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'Title page (not for review)'

Syntactic and lexical context of pauses and hesitations in the discourse of Alzheimer patients
and healthy elderly subjects

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Keywords: Alzheimer's disease, spontaneous speech, speech rate, pauses, lexical
frequency, french language.

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Abstract

Psycholinguistic studies dealing with Alzheimer's disease (AD) commonly consider verbal aspects of language. In this paper we investigated both verbal and non-verbal aspects of speech production in AD. We used pauses and hesitations as markers of planning difficulties and hypothesized that AD patients show different patterns in the process of discourse production. We compared the distribution, the duration and the frequency of speech dysfluencies in the spontaneous discourse of 20 AD patients with 20 age, gender and socio-economic matched healthy peers. We found that patients and controls differ along several lines: patients' discourse displays more frequent silent pauses, which occur more often outside syntactic boundaries and are followed by more frequent words. Overall patients show more lexical retrieval and planning difficulties, but where controls signal their planning difficulties using filled pauses, AD patients do not.

Keywords: Alzheimer's disease, spontaneous speech, speech rate, pauses, lexical frequency, french language

Syntactic and lexical context of pauses and hesitations in the discourse of Alzheimer patients and healthy elderly subjects. Language production is a complex activity involving almost simultaneous planning of content, syntactic structure, lexical retrieval and articulation (Levelt, 1989) involving executive functions to control the execution of this complex, goal-directed activity. In addition, this activity is performed under strict temporal pressure since the average rate of production is around two or three syllables per second.

Temporal characteristics of speech

Speech production cannot be continuously exercised for several reasons including physiological reasons such as respiratory activity and cognitive planning (Zellner, 1994). Psycholinguists investigated the location and duration of cognitive pauses in order to identify a valid psychological unit of planning. Syntactic units rapidly appeared as good candidates. Early studies on pause duration and location demonstrated that hesitation phenomena tend to occur at major syntactic boundaries. The pioneering study by Maclay and Osgood (1959) hypothesized a non-random distribution of pauses. Hawkins (1971) claimed that the clause is an important encoding unit of speech on the basis of the finding that two thirds of pauses were located at clause boundaries and accounted for three quarters of total pause time. The well-known survey by Goldman-Eisler (1972) aiming at assessing the psychological validity of syntactic units also established the link between syntactic properties and temporal organization of speech production. It was shown that the higher the degree of integration between clauses, the fewer pauses were encountered at the junction. Grosjean, Grosjean and Lane's (1979) findings were similar in reading experiments. When asking participants to read sentences at a low rate in order to make pauses more salient, they found that pauses tended to be long and frequent between words that had little cohesion and were shorter and scarcer between words with a high degree of cohesion. Gee and Grosjean (1983) investigated pause patterns further, focusing on the lack of correspondence between syntactic structures

and psycholinguistic structures called 'performance structures'. They found that the sentences are broken into basic units that are 'rather small' (3.46 syllables in a reading experiment in French, Monnin and Grosjean, 1993), independent of respiratory constraints, they show a rich hierarchical structure and they tend to be symmetrical, that is the main pause occurs around the middle of the sentence. The latter characteristic is crucial for explaining the mismatch between syntactic description and performance: while syntactic structures are insensitive to the length of their constituents, length of constituents matters for performance structures (Zellner, 1994).

Speech rate and pauses in normal and pathological aging

Since normal aging involves a slowing of neural processes, it may be expected that speech segments will take longer to produce, and that speech rate should decrease with age. Penny, Mitchell, Saunders, Hunwick, Mitchard and Vrlic (1996) actually found no difference in speech rate between 65 and 90 years of age. With regards to pausing however, several studies on temporal characteristics of speech production in normal aging showed an increase in the frequency and duration of silent pauses, reflecting lexical retrieval difficulties and/or cognitive slowing down (Nef and Hupet, 1992; Kemper, 1992; Schmitter-Edgecombe, Vesneski and Jones, 2000; Burke and Shafto, 1994). Indeed word finding difficulties are known to increase with age (Shwartz, 2005; Mortensen, Meyer and Humphreys, 2006) and they are reflected in pausing (Zellner-Keller, 2007). By contrast, Kynette and Kemper (1986) did not find significant changes in the production of fillers or incomplete sentences between 50 and 90 years of age.

Turning to Alzheimer's disease (henceforth AD), studies comparing temporal features of AD patients to controls found that the former produce more silent pauses than the latter (Illes, 1989; Bucks, Singh, Cuerden and Wilcock, 1997; Singh, Burke and Cuerden 2001;

Hoffmann, Nemeth, Dye, Pakaski, Iinyi and Kalman, 2010). In addition, Singh *et al.* (2001) computed other temporal measures including verbal rate and phonation rate. They found that the proportion of speech time dedicated to pauses is not of critical importance to discriminate AD patients from controls, but these results need to be ascertained because of the small number of participants in the study. A recent work by Hoffmann *et al.* (2010) tends to confirm those results: comparing four temporal parameters (articulation rate, speech tempo, hesitation ratio (i.e. pauses), and rate of grammatical errors) across AD patients and controls, they found significant differences between both groups, especially for hesitation ratio. In addition, temporal characteristics of speech seem to be of critical importance to discriminate AD from other neurodegenerative pathologies (Illes, 1989), and to discriminate healthy elderly individuals from AD individuals, even at the earliest stages of the disease (Hoffmann *et al.*, 2010). Fewer studies have investigated the linguistic context of occurrence of pauses. In an attempt to identify which linguistic forms are more resistant and which ones are more vulnerable to Alzheimer's disease, Tapir-Ladino (2003) demonstrated that verbs are more often preceded by a pause than nouns, suggesting that the latter grammatical category is more robust.

One should be very careful however when interpreting these results because they vary along several lines relating to methodological issues. Concerning the participants, some studies include only a small sample (Illes, 1989: n=10; Singh *et al.*, 2001: n=8). In addition, some studies include participants with mild to moderate stages symptoms of AD (e.g. Illes, 1989) while others also include participants at severe stages of the disease (Singh *et al.*, 2001; Bucks *et al.*, 1997). Another source of variation lies in the control of the level of education of the participants, which we know is likely to have a strong impact on AD patients' cognitive functioning (Turell, Lynch, Kaplan, Everson, Elkala, Kauhanen and Salonen, 2002; Karp, Kareholt, Qiu, Bellander, Winblad and Fratiglioni, 2003; Wilson, Scherr, Hoganbson,

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Bienias, Evans and Bennett, 2005). In Illes' study, participants are matched for this variable, as they are in Hoffmann (2010) where the participants all have a relatively high level of education, with a mean around 12 years. The other studies do not mention whether this possibly important variable was taken into consideration. Another methodological issue relates to the identification, labelling and measurement of the different temporal variables. First, the threshold for detecting silent pauses varies across studies: 200 ms in Illes (1989), 300 ms in Hoffmann *et al.* (2010) while in Tapir-Ladino (2003), Bucks *et al.* (1997) and Singh *et al.* (2001) the threshold is not mentioned. In the latter studies however, one can guess that the threshold was very high since pauses were measured with a stop watch and they found durations around two seconds. With the exception of Illes (1989), filled pauses are usually not taken into consideration. For speech rate, different units are used: number of words per minute (Illes, 1989; Singh *et al.*, 2001), number of phonemes per second (Hoffmann *et al.*, 2010). Another possible source of confusion lies in the labelling of the different temporal variables: some authors use the same label to refer to different phenomena. For instance in Illes (1989), 'Verbal rate' refers to the total number of words per speaking time (minus hesitation time) while in Hoffmann (2010), the same term is used to refer to the total number of phonemes per speaking time (including hesitation time). We claim that these methodological discrepancies should be kept in mind and that comparisons across studies should be very careful. In our view variables such as level of education or socioeconomic status should be carefully controlled and pause time data must be measured as precisely as possible.

Finally, most studies focus on silent pauses without paying attention to filled pauses which, even though less frequent, are nevertheless functionally important as they stand for reliable pragmatic indicators of 'turn protection' (Maclay and Osgood, 1959) as well as

markers of 'preparedness problems' (Clark and Fox Tree, 2002) that can be observed during the process of lexical retrieval.

Word retrieval difficulties

The language of AD patients shows pervasive disturbances even at the earliest stages of the disease, especially in the lexico-semantic domain (see Barkat-Defradas *et al.*, 2008 for a recent review). Word retrieval difficulties are experienced by any speaker, but this phenomenon tends to increase with age (Schwartz and Frazier, 2005; Mortensen *et al.*, 2006; Zellner-Keller, 2007), and is an early sign of AD as demonstrated by naming experiments. But speech production analysis also documents word finding difficulties (Croisile *et al.*, 1996).

Several factors are known to affect lexical retrieval in general as well as in AD patients, among which we will focus on word frequency and grammatical category. Lymperopoulou, Barry and Sakka (2006) investigated the effect of Age-of-Acquisition and frequency in a naming task performed by patients with Alzheimer's disease. They found that the naming accuracy was affected by both factors, which is confirmed in Ferreiro, Davies, Gonzalez-Nosti, Barbon and Cuestos (2009). In free speech, open class items are typically replaced by more general thus more frequent terms such as 'thing, stuff, do' (Bird, Lambon Ralph, Patterson and Hodges, 2000; Meteyard and Patterson, 2009). Turning to the grammatical category of the lexical items prone to retrieval difficulties, naming experiments bring contradictory findings regarding AD individuals' performances in object versus action naming. While some studies find an advantage for verbs (for instance Robinson, Grossman, White-Devine and D'Esposito, 1996), others fail to find differences between verbs and nouns (Cappa, Binetti, Pezzini, Padovani, Rozzini and Trabucchi, 1998; Lee, Tzeng, Hung, Fuh and Wang, 1998) or find an advantage for nouns (Robinson *et al.*, , 1996; Kim and Thompson,

2004). Ferreiro *et al.* (2009) hypothesize that this lack of consensus is due to insufficient control over the stimuli used. When controlling for name agreement, visual complexity, frequency, orthographic neighbourhood, word length, imageability and age of acquisition, they did not find any difference for the grammatical category. In addition, the authors found that AD individuals tend to replace specific verbs by more generic ones in their discourse.

Beyond the inconsistency in the results of previous studies, Kim and Thompson's (2004) work is of special relevance for our research since it includes, among other tasks, a narrative production, which is definitely more ecological than naming tasks. Another promising step lies in focusing on those moments – typical of spontaneous speech – that are not filled with linguistic material. Indeed, we claim that the search for the most vulnerable components of language in AD can benefit from the study of speech temporal characteristics as well as oral dysfluencies.

Pauses as a reliable cue for lexical retrieval difficulties

Hypothesis

Because of the impairment of executive functions and word finding difficulties, AD patients should (i) produce more and longer pauses as well as more hesitations than controls, whilst speech rate should not differ; (ii) break their discourse into smaller units than controls (performance structures); (iii) produce more pauses at minor syntactic boundaries. Besides, if verbs are more difficult to process they should be preceded more often by a dysfluency than nouns. Finally, if patients tend to replace specific words with more generic ones, words following a pause should be more frequent in AD patients.

Method

Participants. Twenty participants diagnosed with probable Alzheimer's disease and twenty healthy controls matched for age, sex, level of education and socioeconomic status (measured with Poitrenaud's scale, 1995) participated in the study. The AD participants were diagnosed using GDS Reisberg, Ferris, de Leon and Crook(1982) and NINCDS-ADRDA criteria (McKhann, Drachman, Folstein, Katzman, Price and Stadlan, 1984) suffered from mild to moderate dementia as gauged by the Mini-Mental State Examination (Folstein, Folstein and McHugh, 1975). All participants were native speakers of French. The participants were tested at home or in a nursing home. Informed consent was obtained either from the participant or from a close relative for some patients prior to testing. Demographic information of the participants is provided in Table 1.

Insert table 1 about here

Procedure. Spontaneous speech data were elicited by the experimenter asking the participants about biographical details such as the best/worst day in their life. The data were then carefully transcribed using Transcriber ® (Barras, Geoffrois, Wu and Liberman, 2000) a freeware tool for segmenting, labelling and transcribing speech.

Coding.

(i) Any silence exceeding 200 ms was coded as a silent pause and its duration was precisely measured. Filled pauses and vocalic lengthenings were also measured. Finally hesitation phenomena were coded. Example (1) shows an excerpt of the transcribed data. The mean number (per number of words) and the mean duration of each type of dysfluency were computed.

(1) PAT: ah ben de toutes façons <Silent pause: 0.67> pour le moment
ce :<Lengthening: 0.45> même <Hesitation : c- ce > qui m'a: <Lengthening: 0.45> <Silent
pause: 0.71> handicapée <Silent pause: 0.25> toute la vie ma belle-mère <Silent pause: 0.58>

(Well, anyway / so far wha:t / handicaped me / my whole life my mother-in-law)

(ii) Speech rate was computed by dividing the number of syllables per the total amount of time, including pause time. Articulation rate was computed by dividing the number of syllables per the total amount of time, excluding pause time.

(iii) These dysfluencies were used as delimiters of speech chunks which were measured in terms of duration and number of syllables.

(iv) Filled and silent pauses were then coded depending on their location following Grosjean and Deschamp's (1972) procedure: at a major syntactic boundary 'external pause' as in (2) or inside a phrase 'internal pause' as in (3). In (2) pauses occur between clauses. In (3), silent or filled pauses break the verb phrase between the auxiliary and the past participle, or break the noun phrase between the determiner and the noun.

(2) PAT: alors je vais vous dire quand j'avais 5 ans <Silent pause: 1.21> j'étais vilaine <Silent pause: 1.08> je prenais le jour pour la nuit bébé déjà <Silent pause: 0.87> et pis j'étais très vilaine.

(So let me tell you when I was five years-old / I was naughty / already as a baby I was mistaking the day for the night / and I was very naughty)

(3) PAT: la même entreprise <Silent pause: 0.49> dont j'avais <Filled pause: 0.32> organisé le <Silent pause: 1.89>: le service

(The same company / for which I had / organized the / service)

(v) Each word reflecting difficulties of lexical retrieval (following Zellner-Keller's principles, 2007) was coded for its grammatical category (Noun, Verb, Adjective) and for its

frequency determined in Lexique 3.01 database (New, Pallier, Ferrand and Matos, 2001). The dependant variables under examination are summarized in Table 2.

Insert table 2 about here

Results

The first set of variables under consideration is related to pause time data. Table 3 provides the mean number of silent and filled pauses, lengthenings and hesitations.

Insert table 3 about here

As can be seen from table 3, silent pauses and hesitations are more frequent in patients' than in controls' speech ($t_{(38)}=2.73$, $p < 0.01$ for silent pauses and $t_{(38)}=3.64$, $p < 0.001$ for hesitations). By contrast, there are no significant differences in the number of filled pauses and lengthenings.

Turning to the proportion of time dedicated to speech and dysfluencies over the total duration of the recording, Table 4 provides the main results.

Insert table 4 about here

Patients dedicate significantly less time to speech and conversely more time to hesitation phenomena than controls ($t_{(38)}=2.42$, $p= 0.02$). The proportion of silent pauses are marginally higher in patients ($t_{(38)}=1.85$, $p= 0.07$) while the difference fails to reach statistical significance for filled pauses and lengthenings.

Turning to the duration of each type of dysfluency, Table 5 shows the main results.

Insert table 5 about here

Even though pauses (filled and silent) and lengthenings appear slightly longer in patients than in controls, these differences are not statistically significant.

Table 6 shows the results for speech rate and articulation rate.

Insert table 6 about here

Overall, patients produce significantly fewer syllables per minute than controls ($t_{(38)}=2.17$, $p=0.035$). However, if pause time is removed in order to calculate articulation rate, this difference is no longer significant.

As for the duration of verbal sequences, as shown in Table 7, it is longer in controls than in patients ($t_{(38)}=2.52$, $p=0.01$). Similarly, verbal sequences are longer in terms of number of syllables in controls ($t_{(38)}=2.58$, $p=0.01$).

Insert table 7 about here

Table 8 below shows the grammatical context where dysfluencies are found. Patients produce more pauses at sites which do not correspond to syntactic boundaries ($t_{(38)}=2.24$, $p=0.03$). Turning to the grammatical category our results show that controls tend to experience more word finding difficulties with nouns ($t_{(38)}=1.95$, $p=0.58$) whilst patients have more word retrieval difficulties with adjectives ($t_{(38)}=2.22$, $p=0.03$). By contrast no difference is found for verbs.

Insert table 8 about here

Table 9 shows that, as expected, patients experience significantly more trouble with lexical retrieval than healthy elderly subjects ($t_{(38)}=2.033$, $p=0.05$). Regarding the mean frequency of words following a pause in patients' and controls' speech, our study reveals that these lexical items are significantly more frequent in patients' speech than in controls' ($t_{(38)}=4.008$, $p=0.0003$).

Insert table 9 about here

Discussion

The results presented in this study were obtained using a strictly controlled methodology which included a reasonably large number of AD participants ($n=20$) matched

for sex, age and sociocultural / socioeconomic levels with controls. Our group of patients was homogenous in terms of the degree of severity of the disease (i.e. no patient at a severe stage of AD was included). Natural spontaneous speech was collected and transcribed manually by experts who carefully measured pause duration using the standard auditory threshold for perception of pauses (i.e. 200-250 ms) as defined by Goldman-Eisler (1972), Grosjean and Deschamps (1972), and Zellner (1994).

Though previous studies have underlined that silent pause duration rather than pause frequency makes a difference between AD individuals and healthy elderly individual's speech (Singh *et al.*, 2001; Tapir-Ladino, 2003), the present work does not replicate these findings. We find no significant differences in the length of silent pauses but instead, we find that their frequency is significantly higher in AD patients' speech. We also find that AD patients produce more hesitations, which is in accordance with previous work. Contrary to our expectations, no statistical difference was noted for filled pauses and lengthenings. These phenomena, that are very frequent in spontaneous speech, indicate uncertainty and are used to maintain control of a conversation while thinking of what to say next (Clark and Fox Tree, 2002). According to Clark (1996), in the framework of the theory of performance, speakers proceed along two tracks of communication simultaneously. They use signals in the primary track to refer to the theme of the discourse and they also use signals in the collateral track to refer to the performance itself, that is to timing, delays, rephrasings, mistakes, repairs, intentions to speak, and the like. A related proposal is that fillers are elements 'whereby the speaker, momentarily unable or unwilling to produce the required word or phrase, gives audible evidence that he is engaged in speech-productive labor' (Goffman, 1981). The analysis we carried out reveals that AD patients do not follow this pattern: although they experience more planning difficulties than healthy elderly individuals, their proportion of filled pauses and lengthening does not increase accordingly. In other words, they do not use

the conventional signals in the collateral track and tend to remain silent. This explains why the total amount of speech is greater in controls' discourse than in patients'.

Regarding speech and articulatory rates, our findings reveal on the one hand that patients' speech rate is slower while articulatory rate does not differ across groups. This suggests that motor aspects of speech production are preserved in AD and underlines the fact that pauses are responsible for the decrease of speech rate in AD. Combining this result with the higher frequency of pauses in AD patients' speech, one can easily understand why verbal sequences are shorter in their discourse and why pauses occur more often outside major syntactic boundaries.

Further analysis enables us to characterize the words occurring next to speech dysfluencies and allows us to identify precisely which lexical category yields more often to dysfluency. We find no difference in the process of retrieval of nouns or verbs. This is consistent with Ferreiro (2009). Similarly, our study on lexical frequency confirms patients' recourse to generic and frequent words when facing word production failure. Finally, an original aspect of our study lies in the use of spontaneous data that enabled us to examine other categories than nouns and verbs that are commonly addressed in previous studies based on naming tasks. We show that the retrieval of adjectives is more problematic for patients. One possible explanation for this can be related to the optional feature of attributive adjectives. Further investigations should be conducted on this little studied but promising category so as to ascertain our preliminary findings.

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