NLP-Oriented Contrastive Study of Linguistic Productions of Alzheimer's And Control People

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Abstract. The increase in Alzheimers disease is due to the aging of the population and is the first cause of neurodegenerative disorders. Progressive development of cognitive, emotional and behavior troubles leads to the loss of autonomy and to dependency of people, which corresponds to the dementia phase. Language disorders are among the first clinical cognitive signs of the disease. Our objective is to study verbal communication of people affected by the Alzheimer's disease at early to moderate stages. One particularity of our approach is that we work in ecological conversation situation: people are faced to persons they know. We study verbal productions of five people affected by the Alzheimer's disease and of five control people. The conversations are transcribed and processed with the NLP methods and tools. Over thirty features grouped in four categories are studied. Our results indicate that the Alzheimer's patients present lexical and semantic deficit and that, in several ways, their conversation is notably poorer than the conversation of the control people.

Keywords: conversation, linguistics, Alzheimer's disease, speech and language therapy, Natural Language Processing

1 Introduction

The Alzheimer's disease (AD) is related to the aging of the population and is the first cause of neurodegenerative dementia. In 2005, 26 million people suffered from the disease and it is estimated that the number can reach over 100 million people worldwide by 2050 [1, 2]. The disease is widespread in the modern society and researchers from various areas address its detection and therapy.

Progressive appearance of cognitive, emotional and behavior troubles causes the loss of autonomy and the dependency, which correspond to the demential stage of the disease. Language troubles, together with memory and executive function troubles, are the first clinical cognitive signs of the disease [3]. During the early stage, patients are mainly affected by mnesic troubles and keep their language capacity almost intact. With the evolution of cognitive and language troubles, the communication troubles become irreversible and severely impact

daily life of the affected persons and of their families. Preservation of communication ability as long as possible is one of the main objectives of the AD therapy. It helps to save social interactions and prevents people from isolation. Hence, it is important to detect the disease as early as possible. In the following of this section, we present the existing studies on assessment of the language capacity in clinical practice and analysis of the conversation AD language.

1.1 Assessment of Language and Communication Troubles

Assessment of language troubles is part of the Speech and Language Therapy used for the diagnosis and therapy of cognitive neurodegenerative pathologies [4–6]. Tests of language capacity (spoken and written, production and perception) are usually performed during dedicated interviews. The most frequent tests are related to the assessment of lexical production (fluency, naming of pictures...) and of oral expression (description of pictures, chat on a given topic...). They allow performing quantitative and qualitative assessment of language capacity in controlled situations. More natural and ecological language productions are studied very poorly, mainly because of large number of features to consider. If the controlled tests can reveal language deficiency, they cannot assess the impact of language troubles on the daily communication of patients. Besides, supervised situations may penalize those people who are not used to them. We assume that non-supervised conversation tests correspond to more natural language exchanges and are more suitable for diagnosing the disease and assessing the language ability of AD patients.

1.2 Conversation Language Analysis

Some previous studies addressed the analysis of free or semi-directed conversation of elderly AD and healthy people. The studied groups contain as least five people. It has been observed that linguistic performance of healthy persons is dependent on their education level and age [7]. Inter-individual difference is frequently reported because, contrary to supervised tests, it becomes salient in free conversation. Among the available observations, we can find that elderly people use the same vocabulary than young people but produce sentences that are more complex syntactically [8]; they have more approximate and ambiguous discourse, with more periphrases and redundancies; they often refer to the past events during the conversation, are more egocentric and seldom consider what their interlocutor is saying; the proposed topics are respected but with frequent digressions while the semantic coherence is poor [9]. Concerning the comparison between AD and healthy people, it appears that: length of utterances and lexical variation is not age-dependent [10]; utterances of AD patients are less diversified syntactically [10, 11]; AD patients mention less ideas and produce less words [12]; they show redundant and less informative discourse [13–16]; they use lesser number of modalizers [13]; pronouns miss reference and reveal inconsistency [15, 16]. We propose to perform a more complete analysis of the AD conversations

and support it by the use of the NLP methods and tools (section 2). The experiments are described in sections 3 and 4. We then present and discuss the results (sections 5 and 6) and indicate the directions for future work (section 7).

2 Objectives and Hypotheses

Our objective is to study the language of AD patients produced in conversation context with known interlocutor. These are more ecologic conditions than usual, and we assume they are more relevant for studying the specificity of the AD language. We propose to enrich the existing knowledge on the disease for its better diagnosis and therapy, and perform for this contrastive analysis of AD and healthy people. To make the analysis systematic and to study wide range of features, we use the NLP methods and tools.

3 Linguistic Material Studied

The two groups studied include homogeneous people as for their age (average=90), gender (women), social and cultural level, and place of life (institutions for elderly people in North of France). Conversations of five AD patients (89 to 99 years) and five control people (83 to 102 years) with known interlocutor are recorded. The AD patients are checked up to make sure they do not have previous neurological and psychiatric history. They must have low or moderate stage of the disease, and be communicating. Medical history of control people is also checked up.

To start the conversation, two pictures are presented (departure by train for vacations and bicycle ride in 1950s). The preferred picture is first chosen, but later the discussion is oriented on the other picture. The interviews are not limited in time: they last from 20 to 40 minutes. The interviews are then transcribed with Transcriber [17], which allow marking additional information. Transcription is done with the standard spelling [18] and some adaptations:

- transcription is orthographic (and not phonetic);
- transcription is lexically and syntactically correct to make possible the use of the NLP tools;
- transcription can contain marking of some features relevant for the study (disfluencies, hesitations, pauses...).

The marking up the features like disfluencies, hesitations and pauses, that are very frequent in spoken language productions, makes the transcriptions close to the original productions and no information is losed at this step. Still, as indicated, the transcription with lexically and syntactically correct sentences makes possible the use of the NLP tools. These two aspects are important for our study. If necessary, it is possible to go back to the original record and to re-analyze the conversation.

Twenty minutes of conversation are transcribed for each speaker, which required over 100 hours of work. Corpora are anonymized.

4 Methodology for Studying the Transcribed Conversations

The analysis proposed addresses two aspects: verbal interaction (section 4.1) and content of conversations (section 4.2). Corpora are POS-tagged with TreeTagger [19] and then corrected with Flemm [20]. Lemmas are morphologically analyzed by Dérif [21]. Data encoded during transcription (time of speech, shift of speakers, disfluencies, hesitations, pauses...) are also exploited. Some features are proposed in the literature, while others correspond to the original contribution of our work. The feature values (average, minimal or maximal) are computed at the level of persons and then at the level of the (AD and control) groups. We also use a set of interjections, such as *oh*, *ah*, *bon (well)*, *là (here)*, *donc (hence)*.

4.1 Analysis of Verbal Interaction

Two verbal interaction features studied are provided by Transcriber:

- *Turns of speech.* Turns of speech allow studying the dynamics of exchanges;
- *Time of speech and overlapping.* Time of speech and overlappings are indicative of the participation of people in conversations and of their interactions.

4.2 Analysis of Conversation Content

We distinguish spoken, lexical and syntactic features. We give examples in English, although work is done on the French data.

Spoken Features. Among the spoken features, we study the following:

- *Breath groups.* Interruptions of utterances are considered as breath groups, and can be linked with people physiology and with their mental processes;
- *Empty pauses.* Empty pauses are integral part of conversations. They ensure fluency of discourse and give time for understanding and thinking. Empty pauses last at least one second and contain no words;
- *Non-empty pauses.* Non-empty pauses contain only disfluencies (*euh*, *hum*...) and lengthened syllables;
- *Primes.* Primes cover different situations [22, 23]: the corrected words may keep the same syntactic function (e.g. *Wha- what*), or change it (e.g. *He will be retired in t- when he is seventy-two*);
- *Repetitions and stutters.* We study disfluency repetitions [23], like in *And then you arrive in in beautiful gardens*. Stylistic repetitions (e.g. *It was raining it was raining* meaning *it was raining a lot*) are not considered. Stutters are repetitions usually caused by articulatory problems;
- *Self-corrections.* Self-corrections can be related to grammatical corrections (*well port-work have has been better paid*), paradigmatic corrections using the same syntactic structure (*we all meet in a at one person home*), or different syntactic structure (*the buildings belong to she is not the owner*);

- *Interruptions.* Interruptions occur when speaker stops the utterance without completing, repeating or correcting it (e.g. *Well, there is...*) [24]. The speaker can then start another utterance or stop speaking at all;
- *Verbal output.* Verbal output is the ratio between the total number of words and the total time of speech (without empty pauses). It is estimated that normal speakers produce 200 words/minute on average.

Lexical Features. Lexical features address lexical variability and complexity:

- *Number of words.* This measure gives global quantitative indication on verbal productions. We compute total number of words without disfluencies;
- *Informativity.* The lack of informativity can be revealed with lexical units such as interjections (*oh*, *ah*, *well*, *here*);
- *Yes/No utterances.* Some utterances may contain only *yes* and *no* words. They also indicate the lack of informativity;
- *Lexical diversity.* Lexical diversity is the number of types of lemmas (nouns, verbs and adjectives);
- *Ratio lemmas/total words.* Ratio lemmas/total words is representative of semantic content of conversations and gives another assessment on lexical diversity of speakers;
- *Morphological complexity.* Morphological complexity of words, computed with the Dérif analyzer, corresponds to number of bases and affixes they contain;
- *Lexical frequency.* Lexical frequency of each lemma is computed in the corpora processed and on the web (in August 2013).

Syntactic Features. Syntactic features address complexity of sentences:

- *Average length of utterances.* Utterance is defined as linguistic unit with common semantics and showing decrease in voice frequency at the end [25]. Average length of utterances, computed without disfluencies, corresponds to the ratio between total number of words and number of utterances;
- *Interpolated clauses and reported speech.* Interpolated clauses and reported speech indicate the distance the speaker has with his own conversation [26]:
  - interpolated clauses are often used to add new information necessary for the understanding (*Then I ask the driver he is very kind the driver to stop near the church.*)
  - reported speech means that the speaker is able to use statements produced by other people and to keep the right references (*He says: "Mary you are not right..."*)
- *Personal pronouns.* The ratio of personal pronouns is computed within the whole number of lemmas;
- *Verbs.* The number of verb lemmas is computed;
- *Distribution within syntactic categories.* We compute the distribution of lemmas among verbs, nouns and adjectives.

Features	AD	Control	Diff.
Verbal interaction			
Turns of speech (avg.)	194.80	181.80	-7
Time of speech (min.)	*7'56"*	*11'08"*	-46
Time of speech (max.)	*13'11"*	*17'24"*	-31
Time of speech (avg.)	11'16"	14'12"	-26
Overlapping (avg.)	*0.59*	*1.01*	-71
Spoken features			
Breath groups (avg. words)	3.90	4.31	-10
Empty pauses (avg.)	*65.00*	*31.00*	52
Non-empty pauses (avg.)	*13.00*	*34.60*	-166
Disfluencies (avg.)	*30.00*	*37.00*	-24
Primes of words (avg.)	*2.8*	*8.4*	-200
Interrupted sentences (avg.)	18.8	19.40	-3
Speech output (max. words/min.)	184.23	> 190	-3

Table 1. Results observed for various features studied with AD and control people.

4.3 Comparison of Average Values

The average values for each feature are compared at the level of groups to detect those features that show important deviation from normal (control) values. Given two average values, A_1 (normal) et A_2 (AD), we compute: $\frac{A_1 - A_2}{A_1} * 100$.

5 Results

In Tables 1 and 2, we present the results obtained for the comparative analysis between AD and control groups. Features are grouped as previously in four sets (verbal interaction, spoken, lexical and syntactic features). Difference between the values is considered as notable if it is higher than 20% in either way. Notable features are marked in italics. We assume these features can be used for the differentiation between AD and control people, and for the diagnosis of the Alzheimer's disease.

Almost all features related to verbal interaction show notable difference: minimal, maximal and average time of speech (usually higher in control group), and overlappings (also higher in control group). The number of turns of speech is similar in the two groups. Also, it should be noticed that we observe important intra-group and personal difference. Indeed, independently on the disease, some people are used to speak more easily and rapidly, while other people may remain reticent even when speaking with know interlocutor.

Several features from the spoken feature set show notable difference. The AD patients produce more empty pauses and less non-empty pauses; less repetitions, self-corrections and primes of words than control people, which is contrary to what is usually observed in the literature [13–15], although their distribution is balanced. Among the features that do not show notable difference, we can find

Features	AD	Control	Diff.
Lexical features			
Number of words (avg.)	*1,778.4*	*2,407.4*	-35
Informativity (avg.)	9	8	11
Yes/No utterances (avg.)	*88.80*	*52.40*	40
Lexical diversity (avg.)	*168.60*	*302.40*	-79
Lemmas/total words ratio (avg. %)	*10*	*14*	-32
Morphological complexity	1	1.07	-3
Lexical frequency in corpora (avg.)	*11*	*8*	25
Lexical frequency on the web (avg.)	*304,000,000*	*227,000,000*	25
Syntactic features			
Length of utterances (avg.)	*4.79*	*7.26*	-51
Interpolated clauses (avg.)	*1.20*	*4.80*	-300
Reported speech (avg.)	*1.60*	*14.20*	-787
Personal pronouns (avg. %)	*36*	*23*	37
Pronoun/noun ratio	1	0.65	6
Verbs (avg.)	*377*	*553*	-46
Ratio of verbs	32	32	0
Ratio of nouns	51	55	-5
Ratio of adjectives	16	14	14

Table 2. Results observed for various features studied with AD and control people (continued).

length of breath groups, number of interrupted sentences, and speech output. Here again, we observe great inter-personal variability. For instance, 2 out of 5 patients in the AD group show high speech output, although people with higher speech output always belong to the control group.

Almost all lexical features show notable difference: number of words (higher in control group), number of *Yes/No* utterances (higher in AD group), lexical diversity (higher in control group), lemmas/total occurrence ratio (higher in control group), average frequencies in the corpora studied (higher in AD group because the lexicon is more redundant) and on the web (higher in AD group because the AD patients use more common and frequent words). Informativity and morphological complexity features are comparable in both groups. Concerning morphological complexity, several common affixes (e.g. *-ment*, *-tion*, *dé-*, *re-*) are not processed currently by Dérif. We assume their treatment may change the impact of this feature.

Syntactic features that show notable difference are: average length of utterances (higher in control group), interpolated clauses and reported speech (higher in control group), personal pronouns (higher in AD group), number of verbs (higher in control group). The two remaining features (pronoun/noun ratio and distribution within syntactic categories) show no notable difference.

6 Discussion

The results we propose contain diversified analysis of the AD patients free conversation. Some features provide salient information while others do not appear to be specific to a given group. With the use of the NLP tools we are able to propose systematic and reproducible analyses of corpora. We propose now the discussion of the results: their interest for the task and current limitations.

6.1 Specificities of the AD Group

Our study points out several linguistic specificities of the AD patients through their comparison with the control group:

- they speak less for the equal speaking time,
- they show higher number of turns of speech, they segment more frequently their discourse and produce shorter utterances,
- their speech output is slower,
- they do not speak at the same time as their interlocutor (overlapping is very low) and do not interrupt sentences,
- they often produce minimal utterances with *Yes/No* words only,
- their discourse contains small number of disfluencies,
- they have more empty pauses and less non-empty pauses,
- they seldom use interpolated clauses and reported speech,
- they use more pronouns, especially at the first person in singular,
- the lexical diversity is poor, whatever the part of speech,
- they use more common and frequent words with higher frequency.

Our hypothesis concerning the possible identification of lexical and semantic troubles seems to be confirmed. Indeed, verbal production of AD patients can be quantitatively and qualitatively differentiated from the verbal production of control people: AD patients speek less, produce shorter and less elaborated utterances. They show tendency to use frequent words, to produce redundant vocabulary and more pronouns without reference. They do not take the initiative for verbal exchanges, remain centered on their own opinions and show low distance from what they are saying. These facts can explain why their discourse does not contain disfluencies, non-empty pauses, interpolated clauses and reported speech, and why they use a lot of *yes* and *no* statements. These are the main findings of our work.

Besides, consideration of a large set of conversation features open new perspectives on the pathological language. If the existing studies of lexical and semantic troubles of the AD patients concentrate on surface features (paraphasias, pauses, self-corrections, repetitions and interrupted utterances), our study indicates that non-observation of these features does not imply the absence of troubles but indicates that the troubles can be revealed differently, such as less elaborated and poorer utterances or lesser participation in verbal interactions. We assume that our study provides the clinicians with additional features to

explore for the correct and more sensitive diagnosis of the disease and for its therapy.

In a recent study on the analysis of semi-directed interviews with aphasic patients, the researchers have also proposed to explore features issued from the NLP methods (e.g. semantic categorization of answers, their coherence and semantic distance [27]). This study revealed that classical clinical features (number of correct answers, time needed for answers...) are more efficient than those issued from the NLP. Our work points out that the application of NLP to this kind of corpora can bring new light and reveal additional information useful for the identification of lexical and semantic troubles and for a better understanding of mechanisms involved in language production by AD and control people. The findings also propose new solutions for helping the patients to save their verbal communication and social interactions. The positive impact of the NLP methods and tools for the study of pathological AD language is another positive finding of our work.

6.2 Other Results

As we have observed, some features are not specific for a given group and do not show notable difference between AD and control groups:

- number of turns of speech and of breath groups, as well as the average speech output,
- distribution of disfluencies,
- distribution of lemmas within syntactic categories and ratio between pronouns and nouns,
- informativity and morphological complexity of words.

We assume that, at early stage of the disease, some aspects of conversation language are preserved by the AD patients and remain similar to those observed with healthy people. The speech therapy should rely on these features to maintain language performance of the AD patients.

As we have noticed, the results must be looked at in the context of their intra-group and inter-individual variability. The main reason of this finding is that people are interviewed in natural situation without constraints, which increases the inter-individual variation: personal factor is more real than in artificial directed test conditions. Independently on pathology, the personality of every people has impact on their performance in real conditions. Similarly, it is necessary to consider how the people are used to be, because some of them may have naturally high or low output, or tendency to interrupt other people. In such conditions, it is more difficult to define the normal values and to compare the performance of speakers. On contrary, larger set of features may partially inhibit this variable. Still, it is necessary to study larger group of people in order to take into account larger set of population and also to take into account previous known performance of people. Another possibility is to consider the combination of features and to study the potential relations these features have among them.

6.3 Limitations of the Current Study

The limitations of current study are related to the exploitation of features, to the data processed and to the NLP and statistical methods.

The Features Exploited. The impact and relevance of features are studied individually, thanks to the comparison of their average values from the two groups (AD and control people). This gives first indications on their importance. We plan to combine these features within common models built with machine learning algorithms for instance. Besides, this perspective can help to test the features during the automatic categorization of new people conversations in order to define whether these people are affected by the disease or not. Concerning the word frequency collected on the web, this feature is not fully reliable *per se*. In the experiments proposed, we wanted to test it, because it was available, and to see whether this feature is interesting to be explored individually or in combination with other features. Our current intuition is that this feature should be combined with other features. The word frequency can also be computed in reference corpora.

The Corpus Studied. Currently, we exploit language production of small number of people: five AD and five healthy people. First of all, the number of people is comparable to the one usually used in this kind of studies and containing at least five people. Indeed, it remains complicated to recruit larger number of homogeneous groups of participants with health specificities such as those aimed in our study. The transcription of the conversations is also a long and tedious task: for the currently studied corpora, totiling ten interviews, we needed up to 100 hours to transcribe the conversations. Nevertheless, we plan to interview larger number of participants in future. One particular reason is that we would like to inhibit the inter-individual variable and to be able to generalize the observations on a better basis. The main difficulty is then to collect the necessary data and to perform their transcription. Despite this limitation, we feel that the currently studied corpora and features provide strong indicators on the difference between the conversations collected with healthy people and the AD patients.

The NLP Methods Used. Concerning the limitations related to the NLP tools, the morphological analyzer Dérif does not fully cover the affixes of the French language. For instance, affixes such as *-ment*, *-tion*, *dé-* or *re-*, that are part of the common competence of speakers, are not analyzed in the current version of the tool. We think that their treatment may allow obtaining more relevant results concerning the morphological complexity of words. Besides, other NLP tools can be used. For instance, syntactic parsers can be used to assess the syntactic complexity of sentences, which can complete the set of features we currently study for the analysis of the AD conversation language.

The Contrastive Measure Used. For the contrastive analysis of the data, we use the numerical difference in percentage between the average values from the two datasets. If this gives some indications, we plan to improve this aspect and to use more sophisticated statistical significance measures, such as *Student's t-test*.

7 Conclusion and Future Work

We have proposed a comparative analysis of spoken transcribed corpora collected with five healthy and five Alzheimer's disease patients, all of which are over 80-year old. These data provided us the possibility to study the conversation language of AD patients and to compare it with productions of healthy people. The analysis of the conversation appears to be complex because of the variety of features involved. In the existing studies on the Alzheimer's disease language, researchers usually analyze small number of features on language productions collected in semi-directed context with non-known interviewers. As we indicated, language productions collected during directed standard language tests are not always good indicators to understand the communication troubles specific to AD patients. We work in the context of free conversation and observe that lexical and semantic deficit is real with AD patients in such natural conditions. It is particularly observable through the reduced conversation competence of speakers. Thus, even if people are communicating, the decrease of the utterance length, the reduced quantity and diversity of vocabulary, and of speech output indicate that AD patients do not have the same linguistic capacity than the one of healthy people. Our analysis also indicates that AD patients find it difficult to communicate in natural situations: they can hardly take the initiative in verbal exchanges, produce complex utterances, and maintain the conversation. Often, AD patients are helped for this by the existing language automatisms elaborated lifelong and preserved despite the loss of informativity, spontaneity and dynamics of language exchanges.

Conclusions of this first study propose a better understanding of the language troubles observed with the AD patients and their possible impact on daily communication. These findings encourage to continue studying conversation productions to propose better protocols for the diagnosis of Alzheimer's disease and its therapy, and to help people maintaining social interaction and autonomy as long as possible. New data to be collected will enrich the corpora studied. Their exploitation will diversify (age, gender of participants for instance) and complete the current study. As we have mentioned, it is necessary to improve the analysis obtained with the NLP tools and to use additional tools for performing syntactic and semantic analysis. For instance, we observed that the use of verbs shows notable difference in the two studied groups. We can make this analysis more detailed and take into account the semantic categorization of verbs [28] and to explore whether the two groups use the same types of verbs. The morphological analyzer is not sufficient and should be enriched with the analysis of more affixes. The features concerned with the verbal interaction have been

studied poorly and should be addressed better in future studies because they are particularly important for the communication situations. The use of the NLP methods and tools provided the possibility to perform quantitative analysis of a large set of features issued from pathological language, and shows the advantage of this kind of approach. Complementarity between language and gesture exchanges can also provide directions for future work. A stronger statistical significance measures will complete the analysis proposed. Finally, the automatic categorization of persons on the basis of their linguistic productions in order to make the diagnosis of the AD is another perspective of our work.

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