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Phonetic and phonological aspects of speech in Alzheimer's disease

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ABSTRACT

Background: Alzheimer's disease (AD) can involve changes in communication and can lead to mutism in severe cases. Oral communication may be impaired by phonetic-motor disorders, such as apraxia of speech (AOS), or by language disorders, such as aphasia. Therefore, the identification of manifestations of AOS and phonemic paraphasias in patients with AD is critical to understanding the communication changes and determining the therapeutic planning.

Aims: To identify the distribution of phonetic-phonological manifestations in older patients with AD and healthy older subjects and assess whether these manifestations indicate the origin of the changes, including a predominantly phonetic-motor origin, a predominantly phonological-linguistic origin, or both.

Methods & Procedures: This cross-sectional study evaluated 90 patients with AD and 30 healthy older volunteers. All of the participants underwent the same repetition task for phonetic and phonological assessments using the current classification of phonetic-phonological manifestations; this classification distinguishes characteristics that are mostly related to AOS from other signs that are mostly related to aphasia. Negative binomial regression analysis was conducted to compare the amount of each manifestation presented by the two groups.

Outcomes & Results: The patients with AD showed significantly more signs of aphasia (self-correction, and vowel and consonant substitutions), AOS (prolonged intervals and extended vowel duration), and AOS or aphasia (distortion, omission, attempts at the syllable level, distorted substitutions, and additions) than the healthy older volunteers.

Conclusions: Older adults with AD presented phonetic and phonological changes of aphasia and AOS and, consequently, limitations in symbolic-linguistic planning and motor planning.

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Introduction

Patients with Alzheimer's disease (AD) can progress to mutism (Gerstner et al., 2007), which impairs human communication. Oral communication may be impaired by motor disorders,

such as apraxia of speech (AOS), or by language disorders, such as aphasia. Studies have indicated the presence of phonetic–phonological manifestations in AD (Cera, Ortiz, Bertolucci, & Minett, 2013; Croot, Hodges, Xuereb, & Patterson, 2000; Gerstner et al., 2007), whereas Lira, Ortiz, Campanha, Bertolucci, and Minett (2011) found no difference in the phonological performance of older adults with and without AD. Other language changes, including semantic and syntactic changes, occur in many neurodegenerative diseases and have been widely described (Laforce, 2013; Lira et al., 2011).

The phonetic–phonological manifestations are important for the differential diagnosis of AOS and aphasia and of some neurodegenerative diseases, including primary non-fluent progressive aphasia, primary progressive logopenic aphasia, and primary progressive AOS. In these diseases, speech or language disorders are the primary symptoms in the early years of the presentation of neurodegeneration (Duffy & Josephs, 2012; Gorno-Tempini et al., 2011; Josephs et al., 2013); however, these changes are not considered in the criteria for diagnosis of AD. Nevertheless, the occurrence of phonetic-motor and phonological–linguistic changes in these diseases has aroused interest in the study of these manifestations in AD.

AOS is a phonetic-motoric disorder of speech production that results in intra- and inter-articulator temporal and spatial segmental and prosodic distortions but not deficits in the processing of sensory or language information (McNeil, Robin, & Schmidt, 2009). AOS is conceptually distinct from aphasia, which is a linguistic disorder (McNeil et al., 2009). The differential diagnosis of AOS and phonemic paraphasias in aphasia is complex because some manifestations, including distortion, omission, and addition, occur in both disorders (Haley, Jacks, & Cunningham, 2013; McNeil et al., 2009). Research results point to distinct phonological and phonetic levels but also refer to close interactions between them (Galluzzi, Bureca, Guariglia, & Romani, 2015). Kurowski and Blumsteins (2016) suggested that some phonemic paraphasias reflect phonetic (articulatory) rather than phonological (selection) impairments, consistent with the view that the processes involved in phonological selection/planning and articulatory implementation stages may not be independent but rather they are inextricably linked.

Nevertheless, particular communication manifestations may indicate whether the disorder is more related to phonetic-motor planning (e.g., a slow rate in phonemically on-target or off-target phrases and sentences, disturbed prosody, schwa intrusion, and attempts and starts at the sound level; Johns & Darley, 1970; McNeil et al., 2009; Pierce, 1991) or more related to phonological and linguistic planning (anticipatory, perseverative, and transposition errors and attempts and starts at the word level; McNeil et al., 2009). The manifestations of communication determine the type of disorder, the therapeutic procedures required, and the treatment objectives and procedures. The proper diagnosis of the disorder involved in communication changes in AD is essential to determine the most appropriate therapeutic intervention.

In neurodegenerative diseases, the manifestations of the differential diagnosis between phonetic failure and phonological failure have been characterized in primary progressive aphasia and primary progressive AOS but not in AD. Josephs et al. (2013) studied the subtypes of phonetic–phonological manifestations in other neurodegenerative diseases and identified three subtypes of AOS: (1) apraxia with a predominance of distortions and distorted substitutions, (2) apraxia with a predominance of syllabic prosody, syllabic segmentation, and increased duration between segments, and (3) apraxia with nonspecific symptoms. Our hypothesis is that our sample has the first or third subtype of AOS, which

considers the co-occurrence of AOS and aphasia and may involve distortion, which is the most common change in the speech of stroke patients with these two disorders (Haley et al., 2013; Johns & Darley, 1970; Odell, McNeil, Rosenbek, & Hunter, 1990) or AD (Gerstner et al., 2007).

Herein, we hypothesize that, compared to healthy older adults, patients with AD present manifestations that involve both phonetic-motor and phonological-linguistic impairments. Therefore, the objectives of this study were to identify the distribution of phonetic-phonological manifestations as per McNeil et al.'s characterization (2009), in a large sample of patients with AD and assess whether these manifestations indicate whether the origin of the communication changes is more phonetic, more phonological, or both.

Materials and methods

This cross-sectional study evaluated a sample of 120 participants: 90 older adults with AD and 30 healthy older volunteers.

This study was approved by the Research Ethics Committee of the Federal University of São Paulo under Protocol No. 0376/11. The study participants or their guardians granted their authorization to participate by signing a free and informed consent form.

The patients with AD were evaluated by neurologists and neuropsychologists at the Behavioural Neurology Clinic of the Discipline of Neurology of the Department of Neurology and Neurosurgery and at the Centre for Brain Ageing at the Universidade Federal de São Paulo-UNIFESP, with comprehensive neuropsychological evaluation and data from clinical and imaging neurological examinations allowing the differential diagnosis between AD and other dementias. In addition, a complete speech and language assessment was performed at the Neurolinguistic Lab in the Speech, Language, and Hearing Sciences Department.

The inclusion criteria for AD patients were age 60 years or older, diagnosis of probable AD according to the clinical criteria of the NINCDS-ADRDA (Dubois et al., 2007), and the supervision by a caregiver who could provide anamnesis and regularly follow the drug treatment regimen recommended by the medical team.

A convenience sample of healthy older volunteers without neurological disorders or a history of psychiatric issues was included.

The exclusion criteria for the study participants were previous or current use of alcohol or illicit drugs; use of psychoactive drugs other than atypical neuroleptics and antidepressants in the past month; previous history of severe neurological or psychiatric disorders (i.e., epilepsy, cancer, and schizophrenia); visual changes and hearing loss; use of poorly adapted dental prostheses that could compromise task execution; absence of verbal expression; complaint of predominant speech or language difficulties; changes in auditory comprehension that could prevent the participant from answering the evaluation questions; and probable diagnosis of other neurodegenerative diseases, such as primary progressive aphasia, Lewy Body disease, and frontotemporal dementia.

For this study, the participants were scored using the following scales:

- The Clinical Dementia Rating, adapted by Morris (1993) and validated for Portuguese by Montaña and Ramos (2005), was used to separate the study participants into: AD and a control group.
- Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975), the Brazilian version, was validated by Brucki, Nitrini, Caramelli, Bertolucci, and Okamoto (2003) and used to assess overall cognition. The performance of the patients with dementia on the MMSE was lower than the average performance found by Brucki et al. (2003) considering the level of education, whereas the performance of the healthy older volunteers was similar to or higher than the average: 19 for illiterate individuals, 25 for patients with 1-4 years of education, 26 for patients with 5-8 years of education, and 28 for patients with more than 9 years of education.
- The Lawton and Brody index (Lawton & Brody, 1969) was used to evaluate the execution of instrumental activities of daily living. The patients with dementia showed dependence while performing instrumental activities of daily living, while the control group was able to perform them independently.
- The Repetition subtest of the protocol for evaluation of verbal and non-verbal apraxia of Martins and Ortiz (2004) was used to analyze phonetic and phonological manifestations. The stimuli used in this protocol included words with different lengths with syllabic structures of different complexity with different word frequencies X and different articulatory complexity among other variables that affect phonetic-phonological performance. The repetition subtest stimuli of this protocol are presented in the [Appendix](#).

Phonetic and phonological analyses

The recordings of the speech evaluations were analyzed and transcribed by a speech therapist with experience in this area (M.L.C.). The intra-rater agreement was evaluated by analysing the speech of 20% of the participants on two occasions with an interval of 3 months. A second reviewer (K.Z.O.) from the same research group conducted an independent non-randomized analysis of 20% of the study sample.

The subjects were instructed to pronounce 154 syllables. Neologisms were not considered in the analysis. Speech productions with common dialectical and allophonic variations were considered correct.

The production of speech in a repetition task was assessed using auditory-perceptual analysis of speech that was performed by recording the numbers of each phonetic and phonological manifestation. Segmental errors in the naming tasks often remain too few, and in repetition tasks, a lack of lexical errors argues for difficulties in retrieving/producing segments rather than in accessing words (Romani, Galluzzi, Bureca, & Olson, 2011). Word repetition tasks are quick and easy to administer, as all patients with post-lexical disorders make individual sound errors that may be unequivocally categorized on the basis of clear criteria (Galluzzi et al., 2015). Thus, only a repetition task was studied and the speech

sample analysis allowed us to assess the presence of 21 manifestations, as proposed by neurolinguistic model of McNeil et al. (2009). These manifestations include the following:

- Phonetic or phonological manifestations: distortions (considered an attempt at the target that did not cross the phoneme boundary but that was produced with perceptible place, manner, or voice deviation(s) from the correct production, examples: /gre'naʒeN/ instead of /dre'naʒeN/, /'tapu/ instead of /'sapu/, or /'ʒorʒi/ or /'ʒorʒi/ instead of /'ʒorʒi/); additions (/za'nõis/ instead of /a'nõis/); omissions (/kasi/ instead of /'klasi/); distorted sound substitutions (/m:edu/ instead of /'dedu/); starters at the syllable level (/RiRi'dikulu/ instead of /Ri'dikulu/); and attempts at the syllable level (/ga'ro-/ga'rota/ instead of /ga'rota/).
- Likely phonological manifestations: substitutions of vowels (/Riza/ instead of /Rizu/) and consonants (/Rifu/ instead of /Rizu/); starters at the word level (/Ri'dikuluRi'dikulu/ instead of /Ri'dikulu/); attempts at the word level (/ga'rota-/ga'rota/ instead of /ga'rota/); self-corrections (/prede//pedre'guļu/ instead of /pedre'guļu/); and anticipation of phonemes (/no'nita/ instead of /bo'nita/), perseveration of phonemes (/kikaN'deiru/ instead of /kitaN'deiru/), and transposition of phonemes (/tikaN'deiru/ instead of /kitaN'deiru/).
- Likely phonetic manifestations: prolonged intersegment intervals (/sa-'peka/ instead of /sa'peka/); extended durations of vowels and consonants; schwa intrusion between syllables (/saN'peka/ instead of /sa'peka/); schwa intrusion in consonants clusters (/pedara/ instead of /'pedra/); starters at the sound level (/ffāN/ instead of /'fāN/); and attempts at the sound level (/f-/fāN/ instead of /'fāN/).

The inter-rater and intra-rater agreement for each manifestation was evaluated by calculating Gwet's AC2. This method was selected because it is the paradox-resistant alternative to the Kappa coefficient when the agreement percentage is high. The coefficient was calculated using the program Agreestat, version 2011.2 (AgreeStata, 2010-2011). The degree of agreement was considered substantial for values higher than .60 and almost perfect for values greater than .80, as proposed by Landis and Koch (1977). The agreement of the total sample was almost perfect and ranged between .84 and 1.00 in the inter-rater analysis and between .85 and 1.00 in the intra-rater analysis.

Statistical analysis

Student's *t*-test (*t*) was used to compare the means of continuous variables (age, educational level, Lawton and Brody index, and MMSE) between the participants with and without AD. The chi-square test (χ^2 ; without Yates' correction) was used to compare categorical data (gender), and Fisher's exact test was used in cases in which Cochran restrictions were present (e.g., the presence of phonetic-phonological manifestations).

Negative binomial regression analysis was performed to assess whether phonetic-phonological manifestations occurred significantly more often in patients with AD than in healthy older volunteers. For this analysis, the number of each manifestation was the dependent variable and the presence of AD was the independent variable. The exponential calculation applied to the regression coefficient generated an effect measure that could be interpreted as

Table 1. Demographic data (gender, educational level, and age), Mini-Mental State Examination scores and Lawton and Brody index.

	Control group (<i>n</i> = 30)	Patients with AD (<i>n</i> = 90)	Statistic	95% CI	<i>p</i> - Value
Men ^a	5 (17%)	25 (28%)	$\chi^2 (1) = 1.5$	–	.224
Age in years ^b	78 (8.5)	80 (7.2)	$t(118) = -1.4$	-5.5; 0.8	.150
Educational level in years ^b	5.5 (4.0)	4.3 (3.6)	$t(118) = 1.5$	0.3; 2.8	.127
MMSE ^b	27 (2.7)	14 (5.2)	$t(98.4) = 17.4$	11.3; 14.2	< .001
Lawton and Brody index ^b	0 (0.3)	12 (4.5)	$t(90.7) = -25.7$	-13.2; -11.3	< .001

AD: Alzheimer's disease.

^a*n* (%).

^bMean (standard deviation).

a ratio of means (RMs). The model used to calculate the effect measures considers the negative binomial distribution of the dependent variable and avoids the phenomenon of over dispersion, as the variance of each manifestation is greater than its mean. The measure compared the mean of each phonetic–phonological manifestation between the groups with and without AD, and the analysis was adjusted for gender, age, and education.

P-values smaller than .05 were considered statistically significant. All tests were two-tailed. The 95% confidence interval (CI) was calculated for the RMs estimates and the difference between means. The data were analyzed using R statistical software version 3.1.1 and IBM SPSS Statistics software version 22.

Results

Demographic data and cognitive and functional performance

By definition, the cognitive and functional performance of the participants with AD was significantly worse than that of the healthy older volunteers, considering the lower MMSE score and Lawton and Brody index of the AD group. Gender, age, and educational level were not significantly different between the two groups (Table 1).

Comparison of phonetic–phonological performance between the groups with regard to the manifestations with zero occurrence in the speech of healthy older adults

The patients with AD presented all manifestations, whereas some manifestations, including prolonged intersegment intervals, extended durations of consonants and vowels, substitutions, distorted substitutions, additions, schwa intrusions, attempts at the sound level, perseverations, and transpositions, did not occur among the healthy older adults (Figure 1).

Among the manifestations presented exclusively by patients with AD, the frequencies of prolonged intersegment intervals (Fisher's exact test, $p = .003$), extended vowel duration ($p < .001$), addition ($p = .003$), distorted substitution ($p = .036$), vowel substitution ($p < .001$), and consonant substitution ($p < .001$) were significantly higher than in the control group.

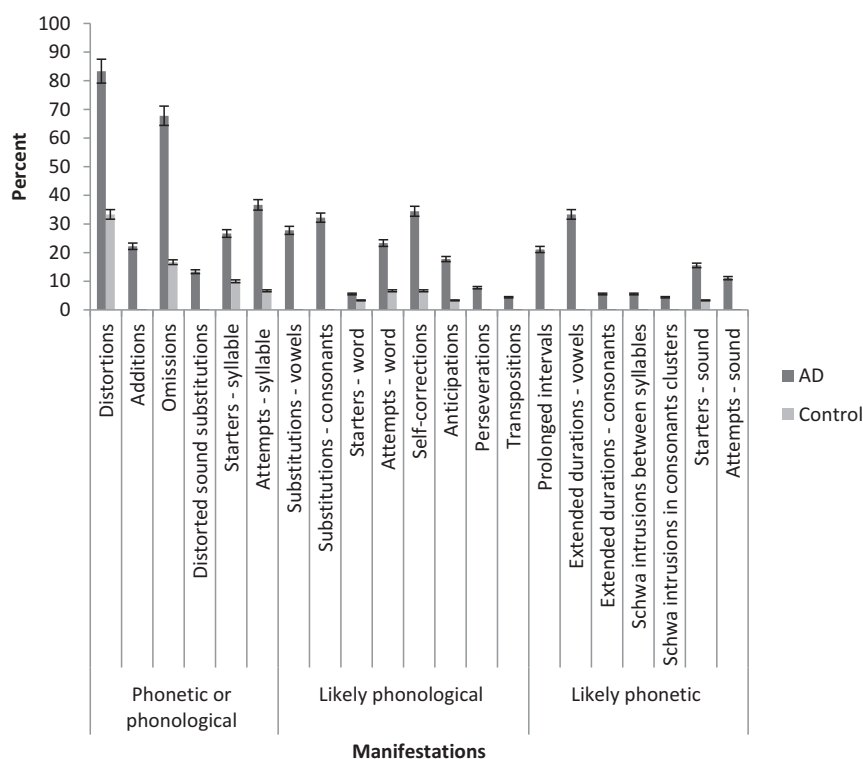


Figure 1. Percentage of older adults with and without AD with phonetic–phonological manifestations.

Comparison of phonetic–phonological performance of older adults with and without AD with regard to the manifestations present in both groups

Distortions, omissions, starters at the syllable level, attempts at the syllable level, starters at the word level, attempts at the word level, self-corrections, anticipations, and starters at the sound level occurred in both study groups (Figure 1).

Distortion and omission were the most frequent phonetic–phonological manifestations in patients with AD, followed by starters at the syllable level, attempts at the syllable level, substitution of consonants, self-correction, and extended duration of vowel (Table 2).

We assessed whether each manifestation occurred significantly more often in the patients with AD than in the healthy elderly volunteers (Table 3). The phonetic–phonological performance of the patients with AD was significantly worse than that of the healthy older volunteers in terms of the number of occurrences of distortions, omissions, attempts at the syllable level, and self-corrections. However, there was no significant difference in the number of attempts at the word level, starters at the sound level, starters at the syllable level, starters at the word level, or anticipations between the two groups.

Discussion

The main finding of this study was that participants with AD had both phonetic-motor planning deficits, characterized by prolonged intersegment intervals and extended vowel

Table 2. Amount of each phonetic–phonological manifestation.

	Control group (30)	AD (90)
	Median (minimum–maximum)	Median (minimum–maximum)
Phonetic or phonological manifestations		
Distortions	0 (0–2)	2 (0–14)
Additions	0 (0–0)	0 (0–3)
Omissions	0 (0–2)	2 (0–12)
Distorted substitutions	0 (0–0)	0 (0–2)
Starters at the syllable level	0 (0–2)	0 (0–3)
Attempts at the syllable level	0 (0–1)	0 (0–4)
Likely phonological manifestations		
Substitutions of vowels	0 (0–0)	0 (0–4)
Substitutions of consonants	0 (0–0)	0 (0–10)
Starters at the word level	0 (0–1)	0 (0–2)
Attempts at the word level	0 (0–1)	0 (0–3)
Self-corrections	0 (0–2)	0 (0–2)
Anticipations	0 (0–1)	0 (0–2)
Perseverations	0 (0–0)	0 (0–1)
Transpositions	0 (0–0)	0 (0–2)
Likely phonetic manifestations		
Prolonged intersegment intervals	0 (0–0)	0 (0–6)
Extended durations of vowels	0 (0–0)	0 (0–3)
Extended durations of consonants	0 (0–0)	0 (0–2)
Schwa intrusions between syllables	0 (0–0)	0 (0–1)
Schwa intrusions in consonant clusters	0 (0–0)	0 (0–1)
Starters at the sound level	0 (0–1)	0 (0–2)
Attempts at the sound level	0 (0–0)	0 (0–3)

durations, and phonological–linguistic planning deficits, characterized by self-correction and substitutions of vowels and consonants. These two disorders in AD were further characterized by the presence of distortions, omissions, attempts at the syllable level, additions, and distorted substitutions. Similar to the results of studies that used specific methodologies for phonetic and phonological evaluation (Cera et al., 2013; Croot et al., 2000; Gerstner et al., 2007), our results revealed changes in these parameters in AD. Although the semantic failure of language has been fully characterized in AD (Kim & Thompson, 2003), our results indicate that other aspects of oral communication are altered in this disease.

Among the predominantly phonetic–motor manifestations, prolonged intersegment intervals and extended vowel durations occurred significantly more often among the patients with AD. Phonetic errors classified as slurred phonemes, distortion, and articulatory effort allowed the differentiation of the two groups studied by Galluzzi et al. (2015) into AOS and phonological failure. The manifestations that we considered predominantly phonetic and indicated worsened phonetic performance in patients with AD were classified by Galluzzi et al. (2015) as slurred phonemes. So, according to Galluzzi et al. (2015), slurred phonemes might also occur in aphasia; however, no statistical analysis has compared the phonetic performance of the aphasia and AOS groups. The main discrepancies in the classification of the errors were that distortion and articulatory effort were considered phonetic errors by Galluzzi et al. (2015). The classification used in our study considered distortion a manifestation that might be both phonetic and phonological (McNeil et al., 2009) and specified what was considered an imprecise manner in regard to distortion. In addition, we subdivided the articulatory effort into starters or attempts at the phoneme, syllable, or word level for words in aphasia and for phonemes in AOS (McNeil et al., 2009). Galluzzi et al. (2015) suggest that phonological simplifications indicate articulatory difficulties, even in cases in which they occur in subjects

Table 3. Results of the negative binomial regression analysis of phonetic–phonological manifestations between the groups with and without Alzheimer’s disease.

	RMs	95% CI	p-Value
Phonetic or phonological manifestation			
Distortions	5.1	2.8; 9.6	<.001
Omissions	7.9	3.3; 19.2	<.001
Attempts at the syllable level	7.5	1.8; 32.5	.007
Starters at the syllable level	2.3	0.7; 7.0	.153
Likely phonological manifestations			
Self-corrections	3.6	1.1; 11.8	.036
Attempts at the word level	3.4	0.8; 14.6	.107
Starters at the word level	3.3	0.3; 43.5	.365
Anticipations	6.2	0.8; 47.7	.081
Likely phonetic manifestations			
Starters at the sound level	5.0	0.6; 40.27	.134

The reference for this regression analysis is the group of healthy older volunteers.

with phonemic paraphasia. In our study, the simplifications corresponded to manifestations of distortion and omission. Therefore, despite the differences in the classification of the manifestations between the studies, it was possible to identify phonetic and phonological characteristics in the patients with AD.

In our study, AOS was characterized also by distortions, omissions, attempts at the syllable level, and distorted substitutions and additions; according to McNeil et al. (2009) and Haley et al. (2013), these manifestations may have a phonetic-motor or phonological-linguistic origin. Haley et al. (2013) suggested that distortion is a typical manifestation of AOS; however, their results indicated that the frequency of distortions was abnormally high in the speech of patients with aphasia. Therefore, despite the tendency to consider distortions a likely phonetic-motor failure, previous studies have shown that distortions may be a motor or linguistic manifestation (Haley et al., 2013; McNeil et al., 2009). McNeil et al. (2009) reported that distortions are often perceived as substitutions. This phenomenon has been called “phonemic false evaluations”, whereby the speaker produced a phonetically distorted target phoneme that is subsequently misperceived by the listener (Buckingham & Yule, 1987). Odell et al. (1990) began to classify distortions as errors involving only one phonological characteristic (articulatory place, articulatory manner, or voicing). A previous study analyzed the manifestations of AOS in a large study sample in AD (Cera, Ortiz, Bertolucci, & Minett, 2011); distortions were considered substitutions, and healthy older adults were not evaluated. The present study used updated international nomenclature for phonetic and phonological manifestations. As mentioned above, distortions, omissions, attempts at the syllable level, distorted substitutions, and additions may also occur in aphasia. Moreover, other studies have indicated that phonological-linguistic manifestations of aphasia also occur in patients with AD. Of the manifestations that McNeil et al. (2009) and McNeil, Odell, Miller, and Hunter (1995) classified as likely caused by aphasia, the rates of vowel and consonant substitutions and self-corrections differed significantly between the groups with and without AD.

The similarities of the phonetic–phonological manifestations between the groups with and without dementia involve five phonological manifestations (anticipation, transposition, perseveration, attempts at the word level, and starters at the word level), five phonetic manifestations (extended consonant duration, starters at the sound level, attempts at the sound level, schwa intrusion between syllables and in consonant clusters), and one manifestation that can be either phonetic or phonological (starters at the syllable level). All these

manifestations were classified according to the methodology of McNeil et al. (2009). Buckingham and Buckingham (2011) consider that anticipations and perseverations are paraphasias that come from perseveration of phonological segments. McNeil et al. (2009) mentioned that anticipatory, perseverative, and transposition errors are generated at the phonological encoding level of speech production and belong exclusively to the phonemic paraphasic errors, whereas Pierce (1991) argued that sound substitutions are a clear sign of phonemic paraphasia. Therefore, if these four manifestations are grouped and designated phonemic paraphasia, it is believed that phoneme anticipation, perseveration, and transposition, in addition to substitution, might be manifestations capable of differentiating the groups with and without AD.

Therefore, the present study indicated that phonetic–phonological failures in AD are associated with both phonological–linguistic planning and phonetic–motor planning. The low frequency of manifestations in the patients with AD suggests the occurrence of mild phonetic and phonological changes in this group. Susceptibility to both AOS and aphasia should be considered in this disease to allow the selection of appropriate preventive and therapeutic strategies, considering that the symptoms gradually worsen.

The low frequency or absence of phonetic–phonological manifestations and the atypical presentations of AD corroborate the controversies related to phonetic–phonological performance in AD (Cera et al., 2011, 2013; Chenery, 1996; Croot et al., 2000; Gerstner et al., 2007; Lira et al., 2011; Mansur, Carthery, Caramelli, & Nitrini, 2005). Croot et al. (2000), Mansur et al. (2005), Gerstner et al. (2007), Cera et al. (2011), and Cera et al. (2013) reported phonetic and phonological impairment in AD, whereas Chenery (1996) and Lira et al. (2011) reported similar phonological performance between participants with and without this disease. The controversy of these findings may be related to differences in the assessment methods that these authors used. In our study, we used repetitions of words and phrases, whereas Chenery (1996) evaluated denominations and Lira et al. (2011) evaluated narratives. The possibility of atypical presentations of cognitive impairment should be considered, as reported by Stopford, Snowden, Thompson, and Neary (2008) and by Belleville, Peretz, and Malenfant (1996); these presentations were evaluated by Croot et al. (2000) and Gerstner et al. (2007) on the basis of phonetic–phonological aspects.

The possible occurrence of subtypes of AOS has also been reported in the atypical presentation of other dementias, such as primary progressive apraxia and primary progressive aphasia (Duffy & Josephs, 2012; Josephs et al., 2013). Our results indicate that the phonetic–phonological performance of patients with AD corresponds to apraxia subtype three, as proposed by Josephs et al. (2013); this subtype is characterized by nonspecific symptoms involving distortions and distorted substitutions, prosodic characteristics of syllabic segmentation (attempts), and an increase in sentence duration (prolongations).

The consideration of groups of phonological manifestations alone or phonetic manifestations alone would facilitate the statistical analysis and confirmation of phonetic failure; however, it would exclude the primary phonetic–phonological manifestations, which may occur because of phonetic–motor failure or phonological–linguistic failure. In this context, distortions and omissions are described in studies on AOS (Cera, Minett, & Ortiz, 2010; Johns & Darley, 1970; Odell et al., 1990); however, these errors would not be exclusively associated with phonetic changes. Therefore, we decided to characterize all phonetic and phonological manifestations.

The analysis was applied to a large sample of Brazilian participants with and without AD and contemplated all phonetic–phonological manifestations that best described their phonetic–motor and phonological–linguistic performance.

The phonetic–phonological classification used in the present study considers the neurolinguistics model of sensorimotor control of speech by Van der Merwe (2009), which shows the concept of division of the events underlying the production of speech into phases: linguistic–symbolic planning, motor planning, motor programming, and execution. It may be somewhat simplistic, but it is useful in discussing brain behavior during speech production and in localizing levels of dysfunction (Van der Merwe, 2009). It would be wrong to assume multilevel processing as strictly hierarchical and thereby implying one-way information flow (Van der Merwe, 2009). Van der Merwe showed that research in this field is abundant and often contradictory due to differences in the criteria for inclusion of participants, differences in experimental techniques, and the nature of the movements studied. Previous studies addressing these differences have been found, especially with regard to the influences of linguistic variations on speech movement characteristics. The effects of utterance length and rate changes on speech movement kinematics in aphasia were observed, and the authors concluded that the findings support the notion that linguistic changes have an impact on the characteristics of speech movements (Bose & van Lieshout, 2008). Our results on phonetic–phonological impairment corroborate the conclusion of Kurowski and Blumsteins (2016) that the phonological selection/planning and articulatory implementation stages are linked. Thus, research about how linguistic factors influence verbal production in AD is interesting in terms of understanding the relationship between linguistic and speech motor processes in this disease.

Our study has limitations. First, the stimuli presented to the participants were in Brazilian Portuguese and may not be generalizable to all languages. However, the classification of the manifestations and the diagnosis of disorders are common in all languages, despite possible differences in the phonetic inventory. Second, the average education level of the study participants was low in both groups. Bennett et al. (2003) observed that individuals with greater cognitive reserve require a greater neuropathological load to manifest clinical dementia. Subjects with higher education may take longer to manifest phonetic–phonological changes. Third, although our sample was large, it was not representative of the entire population. Therefore, the profiles of phonetic–phonological impairment in AD that are found in population studies may differ from those found in this study because AD patients who are not treated in centers that specialize in dementia may have atypical manifestation profiles.

Conclusion

The standardized characterization of manifestations proposed by McNeil et al. (2009) helped to identify changes in the phonetic and phonological performance of patients with AD. Older adults with AD exhibited both phonetic and phonological changes indicative of aphasia and AOS. Van der Merwe (2009) reported that these disorders indicate failures in symbolic–linguistic planning and motor planning. Our results suggest that treatment planning for older adults with AD should cover phonological–language and phonetical–motor strategies with the aim of reducing or preventing manifestations that may compromise communication.

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Appendix

Stimuli from Martins and Ortiz (2004) Apraxia of Speech Protocol

Repetition of words

Sapeca (simple syllable structure and long)
 Conferência (less frequent and long)
 Taubaté (less frequent and long)
 Drenagem (complex syllable structure and long)
 Americana (long)
 Quitandeiro (long)
 Condomínio (more frequent and long)
 Revolução Industrial (less frequent and long)
 Branca de Neve e os Sete Anões (more frequent and long)
 Sapo /sapato /sapateiro (words with different lengths and simple syllable structures)
 Pedra /pedreiro /pedregulho (words with different lengths and complex syllable structures)
 Fã /família /fantástico (words with different lengths)
 Clã /classe /clássico /classificados (words with different lengths)
 Rio /riso /riacho /ridículo /ribanceira (words with different lengths)
 Mimo (simple syllable structure and short)
 Xuxa (less frequent and short)
 Jorge (complex syllable structure and short)
 Dedo (more frequent and short)
 Pipa (simple syllable structure and short)
 Tente (more frequent and short)
 Bebê (more frequent and short)
 Nem (short)

Repetition of sentences

- (1) A garota bonita está dançando (sentence with more frequent words and with simple syllable structures).
- (2) Ontem dei um brinco de presente (sentence with more frequent words and with complex syllable structures).
- (3) O estranho andou ao longo da estrada (sentence with more frequent words and with more complex syllable structures).
- (4) O banqueiro saiu à noite para comer (sentence with less frequent words and with more complex syllable structures).