A Study on the Conversational Voice Intensity in Alzheimer's Disease

Metref Ouarda[1], Belkai Baya[2]

[1,2]Mouloud Mammeri University Tizi Ouzou, Faculty of humanities and social sciences, department of speech language pathology (orthophonia) (Algeria).
The Author's E-mail: ouarda.metref@ummto.dz[1], bayabelkai@gmail.com [2]

Received: 02/2023 **Published: 11/2023**

Abstract:

Recent research has increasingly focused on the acoustic characteristics of voice in diagnosing and assessing degenerative disorders. Therefore, this study aims to identify the impact of Alzheimer's disease on the intensity of conversational voice. The research problem statement can be summarized as follows: Are there statistically significant differences in the intensity of conversational voice between individuals with Alzheimer's disease and the standard intensity? To answer this question, a sample of 41 individuals diagnosed with Alzheimer's disease, ranging in age from 53 to 90 years, was selected. The intensity of their conversational voice was analyzed using the computer program Praat, which objectively analyzes the acoustic characteristics of sound. The mean intensity of their conversational voice was then compared to the mean standard intensity mentioned in the literature using the t-test to study the differences. The results revealed an increase in the intensity of conversational voice in individuals with Alzheimer's disease compared to the standard intensity. This can be attributed to the behavioural and cognitive disturbances commonly observed in Alzheimer's disease.

Keywords: Alzheimer disease, Voice, Intensity, Conversational voice, acoustic characteristics of voice, Automatic acoustic analysis,

Introduction:

Alzheimer's disease is a neurodegenerative disorder characterized by the formation of proteins in the brain, leading to the irreversible death of nerve cells. It is primarily known for memory loss but is not limited to this impairment alone. It also involves cognitive dysfunction, deterioration in executive functions, and psychological disturbances. These symptoms significantly impact the patient's social, emotional, and professional life, affecting their independence (Dubois et al., 2015). The disease begins mildly and progresses towards deterioration, resulting in the loss of short-term memory followed by long-term memory (Selingue, 2019). Alzheimer's disease has become one of the most common neurodegenerative disorders worldwide. Therefore, early detection and intervention have become the most effective preventive approaches. Alzheimer's disease is characterized by progressive pathological neurological changes that may occur before cognitive and functional symptoms appear, Consequently, current efforts have focused on innovative tools or biomarkers for early detection of pre-dementia stages. This is because the diagnosis of Alzheimer's disease in a living body using conventional cognitive tools has an error rate of up to 25% compared to the diagnosis provided through autopsy findings (Beach et al., 2012). Therefore, voice and speech analysis has become increasingly common over the past decade.

Voice holds a prestigious position in the communication process, carrying a message that conveys meaning to the listener. There is no doubt that humans are in dire need of daily oral communication with society. Possessing accurate, clear, and unambiguous speech has a significant and delicate impact on an individual's life. It conveys an individual's identity, satisfies their requirements, and strengthens their societal position. (Guerrero, 2010). Voice is the essential means that conveys this message in the communication process, and we should not overlook its acoustic characteristics (intensity, fundamental frequency, and timbre). Any disturbance in these characteristics may indicate the presence of a disease such as Alzheimer's, where problems in sensory-motor adaptation can be found (Xiu et al., 2022).

Therefore, the acoustic characteristics of their voice, both in general and specifically in terms of intensity, may differ from those of healthy individuals. Scientific advancements in language processing and automated speech recognition have allowed for extracting linguistic and acoustic changes that were previously difficult to measure. Articles related to its use in the detection of neurodegenerative diseases have proliferated. Numerous studies have identified distinctive speech characteristics in general that can be used for accurate discrimination between healthy aging, mild cognitive impairment, and Alzheimer's disease. Speech analysis has been identified as a cost-effective and reliable method for detecting both conditions (König et al., 2015).

Voice contains a wealth of information about people's health status. Many neurodegenerative diseases, pulmonary diseases, cardiovascular diseases, and psychiatric disorders can alter a person's speech patterns. Therefore, speech analysis becomes a key to early diagnosis. The challenge today lies in accurately differentiating between patients with mild cognitive impairment and those in the early stages of Alzheimer's disease on the one hand and individuals experiencing healthy ageing on the other hand. Thus, language in general and speech in particular become important tools for distinguishing these disorders that may mask the early stages of neurodegenerative diseases (Hajjar et al., 2023).Dozens of speech-based methods have been explored for Alzheimer's disease detection.

Research findings indicate a significant correlation between acoustic measures and pathological language features. Additionally, the alterations in acoustic patterns observed in automated language analysis have demonstrated their effectiveness in detecting Alzheimer's disease compared to conventional diagnostic methods, such as conventional assessment tests, electroencephalography (EEG), and magnetic resonance imaging (MRI). Speech analysis and linguistic processing techniques have been studied for Alzheimer's disease detection, yielding remarkable results (Yang et al., 2022). One study by Meilán et al. (2014) examined speech characteristics, including the acoustic properties of sound, in participants with Alzheimer's disease and compared them with characteristics found in normal ageing. They analyzed simple sentences in both groups using the Praat program and found disturbances in the acoustic characteristics of Alzheimer's patients. Regarding fundamental frequency stability, the jitter ratio (rap) ranged from 1.15% to 1.34%, and the jitter (local) ranged from 2.80% to 2.46%, indicating pathological ratios.

The values of 1.44 dB and 1.60 dB represent the mean shimmer measurements in decibels. Likewise, capacity stability shows abnormal proportions. This research revealed 10.74% and 12.66% for shimmer (apq11). The study's findings suggest that both general speech analysis and specific voice analysis are valuable tools for differentiating between individuals with Alzheimer's disease and healthy elderly individuals.

Ranasinghe et al. (2017) found that individuals with Alzheimer's disease exhibited abnormal vocal behaviour compared to healthy individuals. Their study (19 cases) observed compensatory behaviour characterized by an abnormally high fundamental frequency when pronouncing the vowel [a] repeatedly and hearing their voice in real-time through an earpiece. The researchers adjusted the pitch of their voices to see how these individuals would compensate for this vocal frequency anomaly. They linked this compensatory behaviour to executive functional impairment. The study also found that patients with Alzheimer's did not retain this compensatory behaviour compared to healthy individuals, which is attributed to the memory disturbances displayed by these patients.

In the same context, we found a study by Xiu et al. (2022) that examined the vocal characteristics of individuals with Alzheimer's disease. The study included 50 cases, which were divided into four groups, 13 cases with good neurological health, aged between 63 and 81 years, 11 cases diagnosed with mild cognitive impairment (i.e., cognitive decline in normal ageing), aged between 61 and 80 years, 17 cases with Alzheimer's disease, aged over 63 years, 9 cases with vascular cognitive impairment Sound samples, including three vowels (/i/, /a/, /u/), were collected and analyzed. The studied vocal characteristics included fundamental frequency stability (jitter), amplitude stability (shimmer), harmonics-to-noise ratio (HNR), and formant frequencies (F1, F2, F3).

The results indicated statistically significant differences in F3 for the vowel /u/ and F2 for the vowel /a/ in the intensity of conversational voice. Significant differences were found in F0 for male participants across all vowels (/a/, /i/, and /u/). However, no statistically significant differences were found in other examined physical characteristics.

The most recent research is conducted by Hajjar et al. (2023), which highlighted that both semantic and acoustic biomarkers are sensitive to cognitive status and exhibit high diagnostic accuracy. They may also be sensitive in tracking the progression of Alzheimer's disease in its early stages. This study collected data on speech-related biomarkers, neurophysiological indicators, neuroimaging and cerebrospinal fluid markers from 92 cognitively normal participants (40 Aβ+) and 114 participants with cognitive impairment (63 Aβ+). Acoustic and semantic features were derived from the audio recordings using computational tools. The results of this study demonstrated a correlation between the acoustic characteristics of sound and the hippocampus volume in Alzheimer's patients ($p = 0.017$).

Based on the presented results of the studies, it is observed that the intensity of voice has received a different level of attention than other vocal characteristics despite its significant role in communication. Voice intensity reflects the mood and personality of an individual and varies depending on the situation. It is also a distinguishing factor between a strong and weak voice. This is done by posing the following question: Are there statistically significant differences between the conversational voice intensity in individuals with Alzheimer's disease and standard intensity?

Hypothesis:
There are statistically significant differences in the intensity of conversational voice between Alzheimer's disease patients and the standard intensity.

Study Importance:
The significance of this study lies in enriching the field of Alzheimer's disease diagnosis by introducing a new factor. Voice intensity can help identify cognitive impairment in Alzheimer's and predict disease progression. This can give families more time to plan for the future and give doctors greater flexibility in recommending beneficial lifestyle changes.

Study Objectives:

- Assessing the level of control Alzheimer's patients have over the vocal apparatus.
- Determining the impact of cognitive disorders specific to Alzheimer's patients on voice intensity.
- Identifying the influence of behavioural disturbances on voice intensity.

1. Study Terminology;

1.1 Alzheimer's disease:

Alzheimer's disease is a degenerative disorder that affects the central nervous system, leading to gradual loss of cognitive functions, especially memory, and behavioural disturbances. The disease was first described by German psychiatrist and neuropathologist Alois Alzheimer in 1906 in a publication that described anatomical abnormalities in the brain of a 51-year-old patient. Since then, research has continued to evolve, and today, Alzheimer's disease is considered a significant cause of dementia in the elderly (Lapre, 2010). Neurologically, Alzheimer's disease is characterized by two types of extensive lesions in the hippocampal and cortical association areas: neurofibrillary tangles and senile plaques. This neurofibrillary degeneration is caused by pairs of helical filaments composed of abnormal phosphorylated tau protein.This neurofibrillary degeneration progresses systematically and hierarchically: it starts in the hippocampal region and gradually spreads to the temporal cortex, then to the association areas (frontal cortex), and finally throughout the cerebral cortex (Delacourte, 1990).

1.2. Voice:

A dynamic aerial phenomenon adaptable to communication needs, produced by the vibration of the free edge of the vocal cords. This is the primary mechanism of phonation, which is then filtered through the pharynx and the oral cavity to produce consonant and vowel sounds. The larynx, particularly the vocal cords, is central to the sound production system. During the preparatory phase before phonation, the muscles and cartilages of the larynx work together to bring the vocal cords closer to each other (phonatory position), narrowing the glottis. The air in the lungs is then expelled through active exhalation, passing through the vocal cords. The anatomical characteristics of the vocal cords, with their layered structure, allow for the negative vibration of the mucous membrane of the free edge under the influence of respiratory phonation (Giovanni et al., 2014).

1.3. The acoustic characteristics of voice:

The complexity of the voice system gives the human voice the ability to adapt accurately to various situations in which it is used. All vocal changes occur through modifications of the three characteristics of voice: pitch, intensity, and timbre. In this context, we will focus on pitch and timbre while addressing intensity separately since it is the subject of study.

Pitch: Represents the frequency of the sound pressure changes and corresponds to the fundamental frequency of the sound (F0), which is determined by the periodic motion of the vocal cords. The pitch used by an individual depends on various factors, with the size of the larynx being one of the most important. Generally, longer vocal cords produce lower-pitched sounds, while shorter vocal cords produce higher-pitched sounds (Le huche & Allali, 2010).

In addition to individual anatomical variations, the pitch of the voice also varies depending on the type of sound being produced, the conditions of phonation, and the ability to control the muscle contraction force. The internal muscles of the larynx are responsible for tensing and relaxing the vocal cords, resulting in various changes in vocal cord frequency (Mcfarland, 2016).

Timbre: Is a crucial characteristic of sound because it is a distinctive quality that determines an individual's identity when their voice is heard. It primarily results from the harmonic overtones accompanying the fundamental frequency. If different sources produce two sounds with the same pitch and intensity, the timbre differentiates the two sounds. Timbre depends on the vocal cords' interaction and the resonant cavities' anatomical characteristics. A rich and sharp timbre is produced when there is a good interaction among the vocal cords. However, if the interaction is not optimal, a poorer and muffled timbre is generated (Le huche & Allali, 2010).

As for the resonant cavities, their anatomical characteristics provide special features to the timbre, especially after modifying the sound wave at the level of the articulatory organs. The oral and nasal cavities, soft palate, tongue, and lips modify the airflow and the sound wave, enabling the production of speech sounds (Henrich-Bernardoni, 2001).

1.4. Intensity:

Intensity refers to the loudness or strength of sound, which is related to the amount of energy carried by its waves. It depends on the magnitude of the vibrations that occur in the waveform. In human voice, intensity is determined by the subglottal air pressure and is measured in decibels (dB). It varies from person to person and is influenced by the force of inhalation, the amount of air stored in the lungs, humidity, and pressure. It can be said that sound intensity is related to three main factors:

- Subglottal pressure
- Vocal cords contact force
- Vocal cords muscle tension (Heuillet-martin, 2012).

The intensity of voice varies according to the type of sound being produced.

Table 1: Shows the standard intensity of different types of voice

Voice type	Intensity
Conversational voice (Conversation speech)	Between 55 and 65dB
Declamatory voice	Between 65 and 75dB
Calling voice	Between 80 and 85dB
Screaming	Between 80 and 90dB
Opera voice	Up to 120dB

Source : Klein-Dallant, 2001

1.5. Conversational Voice: It is a voice characterized by an average intensity ranging from 55 to 65 dB and is used in quiet conversations (Cornut, 2009). The volume of the voice is not loud, and the process of speaking does not require significant effort. It is the most economical way of communication, as the speaker uses a vertical body posture and a vocal behaviour that requires less energy. It does not require adjusting and aligning the body posture before phonation or specific anticipatory respiratory strategies. Inhalation is not deep and can be either upper chest or abdominal. Similarly, exhalation occurs effortlessly and relies on the flexibility of the lung membranes and the vocal cords (Perriére et al., 2017).

1.6. Automatic acoustic Analysis of voice: It refers to the quantitative measurement of the acoustic characteristics of sound. It is the most reliable method for assessing any disturbances affecting the voice. It is the opposite of subjective analysis, which can vary from person to person and cannot detect subtle differences because the human ear only comprehensively analyzes the sound signal (Baken, 1987). This is insufficient, as highlighted by Morsomme et al.(2006).

In automatic acoustic analysis of voice, the results specifically focus on the vibratory motion of the larynx through fundamental frequency (F0), which remains the best indicator of the biomechanical properties of the vocal cords. This analysis allows for evaluating the average fundamental frequency, the commonly used frequency in daily communication. Additionally, it assesses the degree of control over laryngeal vibration, which is automatically calculated through the standard deviation of various variations detected by the signal analysis program. This analysis goes beyond F0 to assess the short-term frequency's degree of instability (jitter).

Regarding intensity, objective acoustic analysis not only analyses the mean intensity but also examines its instability, reflecting the instability of laryngeal vibratory capacity in the short term. This is done through measures such as shimmer (Baken, 1987).

This evaluation also includes measuring the degree of vibration dominance over noise (HNR). Additional noise indicates turbulent airflow from poor vocal cord closure (Ghio, 2007).

Furthermore, it is crucial to consider the analysis of vocal formants, which also receive quantitative evaluation as they are essential factors in describing the sound's timbre. They are multiples of F0 (fundamental frequency) (Marié Bailly, 2004).

2. Study Methodology:

In this study, we adopted a comparative descriptive approach as it is suitable for describing intensity in conversational voice among individuals with Alzheimer's disease and comparing it with standard intensity.

3. Spatial and Temporal Delimitations:

The study was conducted at the Public Institution for Local Health, The Martyred Brothers Marar Said-Ahmed-Si Amar, in the new city of Tizi Ouzou, Algeria. The study was conducted from June 9th to July 7th, 2022, after obtaining all the necessary administrative licenses and the approval of the patients' families.

4. Study Sample:

The study sample consists of 41 cases of varying degrees of Alzheimer's disease: mild, moderate, and a minority in the severe stage.

The research sample includes both genders, with ages ranging from 53 to 90 years, who are speakers of the Kabyle language. The sample was selected according to the following criteria:

- Patients should have no smoking history, as smoking can affect the vocal cord mucosa.
- Patients should not suffer from functional or organic dysphonia.

- Patients should not have any other neurological disorders in addition to Alzheimer's disease or other conditions that may cause vocal disturbances, such as Parkinson's disease.
- Patients should not have any significant hearing problems that could affect the audio- phonatory control.
- Patients should not have a history of stroke in the past three years.
- Patients should not have any issues with the thyroid-stimulating hormone, which could affect their voice.
- Patients should not suffer from apathy, which could hinder communication with others.

Table 2: Represents the research sample characteristics

Cases	Gender	Age	Age of Alzheimer's disease diagnosis	Degree of impairment according to the test MMSE
A. S	Female	72	71	25/30 (Mild)
KH. F	Female	68	66	16/30 (Moderate)
B. Dj	Female	75	72	24/30 (Mild)
B. W	Female	75	72	23/30 (Mild)
T. W	male	61	59	16/30 (Moderate)
B. F	Female	73	73	19/30 (Moderate)
B. F	Female	75	73	20/30 (Moderate)
H. F	Female	58	57	25/30 (Mild)
B. T	Female	57	57	26/30 (Mild)
F. Z	Female	61	61	20/30 (Moderate)
T. Z	Male	71	67	15/30 (Moderate)
A. N	Female	53	53	22/30 (Mild)
B. W	Male	77	75	18/30 (Moderate)
A. Kh	Female	69	66	12/30 (Moderate)
T. N	Male	71	67	18/30 (middle)
M. F	Male	86	85	20/30 (Moderate)
Z. W	Male	83	82	18/30 (Moderate)
S. M	Male	77	75	25/30 (Mild)
A. H	Female	56	55	18/30 (Moderate)
CH. T	Male	83	82	08/30 (Severe)
A. Dj	Female	70	68	25/30 (Mild)
D. A	Male	70	69	22/30 (Mild)

T. A	Female	75	74	17/30 (Moderate)
S. W	Male	67	66	18/30 (Moderate)
F. KH	Male	80	78	25/30 (Mild)
A. S	Female	58	58	25/30 (Mild)
A. F	Female	78	77	25/30 (Mild)
A. B	Female	73	68	20/30 (Moderate)
L. A	Female	69	69	25/30 (Mild)
S. H. H	Male	69	69	25/30 (Mild)
Q. S	Female	80	75	18/30 (Moderate)
A. M	Female	63	60	12/30 (Moderate)
A. A	Female	80	77	18/30 (Moderate)
M. S	Female	60	60	25/30 (Mild)
S. S	Male	70	70	25/30 (Mild)
B. M. A	Female	68	67	25/30 (Mild)
B. A	Male	77	75	19/30 (Moderate)
B. A	Female	90	90	19/30 (Moderate)
S. R	Male	88	82	10/30 (Severe)
H. S. S	Male	75	74	18/30 (Moderate)
S. A. CH	Female	82	80	17/30 (Moderate)

Source : The Researchers

5. Study Tools:

5.1. Praat Program:

Praat is free program for speech analysis, designed by David Weenink and Paul Boersma in 1996 at the Institute of Phonetic Sciences, University of Amsterdam. It is still under development and updates .This program is used for measuring and analyzing recorded sound signals. It allows for obtaining measurements of intensity, fundamental frequency or pitch (Fo), and timbre. It also provides information about jitter, which indicates variations in the vibratory cycles of the vocal cords during phonation. Furthermore, it provides a standard deviation, which refers to the difference between the three ratios of the fundamental frequency. Another feature is shimmer, which shows the presence or absence of variations in the recorded sound signal's amplitude (Boersma & weenink, 2013).

5.2. Corpus

Regarding the corpus, we recorded the dialogue between the participants and the neurologist. It consisted of four simple questions that the patients answered: What is your name? How old are you? Who accompanied you here? Why did you come here?

5.3. How to Use the Study Tools:

After ensuring no background noise, we recorded the patient's responses to the doctor's questions, using the Praat program in version 6.2.13. We placed the microphone approximately 5 cm away from the patient's mouth. Each time he answered a question, we recorded and saved the response for later analysis. We extracted the mean intensity value and compared it to the mean value of the standard intensity (dB60) calculated in this study based on the standard intensity value mentioned in the literature, ranging between 55 and 65, as mentioned above.

6. Statistical Tools Used:

In this study, the t-test for means was employed to analyze the differences within the single sample, using the Statistical Package for the Social Sciences (SPSS) software package after ensuring the conditions for its use.

7. Presentation and Analysis of Results:

7.1. Quantitative Analysis

Table 3: Represents the intensity of each case and the mean intensity of the cases with the standard intensity

Cases	Gender	Mean Intensity	Cases	Gender	Mean Intensity	Mean of the mean intensity in Alzheimer's cases	Mean standard intensity
A. S	Female	dB 78,48	D. A	Male	dB 70.05		
Kh. F	Female	dB 73,62	T. A	Female	dB 70,17		
B. Dj	Female	dB 77,43	S. W	Male	dB 72,70		
B. W	Female	dB 69,00	F. KH	Female	dB 67,26		
T. W	Male	dB 71,47	A. S	Female	dB 68,91		
B. F	Female	dB 69.53	A. F	Female	dB 75,99		
B. F	Female	dB 69.11	A. B	Female	dB 69.55		
H. F	Female	dB 69,41	L. A	Female	dB 75,43		
B. T	Female	dB 79.07	S. H. H	Male	dB 73.57		
F. Z	Female	dB 70,92	Q. S	Female	dB 69,39	71.05 dB	**60dB**
T. Z	Male	dB 69.54	A. M	Female	dB 70,32		

A. N	Female	dB 68,95	A. A	Female	dB 68,23
B. W	Male	dB 67,76	M. S	Female	dB 69,16
A. Kh	Female	dB 70,21	S. S	Male	dB 74.07
T. N	Male	dB 70,51	B. M. A	Female	dB 67.97
M. F	Male	dB 67,44	B. A	Male	dB 74,68
Z. W	Male	dB 70.10	B. A	Female	dB 74,00
S. M	Male	dB 70,22	S. R	Male	dB 74.11
A. H	Female	dB 69,18	H. S. S	Male	dB 69,29
CH. T	Male	dB 67,84	S. A. CH	Female	dB 70,37
A. Dj	Female	dB 68,16			

Source: The researchers

Table 3 shows that the conversational voice intensity is high in all cases without exception, regardless of gender, age, or stages of disease progression. The results in the table indicate that the mean conversational intensity for all cases is estimated at 71.05. The mean intensity for females is around 73.18 dB, while for males, it is approximately 71.06 dB. These means are higher than the standard intensity mean of 60 Db.

7.2. Statistical Analysis

Table 4: Represents the results of the T value for the differences between the means in one sample

	Sample N	Mean	Mean standard intensity	Standard deviation	T value	df	sig	Adopted significance value
Mean intensity	41	71.05	60	3.07869	22.988	40	0.00	**0.05**

Source: The researchers

From Table 4, we notice that the mean intensity for Alzheimer's cases is 71.05, with a standard deviation of 3.07869. The t-value for the difference in means is 22.988, with 40 degrees of freedom, and the significance value is 0.000 (sig), at a significance level of 0.05.

Since the significance value (sig) for the t-value of the difference in means is 0.00, which is smaller than the chosen significance level of 0.05, it indicates the presence of statistically significant differences between the mean intensity of the Alzheimer's patient sample and the standard intensity. When comparing the mean intensity values of the Alzheimer's patient sample (71.05 dB) and the standard intensity (60 dB), we observe that the value for the Alzheimer's patient sample is higher. This suggests the presence of differences indicating a lack of adaptation of the conversational voice intensity used by Alzheimer's patients to the dialogue situation.

Therefore, we accept the hypothesis of our study, which states that there are statistically significant differences between the mean conversational voice intensity in individuals with Alzheimer's disease and the mean value of the standard intensity.

8. Discussion:

This study revealed an increase in the intensity of conversational voice among Alzheimer's patients compared to the standard intensity for this type of speech. The statistical analysis of the results obtained here demonstrated statistically significant differences between the mean intensity in the patient sample and the standard intensity, consistent with previous studies findings. For instance, a study by Xiu and colleagues (2022) confirmed an increase in fundamental frequency in Alzheimer's patients. As mentioned in the literature, there is a correlation between fundamental frequency and voice intensity. Giovanni and colleagues (2013) discussed the relationship between subglottal pressure, an important factor in controlling intensity, and an increase in fundamental frequency. As subglottal pressure increases, fundamental frequency also rises simultaneously. Huillet-Martin(2012) noted the difficulty of distinguishing between these two factors; only a trained singer can effectively differentiate between them.

After conducting several readings to find an explanation for this increase in sound intensity, we have concluded that it can be attributed to behavioural disturbances, the first of which is the lack of inhibition commonly found in Alzheimer's-type dementia. This is a socially maladaptive behaviour characterized by impulsivity. Adjusting the sound intensity according to the type of speech requires social cognition, which refers to the cognitive processes we use to understand and interact with others (Mazaux, 2016). Any appropriate response and adaptive behaviour, including vocal behaviour, require perception, processing, and interpretation of social information (Bertoux et al., 2016). These processes enable the understanding and representation of others, adaptation, cooperation, social belonging, and benefit from social groups (Frith, 2008). This occurs through verbal and non-verbal processes such as facial expressions, body postures, gestures, and even gaze, which provide information about the person's surroundings (Desmarais et al., 2018).

These behavioural changes associated with a lack of inhibition can be explained by an impairment in executive functioning, particularly due to dysfunction in the frontal cortex and related brain structures. Patients with executive function disorders experience difficulties in initiating and regulating their behaviour and lack voluntary control (Grigsby et al., 1995). Since producing voice is a behavior (Révis & Ravéra-Lassalle, 2021), we can attribute the increase in voice intensity to their lack of voluntary control over the vocal apparatus.

In addition to the lack of inhibition, the elevated voice intensity in Alzheimer's can also be linked to agitation commonly observed in the disease. Patients with Alzheimer's have difficulty in self-control, and agitation leads to discomfort and depletion of patience, indicating a mood disorder (Gil, 2014) characterized by muscular tension (Verret & Massé, 2017).

According to Giovanni et al. (2014), increased muscle tension leads to vocal cord stiffness as the vocal cord fibres are stretched. This, in turn, increases the vibrational frequency (F0) of the vocal cords, resulting in an elevation in voice intensity, as mentioned earlier. In cases of agitation, arousal becomes significant. According to Le Huche (2010), the level of sound pressure, referring to sound intensity, tends to increase when there is a significant emotional state, which is also supported by Pell (2013), who highlighted the presence of strong vocal pressure in anger, commonly observed during agitation (Parneix, 2012).

Further research is needed to provide more accurate findings. In this study, we relied on neuropsychological assessments to diagnose Alzheimer's cases based on the patient's medical records. Therefore, reassessing patients in future studies to confirm the type of dementia will enhance the validity of the association between Alzheimer's and the general disruption of voice physical characteristics.

The current study compared the intensity between the pathological cases and normal intensity based on the standard intensity's mean values in the literature. Using a control sample will more clearly determine the differences in the future.
In addition to the points mentioned in this study, the focus was only on conversational voice, without considering other vocal contexts such as singing and declamatory voices. Including these contexts will enhance the accuracy of the research.

9. Conclusion:

This research addressed the intensity of conversational voice in Alzheimer's patients and compared it to standard conversational voice intensity. The results showed a difference between the two, as we observed an increase in intensity among Alzheimer's patients compared to the standard. This can indicate the emergence and progression of the studied neurodegenerative disease, Alzheimer's. According to the obtained results, this increase in intensity affects all stages of the disease's development. The results revealed differences in voice intensity and highlighted the vocal behaviour and muscle strength of these patients, which, in turn, affected the appropriate body posture for producing a conversational voice. Additionally, as previously discussed, this study elucidated the relationship between behavioural disturbances and the cognitive impairments exhibited by these patients in the vocalization process.

References

Adolphs, R.(2001). The neurobiology of social cognition. *Current Opinion in Neurobiology* 11(2), 231-39. https://doi.org/10.1016/S0959-4388(00)00202-6

Baken J.R. (1987). *Clinical Measurement of Speech and Voice*. College-Hill Press.

Beach, T.G., Monsell, S.E., Phillips, L.E., & Kukull, W. (2012). Accuracy of the clinical diagnosis of Alzheimer disease at National Institute on aging Alzheimer disease centers, 2005-2010. *J Neuropathol Exp Neurol*. 71(4), 266- 273. https://doi.org/10.1097/NEN.0b013e31824b211b

Belyk, M., & Brown, S. (2014). The acoustic correlates of valence depend on emotion family. *Journal of Voice*, 28 (4), 523.e9-523.e18. https://doi.org/10.1016/j.jvoice.2013.12.007

Bertoux, M., Delavest, M., de Souza, L. C., Funkiewiez, A., Lépine, J. P., Fossati, P., Dubois, B.& Sarazin, M. (2012). Social cognition and emotional assessment differentiates frontotemporal dementia from depression. *Journal of Neurology, Neurosurgery & Psychiatry*, 83(4), 411-416. https://doi.org/10.1136/jnnp-2011-301849

Paul Boersma & David Weenink (1992–2022): Praat: doing phonetics by computer [Computer program].Version 6.2.06, retrieved 23 september 2022 from https://www.praat.org.

Cornu, G.(2009). *La voix* [the voice]. Puf.

Delacourte, A., Flament, S., Dibe, E. M., Hublau, P., Sablonnière, B., Hemon, B., Sherrer, V. & Defossez, A. (1990). Pathological proteins Tau 64 and 69 are specifically expressed in the somatodendritic domain of the degenerating cortical neurons during Alzheimer's disease. Demonstration with a panel of antibodies against Tau proteins. *Acta Neuropathologica*, 80 (2), 111- 117. https://doi.org/10.1007/BF00308912

Desmarais, P., Lanctôt, K. L., Masellis, M., Black, S. E., & Herrmann, N. (2017). Social Inappropriateness in Neurodegenerative Disorders. *International Psychogeriatrics* 30(2):197‑207. https://doi.org/10.1017/S1041610217001260

Dubois, B., & Epelbaum, S.(2015). Nouvelle définition de la maladie d'Alzheimer [New definition of Alzheimer's disease]. In J.M.Léger & J-L. Mas (dirs), *Démences* (pp 137-144). Doin.

Frith, C. D. (2008). Social cognition. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 363(1499),2033‑2039. https://www.researchgate.net/publication/5560288_Social_cognition

GHIO , A. (2007). Evaluation acoustique [Acoustic assessment]. In P. Auzou, V. Rolland, S. Pinto, C.Ozsancak, (Eds) Les dysarthries [Dysarthrias] (pp 236-247). Solal.

Gil, R. (2014). *Neuropsychologie* [Neuropsychology] *(6ème édition).* Elsevier-Masson.

Giovanni, A. Lagier, A. & Henriche, N.(2014). Physiologie de la phonation [Physiology of phonation]. *EMC. Otho-rhino laryngologie* 0(0), 1-15. https://www.phoniatrie-laryngologie.fr/wp-content/uploads/2017/11/emc-PHYSIO-PHONATION.pdf

Grigsby, J., Kaye, K. & Robbins, L.-J. (1995). Behavioral disturbance and impairment of executive functions among the elderly. *Archives of Gerontology and Geriatrics*, 21(2), 167-177. https://doi.org/10.1016/0167-4943(95)00636-Y

Grossman M., Payer, F., Onishi, K., Wheit-Devine, T., Morrison, D., D'Esposito, M., Robinson, K., & Alavi, A. (1997).Constraints on the cerebral basis for semantic processing from neuroimaging studies of Alzheimer's disease. *J Neurol Neurosurg Psychiatry*.; 63(2), 152-158. https://doi.org/10.1136/jnnp.63.2.152

Guerrero López, H. A. (2010). *Caractérisation de la voix de l'enfant sourd appareillé et implanté cochléaire: Approches acoustique et perceptuelle et proposition modélisation*[Characterization of the voice of the deaf child with hearing aids and cochlear implant: Acoustic and perceptual approaches and modeling proposal][thèse de doctorat, Université Paul Valéry, Montpellier III]. HAL thèses.

Guenther F.H.(2016). *Neural Control of Speech*. The MIT Press.

Hajjar, I., Okafor, M., Choi, J.D., Moore, E., Abrol, A., Calhoun, V.D., & Goldstein, F.C. (2023). Development of digital voice biomarkers and associations with cognition, cerebrospinal biomarkers, and neural representation in early Alzheimer's disease. Alzheimer's Dementia. 15(1), 12393.https://doi.org/10.1002/dad2.12393

Henrich-Bernardoni, N.(2001). *Etude de la source glottique en voix parlée et chantée: modélisation et estimation, mesures acoustiques et électroglottographiques, perception* [Study of the glottal source in spoken voice and sung: modeling and estimation, acoustic and electroglottographic measurements, perception] [Thèse de doctorat, Université Paris 6]. Thèses.fr.

Heuillet-Martin G., Garson-Bavard H., & Legre A.(2012) *Une voix pour tous: la voix normale et comment l'optimaliser* [A voice for all: normal voice and how to optimize it] (3e éd., Tome 1). Solal.

Jarrold,W., Peintner, B., Wilkins, D., Vergryi, D., Richey, C., Gorno-Tempini, M-L., & Ogar, J. (2014, 27 june). Aided diagnosis of dementia type through computer-based analysis of spontaneous speech [conference]. *the Workshop on Computational Linguistics and Clinical Psychology: From Linguistic Signal to Clinical Reality*, 27–37, Baltimore, Maryland, USA. Association for Computational Linguistics. https://aclanthology.org/W14-3204

Kearney E., & Guenther F.H. (2019). Articulating: the neural mechanisms of speech production. *Language Cognition and Neuroscience*, 34(9), 1214–1229. https://doi.org/10.1080/23273798.2019.1589541

Khodabakhsh A., Kuscuoglu S., & Demiroglu, C.(2014, 23-25 Avril). Detection of Alzheimer's disease using prosodic cues in conversational speech [conference]. 22nd Signal Processing and Communications Applications Conference (SIU). Turkey. http://ieeexplore.ieee.org/xpl/articleDetails.jsp?reload=true&arnumber=6830401

Klein-dallant, C.(2001). *Dysphonies et rééducations vocales de l'adulte* [Dysphonia and vocal rehabilitation in adults]. Solal.

König, A., Satt, A., Sorin, A., Hoory, R., Toledo-Ronen, O., Derreumaux, A., Manera, V., Verhey, F., Aalten, P., Robert, P.H., & David, R. (2015). Automatic speech analysis for the assessment of patients with predementia and Alzheimer's disease. *Alzheimers Dement. Diagnosos. Assessment. Disease. Monitorong.* 1(1), 112–124. https://doi.org/10.1016/j.dadm.2014.11.012

Lapre, E. (2010). *Maladie d'Alzheimer et thérapies non médicamenteuses : évaluation de la stimulation Cognitive et de l'activité physique sur le Fonctionnement exécutif* [Alzheimer's disease and non-drug therapies: assessment of Cognitive stimulation and physical activity on Executive Functioning] [Thèse de doctorat, université de Bordeaux]. These.fr.

Le Huche F. &, Allali, A. (2002). *La voix: thérapeutique des troubles vocaux* [The voice: therapy for vocal disorders](3^e^ éd. tome 4). Masson.

Le Huche, F & Allali, A. (2010). *La voix. Anatomie et physiologie des organes de la voix et de la parole* [The voice. Anatomy and physiology of the organs of voice and the speech](4^e^ éd. Tome 1). Elsevier Masson.

McFarland, D. H. (2016). *L'anatomie en orthophonie* [Anatomy in speech therapy](3^e^ éd.). Elsevier Masson.

Marchal Alain. (2011). *Précis de physiologie de la production de la parole* [Summary of the physiology of speech production]. Solal.

Marié Bailly, I.(2004). *La voix sensorielle: percevoir pour émettre* [The sensory voice: perceive to transmit]. [Mémoire diu de phoniatrie, Université Paris 13] https://muse45.org/wp-content/uploads/2015/07/memoire-imb-phoniatrie-la_voix_sensorielle.pdf

Mazaux, J-M, Pierre-Alain, J., Prouteau, A., & Brun, V. (2016). La cognition sociale [Social cognition]. Sauramps Médical.

Meilán, J.J, Martinez-Sanchez, F., Carro, J., Sanchez, J.A, & Perez, E. (2012). Acoustic markers associated with impairment in language processing in Alzheimer's Disease. The *Spanish Journal of Psychology*,15(2), 487- 494. https://dx.doi.org/10.5209/rev_SJOP.2012.v15.n2.38859

Meilán, J- J. G., Martínez-Sánchez, F., Carro, J., López, D. E., Millian-Morell L., & Arana, J. M. (2014). Speech in Alzheimer's Disease: Can Temporal and Acoustic Parameters Discriminate dementia? *Dementia and Geriatric Cognitive Disorders*, 37 (5-6): 327–334. https://doi.org/10.1159/000356726

Morsomme, D., & Estienne, F. (2006). Bilan vocal [Voice assessment]. In F., Estienne, B. Piérart, (Eds), Les bilans de langage et de voix : fondements théoriques et pratiques [Language and voice assessments: theoretical and practical foundations] (pp. 223-257). Masson.

Parneix,M.(2012). *L'irritabilite dans le spectre des troubles de l'humeur, Ses liens avec les temperaments*[Irritability in the spectrum of mood disorders, Its links with temperaments].[Thèse de doctorat, Université de limoges].

Patel, S., Scherer, K. R., Sundberg, J. & Björkner, E. (2010, 14 May). Acoustic markers of emotions based on voice physiology[conference]. speech prosody, Chicago.

file:///C:/Users/abdoun/Downloads/AcousticMarkers2010.pdf

Perrière, S., Révis, J., & Giovanni, A. (2017). *Rééduquer la voix: 8 étapes en chanson* [retrain the voice: 8steps in song]. Deboeck Superieur.

Ranasinghe, K. G., Gill, J. S., Kothare, H., Beagle, A. J., Mizuiri, D., Honma, S. M., Gorno-Tempini M. L., Miller, B. L., Vossel, K.A., Nagarajan, S.S., & Houde, J. F. (2017). Abnormal vocal behavior predicts executive and memory deficits in Alzheimer's disease. *Neurobiology of Aging*, 52, 71-80. **https://doi.org/10.1016/j.neurobiolaging.2016.12.020**

Révis,J.& Ravéra-lassalle, A.(2021). Le bilan orthophonique de la phonation: analyse du geste et des compétences vocales [The speech therapy assessment of phonation: analysis of gesture and vocal skills]. In A. Giovanni(Eds), la voix: anatomie, physiologie et explorations [the voice: anatomy, physiology and explorations] (pp, 90-98). Deboek superieur.

Riley, K.P., Snowdon, D.A, Desrosiers, M.F., & Markesbery, W.R. (2005). Early life linguistic ability, late life cognitive function, and neuropathology: findings from the Nun Study. *Neurobiology of Aging*, 26(3), 341- 347. https://doi.org/10.1016/j.neurobiolaging.2004.06.019

Rousseau ,T. (1995). *Communication et maladie d'Alzheimer* [Communication and Alzheimer's disease]. édition Ortho.

Selingue, B.(2019). *Vivre au quotidien avec Alzheimer* [Living daily with Alzheimer's]. De boeck supérieur.

Verret,C.,& Massé, L.(2017). *Gérer ses émotions et s'affirmer positivement* [Manage your emotions and assert yourself positively]. Chenelière éducation.

Xiu,N., Vaxelaire,B., Li, L., Ling, Z., Xu, X., Huang, L., Soleil, B., Huang, L., & Rudolph, C. (2022). A study on voice measures in patients with Alzheimer's disease. *Journal of the, voice*, S0892-1997(22)00242-9. https://doi.org/10.1016/j.jvoice.2022.08.010

Yang, Q., Li, X., Ding, X., Xu, F., & Ling, Z. (2022). Deep learning-based speech analysis for Alzheimer's disease detection: a literature review. *Alzheimer Research and Therapy,* 14(1), 1-16. https://doi.org/10.1186/s13195-022-01131-3