Pre-print version of :
Baqué, Lorraine (in press). How do persons with apraxia of speech deal with morphological stress in Spanish ? A preliminary study. *Clinical Linguistics & Phonetics. Doi :* https://doi.org/10.1080/02699206.2019.1622155

How do persons with apraxia of speech deal with morphological stress in Spanish? A preliminary study

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ABSTRACT

Equal stress across adjacent syllables and extended syllable durations are amongst the most salient features of acquired Apraxia of Speech (AOS). Most studies conclude that there is a deficit in durational cue processing, whereas the other acoustic stress correlates remain relatively unimpaired. Spanish is a free-stress language in which stress patterns are contrastive, especially in verbal forms (e.g. *lavo* /ˈlabo/ '[I] wash' vs *lavó* /laˈbo/ '[He/she] washed'). The aim of this preliminary study is to determine whether persons with AOS are able to make the intended stress pattern identifiable and, if so, to determine which acoustic cues they use to avoid the 'equal stress' phenomenon. The results show that, for each parameter considered (duration, intensity, fundamental frequency), apraxic participants' productions differed from those of controls to varying degrees depending on the task. However, 91.7% of the apraxic participants' realisations were perceived as corresponding to the intended tense and person. These results are interpreted as deriving from a motoric deficit affecting morphological stress processing by subjects with AOS combined with an idiosyncratic compensatory use of the stress cues in order to avoid 'equal stress'.

KEYWORDS: Apraxia of speech, Morphological stress, Spanish, Equal stress, Acoustics, Compensation

INTRODUCTION

Although the number of levels of speech processing vary across psycholinguistic models, the last stage of speech production is assumed to be the phonological representation that feeds into the motor control system (see Browman & Goldstein, 1992; Plaut & Kello, 1999; for a different viewpoint). Most accounts of phonological encoding (Caramazza, 1997; Dell, 1986; Garrett, 1980; Levelt, 1989; Levelt, Roelofs, & Meyer, 1999) postulate separate and parallel retrieval of the metrical and segmental representations of word forms (Butterworth, 1992; Levelt, 1989, 1992; Levelt et al., 1999) and some sort of mechanism for (re)syllabification of the words in context. It is usually assumed that during phonological word-form retrieval segmental information is accessed separately from information concerning stress pattern and number of syllables. These two representations are then assembled incrementally by a segment-to-frame mechanism (Keating & Shattuck-Hufnagel, 2002; Levelt, 1989; Levelt et al., 1999; Schiller, 2003; Schiller, Jansma, Peters, & Levelt, 2006; Shattuck-Hufnagel, 1983) in phonological words containing one or more lexical items (Hall & Kleinhenz, 1999; Hayes, 1989; Nespor & Vogel, 2007; Peperkamp & Wiltshire, 1999; Selkirk, 1995) before the articulation is planned and executed.

However, the exact content of retrieved metrical representations differs across models with regard to at least two issues, namely, whether or not the representations include a) the syllable-internal structures (Dell, 1988; Levelt, 1992; Levelt & Wheeldon, 1994; Roelofs, 1997; Roelofs & Meyer, 1998; Sevald, Dell, & Cole, 1995; Stemberger, 1984, 1990) and b) the lexical stress pattern. Concerning the latter, lexical stress assignment is seen as resulting from either a) the retrieval of a stored stress pattern representation for each lexical item (Butterworth, 1992; Laganaro, Vacheresse, & Frauenfelder, 2002), b) the retrieval of stored stress patterns for irregular items and the computation of regular ones (Colombo, 1992; Levelt et al., 1999; Roelofs & Meyer, 1998), c) analogical mechanisms that compute stress pattern on the basis of the stress pattern of similar words, or d) the combination of two different processes: stress pattern retrieval on the one hand and phonological and/or morphological rule-based or statistically-based computation on the other (Butterworth, 1992; Laganaro et al., 2002).

Spanish is a free-stress language in which stress pattern plays a distinctive role at the semantic-lexical level for a few items (*plato* 'plate' /ˈplato/ vs *plató* '[television] studio' /plaˈto/) and very systematically at a morphological level (*cálculo* 'calculation' /ˈkalkulo/, *calculo* '[I] calculate' /kalˈkulo/, *calculó* '[He/she] calculated' /kalkuˈlo/; *tapo* '[I] cover' /ˈtapo/, *tapó* [He/she] covered' /taˈpo/, etc.). Although stress may occur on each one of the three (or four if we take into account some wordforms made up of a verb and two or more pronoun) last syllables of a word, 95%-97% of nouns are either oxytones ending in a consonant or paroxytones ending in a vowel (Hualde, 2005; Alcoba Rueda, 2013). In addition, the stress pattern is constrained by some specific phonological rules (e.g. words ending in a glide are always oxytone). It is worth noting that in the standard dialect used in Spain the vowel system exhibits little variation based on lexical stress (Delattre, 1969; Quilis & Esgueva, 1983) as compared to languages such as English, and no vocalic neutralisation. Thus stress contrasts in Spanish are mainly realised by means of prosodic cues such as fundamental frequency (F0) and duration (Quilis, 1981; Llisterri, Machuca, Ríos, & Schwab, 2014) or F0 and intensity (Llisterri, Machuca, de la Mota, Riera, & Ríos, 2005).

Apraxia of speech (AOS) is an acquired neurological disorder assumed to impair retrieval and/or implementation of articulatory plans, despite the absence of muscle weakness or paralysis. Among the main features of apraxic speech are effortful speech production with groping (Johns & Darley, 1970), articulatory imprecision (Haley, Ohde, & Wertz, 2001), difficulty initiating speech (Johns & LaPointe, 1976), and dysprosodia, characterised by slowed speech rate, syllable segregation, rhythm and intonation abnormalities, and stress contrastiveness reduction—also known as 'equal stress'—not attributable to stress assignment deficits (Duffy, 2013; Gandour & Dardarananda, 1984; Kent & Rosenbek, 1983; Malcolm R. McNeil et al., 2009; Ogar, Slama, Dronkers, Amici, & Gorno-Tempini, 2005; Ouellette & Baum, 1994; Vergis et al., 2014; Walker, Joseph, & Goodman, 2009).

Concerning 'equal stress', it has been argued that it could result from a basic timing deficit (Danly & Shapiro, 1982) that affects durational cue processing (Emmorey, 1987; Gandour, Petty, & Dardarananda, 1989; Marquardt, Duffy, & Cannito, 1995; Ouellette & Baum, 1994; Vergis et al., 2014; but see Ross, Shayya, & Rousseau, 2013; Walker et al., 2009, for different results), while the other acoustic stress correlates remain unimpaired. From this point of view, target weak syllables, usually shorter and showing greater coarticulation than strong ones, could be more difficult for patients with AOS. However, syllable segregation may lead to the production of units with similar not only duration but also intensity and F0, and thus enhance the perception of weak syllables being stressed to a similar degree as strong ones (Odell & Shriberg, 2001). In addition, it has been found that in AOS both task complexity and length of items have an effect on speech production, and particularly on weak syllable lengthening, which is responsible for a difficulty in stress contrast marking that is greater in sentences than in isolated words (Strand & McNeil, 1996; Vergis et al., 2014).

Notwithstanding the foregoing, most studies report no or very few perceived stress pattern errors affecting lexical recognition in AOS (Malcolm R. McNeil et al., 2009; Nickels & Howard, 1999; Odell, McNeil, Rosenbek, & Hunter, 1991; Odell & Shriberg, 2001; Vergis et al., 2014). It might be conjectured that speakers with AOS somehow develop compensatory strategies (Edmonds & Marquardt, 2004; Goldstein, 1939; Kolk & Heeschen, 1990; Lashley, 1929; Luria, 1970; Simmons-Mackie & Damico, 1997) to overcome their difficulties and allow them make the intended stress pattern identifiable by their interlocutor. A compensatory strategy can be defined as the often spontaneously acquired use of atypical (values of) parameters in order to compensate for the impairment of another parameter with the aim of making the intended phonological category successfully cued (Khasanova, Cole, & Hasegawa-Johnson, 2014). Actually, some of the main features of AOS such as slowed speech, syllable segregation, and syllable or phoneme simplifications have been regarded as resulting at least partly from compensatory strategies (Edmonds & Marquardt, 2004; Johns & Darley, 1970; Kent & Rosenbek, 1982). However, though compensation has been mentioned in relation with atypical stress cues (e.g. Odell, McNeil, Rosenbek, & Hunter, 1991)—and in fact we ourselves have argued in a previous preliminary study (Baqué, 2017) that such compensatory strategies may account for some of the characteristics of stress patterns in several patients suffering from non-fluent aphasia and concomitant AOS—to our best knowledge no specific studies have focused on compensation for stress contrast marking difficulties in AOS.

STUDY AIMS

The aim of this exploratory study was to investigate whether persons with AOS are able to make the intended stress pattern identifiable when it conveys a morphological value (paroxytone 1st person of the present tense vs oxytone 3rd person of the preterite tense). To this end, we analysed separately the three acoustic parameters involved in stress contrast marking in Spanish, namely duration, F0 and intensity, in order to determine whether they were equally impaired and, if that was the case, to determine which acoustic cues the patients used in order to avoid the 'equal stress' phenomenon. Since there is in Spanish a very clear tendency towards F0 displacement, especially in paroxytone words in non prepausal position (Llisterri, Marín, de la Mota, & Ríos, 1995), we decided to analyse syllable mean F0 instead of maximum F0 value. Concerning intensity, several acoustic measures have been used to account for lexical stress contrasts (Gordon & Roettger, 2017), including, among other things, mean vowel or syllable intensity, peak syllable intensity, overall intensity or intensity integral, which is related to the increased perception of loudness in a longer stimulus relative to a shorter one. In order to disentangle the processing of duration and intensity cues, we decided to discard composite measures such as intensity integral and focused instead on syllable maximum intensity values, reported by several authors since Fry (1955) as contributing to stress contrasts perception in different languages (for Spanish, see Torreira, Simonet, & Hualde, 2014).

METHOD

Participants

Two small groups of right-handed native speakers of Spanish took part in this experiment, comprising three participants with apraxia of speech (AX) and three non-aphasic controls (N0). Inclusion criteria for all participants were that they had to a) be native speakers of Spanish from the Spanish-Catalan speaking region of Spain, b) be aged between 25 and 50, c) have undergone higher education and d) have given their informed consent. For the AX group the specific inclusion criteria were that they a) had acquired apraxia of speech following a cerebral vascular accident (CVA) or tumour surgery, b) were diagnosed by their speech pathologist with apraxia of speech but no or very minimal aphasia and c) obtained language examination scores according to the MTBA (Labos, Del Río, Zabala, & Nespoulous, 2005), COGNIFON (Baqué et al., 2006) and/or TBR (Peña-Casanova, 2005) examination protocols compatible with apraxia of speech with no or very minimal aphasia as reported by two other speech pathologists. As can be inferred from the obtained examination scores (see Appendix A, Table 3), frequent phonetic deviations but no evidence of agrammatism, oral comprehension deficits, asyntactic comprehension or impairment in phoneme or stress discrimination tasks were found for each of the three participants in the AX group. Controls were subjects with no reported deafness or linguistic, neurological, cognitive or psychiatric disorders. The two groups were matched for age (mean: AX = 39.7 SD 6.4; N0 = 36.0 SD 7.2), sex (two females and one male in each group) and educational level (higher education) (see Appendix A for more detailed information).

Material and procedure

In this study we selected 12 disyllabic CV.CV[1] verbal forms from the Spanish COGNIPROS morphological corpus (Baqué, Estrada, & Daoussi, 2016) on the basis of three factors: 1) the fact that their morphological value (1st person of the present tense vs 3rd person of the preterite tense) is conveyed exclusively by the stress pattern (paroxytone vs oxytone, respectively, as in *lavo* /ˈlabo/ '[I] wash' vs *lavó* /laˈbo/ '[He/she] washed'), 2) lexical frequency (mean logfreqN = 1.23 SD 0.47 in EsPAL, see Duchon, Perea, Sebastián-Gallés, Martí, & Carreiras, 2013) and age of acquisition (mean = 4.94 SD 0.88, following Alonso, Díez, & Fernandez (2016)), and 3) 'imageability' (mean = 4.96 SD 0.90 as measured on a 7-point Likert scale, (Duchon et al., 2013)). Each item could appear either isolated or in a short sentence (e.g. *Lavo / Lavo la taza* '[I] wash / [I] washed the cup').

All participants were asked to perform three tasks, namely 1) a sentence-cued sentence elicitation task using a picture prompt, or what is known as 'sentence naming', 2) reading isolated words and 3) reading short sentences. Since all the verbs selected were transitive and a direct object was therefore obligatory in most cases, the picture naming task was only cued by means of a sentence because we predicted that otherwise participants would probably have responded by naming the action of the verb in infinitive form rather than using the target inflected form. In the three tasks, while viewing the prompt, participants heard a context sentence in which the target morphological value was made explicit such as *Yo, cada día,*

[1] C = consonant; V = vowel.

hago lo mismo de siempre 'Every day, I do the same as always' to target 1st person present tense or *Sara, ese día, hizo lo mismo de siempre* 'That day, Sara did the same as always' to target 3rd person preterite tense.

Participants' speech was recorded with a sampling frequency of 44.1 kHz and 24-bit resolution and stored in WAV PCM format using Adobe Audition CS5.5 software on a PC. The recording equipment consisted of an Audio Technica Condenser Microphone AT2050, a Roland Cakewalk UA-25EX audio interface and an Alesis Multimix 8 mixer device, and all recordings took place in a soundproof room at the Speech Service of the Autonomous University of Barcelona.

Data analysis

We conducted two kinds of analyses: 1) an auditory evaluation of each recording in order to determine whether a) the intended morphological value conveyed by the stress pattern, whether canonically realised or not, was identifiable and b) the main features of AOS were audible; and 2) an acoustic analysis of each production.

For the first analysis, five listeners from the same geographic area as the participants (three phoneticians and two naïve speakers) were asked to independently listen to all the recordings and indicate whether each word or sentence corresponded to a 1st person present tense or a 3rd person preterite tense narrative. In addition, in order to check the on-target morphological value and perceived canonicity of the production, we also asked listeners to assess in a yes/no task whether one or more of the main features of AOS (effortful speech production with groping, articulatory imprecision, slowed speech rate, syllable segregation and 'equal stress') were audible in each produced word or sentence.[2] In both cases, we evaluated inter-listener agreement by calculating Conger's exact kappa (Conger, 1980; Fleiss, 1971) using the 'irr' package (Gamer, Lemon, Fellows, & Singh, 2015) in R (version 3.1.2) (R Core Team, 2014).

As for the acoustic analysis, each word or sentence production was automatically segmented into phones and syllables using the EasyAlign plugin under Praat (Boersma & Weenink, 2014; Goldman & Schwab, 2014) and manually corrected. For each syllable we extracted the duration (in s), the maximum intensity value (in dB) and the mean F0 value of the vowel (in Hz, using Hirst's algorithm (Hirst, 2011)). In order to avoid an inter-speaker effect on duration, F0 and intensity values, we calculated the percentage of variation between the duration of the last and first syllables (VarDurSyl), mean F0 (VarF0Syl) and maximum intensity values (VarIntSyl). We then ran separate analyses for each acoustic parameter by means of several mixed-effects regression models (Baayen, Davidson, & Bates, 2008). Participants and items were entered as random factors. The predictors were Group (AX vs N0), Task (sentence picture naming (SN) vs sentence reading (SR) vs word reading (WR)), Stress Pattern (oxytone (OX) vs paroxytone (PX)) and all their possible interactions. We also carried out mixed-effects linear regression models with the aim of analysing the co-variation between VarDurSyl on the one hand and VarF0Syl and VarIntSyl on the other as a function of Group, Stress Pattern and Task.

In order to identify participants' idiosyncratic behaviours, we added for the various measures and for each case-control mixed-effects regression analyses with items entered as a random factor.

Linear mixed-effects regression models were fitted using the 'lme4' package (Bates, Maechler, Bolker, & Walker, 2015), contrast and comparisons were computed using *lsmeans*

[2] We thank Reviewer #1 for his/her suggestion.

(Lenth & Hervé, 2015) and figures were generated with *ggplot2* (Wickham, 2009) in R software (version 3.1.2) (R Core Team, 2014). Significance level was set at 5%.

RESULTS [3]

Perceived errors and inter-listener agreement

We carried out several logistic regression mixed models in order to determine if there was any effect of Group, Task and/or Stress Pattern on the number of perceived errors (see table 1). When we considered all items (n = 216) classified as an error if the majority of listeners interpreted them as corresponding to the off-target morphological value, no significant effects were found (Group: Wald-$X^2(1) = 3.1111$, p = 0.07776; Stress Pattern: Wald-$X^2(1) = 0.5750$, p = 0.44827; and Task: Wald-$X^2(2) = 1.7035$, p = 0.42667). Similarly, no significant effects were found when we took into account only those 171 items (78.8% of total productions) for which there was perfect inter-listener agreement, that is, that were interpreted as corresponding to either a 1st person present tense or a 3rd person preterite tense narrative by all the listeners (Group: Wald-$X^2(1) = 0.0002$, p = 0.9885; Stress Pattern: Wald-$X^2(1) = 0.0574$, p = 0.8106; and Task: Wald-$X^2(2) = 0.0166$, p = 0.9917). Moreover, the comparison of each aphasic's productions with those of controls also showed no significant effect. When the dependent variable included each evaluation of a production by each listener (n = 216 × 5 = 1080), the results showed an effect of Group (Wald-$X^2(1) = 4.5011$, p = 0.03387) and Task (Wald-$X^2(2) = 6.2127$, p = 0.04476). No other effects were found. As compared to an item produced by the N0 group in the SN task, the probability of an item being perceived as an error by a listener was 2.78 times higher in the AX group, and 1.62 times lower for the SR task (p = 0.163) and 3.09 times lower for the WR (p = 0.014) task. Case-control analysis showed that the probability of perceived errors was significantly higher for those two specific

[3] See Appendixes B and C (Tables 4 to 15) for a comprehensive overview of the statistical results.

participants in the AOS group designated respectively AX2 (14.9%) and AX3 (13.8%) as compared to all controls (N0) (3.2%) as well as the other member of the AOS group, designated AX1 (2.6%).

	Morphological value	1st person present tense				3rd person preterite tense				All
Criterion of selected items	Task / Group	SN	SR	WR	All	SN	SR	WR	All	All
Most listeners' perception (n=216)	N0	0.0%	0.0%	0.0%	0.0%	11.1%	0.0%	0.0%	3.7%	1.9%
	AX	11.1%	5.6%	5.6%	7.4%	11.1%	5.6%	11.1%	9.3%	8.3%
	All	5.6%	2.8%	2.8%	3.7%	11.1%	2.8%	5.6%	6.5%	5.1%
Perfect inter-listener agreement (n=171)	N0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	AX	7.1%	0.0%	0.0%	2.3%	0.0%	0.0%	8.3%	2.9%	2.6%
	All	3.6%	0.0%	0.0%	1.1%	0.0%	0.0%	3.3%	1.2%	1.2%
Each item x each listener (n=1080)	N0	5.6%	5.6%	0.0%	3.7%	11.1%	2.2%	0.0%	4.4%	4.1%
	AX	12.2%	7.8%	6.7%	8.9%	20.0%	10.0%	16.7%	15.6%	12.2%
	All	8.9%	6.7%	3.3%	6.3%	15.6%	6.1%	8.3%	10.0%	8.1%

Table1: Rate of perceived errors by Morphological value, Group and Task, taking into account: a) all items classified according to most listeners' perceived morphological value (n = 18 items × 2 morphological values × 3 tasks × 2 groups = 216 evaluations), b) the 171 items with perfect inter-listener agreement, and c) all the items evaluated by each listener (n = 18 items × 2 morphological values × 3 tasks × 2 groups × 5 listeners = 1080 evaluations).

Since the difference between these results might be explained by an articulatory imprecision in the AX group that resulted in greater inter-listener variability, we decided to calculate Conger's exact kappa (Conger, 1980; Fleiss, 1971) for the five listeners not only overall (n = 216) but also separately for each group (n = 108) and participant (n = 36). The results showed excellent agreement overall (exact-k_C = 0.805) following Fleiss' arbitrary guidelines (Fleiss, 2013). Kappa values varied as a function of Group, being higher for the N0 than the AX group (exact-k_C = 0.883 and 0.726 respectively), Participant (N01: 0.848, N02: 0.900, N03:

0.900; AX1: 0.600, AX2: 0.889, AX3: 0.685) and Task (for N0, SN: 0.883, SR: 0.856 and WR: 1.000; for AX: SN: 0.667, SR: 0.745 and WR: 0.765).

Perceived AOS and inter-listener agreement

As shown in table 2, no word or sentence realisation by any of the participants in the N0 group was perceived to present one or more of the main AOS features. On the other hand, 96.9% of the AX recordings were associated with those characteristics, ranging from 95.5% (AX3) to 98.3% (AX1 and AX2). Because of the lack of variability in the N0 group and in some of the tasks as carried out by the AX group, no statistical between-groups analyses could be conducted. In addition, no effect of Stress Pattern was found. However, a logistic regression mixed model showed a significant effect of Task on the probability of perception of AOS characteristics (Wald-$X^2(2) = 9.259$, $p = 0.00976$): as compared to an item produced in the SR task, the probability of an item being perceived by a listener as showing AOS features was significantly lower in the WR task (predicted means: 50.0% and 45.7% respectively, $p = 0.0271$). No other significant differences were observed. This result can be interpreted as resulting from the length of the item listened to (i.e. there were fewer acoustic cues to help identify atypical speech in words than in sentences; see parallel results in foreign accent identification in Atagi & Bent, 2017) and/or from a greater difficulty in articulatory planning of a longer sequence.

Inter-listener analyses by means of Conger's exact kappa (Conger, 1980; Fleiss, 1971) for the 216 items and five listeners showed excellent agreement overall (exact-$k_C = 0.950$). Kappa values varied as a function of Task, being higher for the SN and SR tasks than for WR task (exact-$k_C = 1$, 0.989 and 0.862 respectively).

Perceived AOS characteristics					
Task / Group	N0	AX1	AX2	AX3	All
SN	0.0%	100.0%	100.0%	100.0%	50.0%
SR	0.0%	100.0%	100.0%	98.3%	49.7%
WR	0.0%	95.0%	95.0%	88.3%	46.4%
All	0.0%	98.3%	98.3%	95.5%	48.7%

Table2: Number of items perceived as presenting some of the main AOS characteristics features by Group and Task, taking into account all the items evaluated by each listener (n = 18 items × 2 morphological values × 3 tasks × 2 groups × 5 listeners = 1080 evaluations).

Overall syllable duration

Concerning syllable duration, the results showed a single significant effect of Group ($F(1, 3.9867) = 20.519$, $p = 0.01066$). As shown in Figure 1, syllable duration was twice as short in the N0 group (0.181 SD 0.069 s) as in the AX group (0.389 SD 0.117 s). As expected, each AX participant presented longer overall syllable duration (AX1: 0.384 s, AX2: 0.468 s, AX3: 0.316 s) as compared to N0 but the case-control difference was significant only for AX1 and AX2.

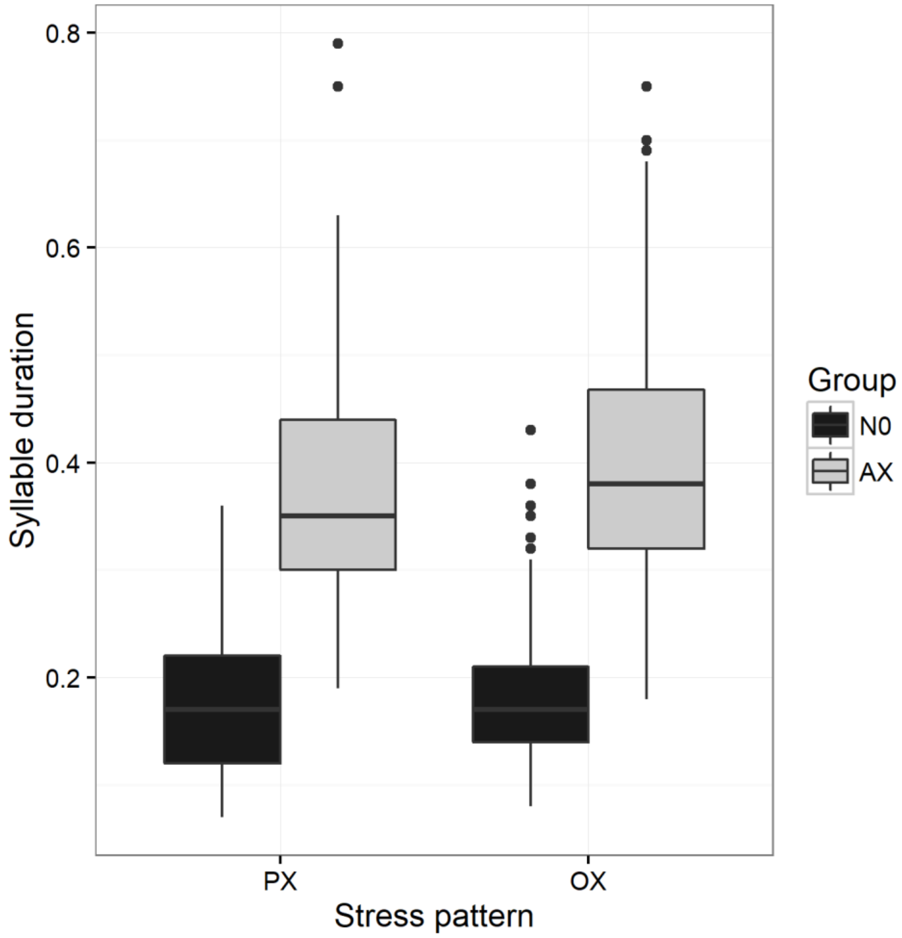

Figure 1: Mean syllable duration (in s) as a function of Stress Pattern (OX: oxytone vs PX: paroxytone) and Group (N0, AX).

Acoustic characteristics of stress contrasts

In the following analyses, we excluded those items (n = 11) considered off-target by at least three listeners.

For all parameters considered there were significant interaction effects involving Task, and post hoc analyses showed in all cases differences between those items produced in isolation (WR) and those included in sentences (SR and SN), which were not significantly different. This is probably due to the fact that in WR (vs SR and SN) the target word was located at the final edge of an assertive utterance, which is usually associated with final pre-pausal lengthening and pitch and intensity decrease.

Since no differences were found for any of the parameters considered between read and named sentences, these two tasks were collapsed. Thus we carried out separate analyses for isolated word production (WR) and for words embedded in sentences (SR + SN).

Intra-word acoustic contrasts: word reading

Results showed a main effect of Stress Pattern and an interaction effect of Stress Pattern and Group on each parameter considered: VarDurSyl ($F(1, 10.158) = 11.4489$, $p = 0.006809$ and $F(1, 51.162) = 10.6283$, $p = 0.001984$), VarF0Syl ($F(1, 60.887) = 47.644$, $p = 3.435e^{-09}$ and $F(1, 60.887) = 6.505$, $p = 0.01329$) and VarIntSyl ($F(1, 10.259) = 72.261$, $p = 5.823e^{-06}$ and $F(1, 51.943) = 14.865$, $p = 0.0003199$).

Concerning the last vs first syllable duration (VarDurSyl), both groups lengthened the final syllable in all cases and this lengthening was greater for OX than PX (N0: +94.4% SD 32.5 vs +33.0% SD 21.8; AX: +58.4% SD 38.4 vs +41.2% SD 43.5). However, this difference was significant only in the N0 group. Case-control analyses showed that VarDurSyl values did not differ from those of controls, except for AX1 in OX (+36.0% SD 25.0 vs N0: +94.4% SD 32.5). Contrary to what was observed in the N0 group, none of the AX participants revealed significant differences as a function of Stress Pattern.

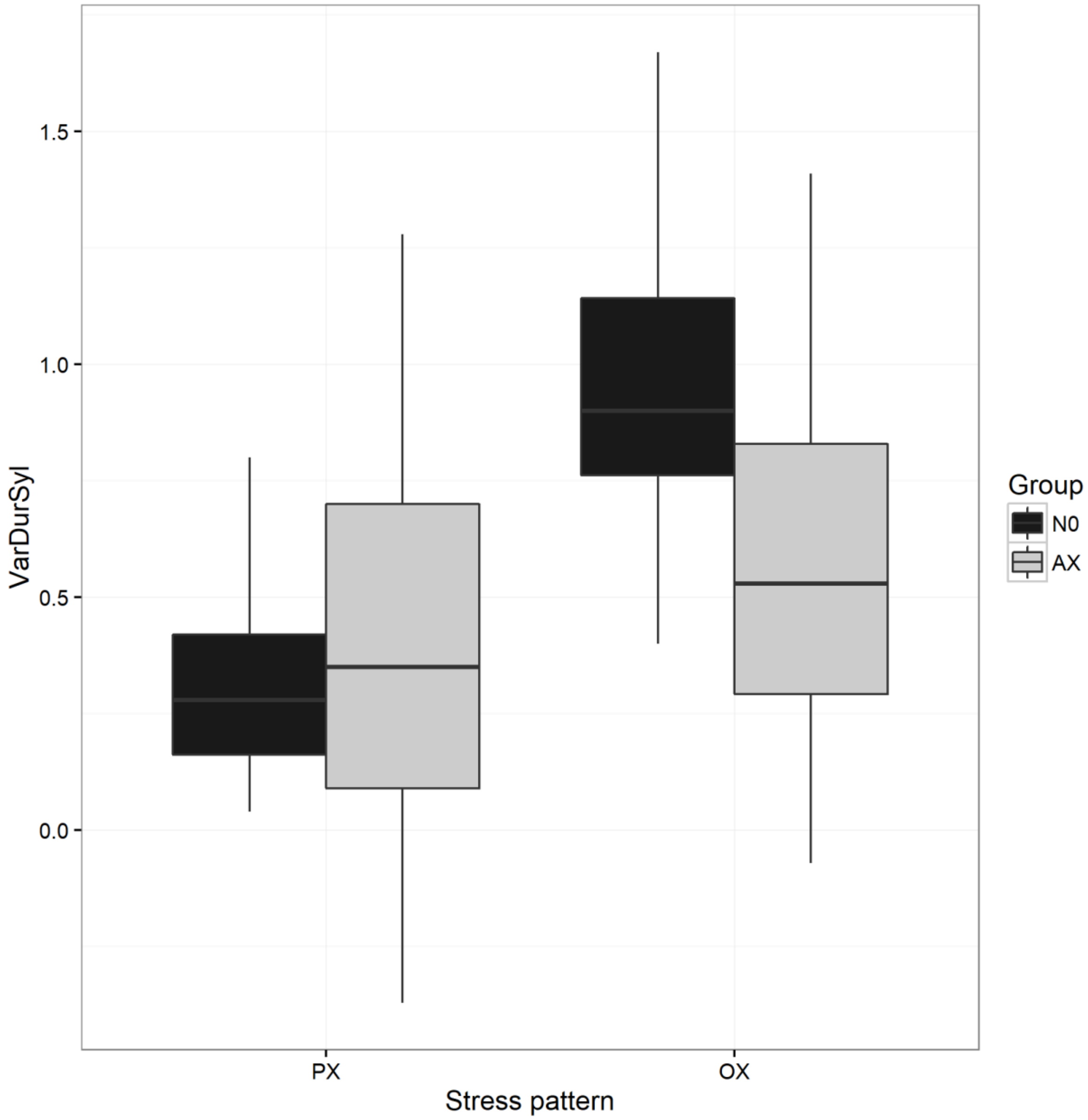

Figure 2: Mean syllable duration variation (VarDurSyl) as a function of Stress Pattern (OX: oxytone vs PX: paroxytone) and Group (N0, AX) in isolated word reading (WR).

As regards the mean F0 of the last vs first syllables (VarF0Syl), as would be expected in final conclusive intonation, in both groups the last syllable, when unstressed (PX), was characterised by a decreased F0 mean (N0: -9.2% SD 6.0 and AX: -12.5% SD 25.1), while VarF0Syl values were positive in OX (N0: +2.1% SD 5.8 and AX: +10.5% SD 15.2). Post hoc analyses showed that contrasts between OX and PX were significant for both groups and for each participant. Case-control comparisons showed similar VarF0Syl values between AX and N0 participants, except for AX3, who increased mean F0 in the last syllable even when it was unstressed (PX: +12.6% SD 22.3). However, this increase was significantly higher in OX (+34.5% SD 4.2).

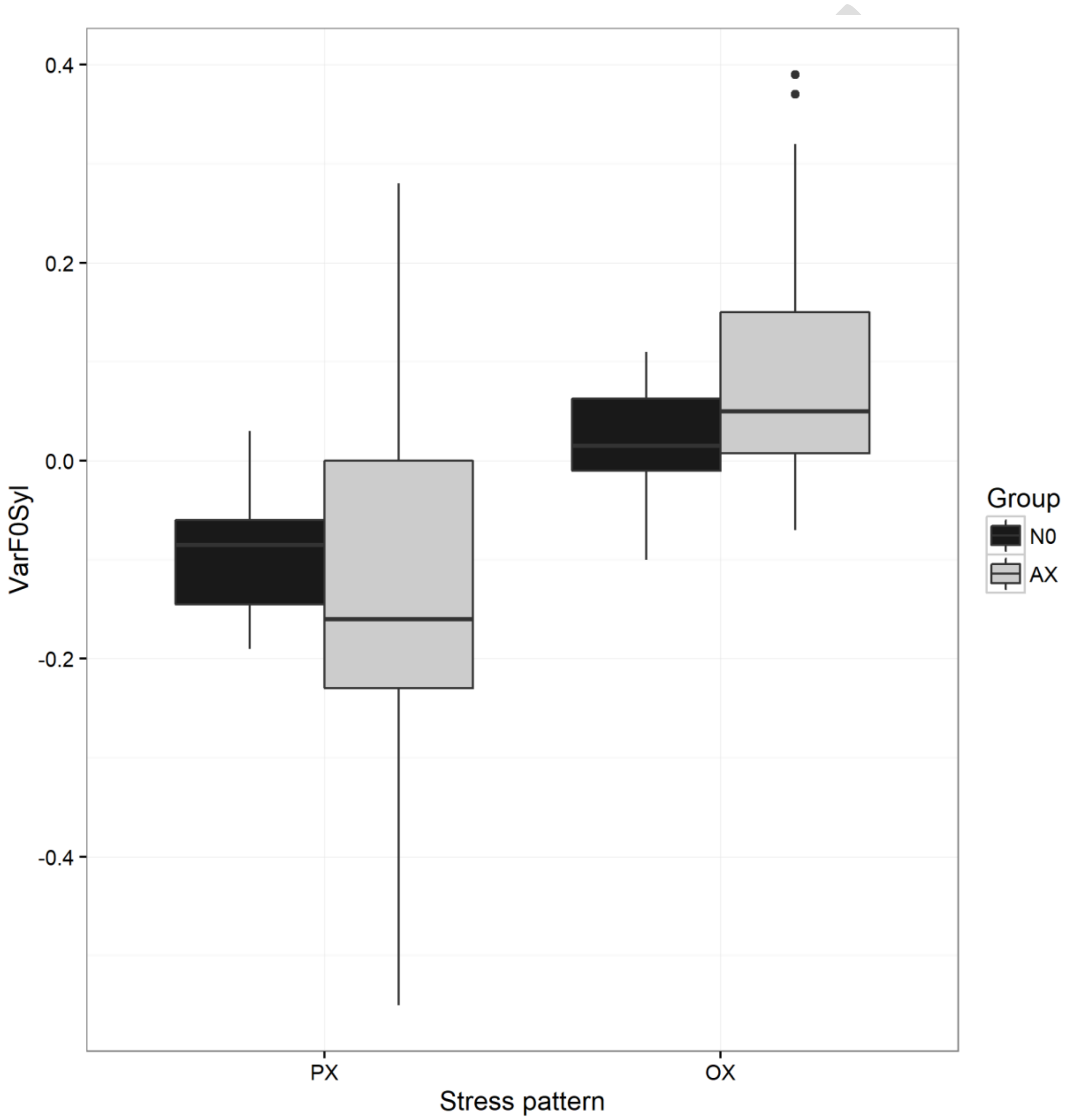

Figure 3: Mean syllable F0 variation (VarF0Syl) as a function of Stress Pattern (OX: oxytone vs PX: paroxytone) and Group (N0, AX) in isolated word reading (WR).

With regard to maximum intensity of the last vs first syllables (VarIntSyl), as would be expected in final assertive intonation, VarIntSyl values were negative for PX (N0: -10.4% SD 5.2 and AX: -7.4% SD 4.3) and almost zero for OX (N0: +3.3% SD 2.8 and AX: -0.9% SD 3.9). Post hoc analyses showed significant differences as a function of Stress Pattern in both groups. Case-control analyses did not show any significant difference between VarIntSyl values of any of the AX participants and controls for either OX or PX. However, differences as a function of Stress Pattern were significant for N0 (PX: -10.4% SD 5.2 vs OX: +3.3% SD 2.8) and AX1 (PX: -10.2% SD 2.5 vs OX: +0.5% SD 5.2) but not for AX2 (PX: -5.0% SD 4.4 vs OX: -0.7% SD 3.9) or AX3 (PX: -6.8% SD 4.5 vs OX: -2.0% SD 2.2).

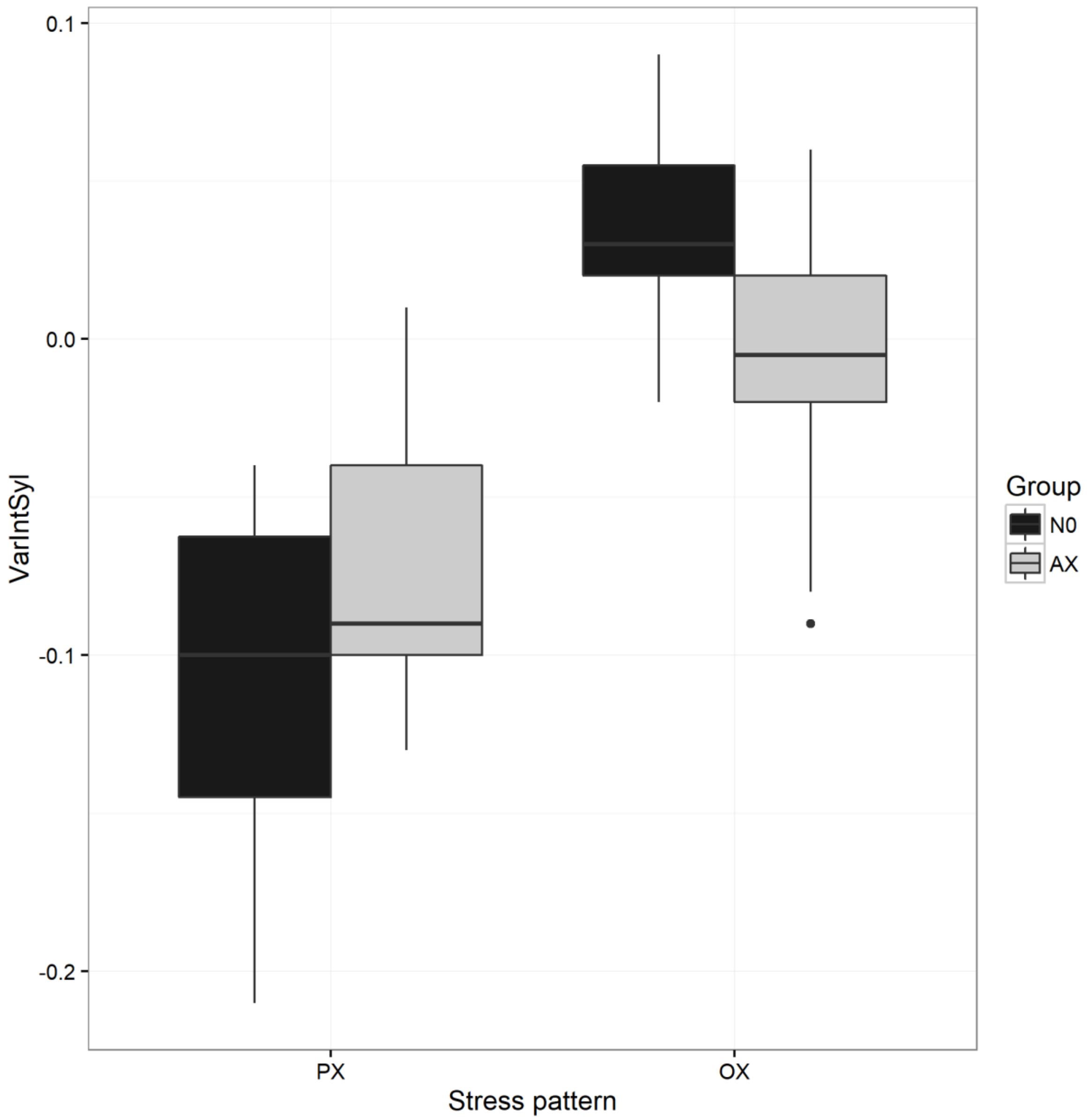

Figure 4: Mean syllable intensity variation (VarIntSyl) as a function of Stress Pattern (OX: oxytone vs PX: paroxytone) and Group (N0, AX) in isolated word reading (WR).

Intra-word acoustic contrasts: sentence reading and naming

Results showed a main effect of Stress Pattern (F(1, 21.542) = 6.1271, p = 0.021682) and an interaction effect of Stress Pattern and Group (F(1, 107.436) = 10.1541, p = 0.001886) on VarDurSyl. In N0 the final syllable was characterised by substantial shortening in PX (-31.5% SD 21.6), contrary to what was observed in OX (-1.8% SD 21.3). No such difference was shown by the AX group (PX: +6.5% SD 28.5 vs OX: +6.4% SD 39.1). Case-control analyses confirmed that none of the AX participants showed significant differences between PX and OX VarDurSyl values (AX1: +17.3% SD 27.7 vs 28.2% SD 28.7; AX2: +16.6% SD 26.7 vs +4.4% SD 16.9; AX3: -14.5% SD 19.7 vs -15.5% SD 51.3).

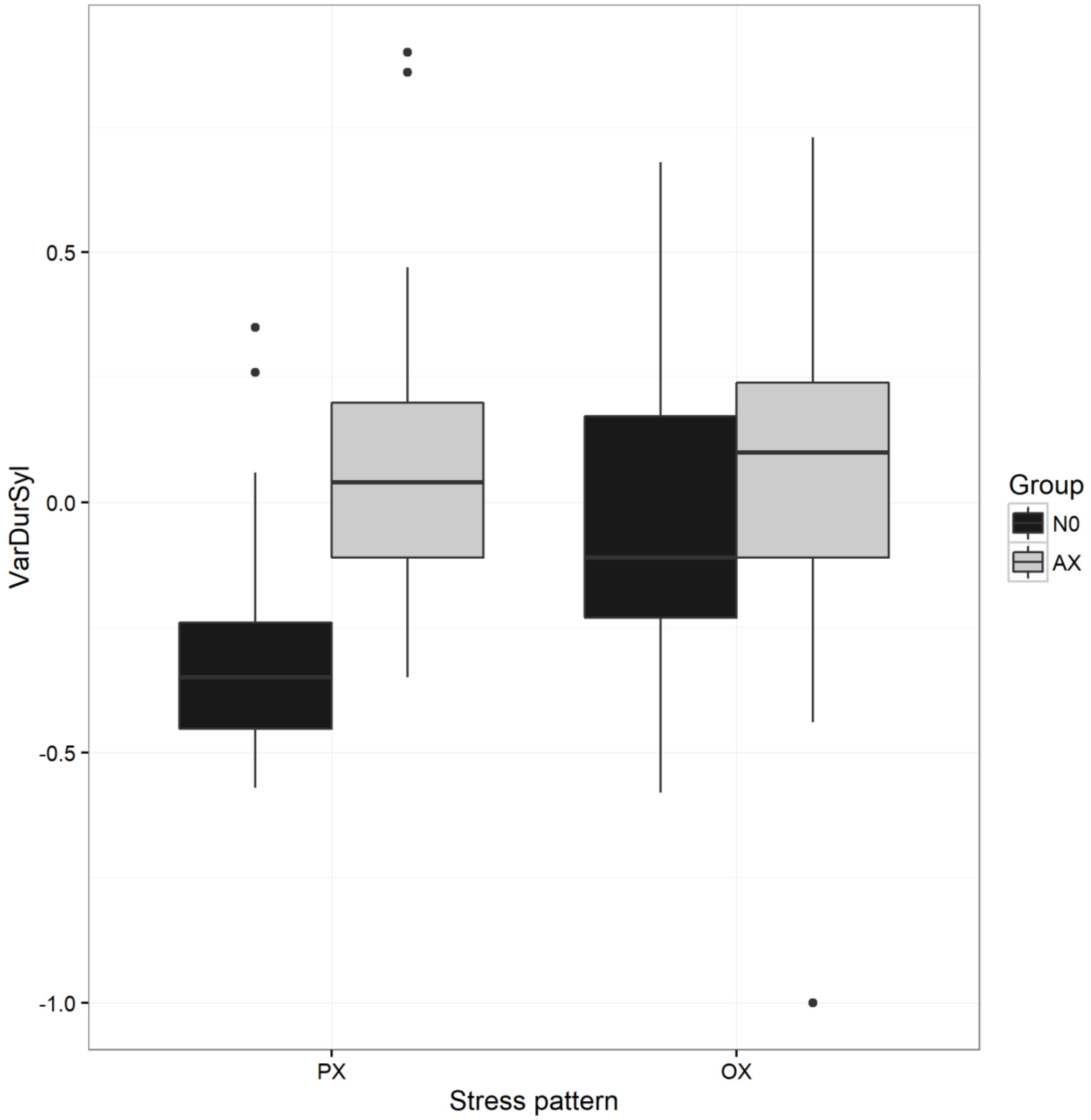

Figure 5: Mean syllable duration variation (VarDurSyl) as a function of Stress Pattern (OX: oxytone vs PX: paroxytone) and Group (N0, AX) in sentence reading and sentence naming (SR + SN).

Concerning VarF0Syl, there was a single effect of Stress Pattern ($F(1, 22.7) = 5.9262$, $p = 0.02321$) and no effect of Group or interaction effect. In OX, the last syllable presented a higher mean F0 value (+10.4% SD 15.7) than in PX (+3.0% SD 16.5). However, case-control post hoc analyses showed no significant intra-individual differences between the two stress patterns in AX, contrary to what was observed in N0.

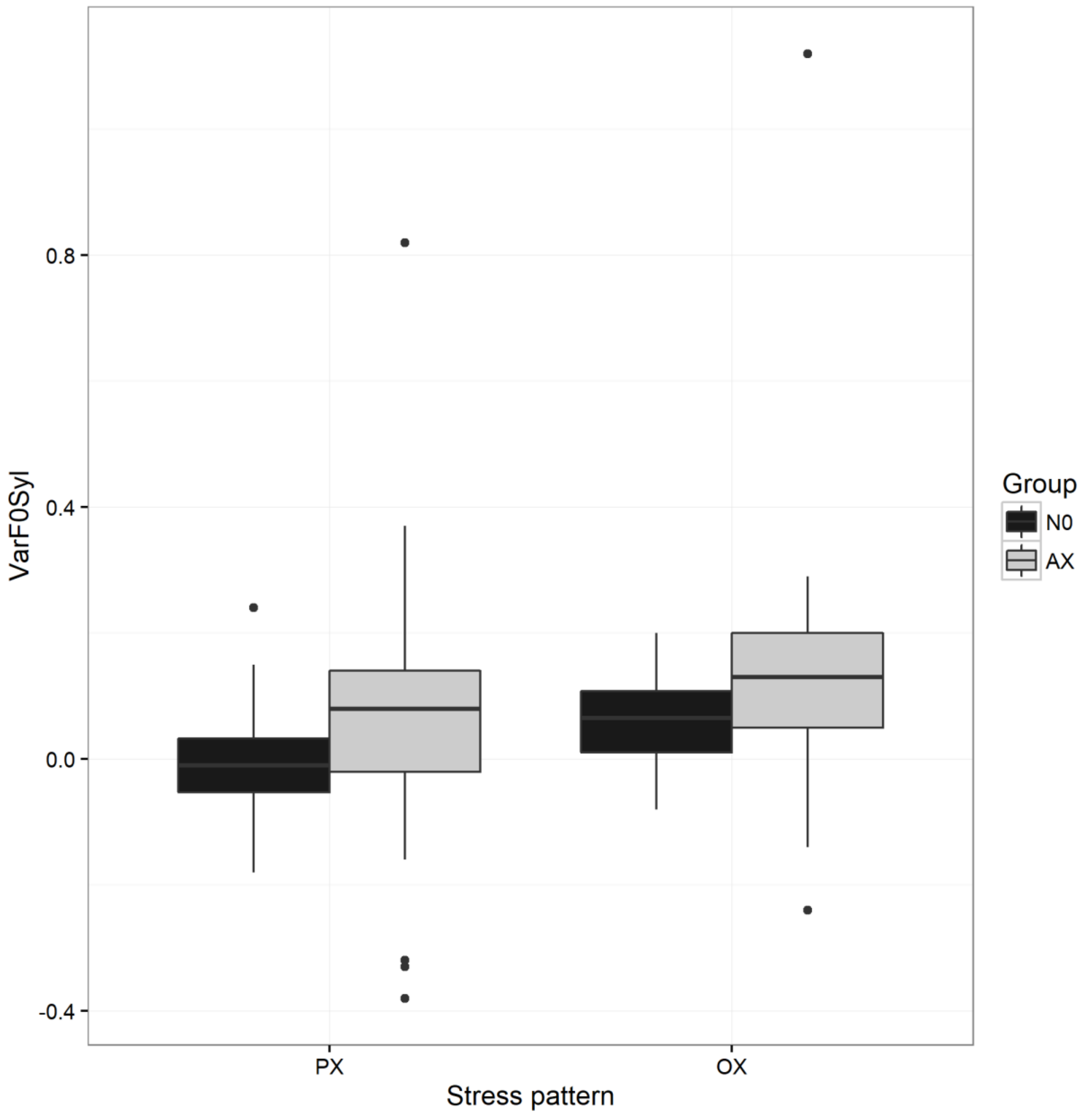

Figure 6: Mean syllable F0 variation (VarF0Syl) as a function of Stress Pattern (OX: oxytone vs PX: paroxytone) and Group (N0, AX) in sentence reading and sentence naming (SR + SN).

As for VarIntSyl, a main effect of Stress Pattern (F(1, 22.814) = 29.824, p = 1.538e^{-05}) and an interaction effect of Stress Pattern and Group (F(1, 108.122) = 15.968, p = 0.0001179) were found. Post hoc analyses showed a significant difference between OX and PX in N0 (+4.2% SD 4.6 vs -0.8% SD 2.5) but not in AX (-1.6% SD 4.0 vs -0.5% SD 2.5). None of the AX participants revealed any significant differences as a function of Stress Pattern.

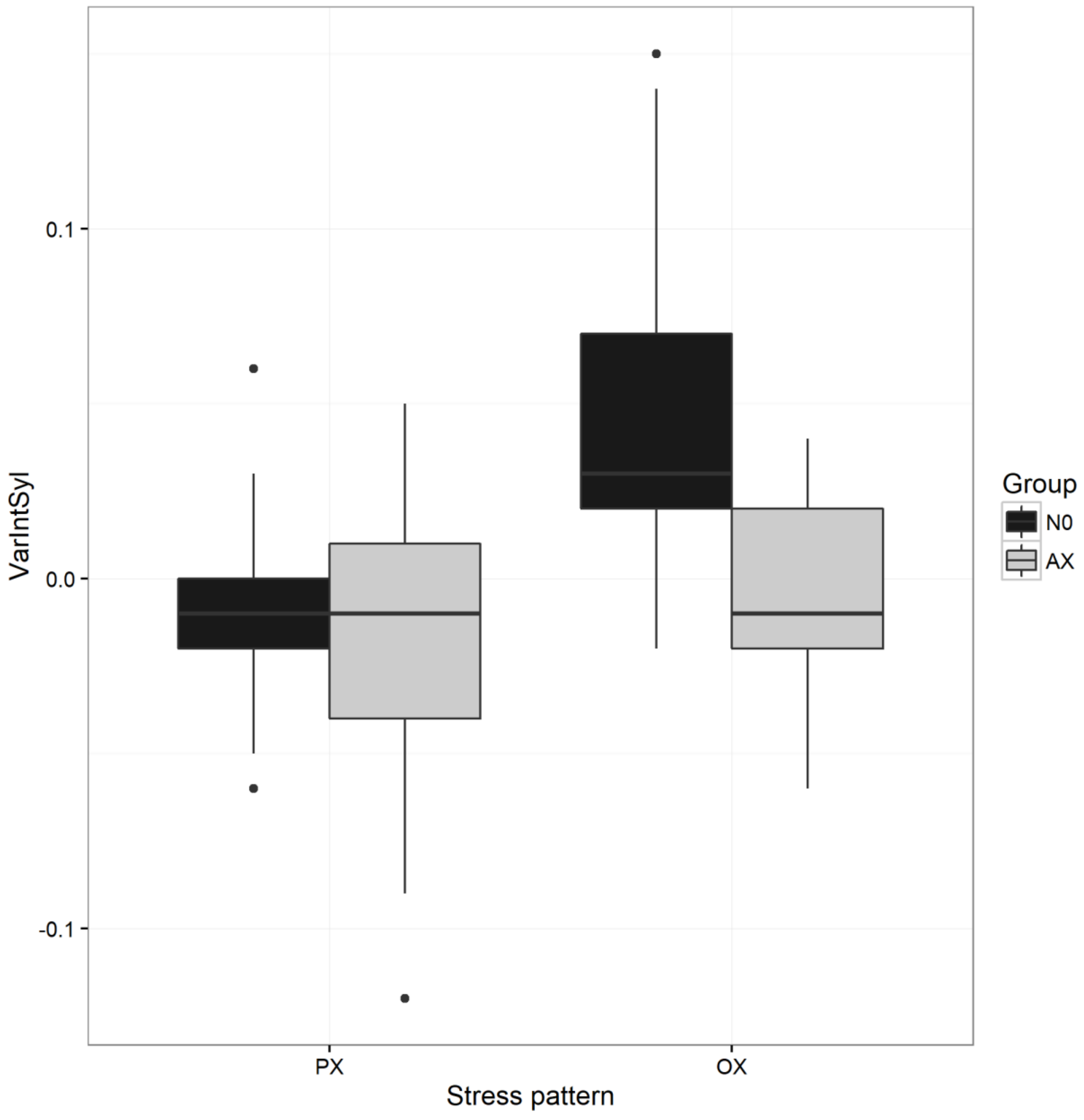

Figure 7: Mean syllable intensity variation (VarIntSyl) as a function of Stress Pattern (OX: oxytone vs PX: paroxytone) and Group (N0, AX) in sentence reading and sentence naming (SR + SN).

Idiosyncratic relationship between acoustic cues: a compensatory strategy?

Word reading

The results of logistic linear mixed models showed an effect of Group (Wald-$X^2(1) = 2.6264e^{+09}$, $p = 2.2e^{-16}$), VarDurSyl(Wald-$X^2(1) = 2.0945e^{+09}$, $p = 2.2e^{-16}$), VarF0Syl (Wald-$X^2(1) = 5.3294e^{+08}$, $p = 2.2e^{-16}$) and VarIntSyl (Wald-$X^2(1) = 1.8254e^{+12}$, $p = 2.2e^{-16}$), and three interaction effects (Group*VarDurSyl: Wald-$X^2(1) = 1.1158e^{+09}$, $p = 2.2e^{-16}$; Group*VarF0Syl: Wald-$X^2(1) = 1.5431e^{+10}$, $p = 2.2e^{-16}$; and Group*VarIntSyl: Wald-$X^2(1\ ) = 1.7059e^{+12}$, $p = 2.2e^{-16}$) on the probability of stress pattern perception (PX, i.e. 1st person present tense, vs OX, i.e. 3rd person preterite tense). However, as compared to the N0 group, significant inter-individual differences were found between AX participants in the way they combined acoustic parameters in order to create stress contrasts. We will present here only the most important results.

N0 distinguished PX from OX words by significantly less final lengthening and by a decrease in F0 and intensity values on the second (unstressed) syllable (in contrast to a slight increase in OX). Case-control analyses showed that none of the AX participants was able to maintain durational contrasts: there was a major overlap of VarDurSyl values in OX and PX (AX1, AX2 and AX3). With the aim of analysing whether the values of VarF0Syl on the one hand and VarIntSyl on the other could compensate for the atypical values of VarDurSyl in the AX group in order to make the intended stress pattern identifiable, we carried out mixed effects linear regression models of VarF0Syl and VarIntSyl as a function of VarDurSyl, Case-Control (AX1, AX2, AX3 vs all N0), Stress Pattern and Task. The results showed significant effects on VarF0Syl of Case-Control ($F(3, 56.738) = 30.496$, $p = 7.130e^{-12}$) and Stress Pattern ($F(1, 13.197) = 41.634$, $p = 2.009e^{-05}$). No effect of VarDurSyl and no interaction effects were found. As for VarIntSyl, the results showed significant effects of Stress Pattern ($F(1, 26.961) = 26.4187$, $p = 2.1e^{-05}$) and RatioDurSyl ($F(1, 60.170) = 4.3849$, $p = 0.040479$) and

Case-Control*Stress Pattern (F(3, 54.286) = 4.5751, p = 0.006286). No other significant effects were found.

As can be seen in figure 8, AX1, in whose productions there was a trend towards a greater final lengthening in PX, cued the stress contrast by means of more substantial final F0 lowering in PX than that observed in controls (VarF0Syl: β = -0.084, p > 0.0273) that tended to be more important when the second syllable of PX was over-lengthened as compared to control productions. In addition, VarIntSyl constrasts between PX and OX were similar in N0 and AX1 productions.

Relative to control participants, AX2 cued stress pattern contrasts by means of a slightly greater (but not significant) F0 lowering in PX and with similar VarIntSyl differences between OX and PX. Concerning AX3, both OX and PX were associated with a final F0 increase, but, despite some overlapping, this was much greater for OX. No significant differences between VarIntSyl values of OX and PX were found for this participant.

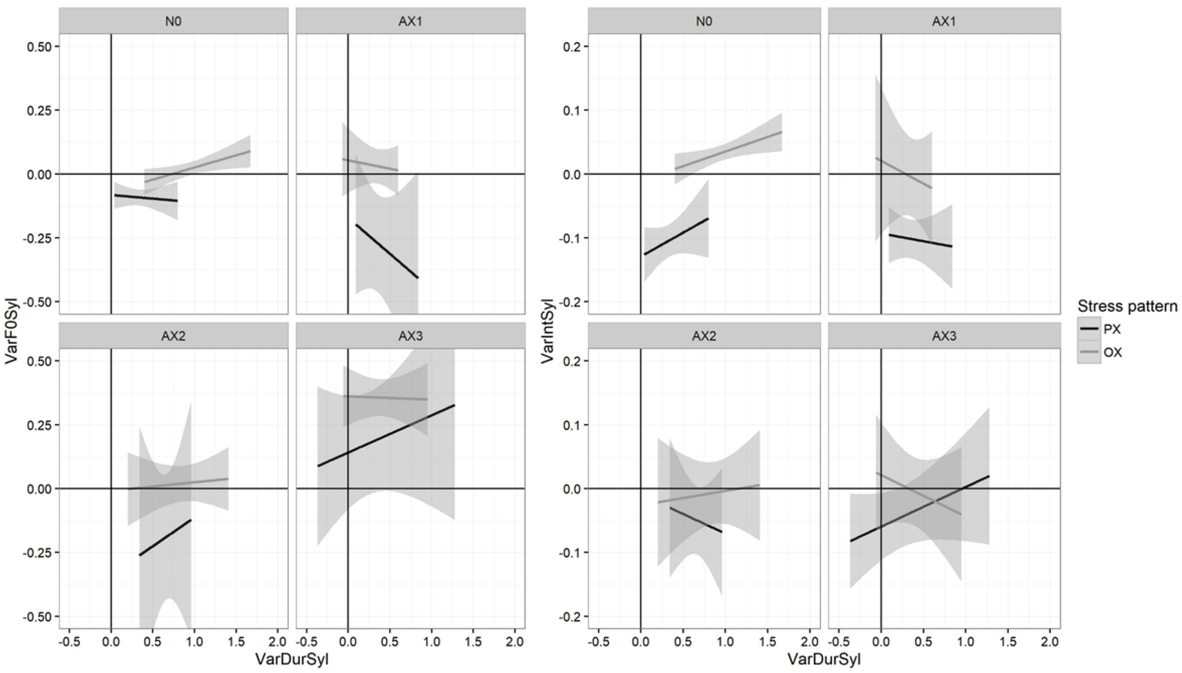

Figure 8: Predicted slopes of VarF0Syl (left) and VarIntSyl (right) as a funcion of Stress Pattern (OX: oxytone vs PX: paroxytone) and VarDurSyl for the N0 group (all participants combined) and each AX participant (AX1, AX2, AX3) in isolated word reading (WR).

Sentence reading and naming

In sentence production (SR+SN) the logistic linear regression model showed significant effects of all variables and interactions considered (Group: Wald-$X^2(1)$ = $1.8316e^{+05}$, p = $2.2e^{-16}$; VarDurSyl: Wald-$X^2(1) = 3.2064e^{+06}$, p = $2.2e^{-16}$; VarF0Syl: Wald-$X^2(1) = 1.1541e^{+08}$, p = $2.2e^{-16}$ and VarIntSyl (Wald-$X^2(1) = 1.0711e^{+09}$, p = $2.2e^{-16}$; Group*VarDurSyl: Wald-$X^2(1) = 1.4060e^{+07}$, p = $2.2e^{-16}$; Group*VarF0Syl: Wald-$X^2(1) = 6.9720e^{+07}$, p = $2.2e^{-16}$; Group*VarIntSyl: Wald-$X^2(1) = 9.5202e^{+08}$, p = $2.2e^{-16}$; VarDurSyl*VarF0Syl: Wald-$X^2(1)$ = $4.5735e^{+07}$; VarDurSyl*VarIntSyl: Wald-$X^2(1) = 6.3118e^{+09}$; VarF0Syl*VarIntSyl: Wald-$X^2(1) = 8.0394e^{+10}$; Group*VarDurSyl*VarF0Syl: Wald-$X^2(1) = 2.8994e^{+08}$; Group*VarDurSyl*VarIntSyl: Wald-$X^2(1) = 3.1172e^{+09}$; Group*VarF0Syl*VarIntSyl: Wald-$X^2(1) = 4.2532e^{+11}$; VarDurSyl*VarF0Syl*VarIntSyl: Wald-$X^2(1) = 2.3386e^{+11}$; Group*VarDurSyl*VarF0Syl*VarIntSyl: Wald-$X^2(1) = 8.0212e^{+11}$) on the probability of stress pattern perception (PX, i.e. 1st person present tense, vs OX, i.e. 3rd person preterite tense).

As shown in the preceding section, in sentence production (SR + SN), fewer acoustic differences were detected between OX and PX (see above), especially in the AX group, than in the word reading (WR) task. While N0 participants tended to produce the second (unstressed) syllable of PX words shorter and with higher F0 values than the first syllable, contrary to what was observed in OX, greater inter-individual variability was observed in the AX group.

The results of mixed linear regression models showed significant interaction effects of Case-Control (AX1, AX2, AX3 vs all N0), Stress Pattern and VarDurSyl on both VarF0Syl (F(3, 106.020) = 3.0834, p = 0.030509) and VarIntSyl (F(3, 106.079) = 3.0173, p = 0.033151). As can be seen in figure 9, there was a negative relationship between the use of duration and F0 cues in those AX participants that experienced difficulty in shortening the second syllable in PX: more lengthened second syllables were associated with lower values of VarF0Syl (AX1: β = -0.101 ± 0.114, AX2: β = -0.292 ± 0.130), contrary to what was observed in OX (AX1: β = +0.043 ± 0.121; AX2 = +0.060 ± 0.247). Such ~~a~~ behaviour was not observed in AX3, who was able to shorten the second syllable of OX and whose stress patterns differed also in terms of VarF0Syl values (see above). Concerning intensity, the slopes of the obtained linear regression equations were negative in OX and positive in PX for AX1 (β = -0.040 ± 0.033 vs β = +0.026 ± 0.031) and AX2 (β = -.042 ± 0.068 vs β = +.002 ± 0.036), while the opposite was observed in AX3 (β = +0.025 ± 0.018 vs β = +0.180 ± 0.046). However, there was a major overlap of VarIntSyl values in OX and PX for each of the AX participants, contrary to what was observed in controls, who distinguished OX from PX by higher values of VarIntSyl.

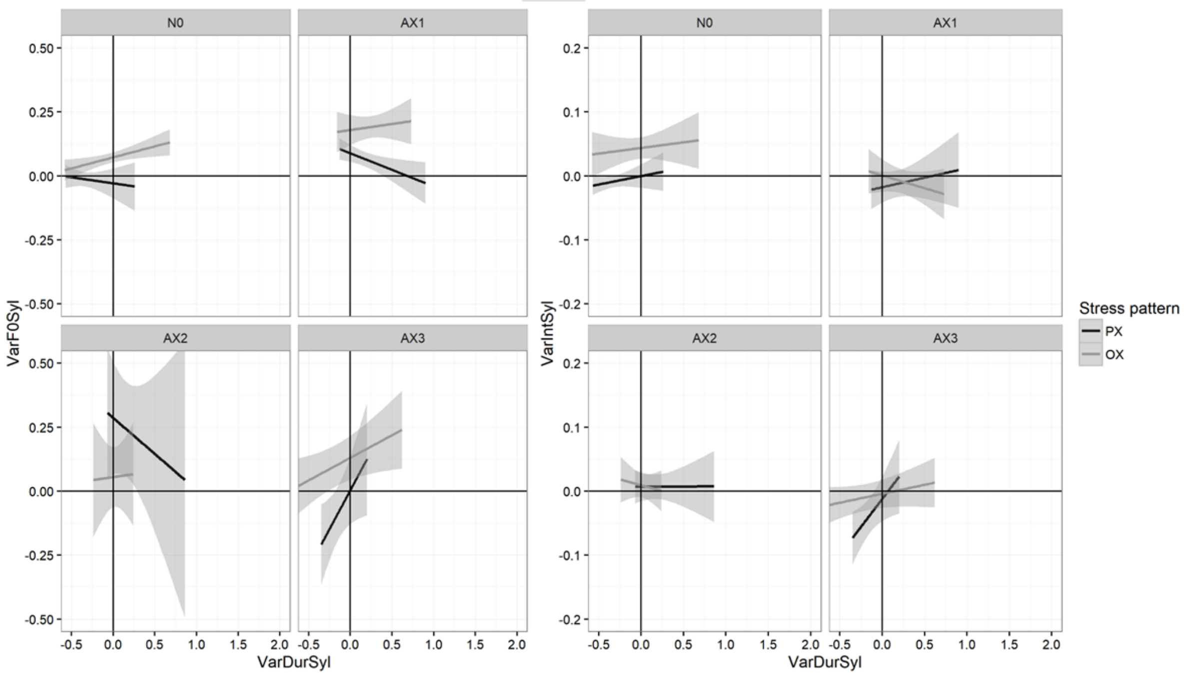

Figure 9: Predicted slopes of VarF0Syl (left) and VarIntSyl (right) as a funcion of Stress Pattern (OX: oxytone vs PX: paroxytone) and VarDurSyl for the N0 group (all participants

combined) and each AX participant (AX1, AX2, AX3) in Sentence Reading and Sentence naming (SR + SN).

DISCUSSION

The current study sought to investigate stress contrasts conveying verbal morphologic values in Spanish words produced in isolated disyllabic word reading and sentence reading and naming tasks by three participants with apraxia of speech but no or very little aphasia (especially, with no evidence of agrammatism, oral comprehension deficits, asyntactic comprehension or impairment in phoneme or stress discrimination tasks) and three controls.

The data indicate that, despite the presence of audible features of AOS (effortful speech production with groping articulatory imprecision, slowed speech rate, syllable segregation and/or 'equal stress') in the overwhelming majority of items (> 99% in SR and SN tasks and > 92% in WR) by participants with AOS, no significant difference was found between control (N0) and apraxic (AX) groups in the number of productions perceived as corresponding to the off-target morphological value. The slightly lower inter-listener agreement with regard to AX participants' output (especially for AX2 and AX3) as compared to that of N0 participants is probably attributable to greater articulatory imprecision. Such results show that AX participants, despite an obvious 'atypicality' in their speech production giving rise to perceived 'equal stress', were essentially able to make the intended stress pattern (and associated morphological values) identifiable.

Since for both groups there was a significant effect of intonation (conclusive in WR, characterised by pre-pausal lengthening and pitch and intensity decrease, vs non-conclusive in SR and SN), we decided to examine isolated word reading (WR) and sentence reading and naming (SR + SN) separately.

In isolated word reading (WR), all participants were able to cue the final assertive intonation by an overall final pre-pause lengthening, both in OX and PX words. This result is consistent with those of other experiments that have shown relatively spared patterns of acoustic cues to sentence-level prosody in productions by left-hemisphere-damaged patients (Baum, Pell, Leonard, & Gordon, 2001; Schirmer, Alter, Kotz, & Friederici, 2001) and does not support, at least in the tasks we used, the difficulty with the production of pre-boundary syllable lengthening reported in several other studies (Baum, Pell, Leonard, & Gordon, 1997; Shah, Baum, & Dwivedi, 2006; Walker et al., 2009).

Interestingly, no effect of task distinguished SR and SN results for either the N0 or the AX group, which is congruent with the idea that the features of AOS should vary not with the type of speech task being performed (Galluzzi, Bureca, Guariglia, & Romani, 2015; Ziegler, 2002) but rather with the length of items and the cognitive complexity they entail (Strand & McNeil, 1996; Vergis et al., 2014). In addition, at least in simple sentences like the ones we used here (three words, five CV syllables, subject-verb-object), the effect of different linguistic processes involved in sentence-level picture naming and reading seems not to lead to an overall different level of simultaneous demand complexity affecting the number of perceived errors or the acoustic characteristics of stress contrasts.

For the most part, besides the expected overall syllable duration lengthening, the acoustic characteristics of the intra-word acoustic contrasts between the last versus the first syllable in OX and PX words did not differ significantly as a function of group. This indicates that AX participants as a group tended to mark stress using strategies similar to those of N0 participants. The main difference concerned the inability of AX participants to reduce final (unstressed) syllable duration in PX words in the SR and SN tasks, suggesting that temporal control deficit in AOS not only affects the overall speech rate, but also somehow impairs the realisation of the phonological rule of syllable shortening.

However, the acoustic data was less consistent in the AX group than in the N0 group, resulting in fewer stress pattern differences (Marquardt et al., 1995; Ross et al., 2013; Walker et al., 2009), which could be related to the perception of 'equal stress'. Actually, while N0 participants cued the stress pattern contrasts by each of the acoustic parameters considered (duration, F0 and intensity) in both isolated words and sentences, none of the AX participants established statistically significant differences between OX and PX words in terms of intra-word acoustic contrasts of duration or intensity alone, and consistent differences in VarF0Syl between OX and PX were only found in the WR task. These results are congruent with those of several authors (Kent & Rosenbek, 1983; Marquardt et al., 1995; Walker et al., 2009) that showed fewer inter-syllabic contrasts in apraxia of speech, involving not only duration (Emmorey, 1987; Gandour, Petty, & Dardarananda, 1988; Ouellette & Baum, 1994), but also intensity.

Taken together, our findings parallel those of Marquardt et al. (1995) in suggesting that our participants with AOS have preserved the ability to retrieve the words' phonological stress pattern and then to apply different phonological rules for syllable lengthening depending on the prosodic unit in question (lexical stress or intonational boundaries) and do not support the hypothesis of a primary prosodic impairment in AOS. Rather, the perception of 'equal stress' seems to be related essentially to a basic temporal control deficit that affects speech rate and the ability to reduce unstressed syllable durations. Possibly related to that are the observed reduced inter-syllable intensity differences (McClean & Tasko, 2003). In addition, since all AX participants were able to make the intended morphological value associated with each stress pattern identifiable by the listeners mostly using acoustic strategies similar to those used by controls, albeit with less consistent acoustic differences between stress patterns, no specific deficit in F0 or intensity cue control can be inferred from our data.

However, the results of examining the relationships between acoustic cues for stress contrast marking revealed very idiosyncratic behaviours in the AX group and can be interpreted as related to the idea that speakers with AOS deploy compensatory strategies in order to avoid the 'equal stress' phenomenon (see above), as they correspond to the idea that two acoustic cues related to the same phonological feature can enter into a compensatory relationship if, when one cue is weakened (i.e. it presents sub-optimal values), the other is strengthened to compensate for this (Khasanova et al., 2014). Since these results correspond to words that were interpreted as corresponding to the on-target morphological value, such spontaneous developed strategies could be useful for speech therapy.

Of interest is the fact that these possible compensatory relationships between acoustic cues appeared in those participants whose acoustic characteristics, for a given stress pattern and task, were very different from those of controls, and this varied according to the task, to wit:

- In WR, none of the AX participants was able to distinguish PX from OX in a way that resembled the performance of the N0 group in terms of duration. However, each of the AX participants preserved stress pattern contrasts by enhancing the difference in VarF0Syl, either by lowering the final F0 in PX more than expected (AX1 and AX2) or by a disproportionate increase in final F0 in OX (AX3). In addition, AX1 was also able to preserve intensity contrasts between OX from PX in a way similar to that of controls.
- In SR and SN, we observed that, unlike OX, N0 produced PX words with a shortened second (stressed) syllable and near zero F0 variation (contrary to OX, in which there was a F0 increase on the second syllable). This was also the case of AX3, but not of AX1 and AX2, who lengthened PX second (unstressed) syllables and presented higher values of F0 variation in OX second (stressed) syllables than in N0. Interestingly, we found a negative relationship between these durational and F0 cues in PX words

produced by these participants with AOS: the more they lengthened the second (unstressed) syllable, the less they enhanced the F0 increase. In addition, in AX1 we observed that F0 contrasts between patterns were preserved by a greater F0 increase in PX than in OX. By contrast, no specific effect of intensity was found for any of the AX participants.

Given that significant intra-speaker differences were observed between word and sentence productions, such possibly compensatory behaviours seem to result from online processes, interacting with other prosodic demands, more than from newly learned articulatory plans.

It is noteworthy, however, that for each participant there were productions that showed similar values in terms of all the acoustic values considered, but which were interpreted by listeners as being on-target for different morphological values (and thus stress patterns). Other parameters, such as sharp intra-syllable F0 variation, sub-syllabic durations or vowel quality could have contributed to this perception of an on-target stress pattern. Concerning the last of these three factors, even if there is no phonological vocalic neutralisation in Spanish as a function of stress, there has been observed an enlarged vowel space area in people with Broca's aphasia and concomitant AOS in stressed (vs unstressed) syllables in Spanish (Baqué, 2015). We may suppose that our participants with AOS could have cued their stress patterns by characteristic modifications of vocalic spectral quality.

There are several possible explanations for the important inter-speaker variability found for all parameters and interactions considered in the AX group. Besides locus of lesion and time post-onset, these differences may reflect idiosyncratic behaviours implemented to compensate for their disability. It is also possible that individuals with tumour-related impairments restructure their skills differently from post-stroke patients, due to a progressive reorganisation of the information encoded in the brain during the development of a slowgrowing tumour (as opposed to sudden destruction of brain areas; see Anderson, Damasio, & Tranel, 1990; Davie, Hutcheson, Barringer, Weinberg, & Lewin, 2009).

Thus, further research is needed, not only to validate these results with systematic studies on larger homogeneous groups and more complex materials, but also to account for other (combinations of) cues used by participants with AOS in stress pattern marking and their relative effectiveness in making the intended stress pattern identifiable.

ACKNOWLEDGMENTS

The author would like to thank Anna Marczyk and María-Jesús Machuca for their help with collecting the data used in this study and the anonymous reviewers for their helpful comments on earlier versions of this manuscript.

DECLARATION OF INTEREST

The author reports no conflicts of interest.

FUNDING

Support for this research was provided by the Spanish Ministry of Economy and Competitiveness, National Programme for Fostering Excellence in Scientific and Technical Research [grant FFI2013-40419-P].

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APPENDIX A

GROUP	APRAXIA OF SPEECH (AX)			CONTROL (N0)		
SUBJECT	AX1	AX2	AX3	N01	N02	N03
GENDER	F	F	M	F	F	H
AGE	35	37	47	38	28	42
DIAGNOSIS	AOS	AOS	AOS	--	--	--
INITIAL DIAGNOSIS	BA	BA	Mutism → BA			
TIME POST ONSET (in months)	12	14	4	--	--	--
AETIOLOGY	Tumour	Tumour	CVA	--	--	--
LESION LOCATION	Frontal operculum (Brodmann area 44)	Frontal operculum (Brodmann area 44)	Middle cerebral artery territory	--	--	--
MTBA: Conversation				--	--	--
- Comprehension	SA	SA	SA			
- Reduction	SA	SA	SA			
- Agrammatism	SA	SA	SA			
- Anomia	SA	SA	SA			
- Phonetic deviations	++	++	++			
- Phonemic deviations	SA	SA	+			
- Verbal deviations	SA	SA	SA			
MTBA: Picture description						
- Comprehension	SA	SA	SA			
- Reduction	SA	SA	SA			
- Agrammatism	SA	SA	SA			
- Anomia	SA	SA	SA			
- Phonetic deviations	++	++	++			
- Phonemic deviations	SA	SA	+			
- Verbal deviations	SA	SA	SA			
MTBA: Auditory Comprehension (Words)	SA	SA	SA	--	--	--
MTBA: Auditory Comprehension (Sentences)	SA	SA	SA	--	--	--
MTBA: Written comprehension (Words)	SA	SA	SA	--	--	--

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MTBA: Written comprehension (Sentences)	SA	SA	SA	--	--	--
MTBA: Repetition - Phonetic deviations - Phonemic deviations	 + SA	 + SA	 ++ SA	--	--	--
MTBA: Reading - Phonetic deviations - Phonemic deviations	 ++ SA	 ++ SA	 +++ SA	--	--	--
MTBA: Naming - "Out of time" - Phonetic deviations - Phonemic deviations - Verbal deviations - Circumlocution - Gestures	 SA + SA SA SA SA	 SA + SA SA SA SA	 SA + SA SA SA SA	--	--	--
MTBA: Automatized sequences	SA	SA	SA	--	--	--
MTBA: Praxias	SA	SA	SA	--	--	--
COGNIFON: Phoneme discrimination (out of 10)	10	10	10	--	--	--
COGNIFON: Stress discrimination (out of 12)	12	12	12	--	--	--
COGNIFON: Syllable segmentation (out of 12)	12	12	12	--	--	--
TBR: Working Memory (out of 10)	6	NA	5	--	--	--

Table 3. Participant demographic and neuropsychological information. MTBA = *Protocolo Montréal-Toulouse-Buenos Aires de examen lingüístico de la afasia* (Labos et al., 2005); COGNIFON= *Protocolo de exploración lingüística del proyecto Cognifon. Versión española*; (Baqué et al., 2006), TBR = *Test Barcelona Revisado (TBR). Programa Integrado de exploración neuropsicológica* (Peña-Casanova, 2005); BA = Broca's aphasia; AOS = Apraxia of Speech; SA = unimpaired; + = mild impairment; ++ = moderate impairment; +++ = severe impairment; NA = not available.

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APPENDIX B. SUMMARY STATISTICS OF THE BETWEEN-GROUP COMPARISONS

<table>
<tr><th colspan="16">Between-group analyses</th></tr>
<tr><th>Predictors</th><th colspan="5">a) All items as perceived by the majority of listeners (n=216)</th><th colspan="5">b) Items with perfect inter-listener agreement (n=171)</th><th colspan="5">c) All items as perceived by each listener (n=1080)</th></tr>
<tr><td>Intercept</td><td colspan="5">***
α=-4.0461±0.9501, z=-4.258, p<.001</td><td colspan="5">***
α=-4.4368±0.7113, z=-6.238, p<.001</td><td colspan="5">***
α=-2.8666±0.3192, z=-8.982, p<.001</td></tr>
<tr><td>Group</td><td colspan="5">.</td><td colspan="5"></td><td colspan="5">*
AX: β=1.1117±0.5125, z=2.169, p<.05</td></tr>
<tr><td>Task</td><td colspan="5"></td><td colspan="5"></td><td colspan="5">*
SR: β=-0.5651±0.4050, z=-1.395, p>.10
WR: β=-1.0917±0.4442, z=-2.457, p<.05</td></tr>
<tr><td>Stress pattern</td><td colspan="5"></td><td colspan="5"></td><td colspan="5"></td></tr>
<tr><td>Group*Task</td><td colspan="5"></td><td colspan="5"></td><td colspan="5"></td></tr>
<tr><td>Group*Stress pattern</td><td colspan="5"></td><td colspan="5"></td><td colspan="5"></td></tr>
<tr><td>Task*Stress pattern</td><td colspan="5"></td><td colspan="5"></td><td colspan="5"></td></tr>
<tr><td>Group*Task*Stress pattern</td><td colspan="5"></td><td colspan="5"></td><td colspan="5"></td></tr>
<tr><td rowspan="2">Model summary</td><td>AIC</td><td>BIC</td><td>logLik</td><td>deviance</td><td>df.resid</td><td>AIC</td><td>BIC</td><td>logLik</td><td>deviance</td><td>df.resid</td><td>AIC</td><td>BIC</td><td>logLik</td><td>deviance</td><td>df.resid</td></tr>
<tr><td>87.8</td><td>97.9</td><td>-40.9</td><td>81.8</td><td>213</td><td>27.8</td><td>37.2</td><td>-10.9</td><td>21.8</td><td>168</td><td>556.1</td><td>595.9</td><td>-270.0</td><td>540.1</td><td>1072</td></tr>
</table>

Table 4. Summary of statistics of the logistic linear regression mixed models of the number of perceived errors as a function of Group, Task and/or Stress Pattern in a) all items as perceived by the majority of listeners (n = 216), b) items with perfect inter-listener agreement (n = 171) and c) all the items as perceived by each listener (n = 2016 x 5 = 1080). Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.10, '' >0.10. When significant, fixed effects statistics for each comparison have been included.

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Between-group analyses					
Predictors	Overall syllable duration				
Intercept	** α= 0.18098± 0.03316, df= 4.32500, t= 5.458, p<.01				
Group	* AX: β= 0.20813 ± 0.04595, df= 3.98700, t= 4.530, p<.05				
Model summary	AIC	BIC	logLik	deviance	df.resid
	-959.3	-939.2	484.7	-969.3	405

Table 5: Summary of statistics of the linear regression mixed models of the overall syllable duration as a function of Group. Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.10, '' >0.10. When significant, fixed effects statistics for each comparison have been included.

Between-group analyses															
Predictors	VarDurSyl					VarF0Syl					VarIntSyl				
Intercept	* α=0.33000±0.12999, df=8.68, t= 2.539, p<.05					α= -0.09167± 0.08202, df= 4.31, t= -1.118, p>.10					*** α= -0.10444± 0.01135, df= 11.83, t= -9.205, p<.001				
Group	AX: β= 0.06935 ± 0.16043, df= 5.87, t= 0.432, p>.10					AX: β= -0.02054 ± 0.11616, df= 4.34, t= -0.177, p>.10					AX: β= 0.03114± 0.01455, df= 11.57, t= 2.140, p<.10				
Stress pattern	*** OX: β= 0.61389± 0.13223, df= 17.57, t= 4.642, p<.001					** OX: β= 0.11222± 0.03564, df= 60.88, t= 3.149, p<.01					*** OX: β= 0.13722± 0.01489, df= 23.88, t= 9.218, p<.001				
Group*Stress pattern	*** AX*OX: β= -0.45142± 0.13847, df= 51.16, t= -3.260, p<.01					* AX*OX: β= 0.13154± 0.05157, df= 60.89, t= 2.551, p<.05					*** AX*OX: β-0.07290± 0.01891, df= 51.94, t= -3.855, p<.001				
Model summary	AIC	BIC	logLik	deviance	df.resid	AIC	BIC	logLik	deviance	df.resid	AIC	BIC	logLik	deviance	df.resid
	53.2	68.9	-19.6	39.2	62	-85.4	-69.8	49.7	-99.4	62	-234.4	-218.8	124.2	-248.4	62

Table 6: Summary of statistics of the linear regression mixed models of the intra-word acoustic contrasts (VarDurSyl, VarF0Syl and VarIntSyl) in Word Reading task as a function of Group and/or Stress pattern. Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.10, '' >0.10. When significant, fixed effects statistics for each comparison have been included.

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<table>
<tr><th colspan="16">Between-group analyses</th></tr>
<tr><th>Predictors</th><th colspan="5">VarDurSyl</th><th colspan="5">VarF0Syl</th><th colspan="5">VarIntSyl</th></tr>
<tr><td>Intercept</td><td colspan="5">*
α= -0.31500 ± 0.08928, df= 6.21, t= -3.528, p<.05</td><td colspan="5">α= 0.03269± 0.03735, df= 7.5250, t= 0.875, p>.10</td><td colspan="5">α= -0.012405± 0.010849, df= 5.89, t= -1.143, p>.10</td></tr>
<tr><td>Group</td><td colspan="5">AX: β= 0.37871 ± 0.12211, df= 5.47, t= 3.101, p<.05</td><td colspan="5"></td><td colspan="5"></td></tr>
<tr><td>Stress pattern</td><td colspan="5">*
OX: β= 0.29624 ± 0.07463, df= 51.38, t= 3.969, p<.001</td><td colspan="5">*
OX: β= 0.07211± 0.02962, df= 22.70, t= 2.434, p<.05</td><td colspan="5">***
OX: β= 0.031935± 0.005806, df= 22.842, t= 5.500, p<.001</td></tr>
<tr><td>Group*Stress pattern</td><td colspan="5">**
AX*OX: β= -0.30082± 0.09440, df= 107.44, t= -3.187, p<.01</td><td colspan="5"></td><td colspan="5"></td></tr>
<tr><td rowspan="2">Model summary</td><td>AIC</td><td>BIC</td><td>logLik</td><td>deviance</td><td>df.resid</td><td>AIC</td><td>BIC</td><td>logLik</td><td>deviance</td><td>df.resid</td><td>AIC</td><td>BIC</td><td>logLik</td><td>deviance</td><td>df.resid</td></tr>
<tr><td>64.7</td><td>85.1</td><td>-25.4</td><td>50.7</td><td>129</td><td>-119.0</td><td>-104.4</td><td>64.5</td><td>-129.0</td><td>131</td><td>-529.8</td><td>-515.3</td><td>269.9</td><td>-539.8</td><td>131</td></tr>
</table>

Table 7: Summary of statistics of the linear regression mixed models of the intra-word acoustic contrasts (VarDurSyl, VarF0Syl and VarIntSyl) in Sentence Naming and Sentence Reading tasks as a function of Group and/or Stress pattern. Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.10, '' >0.10. When significant, fixed effects statistics for each comparison have been included.

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Between-group analyses					
Predictors	Perceived stress pattern by the majority of listeners				
Intercept	*** α=8.582e^{+01}±1.679e^{-03}, z=51118, p<.001				
Group	*** AX: β=-8.604e^{+01}±1.679e^{-03}, z=-51247, p<.001				
VarDurSyl	*** β=-7.683e^{+01}±1.679e^{-03}, z=-45766, p<.001				
VarF0Syl	*** β=-3.876e^{+01}±1.679e^{-03}, z=-23085, p<.001				
VarIntSyl	*** β=2.268e^{+03}±1.679e^{-03}, z=1351088, p<.001				
Group*VarDurSyl	*** AX: β=5.608e^{+01}±1.679e^{-03}, z=33404, p<.001				
Group*VarF0Syl	*** AX: β=2.085e^{+02}±1.679e^{-03}, z=124221, p<.001				
Group*VarIntSyl	*** AX: β=-2.193e^{+03}±1.679e^{-03}, z=-1306106, p<.001				
VarDurSyl*VarF0Syl					
Group*VarDurSyl*VarF0Syl					
Group*VarDurSyl*VarIntSyl					
Group *VarF0Syl*VarIntSyl					
VarDurSyl*VarF0Syl*VarIntSyl					
Group*VarDurSyl*VarF0Syl*VarIntSyl					
Model summary	AIC	BIC	logLik	deviance	df.resid
	42.5	65.3	-11.3	22.5	62

Table 8: Summary of statistics of the logistic linear regression mixed models of the perceived stress pattern by the majority of listeners (OX vs PX) in Word Reading task as a function of Group, VarDurSyl, VarF0Syl and/or VarIntSyl. Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.10, '' >0.10. When significant, fixed effects statistics for each comparison have been included.

Between-group analyses	
Predictors	Perceived stress pattern by the majority of listeners
Intercept	*** α=1.146e^{+01}±1.874e^{-03}, z=6116, p<.001
Group	*** AX: β=-8.021e^{-01}±1.874e^{-03}, z=--428, p<.001

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VarDurSyl	*** $\beta=3.356^{+00}\pm1.874e^{-03}$, z=1791, p<.001				
VarF0Syl	*** $\beta=2.014e^{+01}\pm1.874e^{-03}$, z=10743, p<.001				
VarIntSyl	*** $\beta=6.134e^{+01}\pm1.874e^{-03}$, z=32727, p<.001				
Group*VarDurSyl	*** $\beta=-7.028e^{+00}\pm1.874e^{-03}$, z=-3750, p<.001				
Group*VarF0Syl	*** $\beta=-1.565e^{+01}\pm1.874e^{-03}$, z=-8350, p<.001				
Group*VarIntSyl	*** $\beta=5.783e^{+01}\pm1.874e^{-03}$, z=30855, p<.001				
VarDurSyl*VarF0Syl	*** $\beta=1.268e^{+01}\pm1.874e^{-03}$, z=6763, p<.001				
VarDurSyl*VarIntSyl	*** $\beta=1.489e^{+02}\pm1.874e^{-03}$, z=79447, p<.001				
VarF0Syl*VarIntSyl	*** $\beta=8.470e^{+02}\pm1.936e^{-03}$, z=437576, p<.001				
Group*VarDurSyl*VarF0Syl	*** $\beta=-3.191e^{+01}\pm1.874e^{-03}$, z=-17028, p<.001				
Group*VarDurSyl*VarIntSyl	*** $\beta=-1.081e^{+02}\pm1.936e^{-03}$, z=-55832, p<.001				
Group *VarF0Syl*VarIntSyl	*** $\beta=-1.262e^{+03}\pm1.936e^{-03}$, z=-652165, p<.001				
VarDurSyl*VarF0Syl*VarIntSyl	*** $\beta=1.340e^{+03}\pm1.936e^{-03}$, z=692137, p<.001				
Group*VarDurSyl*VarF0Syl*VarIntSyl	*** $\beta=-1.734e^{+03}\pm1.936e^{-03}$, z=-895610, p<.001				
Model summary	AIC	BIC	logLik	deviance	df.resid
	73.6	124.8	-18.8	37.6	109

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Table 9: Summary of statistics of the logistic linear regression mixed models of the perceived stress pattern by the majority of listeners (OX vs PX) in Sentence Naming and Sentence Reading tasks as a function of Group, VarDurSyl, VarF0Syl and/or VarIntSyl. Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.10, '' >0.10. When significant, fixed effects statistics for each comparison have been included.

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APPENDIX C. SUMMARY STATISTICS OF THE CASE-CONTROL COMPARISONS

Case-control comparisons															
Intercept	*** α=-4.0461±0.9501, z=-4.258, p<.001					*** α=-4.4368±0.7113, z=-6.238, p<.001					*** α=-2.8666±0.3192, z=-8.982, p<.001				
Case-Control											*** AX1: β= -0.2137± 0.4674, z= -0.457, p>.10 AX2: β= 1.6738± 0.2998, z= 5.583, p<.001 AX3: β= 1.5871± 0.3030, z= 5.238, p<.001				
Task											* SR: β= -0.7574± 0.3881, z= -1.952, p<.10 WR: β= -0.8965± 0.3967, z= -2.260, p<.05				
Stress pattern															
Case-Control*Task															
Case-Control*Stress pattern															
Task*Stress pattern															
Case-Control*Task*Stress pattern															
Model summary	AIC	BIC	logLik	deviance	df.resid	AIC	BIC	logLik	deviance	df.resid	AIC	BIC	logLik	deviance	df.resid
	87.8	97.9	-40.9	81.8	213	27.8	37.2	-10.9	21.8	168	556.1	595.9	-270.0	540.1	1072

Table 10: Summary of statistics of the logistic linear regression mixed models of the number of perceived errors as a function of Case-Control (AX1, AX2, AX3 vs all N0), Task and/or Stress Pattern in a) all items perceived as perceived by the majority of listeners (n = 216), b) items with perfect inter-listener agreement (n = 171) and c) all the items as perceived by each listener (n = 2016 × 5 = 1080). Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.10, '' >0.10. When significant, fixed effects statistics for each comparison have been included.

Case-control comparisons					
Predictors	Overall syllable duration				
Intercept	*** α= 0.18100± 0.01469, df= 3.17100, t= 12.322, p<.001				
Case-control	* AX1: β= 0.20275± 0.02614,df=1.99400, t= 7.756 p<.05 AX2: β= 0.28705± 0.02629, df= 2.04000, t= 10.919, p<.01 AX3: β= 0.13451± 0.02632,df= 2.05100, t= 5.109, p<.05				
Model summary	AIC	BIC	logLik	deviance	df.resid
	-969.6	-941.4	491.8	-983.6	403

Table 11: Summary of statistics of the linear regression mixed models of the overall syllable duration as a function of Case-Control (AX1, AX2, AX3 vs all N0). Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.10, '' >0.10. When significant, fixed effects statistics for each comparison have been included.

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Case-control comparisons															
Predictors	VarDurSyl					VarF0Syl					VarIntSyl				
Intercept	** α=0.33000±0.09355, df=17.19, t= 3.528, p<.01					*** α=-0.12328±0.02279, df=63.94, t= -5.411, p<.001					*** α=-0.104444±0.011512, df=6.85, t= -9.072, p<.001				
Case-control	AX1: β= 0.02000± 0.13307, df= 51.17, t= 0.150, p>.10 AX2: β= 0.33667± 0.13307, df= 51.17, t= 2.530, p<.05 AX3: β= -0.16999± 0.14385, df= 52.10, t= -1.182, p>.10					*** AX1: β= -0.08444± 0.03693, df= 63.94, t= -2.287, p<.05 AX2: β= -0.04861± 0.03693, df= 63.94, t= -1.316, p>.10 AX3: β= 0.26864± 0.04132, df= 63.94, t= 6.502, p<.001					AX1: β= 0.002778± 0.020617, df= 5.32, t= 0.135, p>.10 AX2: β= 0.054444± 0.020617, df= 5.32, t= 2.641, p<.05 AX3: β= 0.037340± 0.021875, df= 6.67, t= 1.707, p>.10				
Stress pattern	*** OX: β= 0.61389± 0.13230, df= 17.19000, t= 4.640, p<.001					*** OX: β= 0.17545± 0.02670, df= 63.94, t= 6.572, p<.001					*** OX: β= 0.137222± 0.014807, df= 23.47, t= 9.267, p<.001				
Case-control*Stress pattern	*** AX1*OX: β= -0.60389± 0.18818, df= 51.17, t= -3.209, p<.01 AX2*OX: β= -0.41556± 0.18818, df= 51.17, t= -2.208, p<.05 AX3*OX: β= -0.30095± 0.21415, df= 52.62, t= -1.405, p>.10										** AX1*OX: β= -0.040556± 0.025824, df= 49.23, t= -1.570, p>.10 AX2*OX: β= -0.093889± 0.025824, df= 49.23, t= -3.636, p<.001 AX3*OX: β= -0.088625± 0.029223, df= 51.50, t= -3.033, p<.01				
Model summary	AIC	BIC	logLik	deviance	df.resid	AIC	BIC	logLik	deviance	df.resid	AIC	BIC	logLik	deviance	df.resid
	47.4	72.0	-12.7	25.4	58	-97.0	-79.1	56.5	-113.0	61	-232.5	-207.9	127.2	-254.5	58

Table 12: Summary of statistics of the linear regression mixed models of the intra-word acoustic contrasts (VarDurSyl, VarF0Syl and VarIntSyl) in Word Reading task as a function of Case-Control (AX1, AX2, AX3 vs all N0) and/or Stress pattern. Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.10, '' >0.10. When significant, fixed effects statistics for each comparison have been included.

Case-control comparisons															
Predictors	VarDurSyl					VarF0Syl					VarIntSyl				
Intercept	*** α=-0.31500±0.05194, df=50.23, t= -6.065, p<.001					α=-0.008056±0.031509, df=5.84, t= -0.256, p>.10					α=-0.008333±0.017588, df=2.22, t= -0.474, p>.10				
Case-control	*** AX1: β= 0.48833± 0.09137, df= 105.91, t= 5.344, p<.001 AX2: β= 0.47603± 0.09840, df= 109.28, t= 4.838, p<.001 AX3: β= 0.18083± 0.09463, df= 107.58, t= 1.911, p<.10					AX1: β= 0.080556± 0.056885, df= 4.08, t= 1.416, p>.10 AX2: β= 0.252738± 0.059695, df= 4.93, t= 4.234, p<.01 AX3: β= -0.076286± 0.058179, df= 4.46, t= -1.311, p>.10					AX1: β= -0.007500± 0.034934, df= 2.16, t= -0.215, p>.10 AX2: β= 0.015132± 0.035143, df= 2.21, t= 0.431, p>.10 AX3: β= -0.029176± 0.035029, df= 2.18, t= -0.833, p>.10				
Stress pattern	OX: β= 0.29592± 0.07441, df= 51.44, t= 3.977, p<.001					* OX: β= 0.072359± 0.037659, df= 50.68, t= 1.921, p<.10					** OX: β= 0.051523± 0.007531, df= 58.25, t= 6.842, p<.001				
Case-control*Stress pattern	** AX1*OX: β= -0.18759± 0.12976, df= 106.40, t= -1.446, p>.10 AX2*OX: β= -0.41738± 0.13971, df=109.96, t= -2.987, p<.01 AX3*OX: β= -0.31851± 0.13417, df= 106.88, t= -2.374, p<.05					* AX1*OX: β= 0.034307± 0.064001, df= 105.37, t= 0.536, p>.10 AX2*OX: β= -0.157610± 0.068955, df=108.53, t= -2.286, p<.05 AX3*OX: β= 0.100500± 0.066180, df= 105.76, t= 1.519, p>.10					*** AX1*OX: β= -0.043189± 0.013724, df= 105.31, t= -3.147, p<.01 AX2*OX: β= -0.055397± 0.014756, df= 109.02, t= -3.754, p<.001 AX3*OX: β= -0.022936± 0.014187, df= 105.82, t= -1.617, p>.10				
Model summary	AIC	BIC	logLik	deviance	df.resid	AIC	BIC	logLik	deviance	df.resid	AIC	BIC	logLik	deviance	df.resid
	58.2	90.2	-18.1	36.2	125	-129.7	-97.7	75.9	-151.7	125	-540.0	-507.9	281.0	-562.0	125

Table 13: Summary of statistics of the linear regression mixed models of the intra-word acoustic contrasts (VarDurSyl, VarF0Syl and VarIntSyl) in Sentence Naming and Sentence Reading tasks as a function of Case-Control (AX1, AX2, AX3 vs all N0) and/or Stress pattern. Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.10, '' >0.10. When significant, fixed effects statistics for each comparison have been included.

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<table>
<tr><td></td><td colspan="10">Case-control comparisons</td></tr>
<tr><td>Predictors</td><td colspan="5">VarF0Syl</td><td colspan="5">VarIntSyl</td></tr>
<tr><td>Intercept</td><td colspan="5">***
α=-0.12085±0.02285, df=24.10, t= -5.288, p<.001</td><td colspan="5">***
α=-0.115139±0.013889, df=10.72, t= -8.290, p<.001</td></tr>
<tr><td>Case-control</td><td colspan="5">***
AX1: β= -0.08444± 0.03727, df= 56.61, t= -2.266, p<.05
AX2: β= -0.04861± 0.03727, df= 56.61, t= -1.304, p>.10
AX3: β0.30144± 0.03733, df= 56.96, t= 8.075, p<.001</td><td colspan="5">AX1: β= 0.002084± 0.021226, df= 4.88, t= 0.098, p>.10
AX2: β= 0.042760± 0.021945, df= 5.55, t= 1.949, p>.10
AX3: β= 0.062195± 0.020756, df= 4.48, t= 2.996, p<.05</td></tr>
<tr><td>Stress pattern</td><td colspan="5">***
β= 0.17058± 0.02644, df= 13.20, t= 6.452, p<.001</td><td colspan="5">***
β= 0.114400± 0.018428, df= 43.78, t= 6.208, p<.001</td></tr>
<tr><td>VarDurSyl</td><td colspan="5"></td><td colspan="5">*
β= 0.034705± 0.016573, df= 60.17, t= 2.094, p<.05</td></tr>
<tr><td>Case-control*Stress pattern</td><td colspan="5"></td><td colspan="5">**
AX1*OX: β= -0.019597± 0.027506, df= 53.66, t= -0.712, p>.10
AX2*OX: β= -0.079467± 0.026530, df= 52.37, t= -2.995, p<.01
AX3*OX: β= -0.078669± 0.027887, df= 57.67, t= -2.821, p<.01</td></tr>
<tr><td>Case-control*VarDurSyl</td><td colspan="5"></td><td colspan="5"></td></tr>
<tr><td>Stress pattern*VarDurSyl</td><td colspan="5"></td><td colspan="5"></td></tr>
<tr><td>Case-control*Stress pattern*VarDurSyl</td><td colspan="5"></td><td colspan="5"></td></tr>
<tr><td rowspan="2">Model summary</td><td>AIC</td><td>BIC</td><td>logLik</td><td>deviance</td><td>df.resid</td><td>AIC</td><td>BIC</td><td>logLik</td><td>deviance</td><td>df.resid</td></tr>
<tr><td>-100.3</td><td>-82.1</td><td>58.2</td><td>-116.3</td><td>64</td><td>-239.4</td><td>-212.1</td><td>131.7</td><td>-263.4</td><td>60</td></tr>
</table>

Table 14: Summary of statistics of the linear regression mixed models of the intra-word acoustic contrasts (VarF0Syl and VarIntSyl) in Word Reading task as a function of Case-Control (AX1, AX2, AX3 vs all N0), Stress pattern and VarDurSyl. Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.10, '' >0.10. When significant, fixed effects statistics for each comparison have been included.

	Case-control comparisons	
Predictors	VarF0Syl	VarIntSyl
Intercept	α=-0.03733±0.04282, df=25.23, t= -0.872, p>.10	α=-1.016e^{-02}±2.082e^{-02}, df=3.370 e^{+00}, t= -0.488, p>.10
Case-control	AX1: β= 0.12699± 0.06210, df= 8.55, t= 2.045, p<.10 AX2: β= 0.32980± 0.06498, df= 10.15, t= 5.076, p<.001 AX3: β= 0.04005± 0.06430, df= 9.76, t= 0.623, p>.10	AX1: β= -6.481e^{-03}± 3.858e^{-02}, df= 2.480e^{+00}, t= -0.168, p>.10 AX2: β= 1.660e^{-02}± 3.889e^{-02}, df= 2.560e^{+00}, t= 0.427, p>.10 AX3: β= -1.384e^{-03}± 3.884e^{-02}, df= 2.550e^{+00}, t= -0.036, p>.10
Stress pattern	OX: β= 0.10926± 0.04396, df= 75.31, t= 2.485, p<.05	** OX: β= 5.557e^{-02}± 1.184e^{-02}, df= 7.735e^{+01}, t= 4.693, p<.001
VarDurSyl	β= -0.07340± 0.10022, df= 99.78, t= -0.732, p>.10	β= 3.616e^{-04}± 2.728e^{-02}, df=9.556e^{+01}, t= 0.013, p>.10
Case-control*Stress pattern	*** AX1*OX: β= -0.01870± 0.06846, df= 105.63, t= -0.273, p>.10 AX2*OX: β= -0.34676± 0.06887, df= 109.26, t= -5.035, p<.001 AX3*OX: β= 0.01749± 0.06559, df= 105.96, t= 0.267, p>.10	* AX1*OX: β= -3.824e^{-02}± 1.892e^{-02}, df=1.058e^{+02}, t= -2.021, p<.05 AX2*OX: β= -5.270e^{-02}± 1.895e^{-02}, df=1.086e^{+02}, t= -2.781, p<.01 AX3*OX: β= -4.857e^{-02}± 1.813e^{-02}, df=1.061e^{+02}, t= -2.679, p<.01
Case-control*VarDurS	** AX1*VDS: β= -0.02776± 0.15200, df= 107.52, t= -0.183, p>.10	** AX1*VDS: β= 2.541e^{-02}± 4.155^{e-02}, df=1.047e^{+02}, t= 0.612, p>.10

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yl	AX2*VDS: β= -0.21853± 0.15519, df= 95.37, t= -1.408, p>.10 AX3*VDS: β= 0.66134± 0.18993, df= 106.86, t= 3.482, p<.001					AX2*VDS: β= 1.428e^{-03}± 4.316e^{-02}, df=9.666e^{+01}, t= 0.033, p>.10 AX3*VDS: β= 1.795e^{-01}± 5.240e^{-02}, df=1.074e^{+02}, t= 3.425, p<.001				
Stress pattern*VarDurSyl	OX*VDS: β= 0.16060± 0.11836, df= 101.88, t= 1.357, p>.10					* OX*VDS: β= 1.591e^{-02}± 3.221e^{-02}, df=9.834e^{+01}, t= 0.494, p>.10				
Case-control*Stress pattern*VarDurSyl	* AX1*OX*VDS: β= -0.01606± 0.20476, df= 106.78, t= -0.078, p>.10 AX2*OX*VDS: β= 0.19148± 0.29676, df= 107.20, t= 0.645, p>.10 AX3*OX*VDS: β= -0.56984± 0.20992, df= 107.12, t= -2.715, p<.01					* AX1*OX*VDS: β= -8.124e^{-02}± 5.591e^{-02}, df=1.049e^{+02}, t= -1.453, p<.10 AX2*OX*VDS: β= -5.957e^{-02}± 8.176e^{-02}, df=1.075e^{+02}, t= -0.729, p>.10 AX3*OX*VDS: β= -1.711e^{-01}± 5.785e^{-02}, df= 1.078e^{+02}, t= -2.958, p<.01				
Model summary	AIC	BIC	logLik	deviance	df.resid	AIC	BIC	logLik	deviance	df.resid
	-191.1	-137.0	114.5	-229.1	108	-506.5	-452.5	272.3	-544.5	108

Table 15: Summary of statistics of the linear regression mixed models of the intra-word acoustic contrasts (VarF0Syl and VarIntSyl) in Sentence Naming and Sentence Reading tasks as a function of Case-Control (AX1, AX2, AX3 vs all N0), Stress pattern and VarDurSyl. Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.10, '' >0.10. When significant, fixed effects statistics for each comparison have been included.