timing place, is the hand-in-hand hypothesis (So et al., 2009), which is also discussed in section 3.1.3. This hypothesis states that gesture and speech go hand in hand. Considering the fact that 'simultaneous' (=) is the second most used timing place (N=247), it seems that the used co-speech gestures in this study do go hand in hand with speech a lot of the time. However, it remains important to note that these results are just descriptive and no statistical analysis has been performed.

Further, it is remarkable that the timing place ‘after’ (+) is used in the lowest frequency (N= 6). This means that it almost never occurred that the utterance with the referent took place before the accompanying gesture. It happened more often the other way around, because the timing place ‘before’ (-) is used in a higher frequency (N=43). A hypothesis, discussed in section 3.1.3, that can be connected with the two timing places ‘after’ and ‘before’ is the lexical-retrieval hypothesis. This hypothesis states that gestures play a direct role in speech production through priming the lexical retrieval of words (Wagner et al., 2014). This hypothesis does not seem to be directly reflected in the results of the TL patients in this study. When TL patients make their gestures in order to improve the speech production, the timing place ‘before’ would be expected to appear in an even higher frequency. In itself, this is not surprising considering the nature of the problem of impaired speech in TL patients. TL patients do not have necessarily problems with word retrieval but with the acoustic production of it. But again, this cannot be statistically tested and, therefore, remains speculative.

Looking at the standard deviations of the gesture functions and timing places in Table 3, we see that the category ‘other’ has been found as the highest SD as well among the gesture functions (SD=11.41) as among the timing places (SD=11.03). This result is not surprising considering the characteristics of this category. This category is as well in the classification of the gesture functions as in the timing places additional. Due to the fact that this category has no conditions that the gestures must meet, the gestures within this category occur in different forms and, therefore, are more likely to occur in more different frequencies among the patients than in the other categories.

Looking at the gesture functions used in the time sampling of the TL patients, we see, just as in the gesture types of the TL patients, a resemblance with the results of the annotation (see Figure 12). The gesture function ‘other’, did occur 47% of the time and with the highest frequency (N=23). The gesture function ‘complementary’ is the second most occurring (N=17) function in 35% of the time and the least used gesture functions ‘supplementary’ (N=6) and ‘disambiguating’ (N=3) with respectively a prevalence percentage of 12% and 6%. The fact that the proportions of the frequencies of the different functions show similarities with the results of the annotation shows again that the time sampling is a potential accurate model for the annotation of the used interviews and that the time sampling is more or less representative for the whole recording. However, no statistical analysis has been performed so this idea remains hypothetical.

The third sub question concerned the use of co-speech gestures in healthy controls. Looking at the used gesture types in the time sampling of the healthy controls, a different distribution is visible when compared to the TL patients. The gesture type ‘beats’ is used in the highest frequency (N=18) in 82% of the time and ‘emblems’ (N=2) and ‘iconic’ gestures (N=2) are used both 9% of the time. ‘Metaphoric’ gestures, ‘deictic’ gestures and ‘Butterworths’ were not used by the healthy controls. The type ‘beats’ occurred in the TL patients 41% of the time. This type of gesture was used, by ratio, more frequently in the controls than in the TL patients in this study (82% of the time). In addition, ‘iconic’ gestures, ‘deictic’ gestures and ‘emblems’ are more common in the TL patients in this study than in the healthy controls. These gestures carry more semantic content (iconic and emblems) or are connected with the semantic content in the speech (deictic). Because TL patients in this study make more use of these gestures than the healthy controls and by ratio less use of ‘beats’ than the healthy controls, a possible hypothesis could be that these gestures function like a form of compensation for and as an addition to their impaired speech. This hypothesis would mean that TL patients would use speech and gesture together to convey the same semantic content (in line with the trade-off-hypothesis; discussed in section 3.1.3) whereas the healthy controls are able to transfer this semantic content in their speech only and that they use gestures more as a reinforcement of their speech than a supplement. However, this hypothesis is not in line with the result that ‘complementary’ was after the category ‘other’, the most used gesture type in TL patients. If it is true that the co-speech gestures were used by the TL patients in this study to supplement what they convey in speech more than only to reinforce, it would be expected that the category ‘supplementary’ (N=70) would be in a higher frequency than ‘complementary’ (N=234). In addition, it remains important to note that these hypotheses are only based on the included patients and data obtained in this present study. Further research is necessary to find out whether these ideas apply to the entire TL population.

Finally, it is important to note that the TL patients (because of their type of HME-filter) were only able to make use of one arm while they spoke. The ability to use only one arm for gesticulation could have a possible influence on the use of gestures. It has an effect on the freedom of movement and, therefore, may have been a limiting factor in the use of gestures. However, the fact that the results show a fair amount of co-speech gestures used by the included TL patients (in comparison to the results of Cohen (1977) in healthy controls), may indicate that, along with the use of only one arm, TL patients consider gesticulation important in their communication. Using only one arm while communicating can also play a role in the total amount of gestures (N=60) that were not considered as ‘co-speech gestures’. These were the gestures that took place without accompanying speech. For example, if a patient could only portray something with both arms, this had to be done without speech.

7.2 Strengths, limitations and further research

Although, this study has been set up and conducted with care, it has also a number of limitations. In this section, its strengths will be highlighted and its limitations will be critically discussed

This study has been conducted for the first time. Therefore, it can make a valuable contribution to the existing research field. Furthermore, it can be a starting point of additional research in this domain.

The time sampling made it possible to check whether the annotated minutes were representative for the entire interview. This has been a very valuable additive to this study and has increased the reliability of the results.

Furthermore, the fact that a control group was included for the time sampling, gave the opportunity to compare the use of co-speech gestures in TL patients with healthy people. This made the interpretation of the results of more value. However, the fact that this study is a pilot study also brings some limitations.

One limitation of this study is the small sample size. Because of the fact that only eight laryngectomized patients were included, the sample may not reflect the patient population as adequately as possible. Further, because of this small sample size and because no hypotheses were formulated, it was not possible to perform statistical tests. For this reason, the results remain conceptual and speculative. Additionally, only female patients were included in this study while the incidence of TL is higher in men (Hoffmann, 2021). Kavakli and Chen (2014) investigated gender differences in gesture use in students. Their results showed more diversity in the use of gesture types in females than in males. The total frequency of gesture use was, however, hard to interpret, because the speaking duration of the males and females were not equal. Furthermore, Kavakli and Chen (2014) investigated natural hand gestures and not exclusively co-speech gestures. This study is, therefore, not a proportional comparison. To our knowledge, no further research is done on gender differences in gesture use. It is therefore difficult to predict whether the fact that only female TL patients were included has had a possible influence on the outcomes.

Furthermore, the method in this study is based on a selection of different classifications found in the literature combined into one system. This system has not been proven to work and to be the optimal choice in a study including people with alaryngeal speech. It could be the case that a classification with different gesture types and functions will not result in the category ‘other’ to be the majority in both the gesture functions and timing places but this should also be proven in further research.

During the annotation of the interviews, some limitations and inaccuracies have also been noted. As mentioned in section 7.1 above, the annotation was inaccurate for some gesture types. If stricter requirements of the beginning and ending of the gestures had been predetermined, the annotation could have been more accurately and precisely done. However, an informed decision is made not to do this in the current study.

Because the interviews were annotated and the time sampling was performed only by one researcher (FH), it could be the case that subjective bias has occurred. The researcher was not blind to which gestures belonged to which patient. It may, therefore, be the case that not every single used gesture has received an objective judgement.

Furthermore, it is important to note that the interviews of the healthy controls took place in a different setting. The podcast 'Effe relativeren' was chosen, because the setting was similar to the interview setting of the TL patients in multiple ways. Both situations included an interview about the personal life of the interviewee and in both situations semi-spontaneous speech was used. The duration of both interviews was also approximately the same. Moreover, the hands were clearly visible in both settings. However, it is inevitable that there are differences between the two settings. The interviews of the TL patients and the interviews of the healthy controls were recorded for different purposes. The interviews of the TL patients were conducted for a Quality of Life study (van Sluis et al., 2020) and, therefore, for a scientific purpose. The interviews in the used podcast were conducted to entertain and to provide content on the social media platform Youtube. These interviews were, therefore, more casual. In addition, it is possible that the healthy controls are more used to an interview setting since they are public figures in The Netherlands. It could be possible that they have had mediatraining and were therefore not fully natural in their movements. Finally, only female TL patients were included while in the control group two women and two men were included. This could have had a possible influence on the comparison. This should be investigated in further research.

What is also important to be aware of in further research, is the different kinds of HME-filters (see section 3.2.4). The included patients in this current study all used an HME-filter that does require the assistance of one hand. Since this could have a possible influence on the freedom of movements (and consequently on the use of co-speech gestures) it would be useful to investigate the use of co-speech gestures with use of other HME-filters in further research.

8. Conclusion

In summary, the co-speech gestures used by the TL patients occur in different types, with different functions and in different places. The TL patients show (in comparison to the results of Cohen (1977) in healthy controls) a fair amount of co-speech gestures. It therefore, seems that, along with the use of only one arm, the TL patients in this study do make an effort to assist their speech with gestures.

The gesture type 'beats' was the most used gesture type seen in the TL patients. In as well the gesture functions as the timing places, the category 'other' was annotated the most. The second most used gesture timing place, besides 'other', was 'simultaneous'. This result seems to be in line with the hand-in-hand hypothesis that states that gesture and speech are parallel to each other.

Furthermore, the healthy controls show a different distribution of the gesture types in the time sampling than the TL patients. Whether this result is applicable to the TL patient population has to be investigated in follow up research. In addition, it is striking that the distributions of the gesture types and functions of the annotation and the time sampling in TL patients show similarities with each other. This suggests that the time sampling is, in this study, an accurate model for the use of co-speech gestures in the TL patients.

In further research, the used classification should be adjusted to minimize the gestures in the category ‘other’ in as well the gesture functions as timing places. Furthermore, the use of gestures in TL patients should be investigated in a larger sample. Additionally, in order to keep differences between the patient group and the control group as small as possible, conducting the interviews in the same setting is advised. Further, the role of gender in the use of co-speech gestures should be looked into. Finally, co-speech gestures should be investigated in TL patients with different use of HME-filters to determine if this has had a possible influence on the use of co-speech gestures.

Besides the limitations of this pilot study, the results of this current study are a contribution to the knowledge of the use of co-speech gesture within TL patients using tracheoesophageal speech. Further, this study can be seen as a starting point for further research concerning this domain.

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Appendix A: Protocol for annotating gestures and time sampling in interviews

Step 1: Open ELAN and import the .wmv files from all the interviews of the included patients, and create the tiers 'Gesture type', and 'Gesture function' by clicking 'tier' followed by 'add new tier'.

Step 2: Check the interview of the first patient and see if you can find a part of a duration of 1 minute where the patient seems to make a sufficient amount of gestures. This has to be your judgment. Take +/- 10 gestures as a guide. Once you have found a right minute, write down the time of starting and ending the minute. A handy tool to do this in, is for example Excel.[5]

Step 3: Start to annotate this minute by selecting the gestures in the horizontal time screen. Use the tiers 'Gesture type' and 'Gesture function' that have been created. Try to identify them by the following classification:

Gesture type

- **Iconic gestures (I**): represent the meaning that is closely related to the semantic content of the segments of the accompanied speech and resembles a concrete object, action or event.
- **Metaphoric gestures (M)**: represent the meaning of an abstract concept
- **Deictic gestures (D)**: pointing movements
- **Beat gestures (Be)**: movements that do not present an observable meanin*g*
- **Emblems (E)**: culturally-specific gestures, have names or standard paraphrases, are learned as specific symbols and can be used as if they were spoken words.
- **Butterworths (Bu)**: gestures that accompany a speech failure, sometimes used in the absence of speech when a speaker is attempting to retrieve a specific word or structure an utterance appropriately
-

Gesture function

- **Complementary (C)**: the gesture reinforces the size, shape, movement, path or location of what is expressed in the speech
- **Supplementary (S)**: the gesture adds information about the size, shape, movements, path, or location that is not expressed in speech.
- **Disambiguating (D)**: the gesture specifies the referent of an underspecified speech act.
- **Other (O):** When the gesture does not seem to reflect any of the three functions mentioned above.

Use for the annotation the abbreviations shown within the brackets above. When annotating on the Gesture function tier take the following timing places into account:

Gesture timing

- **Simultaneous (=)**: The gesture is made simultaneous with the word/phrase it seems to refer to.
- **Before (-)**: The gesture is made before the word/phrase it seems to refer to.
- **After (+)**: The gesture is made after the word/phrase it seems to refer to.
- **Other (?)**: It is too unclear to judge if the gesture is related to a word/phrase in the nearby speech or there is no referring word/phrase in the nearby speech

[5] For this current study: see table A1 for the selected minutes

<u>For example:</u>

A patient makes a manual gesture to imitate the act of writing while she is talking about writing. This gesture must be judged as *iconic* with a *complementary* function and is timed *simultaneous* with the word/phrase it refers to. You will note it as followed:

Gesture type (tier): I

Gesture function (tier): C=(writing)

The *writing* in between brackets is used as a reference and to avoid information getting lost. When it is unclear what word/phrase the patient is referring to or the patient does not express it in their speech you <u>do not</u> write the timing and the brackets after the timing.

Step 4: Repeat steps 3 and 4 with the interview of the second patient, followed by the third patient and so on. Eventually ending with the last minute (in this case fifth minute) of the last patient.

Step 5: In this step you will perform time sampling by checking every used interview at ten random generated times[6] to see if the patient is gesturing and if this is the case, what gestures are used. For this step, you will use the random number generator by Google; see https://ap.lc/bn0c0 . You can also find this website by searching the terms ‘random number’ in Google. As a result, a built-in-tool of Google will appear at the top of the page. The reason this method is used is to be able to generate random times within the recording and to specify these times to the second. In this way, the whole recording is included in the generator. You will convert the generated numerical numbers from the random number generator into specific times in the interviews illustrated as following:

When the recording has a total time of 1:29:00, the settings in the number generator will be: Minimum: 1; Maximum: 8900 (89:00 → 1:29:00). Where in 60 to the left of the separating dots is considered to be a full hour, and 60 to the right of the dots is considered to be a full minute. The conversion from a random generated number to a time within the recording works from left to right. To expand the illustration, when the random number generator gives for example the number 8780 this will correspond with the exact moment in the recording of 1:28:20 because from left to right:

1) The number 87 is 27 more than 60 and will therefore correspond to 1 hour and 27 minutes
2) The number 80 is 20 more than 60 and will therefore correspond to 1 minute and 20 seconds

These two lines mentioned above make together the time within the recording of 1:28:20. From this specific moment, you take 1.5 seconds further. This will be 1:28:21.5. If a gesture is used within these 1.5 seconds, you note this down including the Gesture type and Gesture function. You do this 10 times within each interview and note the results down, preferably in Excel.

[6] For this current study: see table A2 for the time samples

Table A1: Used minutes for the annotation of the interviews specified per patient

Patient	*1st minute*	*2nd minute*	*3rd minute*	*4th minute*	*5th minute*
1	3:00-4:00	17:32-18:32	32:21-33:21	54:05-55:05	1:12:39-1:13:39
2	4:03-05:03	11:16-12:16	27:52-28:52	42:58-43:58	1:04:56-1:05:56
3	1st recording 5:00-6:00	1st recording 12:16-13:16	1st recording 24:34-25:34	1st recording 38:50-39:50	2nd recording 3:10-4:10
4	7:58-8:58	13:29-14:29	30:48-31:48	52:00-53:00	1:02:10-1:03:10
5	7:35-8:35	12:12-13:12	27:35-28:35	48:25-49:25	1:05:04-1:06:04
6	6:50-7:50	13:30-14:30	23:02-24:02	42:00-43:00	1:16:46-1:17:46
7	7:40-8:40	11:50-12:50	25:05-26:05	44:50-45:50	1:00:49-1:01:49
8	7:00-8:00	14:04-15:04	30:52-31:52	47:02-48:02	1:00:07-1:01:07

Table A2: Used random generated time samples within the interviews specified per patient

Patient	*1st moment*	*2nd moment*	*3rd moment*	*4thmoment*	*5th moment*
1	32:59	1:07:12	52:00	26:30	02:42
2	9:50	46:11	1:17:02	7:22	56:02
3	1st recording: 39:02	1st recording: 38:30	1st recording: 32:40	1st recording: 15:38	1st recording: 25:04
4	25:37	29:52	1:09:14	55:15	1:09:35
5	33:28	20:27	37:35	44:46	01:06:08
6	1:40:35	1:15:12	1:21:26	10:19	1:19:16
7	7:57	8:05	49:10	1:36:30	48:20
8	49:31	26:20	16:13	33:53	53:16

Patient	*6th moment*	*7th moment*	*8th moment*	*9th moment*	*10th moment*
1	56:23	06:31	21:15	36:37	9:12
2	37:05	49:01	1:09:42	19:37	0:44
3	2nd recording: 16:00	2nd recording: 2:30	2nd recording: 4:39	2nd recording: 19:13	2nd recording: 41:49
4	47:01	1:01:01	8:46	2:28	16:36
5	01:23:10	58:12	1:20:30	1:19:43	1:23:22
6	24:37	43:34	42:39	1:40:09	16:55
7	25:38	35:25	58:39	7:36	1:20:39
8	11:54	20:33	14:03	1:00:38	26:32

Appendix B: Individual time sampling results

Table B1: Individual time sampling results of the frequencies of the different gesture types and –functions

Patient		1	2	3	4	5	6	7	8	**Total**	**Mean**	**SD**
Gesture type	Iconic	2	1	1	0	0	1	2	2	**9**	1,125	0,83
	Metaphoric	0	0	0	0	0	0	0	0	**0**	0	0
	Deictic	1	4	0	1	0	0	0	2	**8**	1	1,41
	Beats	3	3	7	1	0	2	1	2	**19**	2,375	2,13
	Emblems	1	0	0	1	3	1	3	1	**10**	1,25	1,16
	Butterworths	0	0	0	0	0	0	0	0	**0**	0	0
	Total	**7**	**8**	**8**	**3**	**3**	**4**	**6**	**7**	**46**	**5,75**	**2,12**
Gesture function	Complementary	1	4	1	2	2	1	3	3	**17**	2,125	1,13
	Supplementary	2	1	0	0	0	0	1	2	**6**	0,75	0,89
	Disambiguating	0	0	0	0	0	0	1	2	**3**	0,375	0,74
	Other	4	3	7	1	1	3	2	2	**23**	2,875	1,96

Note. SD= standard deviation

Table B2: Individual time sampling results of the frequencies of the different gesture types of the healthy controls.

Participant		1	2	3	4	**Total**	**Mean**	**SD**
Gesture type	Iconic	0	0	2	0	2	0,5	1
	Metaphoric	0	0	0	0	0	0	0
	Deictic	0	0	0	0	0	0	0
	Beats	7	5	3	3	18	4,5	1,91
	Emblems	0	0	1	1	2	0,5	0,58
	Butterworths	0	0	0	0	0	0	0
	Total	**7**	**5**	**6**	**4**	**22**	**5,5**	**1,29**

Note. SD = standard deviation

Appendix C: Declaration on plagiarism and fraud

The undersigned

Femke Hof

Master's student Linguistics at the Radboud University Faculty of Arts,

declares that the assessed thesis is entirely original and was written exclusively by himself/herself. The undersigned indicated explicitly and in detail where all the information and ideas derived from other sources can be found. The research data presented in this thesis was collected by the undersigned himself/herself using the methods described in this thesis.

Place and date:

Groningen, 11th of july, 2021

Signature: