# Introduction

## Speech and Speech Disorders

Human languages consist of sets of vowels and consonants, which are combined to form words. During the speech production process, thoughts are converted into spoken utterances to convey a message, with the speaker selecting the appropriate words and meanings from their individual mental lexicon (Dell & Burger, 1997). This preverbal message is then grammatically encoded, a process wherein a syntactic representation of the utterance is built. The sounds are yet to be specified, but the abstract word symbols are assigned to their grammatical function before being structured in a syntactic frame to determine the order (Cho-Reyes et al., 2016). The message is subsequently phonologically encoded. During this stage, a phonetic or articulatory plan is retrieved for each lemma and the utterance as a whole. Finally, the speaker produces the utterance according to the phonetic plan (Levelt, 2002).

Speech, language, and voice disorders such as apraxia, aphasia, and spasmodic dysphonia affect the vocal cords, nerves, muscles, and brain structure, resulting in distorted language reception or speech production. Depending on the type of disorder, symptoms can vary from the addition of superfluous words and pauses to hoarseness of the voice. However, speech distortions may also occur as a result of a disease that seems unrelated to speech, such as multiple sclerosis, which limits an individual’s articulatory movements and respiratory functions, or chronic obstructive pulmonary disease (COPD), which limits respiratory functions.

This study aims to determine which acoustic parameters are suitable for the automatic detection of exacerbations in patients with COPD by investigating which aspects of speech differ between COPD patients and healthy speakers and between COPD patients in exacerbation and stable COPD patients.

## Chronic Obstructive Pulmonary Disease

### Background

COPD is an umbrella term used to describe progressive lung diseases characterized by airflow limitation. The guidelines provided by the Global Initiative for Chronic Obstructive Lung Disease (GOLD, 2019) define COPD as “a common, preventable and treatable disease that is characterized by persistent respiratory symptoms and airflow limitation that is due to airway and/or alveolar abnormalities usually caused by significant exposure to noxious particles or gases” (p. 2).

### Prevalence

The prevalence of COPD globally is estimated at approximately 12%, but the percentage differs greatly between different subgroups (Lopez et al., 2014). Most COPD patients suffer from stage II COPD (70%), while stage I, III, and IV patients comprise 16%, 11%, and 3%, respectively, of the COPD population. The four greatest predictors of COPD are years and intensity of smoking, age, sex, and body mass index (BMI). Most patients with COPD are smokers with a low BMI, over 50 years old, and male (Lopez et al., 2014).

Taking into account the 3 million annual deaths caused by this condition globally, COPD is currently the fourth leading cause of death in high-income countries, and it was projected to become the third leading cause in 2020 due to higher life expectancy and increasing air pollution (Buist et al., 2007; GOLD, 2019; Postma et al., 2015). However, both the public and the pharmaceutical industry have long overlooked the prevalence of lung disease. This neglect may in part be due to the assumption that COPD is a self-inflicted health condition caused by smoking. Although smoking is the leading cause of COPD in high-income countries, over 15% of COPD patients are nonsmokers (Buist et al., 2007). Nonsmokers often develop COPD as a consequence of work or living circumstances that result in them being exposed to polluted air. COPD is associated with an economic burden, as the disease accounts for approximately 55% of the costs associated with respiratory diseases in Europe (GOLD, 2019).

### Causes

COPD is the result of long-term exposure to noxious gases and particles and is often influenced by host factors such as genetics, poor lung growth, and hyperresponsiveness (GOLD, 2019). The chronic airflow limitation in COPD is caused by a combination of small airway disease and parenchymal destruction or emphysema (Cosio-Piqueras & Cosio, 2001). Chronic inflammation causes narrowing of the small airways and destroys the lung parenchyma. As a result, the alveolar attachments to the small airways weaken or disappear, and lung elastic recoil decreases (GOLD, 2019). This prevents the airways from remaining fully open during expiration (Barnes, 2004).

The understanding of risk factors for COPD remains incomplete, and further investigation is required (GOLD, 2019). COPD seems to be associated with a severe hereditary deficiency of an inhibitor of serine proteases, namely alpha-1 antitrypsin, and a familial risk of airflow limitation has been observed (GOLD, 2019). It remains unknown whether these genetic factors are directly responsible for COPD or markers of causal genes (Cho et al., 2010; GOLD, 2019).

### Diagnosis

The “Standards for the Diagnosis and Treatment of Patients with COPD” (Celli et al., 2004) is an updated version of the position papers on COPD. Both professionals and patients requested that the documents be updated for the following reasons:

1. The prevalence of COPD is increasing;
2. There have been discoveries in the field that could increase the quality of life for COPD patients;
3. There is a need for an online document to ensure accessibility;
4. The care of COPD is now viewed as multidisciplinary; and
5. There are novel insights regarding smoking and its impact on COPD.

COPD is diagnosed by measuring the extent of airflow limitation. In most cases, spirometry is used to measure lung function (GOLD, 2019). Spirometry is more reliable than clinical descriptions such as “patient produces sputum for at least 3 months in 2 consecutive years” given that COPD is heterogeneous in its clinical expression (Postma et al., 2015). Patients with COPD generally exhibit a variety of symptoms, including shortness of breath, tightness of the chest, and coughing (with mucus).

Stable COPD is interrupted by episodes or exacerbations, during which the respiratory symptoms acutely worsen (GOLD, 2019). These exacerbations are occasionally triggered by respiratory infections, but the cause or trigger of exacerbations often remains unknown (Rutschmann et al., 2007). During exacerbations, the peripheral airway limitation results in gas becoming trapped during expiration. This leads to hyperinflation, which is associated with a limited inspiratory capacity and increased dyspnea. As the disease progresses, the gas transfer for oxygen and carbon dioxide worsens, resulting in hypoxemia and hypercapnia. In addition, the submucosal glands enlarge due to chronic airway irritation, leading to mucus hypersecretion (GOLD, 2019).