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The interaction of subsyllabic encoding and stress assignment: A new examination of an old problem in Spanish

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Abstract

This study employs a naming task to examine the role of the syllable in speech production, focusing on a lesser-studied aspect of syllabic processing, the interaction of subsyllabic patterns (i.e. syllable phonotactics) and higher-level prosody, in this case, stress assignment in Spanish. Specifically, we examine a controversial debate in Spanish regarding the interaction of syllable weight and stress placement, showing that traditional representations of weight fail to predict the differential modulation of stress placement by rising versus falling diphthongs in Spanish nonce forms. Our results also suggest that the internal structure of the syllable plays a larger role than is assumed in the processing literature in that it modulates higher-level processes such as stress encoding. Our results thus inform the debate regarding syllable weight in Spanish and linguistic theorizing more broadly, as well as expand our understanding of the importance of the syllable, and more specifically its internal structure, in modulating word processing.

Introduction

Numerous studies have shown that syllables play a crucial role in both visual word recognition and speech production (e.g. Levelt, Roelofs, & Meyer, 1999; Dell, 1986, 1988; Shattuck-Hufnagel, 1979, 1983; Meyer, 1990, 1991; Schiller, Meyer, & Levelt, 1997; Gutiérrez, Palma & Santiago, 2003; Duñabeitia, Cholin, Corral, Perea & Carreiras, 2010; among many others), and this is especially true in syllable-timed languages such as French and Spanish (e.g. Carreiras & Perea, 2002, 2004; Álvarez, Carreiras & Perea, 2004; Carreiras, Ferrand, Grainger, & Perea, 2005; Brand, Rey, & Peereman, 2003; Laganaro & Alario, 2006). A review of the literature finds that syllables modulate processing in various ways. For example, in work on recognition, facilitation has been found in syllable matched priming studies (Carreiras & Perea, 2002; Álvarez et al., 2004; Carreiras et al., 2005), but inhibitory effects surface when syllable frequency is manipulated (Carreiras, Álvarez, & de Vega, 1993; Álvarez, Carreiras, & Taft, 2001; Conrad & Jacobs, 2004; Mathey & Zagar, 2000). In speech production, early data point to facilitative effects of syllable congruency in priming paradigms (Ferrand, Segui, & Grainger, 1996; Ferrand, Segui, & Humphreys, 1997), but more recent work finds that syllabically congruent primes do not facilitate naming (Schiller, Costa & Colomé, 2002; Schiller & Costa, 2006; Brand et al., 2003).

Additionally, while highly frequent syllables cause inhibition in speech recognition, production studies that manipulate syllable frequency find facilitative effects of high-frequency syllables (Levelt & Wheeldon, 1994; Carreiras & Perea 2004; Perea & Carreiras, 1998; Laganaro & Alario, 2006; Cholin, Levelt, & Schiller, 2006; Cholin & Levelt, 2009). Taken together, this range of findings demonstrates that the syllable as a unit can play a central role in processing across a range of languages.

Here, we present an experiment that examines the role of the syllable in production, focusing, however, on a lesser-studied aspect of syllabic processing. Specifically, we examine the interaction of subsyllabic patterns (i.e. syllable phonotactics) and higher-level prosody, in this case, stress assignment. While most studies in the literature have examined the syllable as a single unit, testing its effects in processing, we aim to explore the ways in which the internal structure of a syllable may interact with higher levels of processing. In order to do so, we draw upon a controversial and long-standing debate in Spanish phonology regarding the interaction of so-called syllable weight with stress placement, arguing that the problem can be better understood when viewed through a processing approach. Our results thus inform the debate regarding syllable weight in Spanish, as well as expand our understanding of the importance of the syllable, and more specifically its structure, in modulating word processing.

One way in which syllables have been shown to play a crucial role in the linguistics literature, and an area that, to the best of our knowledge, has received no attention in the processing literature, is the interaction of stress placement and syllable structure in Spanish (Harris, 1983, 1989, 1992, 1995; Roca, 1988, 1990a, 1990b, 1991b, 1997b, 2005; Lipski, 1997; Aske, 1990; Eddington, 2000, 2004; Face, 2000, 2004, 2005; Bárkányi, 2002). How best to account for the Spanish stress system constitutes one of the long-standing conundrums in Hispanic linguistics. Linguistic theoretic approaches that have addressed the issue have generated much debate regarding the degree to which syllable structure restricts the placement of stress. The examination of the interaction of these two factors, stress assignment and syllable phonotactics, in a processing task may offer new data to this ongoing discussion.

Of interest here, stress in Spanish must fall on one of the last three syllables of a word, the so-called three-syllable window. However, stress assignment is constrained by the shapes of a word's final two syllables, with certain structures reducing the stress window from three syllables to two. A common approach in the linguistics literature has been to argue that stress is sensitive to syllable weight, with certain "heavy" syllables attracting stress and thus blocking stress placement farther to the left in the word. Other researchers argue that a quantity-sensitive approach fails to account for words that are exceptions to the stress placement generalizations. Consequently, the putatively modulating role of syllable structure in the Spanish stress system remains a point of ongoing discussion in the literature.

A fundamental drawback of the linguistic theoretic accounts of Spanish stress placement is that such approaches are often disconnected from psychologically grounded theories regarding the cognitive representation and processing of language. This study begins to address this gap by providing behavioral data which shed light on how syllable structure interacts with stress placement in Spanish. Specifically, we present an experiment that employs a nonword naming task to investigate how native speakers process the three-syllable window for Spanish stress assignment. We examine one of the most vexing problems involving the interaction of syllable weight and stress by testing for differential effects of rising and falling diphthongs on stress placement. To contextualize the problem, we briefly review the necessary background regarding the interplay of stress and syllables containing diphthongs within the three-syllable stress window in the language.

Quantity Sensitivity and the Three-Syllable Window in Spanish

Based on a wide range of data from numerous languages, phonologists have generally motivated a distinction between heavy and light syllables. This has been modeled in a number of ways. Moraic theory (e.g. Hyman, 1985; Hayes, 1989), for example, distinguishes between syllables in terms of the number of weight units (i.e. moras) they contain. Light syllables are typically those that contain only a single mora, such as syllables with an onset consonant or onset consonant cluster and a simple monophthong vowel. By contrast heavy syllables are customarily those that contain two moras, such as syllables with long vowels, diphthongs, or consonants that appear in coda position after the syllable's nuclear vowel. In Latin, from which Modern Spanish descends, classifying CVC syllables as heavy contributes to accounts of multiple rules and constraints, such as iambic shortening, metrics, and most applicable to this work, stress (Hayes, 1989). Latin stress is a generally straightforward trochaic system, with stress computed from the right edge of the word. Given that all final Latin syllables fall outside the stress window, stress is always assigned to heavy penultimate syllables, or in the case of a light penult, on antepenultimate syllables (Mester, 1994). Thus, Latin stress is quantity sensitive. Heavy penults are always stressed. Light penults are always skipped, rendering an antepenultimate stress pattern. In this sense, the current Spanish three syllable window can be understood as inherited directly from Latin. For Modern Spanish, however, the literature on quantity sensitivity itself is less conclusive (see varying accounts in Bárkányi, 2002; Lipski, 1997; Harris, 1992; Roca, 1991; Den Os & Kager, 1986; Otero, 1986), and the three-syllable window is frequently cited as demonstrative of the importance of syllable weight to Spanish stress assignment.

It is well documented that all nonverbals in Spanish carry primary stress on one of the last three syllables of the word (Hualde, 2005; Harris, 1983, 1992, 1995; Roca, 1991; Contreras, 1977; Hooper & Terrell, 1976).¹ This yields a set of three possible stress patterns in Spanish, as transcribed below, with accent marks showing stress placement.

<i>Penultimate stress</i>	<i>Antepenultimate stress</i>
a. [ka.mí.sa] "shirt"	c. [má.xi.ko] "magical"
[ú.til] "useful"	
<i>Final stress</i>	
b. [so.fá] "sofa"	
[a.ni.mál] "animal"	

These examples of possible stress patterns are listed in the order of their frequency in the Spanish lexicon. Núñez Cedeño & Morales-Front (1999) point out that approximately 64% of all words in Spanish carry penultimate stress, and this is considered the unmarked stress pattern. Final stress is found for 28% of words, and antepenultimate stress is the least common pattern, being found in only 8% of the lexicon. The low frequency of antepenultimate stress is in part due to phonotactic constraints which restrict its occurrence. These involve the segmental composition of the penultimate and final syllables, which can reduce the stress window to two syllables. One such pattern involves heavy syllables in penultimate position, as seen below.

¹The Spanish language exhibits separate stress patterns for verbal and nonverbal forms. The verbal stress system is considerably straightforward and predictable. For our purposes here, we focus on nonverbal stress in Spanish and its ambiguities. For further reading on verbal stress in Spanish, we direct the reader to Harris (1989) and Roca (1990b).

Heavy penults

- a. Consonant in coda position of the penultimate syllable
- i. [im.pák.to] “impact” ii. *[ím.pak.to] (proscribed form)
- b. Diphthong in the penultimate syllable
- i. [mo.sáj.ko] “mosaic” ii. *[mó.saj.ko] (proscribed form)
-

Above, adopting the notational standards of the linguistics literature, starred items represent ungrammatical forms, i.e. forms that are claimed to be proscribed by the phonotactic grammar of the language due to the presence of a filled coda or a diphthong in the penultimate syllable.

A similar generalization applies to almost all final syllables.

Heavy final syllables

- a. Consonant in coda position of the final syllable
- i. [a.ni.mál] “animal” ii. *[á.ni.mal] (proscribed form)
- iii. [a.ní.βal] “Hannibal” iv. *[á.ni.βal] (proscribed form)
- b. Diphthong in the final syllable
- i. [gi.ri.γáj] “hubbub” ii. *[gí.ri.γaj] (proscribed form)
-

These examples appear to support weight sensitivity in Spanish, insofar as the presence of a heavy syllable in either of the two final syllables of Spanish words reduces the Spanish stress window to the final two syllables of the word. However, Roca (cf. Roca, 1988, 1990a, 1991, 1997, 2005) has written extensively against quantity-sensitive approaches to Spanish stress, arguing that native toponyms such as *Frómista* and borrowings such as *Mánchester* and *Wáshington* demonstrate that heavy final and penultimate syllables do not systematically block antepenultimate stress. Conversely, Harris (1992) argues for quantity sensitivity in Spanish, suggesting that loan words exhibiting their original stress patterns tell us nothing more than that mimicry of foreign stress patterns is possible. He further stresses that it is the spontaneous pronunciations in which these words appear with final stress (e.g. “Washington”) that require explanation. Harris claims that this shift to final stress occurs to bring inadmissible stress patterns into conformity with native rules. Roca (1991) also argues that simply accenting heavy syllables does not account for the distribution found in Spanish. For example, Spanish exhibits words in which heavy final syllables are not stressed, exhibiting a penultimate stress pattern (e.g. *álbum* (album), *hábil* (adept), *cadáver* (corpse)). There is also a small amount of words in Spanish that end in consonants but carry antepenultimate stress, e.g. *régimen* (diet/regime).

Additional evidence that has been claimed to support a weight-sensitive account of Spanish stress comes from Núñez Cedeño’s (1986) work in the Dominican Republic. He finds that in regions of the country where deletion of [s] in coda position is the norm, hypercorrection in which [s] is inserted into words where it never existed, referred to as *hablar fíño*, never produces forms in which the [s] has been inserted into the penultimate syllable of an antepenultimately stressed word. Thus, the word *hipopótamo* (hippopotamus) may undergo hypercorrection to produce *hispopótamo*, *hipospótamo*, or *hipopóstamo*, but never **hipopótasmo*. He argues that it is unclear why speakers would exclude only the latter form if the phonological grammar does not prohibit it.

In sum, the linguistic theoretic approaches have not reached consensus on the issue of quantity sensitivity in Spanish stress. What is not in doubt, however, is the reality of the three-syllable window. The debate revolves around how to best characterize theoretically the enforcement of these restrictions on the Spanish stress system. We will now turn our attention to the specific issue under investigation here: the behavior of rising and falling diphthongs.

The differential patterning of rising vs. falling diphthongs in Spanish

As seen above, falling diphthongs (tautosyllabic *vowel-glide* sequences) tend to pattern with syllable-final consonants in that they both shrink the three-syllable window to one of two syllables and also attract stress to the syllable in which they appear, with stress assignment proceeding in a right to left fashion. The interaction of diphthongs and stress becomes less clear, however, when we examine how rising diphthongs (tautosyllabic *glide-vowel* sequences) modulate stress placement in Spanish.

Rising diphthongs

Prevocalic glide in the penultimate syllable

- i. [ba.rjá.βle] “variable” ii. *[bá.rja.βle] (proscribed form)

b. Prevocalic glide in the final syllable

- i. [fa.mí.lja] “family” ii. *[fá.mi.lja] (proscribed form)
-

In these examples, rising diphthongs pattern with falling diphthongs in that both diphthong types in either the final or penultimate syllable block antepenultimate stress assignment. Curiously, however, unlike falling diphthongs, rising diphthongs do not systematically attract stress themselves, as seen in [fa.mí.lja] (family). Here, despite a rising diphthong in the final syllable, stress falls on the penult. If rising diphthongs always attracted stress, then the stress should fall on the final syllable, *[fa.mi.lja]. This is clearly not the case, given the wealth of words in Spanish with rising diphthongs in the final syllable that are assigned penultimate stress. A search of the Alameda & Cuetos (1995) database revealed over seven hundred nonverbal words of this type, such as [sí.tjo] (place), [am.bí.ɣwa] (ambiguous), and [es.pé.θje] (species). These examples mark a clear difference in patterning between rising and falling diphthongs in the Spanish lexicon.

A possible comparison to be made is between rising diphthongs and complex onsets. Take for example the following words:

Rising diphthongs vs. complex onsets

- a. [a. wá.na] “customs”

- b. [tem.prá.na] “early”
-

Here we see two words, one containing a rising diphthong in the penultimate syllable (a.) and the other a complex onset (b.). They share the same final syllable and carry penultimate stress. It appears that they pattern identically. However, if rising diphthongs and complex onsets pattern equally, then the latter should also block antepenultimate stress. There are, however, many words in the Spanish lexicon that permit antepenultimate stress with a complex onset in the penult, as seen below.

Antepenultimate stress with complex onsets in the penult

a. [bjo.ɣɾa.fo] “biographer” c. [ru.βɾi.ka] “rubric”

b. [lá.ɣɾi.ma] “tear” d. [re.pú.βli.ka] “republic”

This observation led Harris (1983) to classify rising diphthongs as an example of a branching nucleus (equivalently bimoraic in moraic theory) in his treatment of Spanish syllable structure (see also Hualde, 1991, 1999; Hualde & Prieto, 2002). According to his account, antepenultimate stress is impossible with *either* a branching nucleus or a branching rime (a consonant in syllable-final position fills the coda position, causing branching at the rime level, rather than at the nuclear level). Therefore, a distinction is made between rising and falling diphthongs and syllables closed by a consonant. While Roca (1991) observes that there are multiple violations of the two-syllable window when the final syllable is closed by a consonant, such as *Wáshington*, *Mánchester*, and *Frómista*, there appear to be no exceptions to the two-syllable window when the penult contains either a rising or falling diphthong. Regarding the two diphthong types, what is most important is that neither Harris’s nor Roca’s theory of syllable structure differentiates between the rising and falling diphthongs themselves. Roca makes no claims about the difference, because he does not believe that quantity sensitivity is active in Spanish and therefore needs to make no claims about syllable weight. Harris does argue in favor of quantity sensitivity but puts forth no direct theoretical claims about the differential behavior of the two diphthong types. He simply argues that they both represent branching nuclei and reduce the three-syllable window to two syllables.

In summary, it remains unclear whether Modern Spanish is sensitive to syllable weight, as its antecedent Latin clearly was. If Spanish is a quantity-sensitive language, it is also not clear whether native speakers represent a binary categorical distinction between light and heavy, or if they are sensitive to more finely grained patterns in the lexicon. The distributional differences observed between rising and falling diphthongs suggests that this central tension in the debate on Spanish stress involves two separate issues: 1) the effect of weight in conditioning the span of the Spanish stress window, and 2) the effect of weight in actually attracting stress to the heavy syllable within the window.

In the following experiment, we investigate the processing of the restrictions syllable structure places on stress assignment in Spanish. We build upon previous psycholinguistic work (e.g. Carreiras & Perea, 2004; Laganaro & Alario, 2006; Cholin & Levelt, 2009), adapting similar methodology, to study other ways the syllable can modulate processing. A close look at the Spanish problem of syllable weight through the lens of processing may help us better understand the cognitive representation of the linguistic dichotomy between light/heavy syllables. It is also a useful point of inquiry for examining the role of syllables in speech planning and the relationship between the syllable and higher (i.e. stress) and lower (i.e. syllable-internal phonotactics) levels of representation.

Experiment

This experiment tests the processing of syllable-level and stress-level encoding by means of a nonword naming task. Specifically, this experiment examines how native speakers process the three-syllable window for Spanish stress assignment by exploiting critical nonce forms which are segmentally licit, but which violate the putative synchronic stress assignment constraints of the language. As discussed above, both rising and falling diphthongs constitute heavy syllables within traditional accounts of Spanish syllable structure. Given

the binary (“light” versus “heavy”) nature of such approaches to weight, traditional phonological theory predicts that there should be no difference in behavior between the two diphthong types. Nevertheless, we have noted that while both rising and falling diphthongs reduce the Spanish stress window in extant forms from three syllables two, only falling diphthongs systematically attract stress. This opens the possibility that the two diphthong types may differentially modulate performance in the task.

As the issue under scrutiny is phonological in nature, naming provides a useful methodology in that it forces phonological activation. This task is a simple yet novel approach to the study of the Spanish stress system given that most work in the linguistics literature has focused on metalinguistic interpretation and introspection. By contrast, the naming task provides a processing-driven perspective on the relationship between syllable structure and stress in the language. We employ a nonword naming task in order to test the strength of the way in which rising and falling diphthongs, respectively, constrain the window for stress assignment when speakers process novel forms.

Participants

23 functionally monolingual, Spanish-speaking undergraduates at the University of Jaén, Spain participated in the experiment. One participant’s data were excluded due to technical errors with the digital recording.

Materials

Critical stimuli consisted of 56 trisyllabic nonce words with either a rising diphthong (CV.CGV.CV) or falling diphthong (CV.CV~~G~~.CV) in the penultimate syllable. Orthographically, rising diphthongs were represented by *ia* or *ie* (e.g. *dó**bi**ana* or *gó**vi**ego*), and falling diphthongs by *ai* or *ei* (*mó**ma**ino* or *fá**te**iga*). The segmental makeup of the stimuli was controlled so that all consonants and vowels in the antepenultimate and final syllables appeared equally across all conditions. A set of monophthong control stimuli served as a comparison to the diphthong condition. These items matched the diphthong stimuli segmentally, with the exception of the penultimate syllable, which contained a monophthong instead of the diphthong (e.g. *fá**ta**ga*).

All critical and control items were presented both with and without a written accent mark on the antepenultimate syllable. Given the orthographic conventions of Spanish, a written accent over the initial syllable of a three-syllable word always indicates antepenultimate stress. If a Spanish word ends in a vowel, as do all of our stimuli, and no written accent mark is present, the word is always interpreted with penultimate stress. These orthographic regularities allow for the comparison of otherwise segmentally identical stimuli in two stress conditions. Nevertheless, to avoid possible priming effects if participants were to see identical syllable sequences twice, stimuli with and without orthographic accent marks were counterbalanced. Thus, if participant 1 saw *dó**bi**ana*, participant 2 saw *dobiana*, and so forth. 112 critical items and controls were seen by each participant.

Participants also saw 168 filler stimuli. Additional nonword fillers consisted of 28 CV.CV.CV items that were not segmentally similar to the critical items. 140 real word fillers were also chosen from Alameda & Cuetos (1995), consisting of both high and low frequency items in three categories of antepenultimate, penultimate and final stress. In total, there were thus 140 nonword items and 140 real words. The stimuli are provided in Appendix 1.

Table 1 provides examples of the critical items and nonword controls with quantities of each listed in parentheses. It is particularly important to note the diphthong stimuli, both rising

and falling, in the antepenultimate condition. These word shapes are theoretically proscribed forms, because the diphthongs in the penultimate syllable arguably reduce the stress window to the last two syllables of the word. Marking the first syllable for stress placement renders these forms illicit. The stimuli presented with penultimate stress, while nonextant forms, are phonotactically licit in that stress is permitted on the penultimate syllable with either monophthongs or diphthongs in the penult. Lastly, the monophthong controls contain only light syllables, and thus should allow both antepenultimate and penultimate stress. The first critical comparison then is between the proscribed forms containing diphthongs with antepenultimate stress and the remaining stimuli. Given the ambiguous patterning of the rising diphthongs, a second critical comparison is between the two proscribed forms, rising vs. falling diphthongs. These theoretical distinctions may be borne out in the naming task as distinct patterns of error rates and reaction times.

Procedure

Participants were tested individually in a quiet room and performed a naming task. They were seated in front of a computer screen and two microphones, the first connected to a PST Serial Response Box and the second to a digital recorder (Marantz PMD660 sampling at 48 kHz). The Serial Response Box served as a voice key, and the PMD660 recorded the experimental session for subsequent coding of response accuracy. An instructions screen in Spanish informed participants that they would see words one-by-one on a computer screen, and that they should read the words aloud as quickly and accurately as possible. Each trial consisted of a fixation point (+) in black font in the center of a white screen. The fixation point appeared for 500 ms to direct the participants' attention to the center of the screen and to cue to them that a word was about to appear. Following the fixation point was a 500 ms delay, after which the experimental item was presented in the center of the screen. The word remained on the screen until the participant spoke. Once the computer registered a response, the following trial began. Participants first performed a practice session with 12 items (6 words and 6 nonwords), none of which contained the critical structures under examination. Following the practice trials, the experimental stimuli were presented in random order over two experimental blocks with a 30-second break between blocks.

Results

Data Coding and Analysis

Both accuracy and latency analyses were carried out for this experiment. For the accuracy analysis, one native and two near-native speakers of Spanish, trained in phonetics, listened to recorded audio files of each experimental session. A response was coded as accurate if the participant provided the expected pronunciation of a stimulus given its presentation on the screen. If participants misspoke the stimulus, it was coded as an error. The first and second authors randomly checked 100 tokens of each coders' work to check for reliability and found no disagreement in accurate-error decisions between themselves. Overall, the less than 2% disagreement in error coding across the three coders was resolved by the first two authors in all cases.

Qualitatively, we identified three categories of errors. First, stress shifts were the most frequent type of error, accounting for 56% of errors among the critical items in the experiment. In such errors, participants shifted stress to another syllable in the word as in *dóbiana* > *dobíana*. These errors were perceptually robust, and easily identifiable by all coders (and by any fluent speaker of Spanish), given the contrastive nature that stress placement plays in the language. We classified a second class of errors as segmental errors. As with the stress errors, segmental errors were highly salient and occurred when participants altered the segmental composition of the stimuli. Examples included additions

and deletions, such as *jómaiga* > *jórmaiga*, and *záteino* > *zátino*, respectively; alterations, such as *báveno* > *báñeno*; and switches, involving movement of a segment from one syllable to another, as in *fáriena* > *fáirena*. Overall, segmental changes represent 26% of the errors provoked by the critical stimuli. A final class of errors present in the data were disfluencies in which participants paused between syllables, as in *dótaiga* > *dó...taiga*, or when participants did not complete the word. Disfluencies accounted for approximately 18% of the total errors on critical items. Technical errors in which microphone sensitivity failed to register a voice key response were eliminated from all analyses.

In carrying out the latency analysis, all items produced with errors were excluded. Subsequently, the correct responses were cleaned in two steps. First, correct responses faster than 200 ms and slower than 2000 ms were eliminated. Second, response latencies 2.5 standard deviations above or below each participant's mean reaction time were also removed.

Reaction time and error data were submitted to separate repeated measures ANOVAs by participants (*F1*) and by items (*F2*). Main effects and interactions were followed by Tukey's HSD post-hoc tests to identify independent effects across the experimental categories and conditions.

Error Rates

Due to programming problems, four diphthong and one monophthong nonce words were eliminated from all analyses. ANOVAs comparing diphthongs generally (i.e. both rising and falling diphthongs together) to their monophthong controls revealed a significant main effect of word type (diphthongs (pooled) vs. monophthongs in the penultimate syllable), $F(1, 21) = 26.41, p < .001$; $F(1, 105) = 25.08, p < .001$, a significant main effect of stress type (antepenultimate vs. penultimate), $F(1, 21) = 12.55, p < .002$; $F(1, 105) = 22.79, p < .001$, and a significant interaction of word type and stress type, $F(1, 21) = 69.09, p < .001$; $F(1, 105) = 95.81, p < .001$. The interaction shows that diphthongs patterned distinctly from monophthong controls by provoking significantly more errors in the antepenultimate stress condition ($p < .001$). The opposite occurred in the penultimate stress condition, where monophthong controls provoked significantly more errors than diphthongs ($p < .05$). This is shown in Table 2.

The second goal of the experiment was to test for differences in the behavior of the two diphthong types. ANOVAs comparing error rate differences between rising and falling diphthongs found a significant main effect of diphthong type, $F(1, 21) = 14.67, p = .001$; $F(1, 50) = 11.33, p < .002$, a significant main effect of stress, $F(1, 21) = 105.25, p < .001$; $F(1, 50) = 162.40, p < .001$, and a significant interaction of diphthong type and stress type, $F(1, 21) = 17.02, p < .001$; $F(1, 50) = 13.84, p < .001$. As shown in Table 2, the interaction is driven by the difference between the two diphthong types in the critical antepenultimate stress condition, where falling diphthongs provoked higher error rates than do rising diphthongs ($p < .001$). By contrast, in the penultimate condition, there was no significant difference in error rates between diphthong types.

As an anonymous reviewer noted, an analysis of the distribution of errors in our data is also warranted. Table 3 shows the percentage of each error type, broken down across critical word and stress conditions. In the top panel of the table, we show the error rates for the pooled diphthongs and their monophthong controls, and in the bottom panel we provide the breakdown of the errors between the two diphthong types.

When we examine the comparison between diphthongs versus monophthong controls, as well as between rising and falling diphthongs, the most striking pattern emerges in the stress

shift errors. This is to be expected given our hypotheses. In our analyses above, we made the conservative decision to include all errors rather than assume a priori that stress shift errors alone should form the basis for our statistical tests. However, given the pattern of errors presented in Table 3, as an additional follow-up, we submitted each error type to separate statistical analyses to identify any different patterns that might emerge among them. The results of these tests show that the stress errors alone are indeed what drive the general pattern we find in Table 2. For purposes of space, the individual statistical analyses comparing error type are reported in Appendix 2.

Reaction Times

Analyses of reaction times comparing diphthongs (pooled) to their monophthong controls reveal a significant main effect of word type, $F(1, 21) = 14.84, p < .001$; $F(1, 105) = 6.55, p < .02$, a significant main effect of stress type, $F(1, 21) = 18.33, p < .001$; $F(1, 105) = 4.91, p < .03$, and a significant interaction of word type and stress type, $F(1, 21) = 10.30, p < .01$; $F(1, 105) = 5.89, p < .02$. Examining the interaction, we see that diphthong stimuli yielded significantly longer naming latencies than monophthong controls when presented in the antepenultimate stress condition ($p < .001$). There was no significant difference between diphthongs and monophthongs in the penultimate stress condition ($p > .22$). Table 4 illustrates the latency data for the diphthong stimuli and their controls in both stress conditions.

The analysis of reaction times to test the subtler difference between the two diphthong types is more difficult given the high error rates provoked by items marked for antepenultimate stress that contain diphthongs in the penultimate syllable. In running ANOVAs by participants on latencies comparing diphthong type and stress type, one participant had to be eliminated due to empty cells. The results reveal a significant main effect of stress type, $F(1, 20) = 20.15, p < .001$; $F(1, 50) = 6.82, p < .02$. No significant main effect of diphthong type was found, $F(1, 20) = 0.01, p > .05$; $F(1, 50) = 1.35, p > .05$, and there was also no interaction of stress type and diphthong type, $F(1, 20) = 0.23, p > .63$; $F(1, 50) = 0.67, p > .41$. Table 4 above provides the latency results for rising and falling diphthongs when presented with antepenultimate and penultimate stress.

Fillers

Lastly, as a control to confirm that participants were processing lexically, i.e. that the production task was engaging expected processing mechanisms, the real-word filler items were submitted to separate analyses of variance to test for the word frequency effect. Approximately 2% of real word fillers provoked production errors. The ANOVAs for reaction time data on accurate real word fillers trials found a significant main effect of stress type (final, penultimate, or antepenultimate), $F(2, 42) = 12.39, p < .001$; $F(2, 134) = 10.72, p < .001$, a significant main effect of frequency, $F(1, 21) = 21.07, p < .001$; $F(1, 134) = 55.43, p < .001$, and no significant interaction of stress type and frequency, $F(2, 42) = 2.69, p > .07$; $F(2, 134) = 0.78, p > .45$. As illustrated Table 5, a robust frequency effect was obtained.

Discussion

Broadly speaking, the results of this experiment appear to be congenial with the hypothesis that, synchronically, stress is weight sensitive in Spanish. This is apparent in the error rate data for the comparison of diphthongs versus monophthongs, and, in particular, in the interaction between word type and stress position. The data show that diphthongs in items such as *dóbiana* or *fâteiga* trigger significantly more errors in the target items marked for antepenultimate stress than do controls containing monophthongs (e.g. in forms such as

dóbana or *fátega*). If diphthongs are assumed to contribute weight to the penultimate syllable in which they appear in our critical items, then they should attract stress and thus reduce the three-syllable window for stress assignment in the language. The robustly higher error rate for antepenultimate stress in forms containing a diphthong in the penultimate syllable confirms this prediction. Interestingly, the interaction also reveals a significant difference in the other direction for items marked for penultimate stress; for these items, there are significantly more errors in pseudowords containing monophthongs (such as *fataga*). Arguably, this is attributable to the fact that for such forms both antepenultimate and penultimate stress are phonotactically licit patterns in the language. That is, given the availability of both stress patterns and the large number of stimuli marked for antepenultimate stress in our task, we might thus expect to find more errors for forms marked for penultimate stress that contain monophthongs, i.e. that forms such as *fataga* might be erroneously produced as *fátaga*.

The overall pattern of results provides a picture in which diphthongs attract stress to the penultimate syllable, exhibit a higher error rate in the antepenultimate condition, and induce a reduced error rate in the penultimate condition when compared to the monophthong controls. The reaction time results (calculated on correct responses only) concord with the error rate data. Specifically, the interaction between word type and stress location shows that the diphthong stimuli yielded significantly longer naming latencies than monophthong controls in the antepenultimate stress condition ($p < .001$), but no significant difference in the penultimate condition ($p > .22$), where both patterns are attested in the language.²

The second goal of this study involved testing for whether differences emerge depending on whether participants produced forms with rising diphthongs (e.g. *dóbiana/dobiana*) or falling diphthongs (e.g. *fáteiga/fateiga*). Strikingly, our results show that rising and falling diphthongs do pattern differently. As seen in Table 2 above, the significant interaction of stress and diphthong reveals a robust difference in error rates in the antepenultimate stress condition ($p < .001$), where falling diphthongs induce a significantly higher error rate than do rising diphthongs. By contrast, in the penultimate stress condition—for which both diphthongs are phonotactically licensed—we found no significant difference in error rates between forms containing rising and falling diphthongs. The absence of a significant difference in the penultimate stress condition is crucial, because it indicates that the difference found in the antepenultimate condition cannot be explained simply by hypothesizing, for example, that falling diphthongs somehow incur a higher processing cost in the production task and thus yield higher error rates. Rather, the data indicate that the difference between the two diphthong types resides in the magnitude of the effect that they have over what has long been assumed to be a single banned phonotactic pattern, that is, over the prohibition against antepenultimate stress in words containing any kind of diphthong in the penultimate syllable.

Regarding reaction time, the robust main effect of stress position confirms that participants are faster to respond to phonotactically licit forms with stress on the penultimate syllable than to proscribed forms marked for stress on the antepenult. This reflects, as we note above, the added processing load incurred when participants must prepare forms for production that violate the prosodic constraints of the language. However, no significant differences were

²As an anonymous reviewer points out, we might consider whether the source of the longer latencies evidenced by the diphthong stimuli in the antepenultimate condition is due to the fact that these stimuli contain one grapheme more than the monophthong controls. However, the results discussed here allow us to discard this hypothesis, because, if processing is slowed by the additional grapheme, we should expect to find evidence of this lag in reaction time in the penultimate stress condition as well, which we do not. Given that the two word types pattern together in the phonotactically licit penultimate stress condition, but differently in the theoretically restricted antepenultimate condition, we are left with an explanation that takes into consideration the structure of the syllable above the level of individual segments that comprise it.

found between diphthong conditions in either the penultimate or antepenultimate position. This indicates that the difference in processing cost between the two is manifest in the error data alone.

In sum, the results of this experiment prove problematic for theories in which a binary distinction in syllable weight modulates the placement of Spanish stress by conditioning the size of the stress window at the right edge of words. Close scrutiny of differences between the effects of rising versus falling diphthongs pose important and surprising challenges for such a view in that the error rate differences between diphthong types in antepenultimately stressed items are unexpected under standard treatments of Spanish phonotactics. However, as we discuss above, the error rate differences are less surprising if we hypothesize that speakers are sensitive in a more granular fashion to the subtle differences between how rising and falling diphthongs interact with stress placement in the lexicon as a whole. Put simply, the error rate results suggest that rising diphthongs behave in a sense as *less heavy* or *more word-like* in the context of nonword phonotactics, than do falling diphthongs, while still inducing significantly more errors in the antepenult position than do monophthong controls.

Broadly speaking, these results add another layer of complexity to our increasing understanding of the role the syllable plays in speech planning. Given the interaction we see in these results between syllable structure and stress placement, these data highlight the importance of syllable-level encoding when examining speech production processes.

Conclusion

The aim of the present study was to present a novel perspective on the role of the syllable structure in the modulation of stress assignment in Spanish. We employed a word naming task, which has often been used to examine the role of the syllable as a whole in word processing—via the manipulation of syllable frequency and/or congruency between target items and matched primes, for example—to examine the less well understood interaction of syllable-internal phonotactics with higher levels of speech planning. Specifically, we presented an experiment which addressed from a processing perspective a longstanding debate regarding the putative effects of syllable weight on stress placement in Spanish. Our results were surprising in that they only partially support a traditional quantity sensitive view of Spanish stress. In broad terms, the results discussed in this paper might be viewed as consistent with quantity sensitive approaches to Spanish stress. The different treatment of diphthongs and monophthongs in the antepenultimate stress condition, and the absence of differences in the penultimate condition, appears to indicate that the theoretically “heavy” diphthongs do shrink the Spanish stress window from three to two syllables when participants are asked to produce lexically unattested patterns such as *dóbiana* or *fáteiga*. At this level of granularity, then, the data are congenial with traditional accounts of Spanish stress. However, upon closer examination, we found significantly different patterning for rising and falling diphthongs. This result is unexpected and surprising, given that traditional linguistic approaches to Spanish stress, and to syllable weight more broadly, assume a categorical distinction between “heavy” and “light” syllables. Of relevance here, diphthongs pattern uniformly as “heavy”, while monophthongs are treated by the theory as “light”. Thus, both diphthong types are predicted to reduce the stress window equally. In the present study, the different degrees of modulation in the strength of the restriction for rising versus falling diphthongs is a striking result.

We suggest that a better characterization of the constraints that the phonology imposes on antepenultimate stress in Spanish is one that derives from approaches rooted in speakers’ experiences with language, i.e. a view that grammatical “rules” can be understood as

emergent generalizations of patterns across the lexicon (Pierrehumbert, 1999, 2001a, 2001b; Bybee, 2001; Bailey & Hahn, 2001; Bresnan & Hay, 2008; Treiman, Kessler, Knewasser, Tincoff, & Bowman, 2000; Vitevitch, Luce, Pisoni, & Auer, 1999; Croot, 2010). Here, the distinct patterning of the two diphthong types in our results may arise from the experience that native speakers have with rising and falling diphthongs and their effect on stress placement in extant words. As noted in the introduction, Spanish contains no words with antepenultimate stress and a diphthong in the penultimate syllable. This is true of both rising and falling diphthongs. However, the situation is distinct for diphthongs in the final syllable of words. A search of Alameda and Cuetos (1995), for example, reveals very few polysyllabic forms (14 in all) with final falling diphthongs, of which 12 have word-final stress and the 2 which are penultimately stressed are the non-native words *masai* and *bonsai*. By contrast, there are over seven hundred nonverbal forms containing a rising diphthong in the final syllable, in which stress does not fall on the putatively heavy, and thus stress attracting, diphthong, but rather, falls on the penultimate syllable. While our goal is not to address the complexities of the Spanish stress assignment system as a whole, what is clear from the corpus data is that speakers do not uniformly treat rising diphthongs as heavy in the language. There is a paucity of evidence in which falling diphthongs can ever be claimed to show ambiguity with respect to their syllable weight. In this sense, under an emergentist rather than a strict categorical view of weight, the differential effect of rising versus falling diphthongs in the nonce words in this experiment can arguably be attributed to the experience that speakers have with the more ambiguous relationship between stress and rising diphthongs across the lexicon. The results of the present study thus offer novel data which inform theories of syllable weight and stress in linguistic theory and contribute to our understanding of the complex relationship between the syllable and other levels of speech planning.

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TABLE 1

Stimuli Summary

	Stress Type	
	Antepenultimate	Penultimate
<i>Word Type</i>		
Rising Diphthongs	dobiana (28)	goviano (28)
Falling Diphthongs	fateiga (28)	zateino (28)
Controls	mosago (56)	morega (56)

TABLE 2

Percentage of errors

	Stress Type	
	Antepenultimate	Penultimate
<i>Word Type</i>		
Diphthongs (pooled)	45.4	14.9
Controls	14	24.7
Rising Diphthongs	35.5	14
Falling Diphthongs	55.2	15.7

TABLE 3

Percentage of total errors

	Error Type		
	Stress	Segment	Disfluency
<i>Word Type x Stress Type</i>			
Diphthongs (pooled)			
Antepenultimate	28.7	9.4	7.6
Penultimate	2	8.5	4.6
Controls			
Antepenultimate	5.1	5.1	3.3
Penultimate	19.8	2.7	2.5
Rising Diphthongs			
Antepenultimate	20.1	7.7	7.7
Penultimate	2.5	6.7	5
Falling Diphthongs			
Antepenultimate	36.9	10.9	7.4
Penultimate	1.4	10.1	3.9

TABLE 4

Mean reaction times (in ms)

	Stress Type	
	Antepenultimate	Penultimate
<i>Word Type</i>		
Diphthongs (pooled)	729	669
Controls	649	644
Rising Diphthongs	736	663
Falling Diphthongs	731	665

TABLE 5

Mean reaction times (in ms) of real word fillers

	Stress Type		
	Antepenultimate	Penultimate	Final
<i>Word Type</i>			
High Frequency	555	540	553
Low Frequency	604	573	568

APPENDIX 1

Rising Diphthongs (presented both with and without accent marks)									
<i>báviana</i>	<i>gómiana</i>	<i>cóviana</i>	<i>jóriana</i>	<i>dóbiana</i>	<i>lótiano</i>				
<i>fátigo</i>	<i>mórtigo</i>	<i>pávigo</i>	<i>nátigo</i>	<i>rámiena</i>	<i>bátigo</i>				
<i>sómiena</i>	<i>córtigo</i>	<i>távigo</i>	<i>dórtigo</i>	<i>zárigo</i>	<i>fárena</i>				
<i>pámiana</i>	<i>górtigo</i>	<i>rátigo</i>	<i>sórtigo</i>	<i>támiana</i>	<i>zátiana</i>				
<i>jómigo</i>	<i>lórtena</i>	<i>mómiena</i>	<i>nátiena</i>						
Falling Diphthongs (presented both with and without accent marks)									
<i>bátaiga</i>	<i>mónaino</i>	<i>cótaiga</i>	<i>nóraiga</i>	<i>dótaiga</i>	<i>póvaino</i>				
<i>fáraiga</i>	<i>rámaino</i>	<i>báveino</i>	<i>sómaino</i>	<i>lótetiga</i>	<i>rátetiga</i>				
<i>móreiga</i>	<i>sóreiga</i>	<i>náteiga</i>	<i>támeino</i>	<i>pámeino</i>	<i>zátetino</i>				
<i>fávaiga</i>	<i>góvaino</i>	<i>jónaiga</i>	<i>loraiga</i>	<i>závaino</i>	<i>jóveino</i>				
<i>cóveino</i>	<i>dóveino</i>	<i>fáteiga</i>	<i>gómeino</i>						
Monophthong Controls (presented both with and without accent marks)									
<i>rádano</i>	<i>dóveno</i>	<i>góméno</i>	<i>nárega</i>	<i>zárego</i>	<i>córaga</i>				
<i>bávaza</i>	<i>pámaca</i>	<i>móména</i>	<i>jómaga</i>	<i>fátaga</i>	<i>bátaga</i>				
<i>góvaro</i>	<i>mónaso</i>	<i>dósego</i>	<i>mósago</i>	<i>póvapo</i>	<i>sórago</i>				
<i>lóraga</i>	<i>jóteno</i>	<i>sódano</i>	<i>fátago</i>	<i>lótigo</i>	<i>nórago</i>				
<i>jónego</i>	<i>záténo</i>	<i>rádago</i>	<i>lórada</i>	<i>lórega</i>	<i>páméno</i>				
<i>nárena</i>	<i>zátano</i>	<i>fátaga</i>	<i>sóména</i>	<i>góvego</i>	<i>sórega</i>				
<i>bánego</i>	<i>fárena</i>	<i>támaca</i>	<i>jórava</i>	<i>cólana</i>	<i>távigo</i>				
<i>pávigo</i>	<i>dófaga</i>	<i>násago</i>	<i>rátetiga</i>	<i>bávénno</i>	<i>rátetena</i>				
<i>cótego</i>	<i>cóveno</i>	<i>fátetiga</i>	<i>dóvasa</i>	<i>mórega</i>	<i>zátana</i>				
<i>táméno</i>	<i>gódana</i>								
Nonword Fillers									
<i>pajeto</i>	<i>nalato</i>	<i>zodilo</i>	<i>coludo</i>	<i>tarilo</i>	<i>fofeto</i>				
<i>fonega</i>	<i>litime</i>	<i>subima</i>	<i>manigo</i>	<i>miresa</i>	<i>parilo</i>				
<i>ranaba</i>	<i>gerida</i>	<i>vanezo</i>	<i>suleda</i>	<i>ligoco</i>	<i>pirago</i>				
<i>culuma</i>	<i>boleda</i>	<i>tanavo</i>	<i>pomera</i>	<i>jubato</i>	<i>maneco</i>				
<i>videna</i>	<i>jarita</i>	<i>pelato</i>	<i>varido</i>						
Real Word Fillers – High Frequency									
Antepenultimate Stress									

\$watermark-text

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<i>máquina</i>	<i>lógica</i>	<i>técnica</i>	<i>lágrimas</i>	<i>método</i>	<i>título</i>
<i>género</i>	<i>médico</i>	<i>término</i>	<i>número</i>	<i>línea</i>	<i>crítica</i>
<i>práctica</i>	<i>público</i>	<i>físico</i>	<i>cámara</i>	<i>música</i>	
Penultimate Stress					
<i>derecho</i>	<i>lectura</i>	<i>mercado</i>	<i>vestido</i>	<i>manera</i>	<i>mentira</i>
<i>dinero</i>	<i>fortuna</i>	<i>camisa</i>	<i>figura</i>	<i>ventana</i>	<i>tamaño</i>
<i>gobierno</i>	<i>persona</i>	<i>memoria</i>	<i>modelo</i>	<i>cultura</i>	<i>cadena</i>
<i>futuro</i>	<i>misterio</i>	<i>cocina</i>	<i>caballo</i>	<i>distinto</i>	<i>camino</i>
<i>botella</i>	<i>conjunto</i>	<i>marido</i>	<i>comida</i>	<i>secreto</i>	<i>tristeza</i>
<i>sistema</i>					
Final Stress					
<i>natural</i>	<i>calidad</i>	<i>cultural</i>	<i>soledad</i>	<i>popular</i>	<i>profesor</i>
<i>propiedad</i>	<i>militar</i>	<i>cantidad</i>	<i>juventud</i>	<i>personal</i>	<i>director</i>
<i>general</i>	<i>voluntad</i>	<i>superior</i>	<i>capital</i>	<i>principal</i>	<i>nacional</i>
<i>libertad</i>	<i>sociedad</i>	<i>material</i>	<i>familiar</i>		
Real Word Fillers – Low frequency					
Antepenultimate Stress					
<i>trámite</i>	<i>gótico</i>	<i>búfalo</i>	<i>pócima</i>	<i>rábano</i>	<i>tónica</i>
<i>vínculo</i>	<i>náufrago</i>	<i>plátano</i>	<i>vértice</i>	<i>pómulo</i>	<i>válvula</i>
<i>vibora</i>	<i>ráfaga</i>	<i>cólico</i>	<i>cláusula</i>	<i>ciática</i>	<i>vómito</i>
<i>sífilis</i>	<i>píldora</i>	<i>slaba</i>	<i>dígito</i>	<i>báscula</i>	
Penultimate Stress					
<i>cuchara</i>	<i>paleta</i>	<i>califa</i>	<i>canica</i>	<i>bellota</i>	<i>bisagra</i>
<i>bombero</i>	<i>bautizo</i>	<i>canela</i>	<i>canguro</i>	<i>cazuela</i>	<i>gemelo</i>
<i>bizcocho</i>	<i>bocina</i>	<i>dialecto</i>	<i>coraza</i>	<i>paella</i>	<i>canario</i>
<i>decreto</i>	<i>bayeta</i>	<i>cajero</i>	<i>caldera</i>	<i>botijo</i>	<i>bolero</i>
Final Stress					
<i>pesadez</i>	<i>tirador</i>	<i>dejadez</i>	<i>senador</i>	<i>ruiseñor</i>	<i>secador</i>
<i>titular</i>	<i>comprador</i>	<i>coronel</i>	<i>sucursal</i>	<i>tropical</i>	<i>funeral</i>
<i>vestidor</i>	<i>tocador</i>	<i>diagonal</i>	<i>girasol</i>	<i>delantal</i>	<i>tenedor</i>
<i>litoral</i>	<i>marginal</i>	<i>varonil</i>	<i>virginal</i>	<i>solidez</i>	

APPENDIX 2

Error Type Analyses

Error Type	Level of Analysis	Comparison	Results
Stress Errors	Diphthongs (pooled)/Controls	Word Type	$FI(1, 21) = 1.97, p > .17$ $F2(1, 105) = 3.64, p > .05$
		Stress Type	$FI(1, 21) = 2.87, p > .10$ $F2(1, 105) = 10.2, p < .01$
		Interaction	$FI(1, 21) = 82.7, p < .01$ $F2(1, 105) = 119.09, p < .01$
	Rising Diphthongs/Falling Diphthongs	Word Type	$FI(1, 21) = 22.53, p < .01$ $F2(1, 50) = 13.49, p < .01$
		Stress Type	$FI(1, 21) = 44.95, p < .01$ $F2(1, 50) = 162.47, p < .01$
		Interaction	$FI(1, 21) = 29.33, p < .01$ $F2(1, 50) = 17.79, p < .01$
	Diphthongs (pooled)/Controls	Word Type	$FI(1, 21) = 11.64, p < .01$ $F2(1, 105) = 14.44, p < .01$
		Stress Type	$FI(1, 21) = 1.9, p > .18$ $F2(1, 105) = 2.81, p > .09$
		Interaction	$FI(1, 21) = 0.7, p > .41$ $F2(1, 105) = 0.45, p > .50$
Segment Errors	Rising Diphthongs/Falling Diphthongs	Word Type	$FI(1, 21) = 2.46, p > .13$ $F2(1, 50) = 2.42, p > .12$
		Stress Type	$FI(1, 21) = 0.22, p > .64$ $F2(1, 50) = 0.4, p > .52$
		Interaction	$FI(1, 21) = 0.01, p > .91$ $F2(1, 50) = 0.006, p > .93$
	Diphthongs (pooled)/Controls	Word Type	$FI(1, 21) = 11.33, p < .01$ $F2(1, 105) = 10.46, p < .01$
		Stress Type	$FI(1, 21) = 3.59, p > .07$ $F2(1, 105) = 5.74, p < .02$
		Interaction	$FI(1, 21) = 1.7, p > .20$ $F2(1, 105) = 1.56, p > .21$
Disfluency Errors	Rising Diphthongs/Falling Diphthongs	Word Type	$FI(1, 21) = 0.26, p > .61$ $F2(1, 50) = 0.3, p > .58$
		Stress Type	$FI(1, 21) = 3.88, p > .06$ $F2(1, 50) = 4.39, p < .05$
		Interaction	$FI(1, 21) = 0.101, p > .75$ $F2(1, 50) = 0.1, p > .75$
	Diphthongs (pooled)/Controls	Word Type	$FI(1, 21) = 0.26, p > .61$ $F2(1, 50) = 0.3, p > .58$
		Stress Type	$FI(1, 21) = 3.88, p > .06$ $F2(1, 50) = 4.39, p < .05$