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Lexical stress contrast marking in fluent and non-fluent aphasia in Spanish: the relationship between acoustic cues and compensatory strategies

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ABSTRACT

This study sought to investigate stress production in Spanish by patients with Broca's (BA) and conduction aphasia (CA) as compared to controls. Our objectives were to assess whether: a) there were any abnormal acoustic correlates of stress as produced by patients; b) these abnormalities had a phonetic component and c) ability for articulatory compensation for stress marking was preserved. The results showed abnormal acoustic cues in both BA and CA's productions, affecting not only duration but also F0 and intensity cues, and an interaction effect of stress pattern and duration on intensity cues in BA, but not in CA or controls. The results are interpreted as deriving from two different underlying phenomena: in BA, a compensatory use of intensity as a stress cue in order to avoid ‘equal stress’; in CA, related to either a ‘subtle phonetic deficit’ involving abnormal stress acoustic cue-processing or to clear-speech effects.

KEYWORDS: Aphasia, Apraxia of speech, Lexical stress, Acoustics, Compensation

INTRODUCTION

Beyond their theoretical differences, psycholinguistic models of speech production (Garrett, 1975; Dell, 1986; Levelt, 1989; Caramazza, 1997; Levelt et al., 1999) assume that processing occurs at different levels such as conceptual preparation, lexical access, word form encoding (involving morphological, phonological and phonetic encoding) and articulation.

Segmental and metrical representations in phonological encoding

Phonological encoding of a word seems to include separate and parallel access to segmental representation (that is, the ordered set of phonemes) on the one hand and metrical representation on the other (Butterworth, 1992; Levelt, 1989, 1992; Levelt, Roelofs, & Meyer, 1999). Psycholinguistic models differ with respect to the content of metrical representations, depending in particular on whether they include or not the syllable-internal structures in terms of sequences of consonantal and vocalic positions (Stemberger, 1984, 1990; Dell, 1988; Sevald, Dell, & Cole, 1995; vs Levelt, 1992; Levelt & Wheeldon, 1994; Roelofs, 1997; Roelofs & Meyer, 1998), but agree that the information concerning the word's number of syllables and stress pattern is accessed separately from the segmental information during phonological word-form retrieval. These two representations (segmental and metrical) are then assumed to be assembled incrementally (Levelt, 1989; Levelt et al., 1999; Schiller, 2003, 2006) by a segment-to-frame mechanism, such as the so-called 'slot-and-filler' (Shattuck-Hufnagel, 1983; Keating & Shattuck-Hufnagel, 2002) whereby phonemes are inserted into slots made available by the metrical frame and the result is a phonological word (Hayes, 1989; Selkirk, 1995; Hall & Kleinhenz, 1999; Peperkamp & Wiltshire, 1999; Nespor & Vogel, 2007) containing one or more lexical items. Phonological words are processing units usually defined as bearing one single main stress and being the domain in which resyllabification and phonotactic constraints may occur.

Lexical stress: retrieved or computed?

The representation of lexical stress is still a controversial issue and is assumed to depend on language-specific properties. For languages such as French in which lexical stress position is fixed, for example, one might conjecture that stress pattern needs not be stored in the word's phonological representation and can be assigned by default (e.g. Levelt et al., 1999).

In free-stress languages such as Spanish or English, on the other hand, stress pattern plays a distinctive role. In these languages, lexical stress assignment may occur through a) access to the lexically stored information (e.g. Spanish *sábana* 'bed sheet' /ˈsabana/ vs *sabana* 'savannah' /saˈbana/), b) the application of language-specific rules associating phonological or morphological information with stress patterns (e.g. in Spanish, words ending in a glide are always oxytone, as in *convoy* 'convoy' /conˈboj/; every verb-form has a predictable stress: amo 'I love' /ˈamo/ vs amó 'he/she loved' /aˈmo/, beso 'I kiss' /ˈbeso/ vs besó 'he/she kissed' /beˈso/, etc., (Harris, 1983), and/or c) distributional properties (e.g. in Spanish, 90% of nouns, adverbs and adjectives are paroxytones (Harris, 1995) and, more specifically, 95%-97% of nouns are either oxytones ending in a consonant or paroxytones ending in a vowel (Hualde, 2005; Alcoba Rueda, 2013)).

There are two main theoretical approaches dealing with the issue of how stress position is assigned in free-stress languages. While some authors argue that the stress pattern of all lexical items is stored in such languages (Butterworth, 1992; Laganaro, Vacheresse, & Frauenfelder, 2002), others claim that regular stress patterns are computed and only irregular ones are stored and retrieved during word encoding (Colombo, 1992; Roelofs & Meyer, 1998; Levelt et al., 1999). In addition, an analogical mechanism that assigns stress pattern to a word on the basis of the stress pattern of similar words (e.g. in Italian, words sharing a particular ending and stress pattern, see Burani, Paizi, & Sulpizio, 2014) has also been considered (Daelemans, Gillis, & Durieux, 1994; Gupta & Touretzky, 1994; Arciuli, Monaghan, & Seva, 2010; Domahs, Plag, & Carroll, 2014). An alternative possibility is that stress assignment combines two different processes in free-stress languages: a) the retrieval of a stored representation and b) the computation of stress pattern on the basis of linguistic (phonological and/or morphological) rules or statistical distribution (Butterworth, 1992; Laganaro et al., 2002). Then the issue is to determine the relative contribution of each of them at each stage of language processing being considered.

Lexical stress deficits in aphasia

In aphasiology, stress assignment deficits have received less attention than other phonological deficits, because it has often been assumed that phonetic and phonological impairments concern segmental content while stress patterns remain unimpaired in both fluent and non-fluent aphasia (e.g. Ellis, Miller, & Sin, 1983; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Nickels & Howard, 1999). However, some studies have reported the existence of specific stress errors in fluent aphasics in several tasks such as naming, repetition or reading (e.g Miceli & Caramazza, 1993; Cappa, Nespor, Ielasi, & Miozzo, 1997; Laganaro et al., 2002) and even postulate a double dissociation between segmental and metrical deficits in phonological encoding (Cappa et al., 1997; Aichert & Ziegler, 2004). In these studies, most observed stress assignment errors affected lexical items with a non-dominant stress pattern in the language under consideration and/or whose stress pattern was unpredictable on the basis of syllabic structure. These errors resulted mostly in a shift to the regular stress pattern. However, one case has been described (Laganaro et al., 2002) of an aphasic patient who did not produce all non-words with the default stress pattern, but instead respected the frequency of occurrence of each type of stress within the language (for a similar result in non-aphasic subjects, see Colombo, 1992).

Patients with non-fluent aphasia and concomitant apraxia of speech are thought to suffer from speech motor planning impairments and have often been associated with, among other symptoms, stress contrastiveness reduction (also known as 'equal stress') in the absence of stress assignment deficit (Kent & Rosenbek, 1983; Gandour & Dardarananda, 1984; Ouellette & Baum, 1994; Ogar, Slama, Dronkers, Amici, & Gorno-Tempini, 2005; McNeil, Robin, & Schmidt, 2009; Walker, Joseph, & Goodman, 2009; Duffy, 2013; Vergis et al., 2014). The effect of a word's metrical structure and stress pattern on segmental errors in apraxia of speech (AOS) has also been reported (Ziegler, Thelen, Staiger, & Liepold, 2008; Aichert, Büchner, & Ziegler, 2011). A recent study (Ziegler & Aichert, 2015) has proposed a model for the motor planning requirements of word articulation by means of a nonlinear regression model trained to predict the likelihood of word production errors in apraxia of speech. In this model lexical stress plays a major role.

Concerning the acoustic characteristics of stress production by aphasic patients in several languages, there has generally been found to be a deficit in durational cue processing (Emmorey, 1987; Gandour, Petty, & Dardarananda, 1989; Ouellette & Baum, 1994; Marquardt, Duffy, & Cannito, 1995; Vergis et al., 2014; but see ; Walker et al., 2009; Ross, Shayya, & Rousseau, 2013 for different results) in non-fluent aphasia and apraxia of speech, often interpreted as a secondary consequence of a basic timing deficit (Danly & Shapiro, 1982). By contrast, other acoustic stress correlates remain relatively unimpaired. A 'subtle phonetic deficit' affecting stress realisations in fluent aphasia has also been reported (Grela & Gandour, 1999).

Compensatory strategies

Though aphasiology has tended to be much more concerned with identification of the underlying deficit behind aphasics' speech errors, most clinicians agree with the well-known statement that 'aphasics communicate better than they speak' (Holland, 1977: 173).

Since the early 20th century (Lashley, 1929; Goldstein, 1939; Luria, 1970 [1947]), many researchers and clinicians have been interested in the concept of compensatory or adaptive strategies, which are assumed to allow aphasic subjects to overcome communicative difficulties (Penn, 1987; Bertoni, Stoffel, & Weniger, 1991; Kolk & Heeschen, 1990, 1996; Simmons-Mackie & Damico, 1997; Oelschlaeger & Damico, 1998; Heeschen & Schegloff, 1999, 2003; Laakso & Klippi, 1999; Wilkinson, Beeke, & Maxim, 2003; Nespoulous & Virbel, 2004; Simmons-Mackie, Kearns, & Potechin, 2005; Wilkinson, Gower, Beeke, & Maxim, 2007; Salis & Edwards, 2004; Beeke, Wilkinson, & Maxim, 2009; Sahraoui & Nespoulous, 2012; Nespoulous, Baqué, Rosas, Marczyk, & Estrada, 2013; Rhys, Ulbrich, & Ordin, 2013).

A compensatory strategy can be defined as '*a new or expanded communicative behaviour, often spontaneously acquired and systematically employed, to overcome a communication barrier in an effort to meet both transactional and interactional communicative goals*' (Simmons-Mackie & Damico, 1997: 770).

Among the most frequently reported compensatory phenomena for a lexical, syntactic or pragmatic processing problem especially in non-fluent agrammatic aphasics are strategic avoidance, contextual cueing and usage of meaningful gestures and/or eye gaze strategies, enhancement of prosodic cues, 'telegraphic style' itself, the use of 'general meaning' lexical items or specific grammatical structures such as left- or right-dislocations.

Within compensation and/or adaptation frameworks there are two main assumptions: 1) compensatory adaptation is pervasive in both ordered and disordered communication (Nespoulous & Virbel, 2004; Perkins, 2007) and occurs when various underlying semiotic, cognitive and sensorimotor capacities both within and between individuals become inefficient for interpersonal communication; and 2) disordered speech output (in our case, aphasic speech output) is not the direct reflection of the underlying linguistic impairments but rather the result of strategic choices developed in order to face these disorders and to improve communicative effectiveness.

Compensation at the phonetic level has attracted less attention than compensation at lexical, syntactic or conversational levels. However, several studies have investigated the ability of aphasic patients to compensate for an external articulatory perturbation, such as jaw fixation by a bite block. Sussman, Marquardt, Hutchinson and MacNeilage (1986) observed that aphasics with lesions in Broca's area were unable to compensate for fixation of the mandible. They concluded that the integrity of Brodman's area 44 is necessary for articulatory compensation. But major criticisms of this study have been formulated, involving both methodological and theoretical issues (Katz & Baum, 1987). Several authors have reported that compensatory abilities for external and internal articulatory perturbations have been preserved in both fluent and non-fluent aphasics (e.g. Code & Ball, 1982; Robin, Bean, & Folkins, 1989; Kim, 1995; Baum, Kim, & Katz, 1997; Baum, 1999; Jacks, 2008; Nespoulous et al., 2013; Marczyk, 2015).

STUDY AIMS

The aim of the first part of this exploratory study was to investigate whether there is some kind of phonetic impairment in fluent and non-fluent aphasics' realisation of lexical stress contrasts in the most frequent stress patterns in Spanish, namely paroxytone CV.CV and oxytone CVC.CVC words (Guerra, 1983; Quilis, 1983). Since in Spanish stress contrasts seem to involve characteristic modifications of both F0 and duration (Quilis, 1981; Llisterri, Machuca, Ríos, & Schwab, 2014), or F0 and intensity (Llisterri, Machuca, de la Mota, Riera, & Ríos, 2005), we have analysed these three parameters in order to determine the relative impairment/preservation of each of them.

In the second part of this study, we aimed at examining articulatory compensation for stress marking in both fluent and non-fluent aphasia. For this purpose we applied the method offered by Khasanova, Cole and Hasegawa-Johnson (2014) based on the notion that two acoustic cues related to the same phonological contrastive feature enter into a compensatory relationship 'when one of the cues is sub-optimal and the other is realised at an increased level of optimality'. Thus the aim here was to assess whether the 'atypical' (sub-optimal) values of a stress acoustic cue observed in the first part of the study were compensated for by another acoustic cue related to stress contrasts in Spanish.

METHOD

Participants

Three groups of right-handed native speakers of Spanish took part in this experiment: 4 fluent aphasics, 4 non-fluent aphasics and 4 non-aphasic controls. Inclusion criteria for all participants were: a) native speaker of Spanish from the Spanish-Catalan speaking region of Spain, b) aged between 30 and 75, c) secondary educational level and d) signed informed consent. For CA and BA groups the specific inclusion criteria were: a) acquired aphasia following a cerebral vascular accident (CVA) or tumour, b) globally preserved oral comprehension, and c) language examination scores compatible with conduction (CA) and Broca's aphasia with apraxia of speech (BA), phonetic and/or phonemic paraphasias reported by their speech pathologist. Controls were subjects with no reported deafness or linguistic, neurological, cognitive or psychiatric disorders. The three groups (see Appendix for more detailed information) were matched by age (mean: BA=53.3 SD 13.5; CA=53.0 SD 4.7; N0=54.5 SD 12.7), sex (3 males and 1 female in each group) and educational level (secondary school).

Material and procedure

In this study we used all the 45 disyllabic words from the Spanish COGNIFON lexical corpus (Baqué, Estrada, Le Besnerais, Marczyk, & Nespoulous, 2006) in which the two syllables of the word share the same structure. 27 of these words were CV.CV paroxytones, such as ‘faja’ (Eng. ‘girdle’) and 18 were CVC.CVC oxytones, such as ‘forjar’ (Eng. ‘to forge’).

All participants (BA, CA and N0) were asked to repeat each of these 45 words uttered in isolation with a falling conclusive intonation by a native speaker of Spanish with the same dialectal background. All subjects were recorded using a Sony ICD-CX50 Visual Voice Recorder and a Sony High Quality Microphone (.wav format, sample frequency = 44.1 kHz, 16-bit resolution) in a soundproof room at the Bellvitge University Hospital or at the Speech Service of the Autonomous University of Barcelona.

Data analysis

We excluded from the analyses those productions that presented an intra-lexical pause or number of syllables other than two (0-4 items per subject). Three phoneticians and one naïve speaker from the same geographic area were asked to independently listen to all the recordings and indicate all stressed syllables. We conducted an interrater reliability test using Fleiss' kappa, and this showed very good interrater agreement (for the 3 phoneticians (N=1017): kappa=0.993, z= 54.9, p=0; and for the 4 listeners: kappa=0.992, z=77.5, p=0). We then excluded those items that were associated by at least one of the listeners with an ambiguous or erroneous stress pattern (0-2 items per subject) in order to minimize the potential non-phonetic or motoric influences. It is worth mentioning that no significant relationships were found between perceived stress errors and stress pattern or pathology for any of the subjects, contrary to what has been observed in studies about selective (phonological) impairment of lexical stress assignment (e.g. Laganaro et al., 2002). The assumption was made that when speakers achieved systematic on-target production of stress pattern, the observed acoustic differences could be interpreted as possibly related to a motor control issue. It is hard to disentangle phonetic from phonological underlying deficits from acoustic data. Our analyses are based on the hypothesis that phonological impairments would result in acoustic patterns consistent with those of controls (that is, either in on-target or off-target ‘typical’ oxytones and paroxytones), while phonetic impairments would be associated with ‘atypical’ acoustic differences across conditions.

All the remaining productions were automatically segmented into phones and syllables using the EasyAlign feature offered by the Praat software package (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 F0 and intensity values, we calculated:

- For the first part of the study: the ratio of the mean F0 value of each vowel divided by the mean F0 value of the entire word and the ratio of the maximum intensity value of the vowel divided by the maximum intensity value of the entire word;
- For the second part of the study: the increase (as a percentage) in the stressed vs unstressed syllable duration (DUR_iperc) and maximum intensity value (INT_iperc).

In order to analyse the effect of group on the acoustic characteristics for stress marking, we carried out several mixed-effects regression models (Baayen, Davidson, & Bates, 2008) in which participants and items were entered as random factors. Oxytone and paroxytone words are hardly comparable. Therefore, we ran separate analyses for oxytones and paroxytones, and for each acoustic parameter (syllable duration, mean F0 ratio, maximum intensity ratio). The predictors were in all cases Group (Broca's aphasics, conduction aphasics and controls, hereafter BA, CA and N0 respectively), Stress (stressed vs unstressed syllable) and the interaction between these two variables.

As for the second part of the study, we analysed the data by means of mixed-effects regression models in which participants and items were entered as random factors. The dependent variable was the Increase (as a percentage) in stressed vs unstressed syllable intensity (INT_iperc). The predictors considered were Group (BA, CA and N0), Stress pattern (Oxytone vs Paroxytone), the Increase (as a percentage) in stressed vs unstressed syllable duration (DUR_iperc), and all their possible interactions.

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

Linear mixed-effects regression models were fitted using the *lmer* function (Bates, Maechler, Bolker, & Walker, 2015), contrast and slope comparisons were computed using *lsmeans* and *lstrends* (Lenth & Hervé, 2015) and figures were generated with *ggplot2* (Wickham, 2009) in R software (version 3.1.2) (R Core Team, 2014).

RESULTS

This section is divided in two parts. In the first one we present the acoustic characteristics of stress contrast marking by the three groups (BA, CA and N0). In the second we examine whether the relationship between duration and intensity cues in BA and CA productions can be interpreted as the result of a compensatory strategy.

Acoustic characteristics of stress contrasts

Oxytones

Concerning syllable duration in oxytones, the results showed main effects of Group ($F(2, 9.06)=6.08$, $p<.05$) and Stress ($F(1, 34.74)=119.96$, $p<.001$), and an interaction effect of Group per Stress ($F(2, 338.54)=19.49$, $p<.05$).

As can be seen in figure 1, syllable duration was shorter in N0 (0.343 SD 0.082 s) and CA productions (0.422 SD 0.108 s) than in BA productions (0.510 SD 0.142 s), and shorter in unstressed syllables than in stressed ones in all three groups (N0: 0.283 SD 0.058 vs 0.402 SD 0.054 s; BA: 0.463 SD 0.147 vs 0.557 SD 0.120 s; CA: 0.378 SD 0.099 vs 0.466 SD 0.100 s).

Post-hoc analyses showed that CA syllable durations were not significantly different from those of N0 syllables. BA values, by contrast, were significantly longer ($p<.05$) for both syllables, but especially for the initial unstressed one. Thus it seems that Broca's aphasics find it difficult to reduce the first syllable duration, which may be related to the 'equal stress' phenomena reported in the literature (see Introduction).

Moreover, the comparison of each aphasic' productions with those of controls showed that final stressed syllable lengthening was globally greater in N0 productions (+48.8% SD 5.3) than in CA and BA. Mean lengthening was less important for all CA subjects (range from +16.9% to +38.0%) but the differences were significant ($p<.05$) only for subjects CA1 and CA3. Concerning the BA group, three subjects (BA1, BA2 and BA3) showed significantly less lengthening (range from +9.9% to +30.4%) while BA4 showed values similar to those of controls (+49.6%).

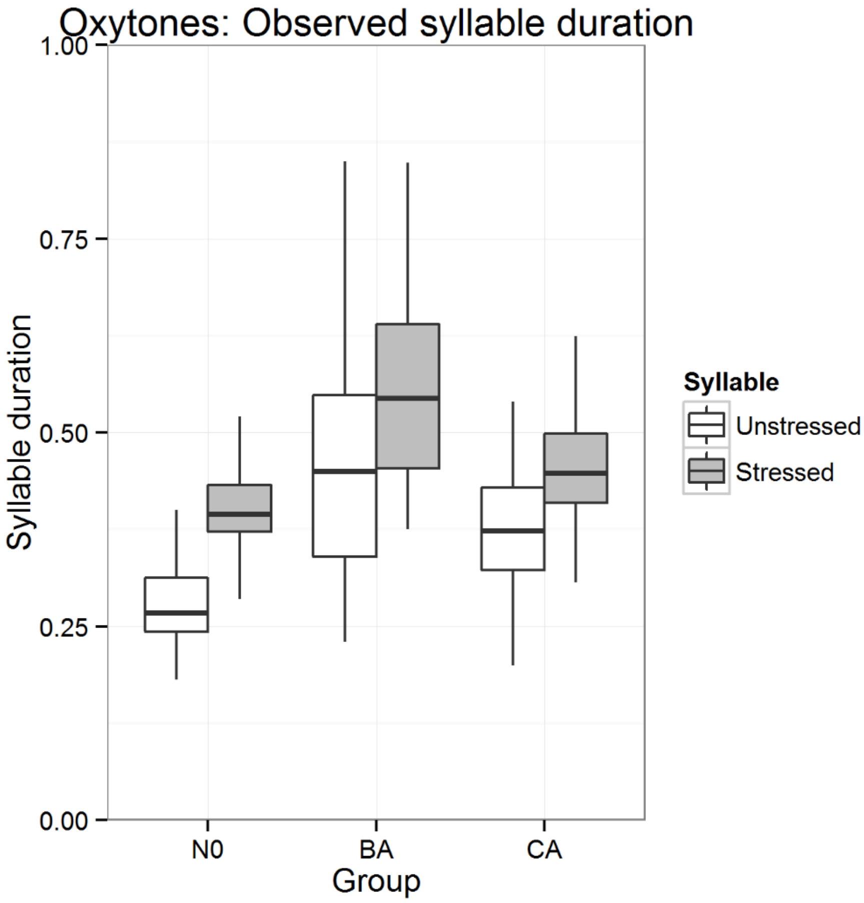

Figure 1: Mean syllable duration as a function of Stress (stressed vs unstressed syllable) and Group (BA, CA, N0) in oxytones.

Concerning the F0 cue in oxytones, the results showed a main effect of Stress (F(1, 30.12)=19.03, p<.001) and an interaction effect of Group*Stress (F(2, 338.25)=53.01, p<.001).

As seen in figure 2, the post-hoc analyses showed that in the CA group the final stressed syllable was characterised by a higher mean F0 ratio as compared to the initial unstressed one (1.05 SD 0.06 vs 0.95 SD 0.06, p=.000), even in falling conclusive intonation, contrary to what was observed in N0 productions (0.98 SD 0.05 vs 1.02 SD 0.04, p=.001). On the other hand, there is no difference between the two syllables in BA productions (1.01 SD 0.07 vs 0.99 SD 0.07, p=.676).

Case-control analyses showed that controls' final stressed syllables were associated with lower mean F0 values than initial unstressed ones (-3.8% SD 1.5), while each CA subject presented significant ($p<.05$) higher values (range from +2.2 to +17.6%). Concerning the BA group, no significant difference was found between controls and BA1 (-1.1%) and BA3 (-2.8%), while BA2 and BA4 showed significant greater values (+3.5 and +9.7%, respectively).

Thus it seems that both aphasic groups, especially CA, tend to use F0 increase as an additional stress cue in oxytones, even in conclusive intonation.

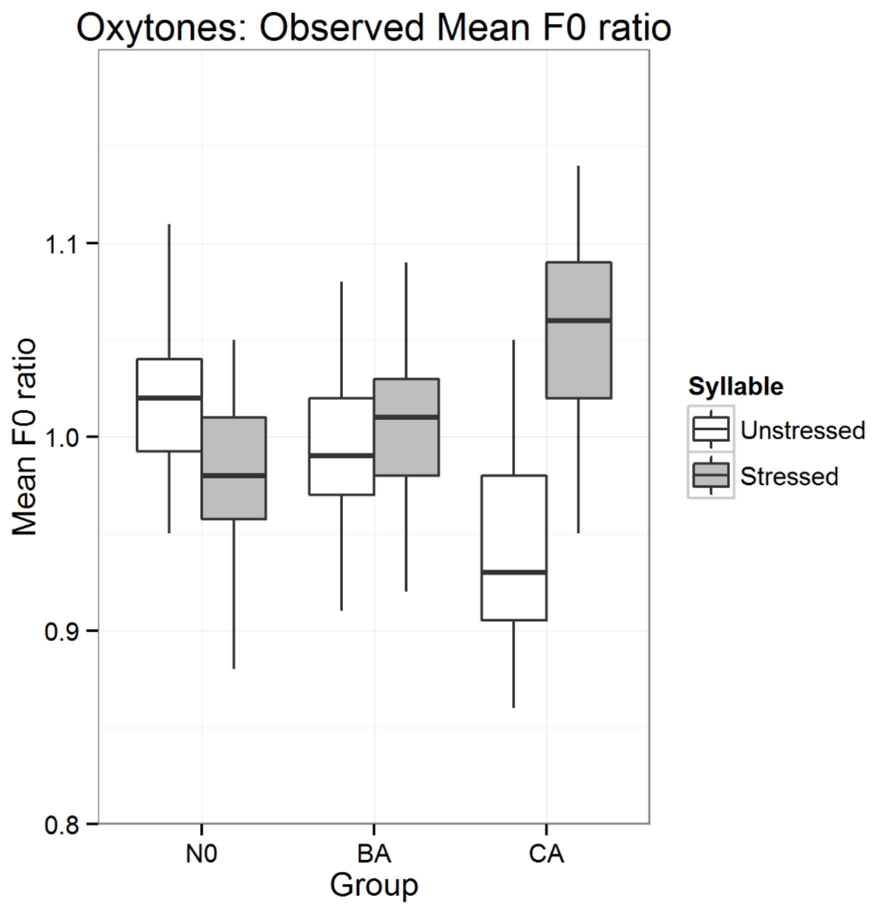

Figure 2: Mean F0 ratio as a function of Stress (stressed vs unstressed syllable) and Group (BA, CA, N0) in oxytones.

As for the last cue in oxytones under study, namely the maximum intensity ratio, there was a main effect of Stress (F(1, 371.59)=117.50, p<.001) and an interaction effect of Group*Stress (F(2, 371.59)=26.12, p<.001).

As can be seen in figure 3, there was no difference between initial unstressed and final stressed syllable in the control group (1.00 SD 0.02 in both cases), contrary to what was observed in both aphasic groups. These latter two populations increased intensity on the stressed syllable (BA: 1.01 SD 0.03 vs 0.99 SD 0.03, p=.000; CA: 1.03 SD 0.03 vs 0.97 SD 0.03, p=.000). Similar to what was observed with mean F0 ratio, both aphasic groups and especially CA seem to use intensity increase as an additional stress cue in oxytones even in conclusive intonation.

Case-control analyses showed that controls' final stressed syllables were produced with intensity values similar to those of their initial unstressed syllables (+0.6% SD 0.7), while intra-subject values observed in the CA group were significantly greater for all patients (range from +3.7 to +9.0%). Similar differences were observed for BA2 and BA4 (+8.8 and +4.4%, respectively), while for BA1 and BA3 values (-0.4 and -1.3%, respectively) were not significantly different from those of controls.

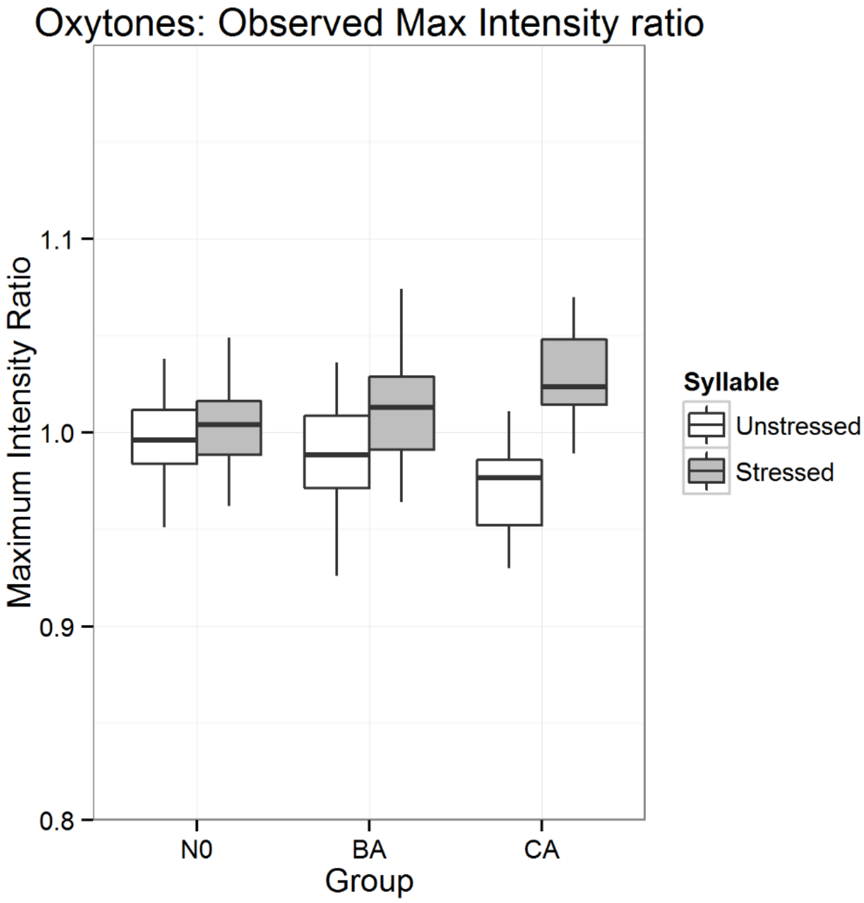

Figure 3: Maximum intensity ratio as a function of Stress (stressed vs unstressed syllable) and Group (BA, CA, N0) in oxytones.

Paroxytones

In paroxytones, the results showed main effects of Group (F(2, 8.96)=5.78, p<.05) and Stress (F(1, 52.79)=10.38, p<.005) and an interaction effect of Group*Stress (F(2, 569.10)=4.35, p<.05) on syllable durations.

Similar to what we see in oxytone words, mean syllable duration was shorter in N0 and CA groups (0.258 SD 0.05 and 0.302 SD 0.08 s) than in BA (0.367 SD 0.122 s). But subsequent post-hoc analyses (see Figure 4) showed that differences between initial stressed and final unstressed syllables differ depending on group. We observe the usual final (unstressed) syllable lengthening reported for Spanish (see Rao, 2010, for a review) in both CA (0.322 SD 0.08 vs

0.282 SD 0.09 s, p=.023) and N0 (0.281 SD 0.05 vs 0.236 SD 0.04 s, p=.005) groups, while there is no significant difference between the two syllables in BA productions (0.370 SD 0.103 vs 0.365 SD 0.140, p=.999), whose initial stressed syllable is much longer as compared to that of controls (0.370 vs 0.281, p=.026). This could be related to the BA group's inability to reduce initial stressed syllables duration (Baum, 1992; Seddoh, 2004).

However, the comparison of each aphasic's productions with controls' showed that their initial stressed syllable was overall shorter in N0 productions (-13.2% SD 3.6) than in CA and BA. Mean shortening was significantly (p<.05) less important for three CA subjects (CA1, CA3 and CA4, range from -8.4% to +3.9%) and greater for CA2 (-28.8%). Concerning the BA group, three subjects (BA1, BA2 and BA4) showed significantly less shortening (range from -7.4% to +21.8%) while no significant difference was observed between BA3 (-11.8%) and controls.

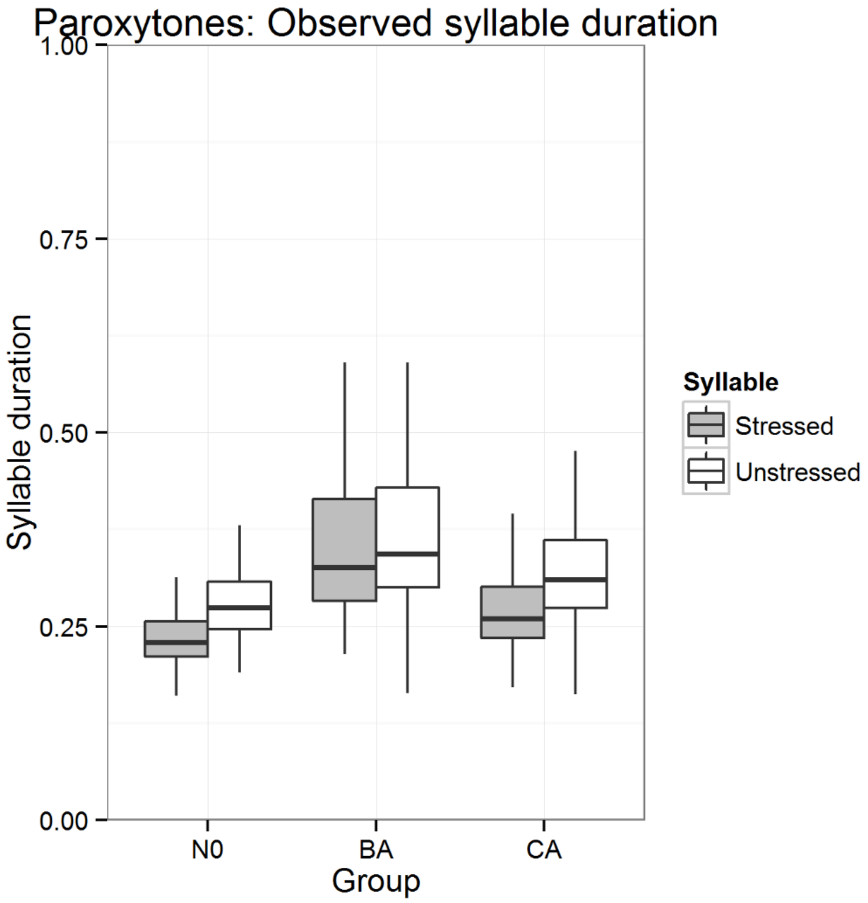

Figure 4: Mean syllable duration as a function of Stress (stressed vs unstressed syllable) and Group (BA, CA, N0) in paroxytones.

Concerning the F0 cue in paroxytones, the results showed a main effect of Stress ($F(1, 48.66)=212.44$, $p<.001$) and an interaction effect of Group*Stress ($F(2, 527.59)=13.41$, $p<.001$).

As can be seen in Figure 5, in all three groups' productions, the initial stressed syllable presented a higher mean F0 ratio compared to the final unstressed one but this difference was greater in the CA (1.11 SD 0.12 vs 0.88 SD 0.12, p=.000) and N0 (1.09 SD 0.13 vs 0.90 SD 0.13, p=.000) groups than in the BA group (1.05 SD 0.11 vs 0.95 SD 0.12, p=.000).

Case-control analyses, however, showed that these differences between patients and N0 are not statistically significant. Controls' initial stressed syllable presented higher mean F0 values than their final unstressed one (+32.8% SD 5.5). No significant difference was found between any of the CA subjects (range from +14.5 to +38.2%) and controls. In the BA group, each subject showed lower values as compared to controls (range from +12.0 to +16.1%) but no difference reached significance at $p<.05$.

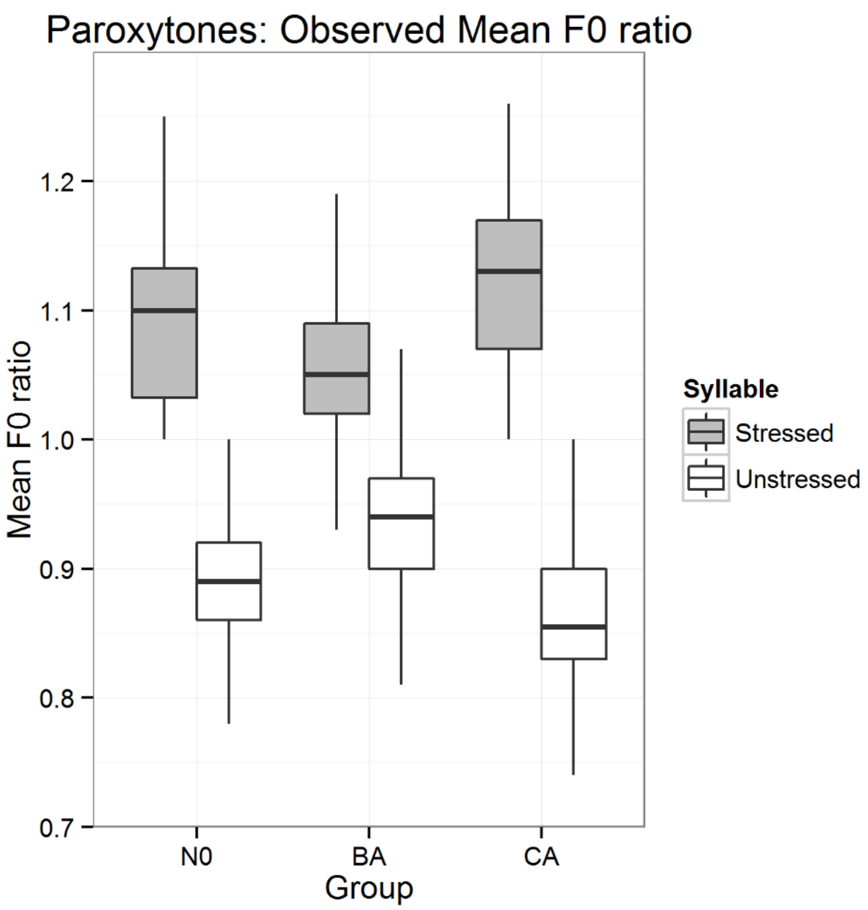

Figure 5: Mean F0 ratio as a function of Stress (stressed vs unstressed syllable) and Group (BA, CA, N0) in paroxytones.

As for the last acoustic cue under consideration, the maximum intensity ratio, there was a main effect of Stress ($F(1, 53.68)=720.09$, $p<.001$) and an interaction effect of Group*Stress ($F(2, 568.35)=31.69$, $p<.001$) in paroxytones.

As seen in Figure 6, all three groups marked the initial stressed syllable by a higher intensity, but the difference between the two syllables was larger in the control group (1.07 SD 0.03 vs 0.93 SD 0.03, $p=.000$) than in both aphasic groups (BA and CA: 1.05 SD 0.04 vs 0.95 SD 0.04, $p=.000$ and CA: 1.05 SD 0.03 vs 0.95 SD 0.03, $p=.000$).

In N0, initial stressed syllables were produced with significantly higher intensity values than final unstressed ones (+15.5% SD 0.9). Case-control analyses showed that in each aphasic group three out of four subjects presented significant ($p<.05$) less important differences between the two syllables (range from +6.1 to +9.9% in BA and from +7.8 to +10.5% in CA). BA4 and CA3 presented values that were similar to controls' (respectively, +17.0% and +15.7%).

Thus it seems that, for paroxytones spoken with a conclusive intonation, intensity plays a less important role in stress contrast marking in both aphasic groups than in the control group.

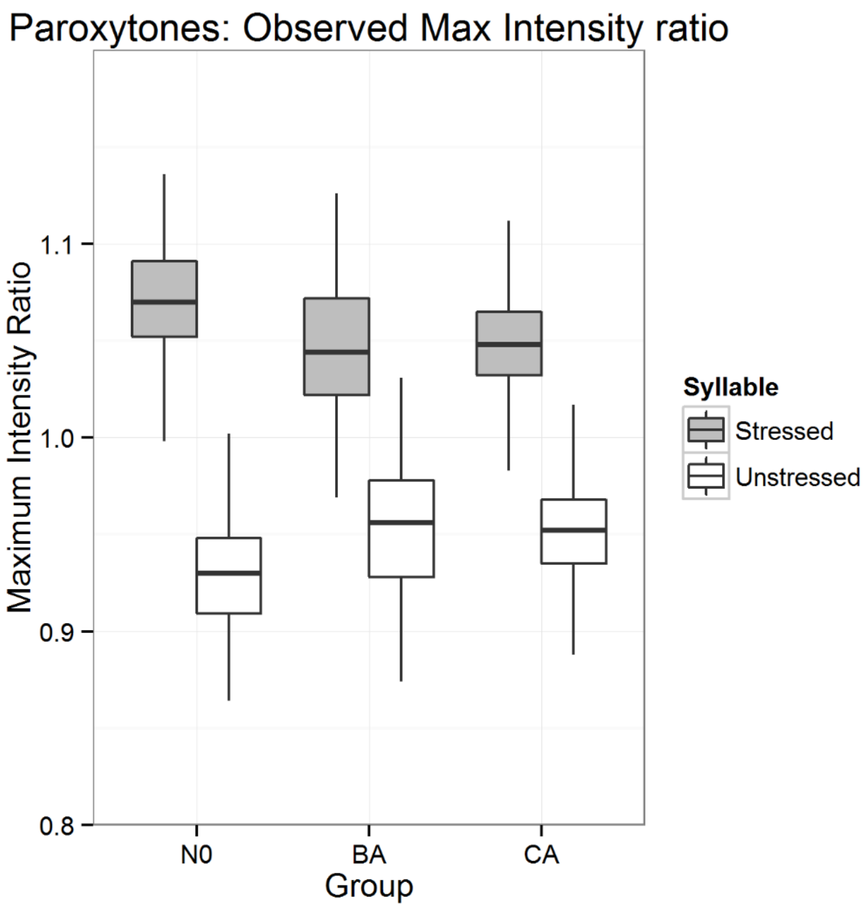

Figure 6: Maximum intensity ratio as a function of Stress (stressed vs unstressed syllable) and Group (BA, CA, N0) in paroxytones.

Relationship between duration and intensity cues: a compensatory strategy?

An overall analysis showed three interaction effects on Increase (as a percentage) in stressed vs unstressed syllable intensity (INT_iperc): Group*Stress pattern (F(2, 458.95)=13.48, p<.001), Group*DUR_iperc (F(2, 469.17)=3.4414, p=0.033) and Stress pattern*DUR_iperc (F(1, 481.07)=5.3168, p=.022). Thus we decided to carry out separate analyses for each group.

In the control group’s productions (see Figure 7), we observed an effect of Stress pattern (F(1, 45.446)=151.11, p=.000) but no effect of DUR_iperc and no interaction effect.

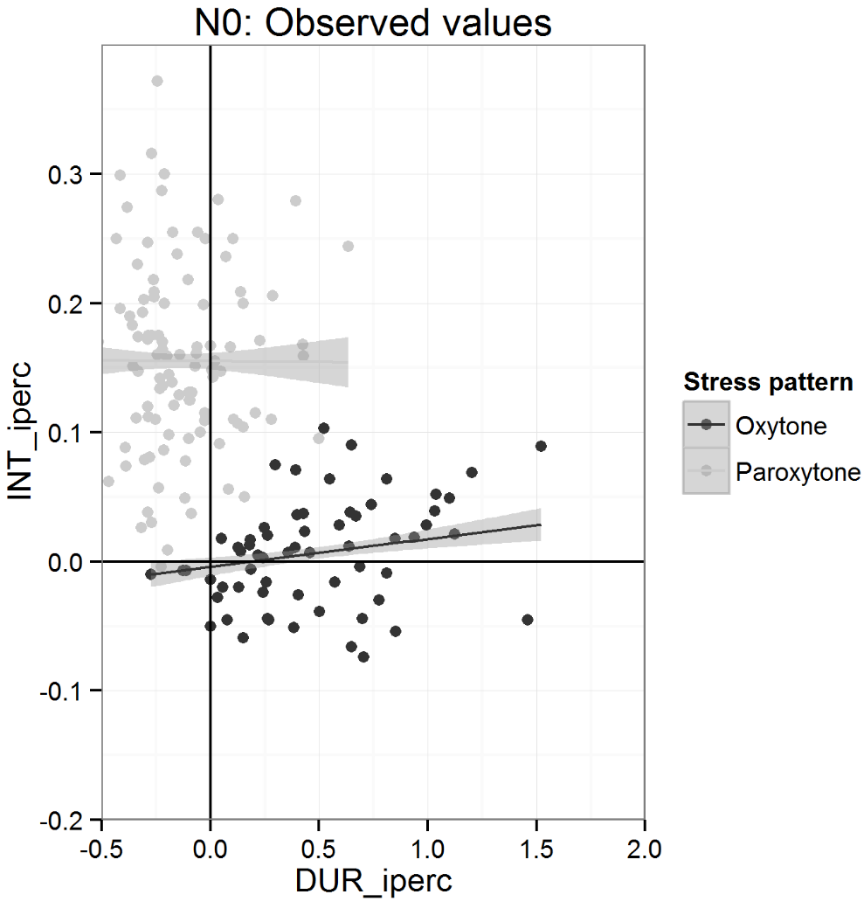

Figure 7: Values and predicted slopes of INT_iperc as a function of Stress pattern*DUR_iperc in control group (N0).

In the CA group (see Figure 8), both Stress pattern and DUR_iperc were seen to have a significant effect on INT_iperc ($F(1, 161.10)=28.6822$, $p=.000$ and $F(1, 163.09)=4.7253$, $p=.031$ respectively), but in a similar way, being positive ($\beta= 0.031$) for both oxytones and paroxytones. Individual data for regression slopes between DUR_iperc and INT_iperc were positive for each subject for both stress patterns (β range from +0.000 to +0.095 in oxytones and from +0.006 to +0.100 in paroxytones).

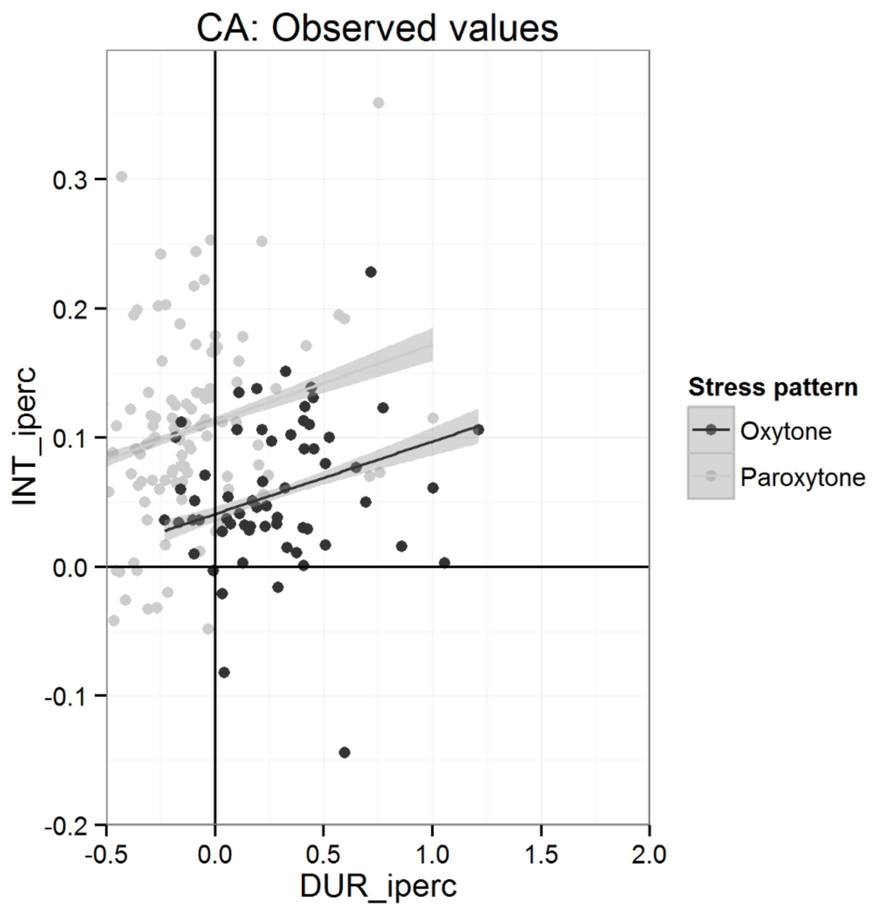

Figure 8: Values and predicted slopes of INT_iperc as a function of Stress pattern*DUR_iperc in conduction aphasic productions (CA).

As for the Broca's aphasics (see Figure 9), we observed a main effect of Stress pattern (F(1, 68.503)=13.9436, p<.001) and an interaction effect of Stress pattern*DUR_iperc (F(1, 160.569)=5.3169, p=.022). In paroxytones, we found a positive relationship between DUR_iperc and INT_iperc (β=0.027), while in oxytones the relationship was negative (β=-0.067), with intensity increasing as lengthening diminished. For each BA patient, intra-subject regression slopes were negative in oxytones (β range from -0.010 to -0.095) and positive in paroxytones (β range from +0.009 to +0.122).

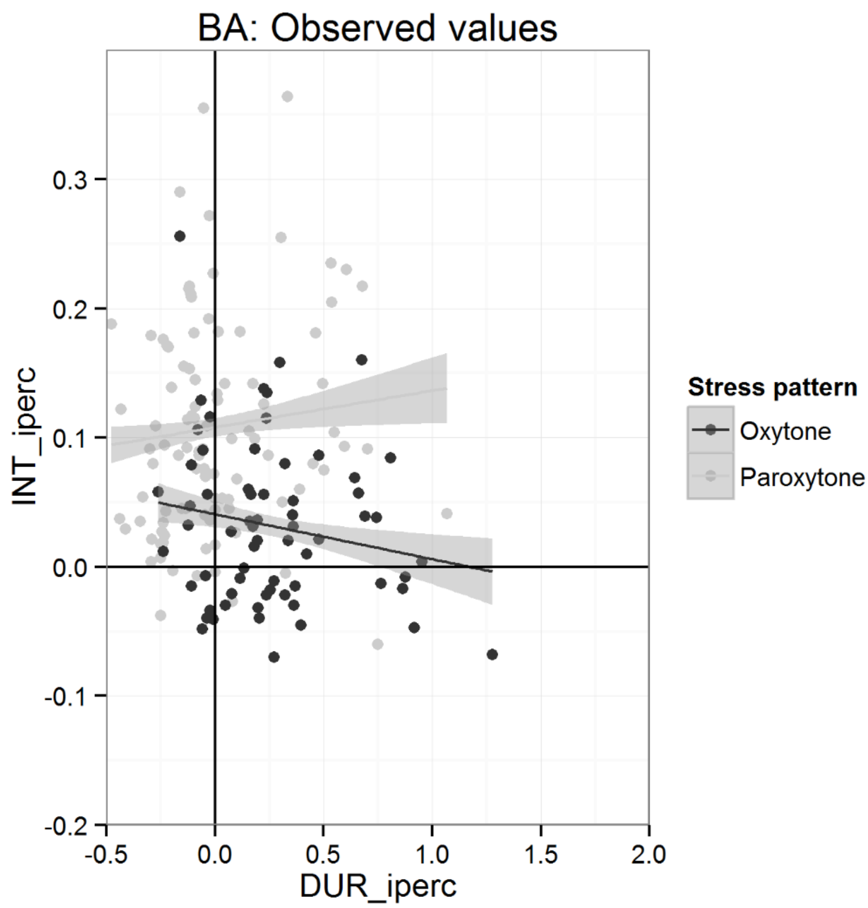

Figure 9: Values and predicted slopes of INT_iperc as a function of Stress pattern*DUR_iperc in Broca's aphasic productions (BA).

DISCUSSION

The current study sought to investigate lexical stress contrasts in fluent and non-fluent aphasia in Spanish disyllabic word repetition tasks. Since we failed to find any relationship between the (very few) perceived stress errors and stress pattern (for none of the subjects) or pathology, contrary to what has been observed in studies about selective impairment of lexical stress assignment (e.g. Laganaro et al., 2002), we aimed at examining the phonetic (acoustic) realisation of stress contrasts by the three groups under consideration.

Taken all together, the results of the first part of the study show that the acoustic correlates of lexical stress in both aphasic groups (and, despite some inter-subject variability, in each aphasic patient) differ from those of controls. These differences concern not only duration, but also F0 and intensity cues, contrary to what has been observed by other authors (Emmorey, 1987; Gandour, Petty, & Dardarananda, 1988; Ouellette & Baum, 1994). In conduction aphasia, we found some evidence of phonetic abnormal stress marks, affecting in particular intensity and F0 cues, especially in oxytones. As for Broca's aphasia, our results are congruent with previous studies that report a durational cue processing deficit, which may be related to an inability to reduce the first syllable duration (Baum, 1992; Vergis et al., 2014). But we observe a contradictory use of duration, on the one hand, and F0 and intensity, on the other: in those cases in which lengthening is insufficient (in oxytones), our results show higher values of F0 and intensity, while the opposite is observed in paroxytones in which the stressed syllables are over-lengthened relative to what controls produced. Thus we decided to further investigate the extent to which this differential use of acoustic cues could be related to some kind of compensatory strategy.

In the second part of the study, we analysed the relationship between duration and intensity cues for stress contrast marking using the method of Khasanova et al. (2014). In the control group, both duration and intensity varied as a function of stress pattern, but no significant relationship was found between these two acoustic cues. In conduction aphasia, there was a systematic positive relationship between duration and intensity cues in both oxytones and paroxytones. A possible explanation for these results is an underlying 'subtle phonetic deficit' (Blumstein, Cooper, Goodglass, Statlender, & Gottlieb, 1980; Grela & Gandour, 1999) in conduction aphasia that may not allow speakers to disengage the realisation of two acoustic cues which are often associated across languages in syllable production (Vaissière, 1983). Nevertheless, as noted by Vijayan and Gandour (1995), the notion of a 'subtle phonetic deficit' lacks an operational definition. Most investigations that have addressed this notion in fluent aphasia have inferred it from subtle acoustic or physiological differences relative to controls' productions that are not ‘apparent from simply listening to their speech output’ (Ryalls, 1986: 65). Another unsolved problem involves determining whether such differences can be interpreted as resulting from some kind of ‘impairment’ or instead are a consequence of other phenomena such as, for example, ‘clear speech’ style. Actually such a ‘uniform’ co-variation between two cues has also been associated in studies about the phonetic realisation of segmental phonological oppositions with ‘clear speech’ (concomitant strengthening) (Uchanski, 2005; Ferguson & Kewley-Port, 2007) and reduction processes (concomitant weakening) phenomena (van Son & Pols, 1999; Mooshammer & Geng, 2008), and related to prosodic strengthening (Cho, 2005; Cole, Kim, Choi, & Hasegawa-Johnson, 2007), mostly interpreted within the hypo-articulation and hyper-articulation (H&H) theory framework (Lindblom, 1990). In a previous study (Baqué, 2015; Marczyk & Baqué, 2015) involving the same patients, we observed that some segmental phonological contrasts in vowel and consonant productions were enhanced under stress and reduced in unstressed syllables and interpreted these results as possibly related to an H&H phenomena. Thus, further, more focused analyses are needed in order to identify the main factors underlying intensity and duration co-variation in stress contrast marking in conduction aphasics’ speech and to determine the extent to which the observed acoustic differences result from a subtle phonetic impairment or are related to speech style and/or monitoring effects (e.g. Waldron, 2013).

Concerning Broca’s aphasics with AOS, an interaction effect of duration and stress pattern on intensity values was found. In oxytones, in which the last (stressed) syllable was under-lengthened in comparison to what we saw produced by the control group, possibly due to these aphasics’ inability to reduce the first syllable duration, we observe a negative relationship between the two cues, while the opposite was true in paroxytones, where the initial stressed syllable was over-lengthened relative to control productions. These results, on the one hand, show that Broca’s aphasics with AOS are able to disengage the realisation of these two acoustic cues under certain circumstances, and, on the other hand, can be interpreted as a compensatory use of intensity as a stress cue in the oxytone stress pattern in order to avoid the ‘equal stress’ phenomena by patients with a durational cue processing deficit (Gandour & Dardarananda, 1984; Ogar et al., 2005; Duffy, 2013; Vergis et al., 2014). These results seem to confirm that the articulatory compensation ability is preserved in Broca’s aphasia, not only at a segmental level, but also at a prosodic level.

To summarise, none of the aphasics studied here showed a specific phonological stress pattern assignment deficit, but both aphasic groups differed from the control group in lexical stress realisation, and showed abnormal values of duration, F0 and intensity cues. In addition, we found an interaction effect of stress pattern with duration and intensity cues in BA, but not in CA or controls. These results could be interpreted as evidence of two different underlying phenomena affecting phonetic encoding level: the use of intensity as a stress cue in BA to compensate for durational cue processing deficit on the one hand and, on the other hand, in CA either a ‘subtle phonetic deficit’ resulting from the inability to disentangle duration and intensity cues for stress marking or as the result of ‘clear speech’ phenomena.

However, it is worth bearing in mind the limitations of this preliminary study: only disyllabic words were taken into account and stress patterns were the most predictable and frequent as a function of syllable structure. It has been argued that deviant timing deficits in fluent aphasia is observed only for longer words and that phonological rules could be impaired in stress marking for irregular stress patterns (see Introduction). Future research is needed in order to validate these effects. In addition, our findings could also be interpreted in the light of connectionist models of speech production that postulate an interaction between phonological and phonetic levels of encoding in terms of cascading activation from lexical-phonological to phonetic representations (see Laganaro, 2012 and Ziegler, Aichert, & Staiger, 2012, for a review).

Since these results correspond to words in which no stress assignment errors have been perceived, such a spontaneous developed strategy could be useful for speech therapy. However, this is only a very preliminary study and further analyses with a larger sample of participants, an expanded corpus and different elicitation tasks would provide a more complete picture of the realisation of stress contrasts in aphasia.

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DECLARATION OF INTEREST

The author reports no declarations of interest.

APPENDIX

Insert table 1 about here

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Appendix

Table 1. Participant demographic and neuropsychological information.

GROUP	BROCA'S APHASIA (BA)				CONDUCTION APHASIA (CA)				CONTROLS (N0)			
SUBJECT	BA1	BA2	BA3	BA4	CA1	CA2	CA3	CA4	N01	N02	N03	N04
GENDER	F	M	M	M	F	M	M	M	M	M	F	M
AGE	61	68	39	45	48	57	50	57	50	58	40	70
DIAGNOSIS	BA+AOS	BA+AOS	BA+AOS	BA+AOS	CA	CA	CA	CA	--	--	--	--
TIME POST ONSET (in months)	8	6	36	6	17	10	7	8	--	--	--	--
AETIOLOGY	CVA	CVA	CVA	CVA	CVA	CVA	CVA	Tumor	--	--	--	--
LESION LOCATION	Left Fronto-parietal	Left Fronto-parietal	Left Fronto-parietal	Multiple left fronto-parietal	Subdural left parietal hematoma	Left temporo-parietal	Lenticular region, left MCA, bypassing the insular and parietal region	Left temporo-parietal	--	--	--	--
MTBA: Conversation	++	++	++	+	++	+	+	+	--	--	--	--
MTBA: Auditory Comprehension (Words)	SA	SA	SA	SA	SA	SA	SA	SA	--	--	--	--
MTBA: Auditory Comprehension (Sentences)	+	+	+	+	+	SA	SA	SA	--	--	--	--
MTBA :	SA	SA	+	+	SA	SA	+	SA	--	--	--	--

Written comprehension (Words)												
MTBA : Written comprehension (Sentences)	+	+	++	+	SA	SA	SA	+	--	--	--	--
MTBA : Repetition	+	++	++	+	++	+	+	++	--	--	--	--
MTBA : Reading	+	+++	+++	SA	+	SA	+	+	--	--	--	--
MTBA : Naming	+	SA	+++	SA	++	SA	+	+	--	--	--	--
MTBA : Automatized sequences	SA	SA	++	SA	+	SA	SA	SA	--	--	--	--
Working Memory (out of 10)	3	4	5	3	2	7	3	2	--	--	--	--

Note: MTBA=*Protocolo Montréal-Toulouse-Buenos Aires de examen lingüístico de la afasia* (Labos et al., 2005); BA=Broca's aphasia ; AOS=Apraxia of Speech ; CA=Conduction aphasia ; SA=unimpaired; +=light impairment; ++: mild impairment; +++=severe impairment.