



Acoustic Properties of Canonical and Non-Canonical Stress in French, Turkish, Armenian and Brazilian Portuguese

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Abstract

Languages are often categorized as having either predictable (fixed or quantity-sensitive) or non-predictable stress. Despite their name, fixed stress languages may have exceptions, so in fact, their stress does not always appear in the same position. Since predictability has been shown to affect certain speech phenomena, with additional or redundant acoustic cues being provided when the linguistic content is less predictable (e.g., Smooth Signal Redundancy Hypothesis), we investigate whether, and to what extent, the predictability of stress position affects the manifestation of stress in different languages. We examine the acoustic properties of stress in three languages classified as having fixed stress (Turkish, French, Armenian), with exceptions, and in one language with non-predictable-stress, Brazilian Portuguese. Specifically, we compare the manifestation of stress in the canonical stress (typically “fixed”) position with its manifestation in the non-canonical (exceptional) position, where it would potentially be less predictable. We also compare these patterns with the manifestation of stress in Portuguese, in both the “default” penultimate and the less common final position. Our results show that stress is manifested quite similarly in canonical and non-canonical positions in the “fixed” stress languages and stress is most clearly produced when it is least predictable.

Index Terms: fixed stress, redundancy, predictability

1. Introduction

Languages are often categorized as having either predictable (non-contrastive), or non-predictable (contrastive) stress. Predictable-stress languages can be divided into fixed-stress (e.g., Turkish: word-final, Hungarian: word-initial) and quantity-sensitive stress languages (e.g., Arabic). In non-predictable stress languages (e.g., Portuguese, English, Russian), stress may appear in different positions, and while there may be some phonological or morphological patterns, the position of stress is not fully predictable. Consequently, there may be minimal pairs distinguished only by stress.

Predictability has been argued to affect the speech patterns of languages, with additional, redundant, acoustic cues being provided when the linguistic content is otherwise less predictable (e.g., Smooth Signal Redundancy Hypothesis [1, 2, 3]). For example, previous studies have shown that contextually predictable syllables and words have shorter durations than non-predictable ones [2, 3], and that predictable vowels are more centralized than non-predictable ones. Also, predictable words have lower F0 than non-predictable ones [3, 4]. There is also evidence that predictability from probability (frequency) can affect speech patterns, with more frequent words being shorter in duration than less frequent words [5].

The relationship between predictability and redundancy is observed with different aspects of speech, and thus appears to be basic enough to possibly constitute a core aspect of human language in general. In the present paper, we extend the examination of the effect of predictability within the domain stress, and compare languages with different types of stress systems. Specifically, we ask to what extent there are cross-linguistic generalizations regarding the predictability of stress and its acoustic manifestation. We investigate the main prosodic properties, duration, F0, vowel centralization and intensity in stressed and unstressed vowels in Turkish, Armenian, French and Portuguese. Interestingly, these are the same acoustic properties that previous research has found to be sensitive to other types of predictability [2, 3, 4].

2. Fixed and Non-Predictable Stress

Contrary to what is implied by the term “fixed-stress language”, stress does not always appear on the same syllable in these languages. Different types of exceptions may result in stress appearing in a position other than the canonical, fixed position. Such languages are particularly interesting with regard to the role of predictability since, on one hand, they seem to have predictable fixed stress, but on the other hand, they allow alternate patterns as well. We investigate three such languages, Turkish, French, Armenian (hereafter, simply “fixed-stress languages”), and compare them to a language that has non-predictable stress, (Brazilian) Portuguese.

2.1. Fixed Stress Languages

In Turkish, the canonical, and most frequent, stress position is on the final syllable (1a). Non-canonical (i.e., non-final) stress, however, is also largely predictable, mostly appearing to the left of certain suffixes (1b). It may also appear on a non-final syllable in some place names and borrowings in accordance with the quantity-sensitive Sezer Stress Rule [6, 7, 8], (1c).

(1) Turkish stress examples

- a) Canonical: [kara-dá] ‘land’- LOCATIVE
- b) Non-Canonical: [kará-dʒa] ‘land’- ADVERBIAL
- c) Non-Canonical: [án.ka.ra] ‘Ankara’ (Sezer Stress)

Armenian is similar to Turkish, with canonical stress on the final syllable (2a), and non-canonical stress preceding certain suffixes (2b). More generally, and differently from Turkish, however, the non-canonical stress is fully predictable since it just avoids any final syllable with a schwa, even if it does not involve a suffix (2c) [9].

(2) Armenian stress examples

- a) Canonical: [papak-i] ‘desire’- GENTIVE/DATIVE
- b) Non-Canonical: [papák-ə] ‘desire’- DEFINITE
- c) Non-Canonical: [yerpémən] ‘sometimes’

Finally, French exhibits some similarity to Armenian, in that stress falls on the rightmost full vowel (3a), thus non-finally when the final vowel is schwa (3b). Unlike Armenian, though, pre-stressing in the presence of schwa is only sporadic, since final schwas are often not pronounced, causing the stressed vowel to effectively be word-final (3c). Under certain phonological conditions, however, the likelihood of final schwa production is increased, specifically following a CC cluster that violates the Sonority Sequencing Principle, and even more so, if the following word starts with a consonant. Ultimately, though, the manifestation of schwa is additionally subject to stylistic and individual variation [10].

(3) French stress examples

- a) Canonical: [avoká] ‘lawyer’
- b) Non-Canonical ([ə] present): [byvábɫə] ‘drinkable’
- c) Canonical ([ə] deleted): [byváb(l)] ‘drinkable’

It should be noted that in some studies it has been claimed that French does not have word stress, but only phrasal stress (e.g., [11]). While phrasal stress may typically be more prominent than lexical stress, this position neglects other research and phonological facts that indicate the presence of lexical stress. Recent research on both “stress deafness” and prosodic bootstrapping crucially rests on the assumption of (final) lexical stress in French [12, 13, 14, 15]. It has also been argued that (word) stress is responsible for certain, albeit morphologically limited, vowel alternations [16]. The presence of word stress has also been demonstrated, and acoustically supported, with a more productive phenomenon, the Iambic Reversal (Rhythm) Rule (IR), in structures such as *ba'teau* ‘boat’, but *'bateau mouche* ‘sight-seeing boat’ and *der'nier* ‘last’ but *'dernier mot* ‘last word’ [17, 18, 19]. If there is no word stress, “stress clash,” the motivation for IR, would be undefined in such cases, and no stress alteration or reversal would be observed (i.e., there would be nothing to reverse). The evidence argues otherwise.

Returning to the general issue of canonical and non-canonical stress, it can be observed that the presence of non-canonical stress is least predictable in French, due to the limited options for schwa deletion, specifically, the specific phonological contexts, and the additional possibilities of stylistic and individual variability. By contrast, the presence of non-canonical stress in Armenian is fully predictable on the basis of phonological information. Turkish falls in between, since specific morphemes reliably predict non-final stress, and the Sezer Stress Rule typically applies to particular classes of words (places and borrowings), and operates according to specific phonological criteria (similar to the Latin Stress Rule); however, it still has exceptions, so it is not possible to conclusively determine the position of stress in this case.

2.2. Non-Predictable Stress Languages

Differently from the fixed-stress languages, non-predictable-stress languages exhibit stress on different syllables, and often have minimal pairs dependent only on stress position. For

example, Portuguese, the language examined here, readily allows stress on one of the last three syllables [20], the “tri-syllabic window” found in many Romance languages, (4).

(4) Brazilian Portuguese stress examples

- a) Initial Stress: *'xicara* ‘cup’
- b) Penultimate Stress: *ca'chorro* ‘dog’
- c) Final Stress: *jabu'ti* ‘turtle’
- d) Minimal triplet: *'sábia* ‘wise’—FEM vs. *sa'bia* ‘(s/he) knew’ vs. *sabi'á* ‘Brazilian thrush’ [21]

While there are some morphological and phonological sub-patterns, stress is not consistent enough to result in overall predictability in Portuguese. Nevertheless, the penultimate position is reported to be the most frequent (53%), followed by final stress (35%); initial stress is relatively rare (12%) [22] (cited in [23]).

3. Present Study

Given that fixed stress constitutes a type of linguistic predictability, we test two hypotheses to probe the relationship between stress predictability and redundancy, as manifested by the clarity of the acoustic properties of stress. Specifically, Hypothesis 1 examines canonical stress position as a type of linguistic predictability, non-canonical stress being less predictable, and less frequent overall.

Hypothesis 1 (H1): Non-canonical stress is more robustly manifested in a language than canonical stress.

The prediction of H1 is that French, Turkish and Armenian stress cues will be stronger on the penultimate than on the final syllable. In Portuguese, considering penultimate stress to be “canonical”, it is predicted that the stress cues will be stronger on the final syllable than on the penult.

Since, as noted, some non-canonical stresses in fixed-stress languages are predictable, we test a second hypothesis. According to Hypothesis 2, any type of stress predictability, not just canonical position, will reduce the clarity of the manifestation of stress.

Hypothesis 2 (H2): Unpredictable stress is more robustly manifested than predictable stress.

H2 makes somewhat different predictions from H1. Since in Turkish and Armenian the penultimate stresses are fully predictable, morphologically and phonologically, respectively, H2 predicts that they will not be robustly manifested, and thus be similar in (lack of) clarity to final stress. By contrast, in French, while penultimate stress is favored in some contexts, it is not strictly predictable, and thus it will have stronger cues than final stress. In Portuguese, where neither final nor penultimate stress is predictable, both will be clearly manifested.

Clarity and robustness are measured in the present study as the percent of data correctly classified as stressed and unstressed vowels in our statistical analyses. The higher the percentage, the clearer and more robust the properties of stress.

4. Method

The data examined here are part of a larger cross-linguistic study on stress and focus. The structure of the stimuli and the methodology conform to those of the larger project [24].

4.1. Participants

We tested 10 native speakers of Turkish, French, Armenian and Brazilian Portuguese (18 – 30 years). They were all university students or recent graduates, and they were tested by a native speaker of their language.

4.2. Stimuli

The stimuli were real trisyllabic words of the form CVCVCV, to the extent possible. The target vowel was always in an open syllable. For each language, one set of words was stressed on the penultimate syllable, and a second set on the final syllable. In each set, the targets were 10 penultimate and 10 final vowels (N = 400 vowels / language). In Turkish, non-canonical, penultimate stress was elicited using words with the pre-stressing suffix [-dʒa] (ADVERBIAL). In Armenian, penultimate stress was elicited using words with a schwa in the final syllable (usually the suffix [-ə] (DEFINITE)). In French, too, penultimate stress was elicited using words with a schwa in the final syllable, specifically, in the context most likely to induce its production (i.e., following an obstruent + liquid consonant cluster, which violates the Sonority Sequence Principle). (Table 1).

Table 1: *Examples of stimuli with canonical and non-canonical stress (stressed vowel bolded)*

	Canonical Stress: Final	Non-Canonical Stress: Penultimate
French	avocat ‘lawyer’	buvabl[ə] ‘drinkable’
Turkish	karada ‘on the land’	kabaca ‘rough’
Armenian	[baraka] ‘condition’	[gadagə] ‘the joke’
	Canonical Stress: Penultimate	Non-Canonical Stress: Final
Portuguese	sapato ‘shoe’	vatapa ‘type of food’

4.3. Procedure

In the larger study, speakers were recorded reading two types of dialogues, one priming narrow focus on the target, the other focus on a subsequent word. For the present investigation, we only consider the data without focus, so we can examine the acoustic properties specifically associated with stress. Only the target word in the answer was used for analysis, underlined in (5); the focused word is bolded.

(5) *Example of French Non-Focus dialogue*

*Est-ce que Marie a dit «buvable» ce **matin**?*
‘Did Marie say “buvable” this **morning**?’

*Non. Marie a dit «buvable» cet **après-midi**, pas ce matin.*
‘No, Marie said “buvable” this **afternoon**, not this morning.’

4.4. Acoustic Analysis

The data were segmented and analyzed using Praat. For each vowel, we measured duration, F0, intensity, and vowel centralization. For F0, we measured the overall mean, and the mean of the first and last quarter of the vowel to quantify the contour (i.e., $\Delta F0$: change from first to last quarter). Vowel centralization was measured as the Euclidian distance of the vowel from the center of the vowel space for each speaker. All of the data were Z-normalized to eliminate differences between speakers. We excluded French targets with intended penult stress if the final schwa was not produced.

4.5. Statistical Analysis

The data were statistically evaluated with Binary Logistic Regression Analyses (BLRAs). These analyses tested the statistical significance of the distinction (classification) of stressed vs. unstressed vowels in the penultimate and final syllables. For each language, initial BLRA analyses used all of the acoustic properties to determine to what extent the vowel categories in question were distinguishable / accurately classified (e.g., stressed vs. unstressed vowels in word final position). These analyses also provided information as to whether each property showed a significant difference between the two categories. For each property that did show a significant difference, a follow-up BLRA was run to determine to what extent it could distinguish the categories when used as the sole classifying property.

5. Results

The results presented here are the classification rates provided by our BLRA analyses. The Overall Classification rates are based on the use of the full set of acoustic properties. The Main Classifiers are the two properties that yielded the greatest classification rates when used as the sole classifier; the percentages show the rates of classification achieved by these individual properties.

5.1. Stress Position: canonical vs. non-canonical

The first analysis examines the distinction between the properties of the stressed vowels appearing in the canonical and non-canonical positions for each language (Table 2). In French, Turkish and Armenian, final stress is the canonical pattern and penultimate stress is the non-canonical pattern. In Portuguese, we considered the more frequent penultimate stress to be canonical, and final stress non-canonical.

Table 2: *Comparison of Stressed Vowels in canonical vs. non-canonical position (overall classifications and main classifiers; chance = 50%)*

	Canonical vs. Non-Canonical Stress	
	Overall Classification	Main Classifiers
Turkish	62%	$\Delta F0$ (61%)
Armenian	67%	Int (57%)
French	68%	Int (69%)
Portuguese	69%	Int (68%)

All of the languages exhibit relatively weak overall rates of classification, or distinction, between the stressed vowel in the canonical position and in the non-canonical position. While the classification rates cannot be directly compared across the languages, it is clear that in all cases, there is a similar outcome. This shows that just being in the non-canonical position does not result in a manifestation of stress that is very different from the manifestation of stress in the canonical position.

5.2. Stress Manifestation: canonical vs. non-canonical

We also examined the properties of canonical and non-canonical stress by comparing the acoustic properties responsible for the stress vs. unstressed distinction in each case (Table 3). In Turkish and Portuguese, we tested the distinction between stressed and unstressed /a/ in the final and penultimate syllables, the former being canonical for Turkish,

the latter for Portuguese. Since Armenian and French only permit schwa as the unstressed vowel in the final syllable, we could not make the same comparison for words with penultimate stress; instead, the stressed and unstressed /a/ in the penultimate syllable were compared to gain insight into the manifestation of non-canonical stress.

Table 3: *Comparison of Stressed vs. Unstressed Vowels in canonical and non-canonical positions (overall classifications and main classifiers; chance = 50%)*

	Canonical Stress		Non-Canonical Stress	
	Overall	Main Classif.	Overall	Main Classif.
Turkish	71%	$\Delta F0$ (61%), Int (60%)	66%	F0 (59%), Dur (55%)
Armenian	81%	F0 (77%), $\Delta F0$ (67%)	77%	F0 (72%), $\Delta F0$ (59%)
French	71%	$\Delta F0$ (75%), Dur (61%)	79%	$\Delta F0$ (76%), Int (72%)
Portuguese	81%	Dur (72%), $\Delta F0$ (67%)	88%	Dur (69%), F0 (57%)

Again, it is not possible to directly compare the classification rates across languages; however, the patterns of stress position and manifestation can be examined within each language, and their relationships compared. As can be seen, there is a slight drop in overall classification rates in the non-canonical stress position in Turkish and Armenian, but an increase in French and Portuguese. F0, mean or change, played a major role in the stress distinction in all of the languages; duration and intensity played a role in some cases as well. No single property, however, accounted for the stress distinction very strongly on its own, the strongest being in the canonical (final) stress position in Armenian (77%).

6. Discussion

Predictability has been found to affect the manifestation of a number of linguistic phenomena, altering, for example, duration, F0, and vowel centralization [2, 3, 4]. It has also recently been shown that a number of the same properties, which largely coincide with the acoustic properties associated with stress, are typically less consistently used for cuing stress in languages with predictable (fixed) stress (Hungarian and Turkish), as opposed to those with unpredictable (contrastive) stress (Spanish and Greek) [24]. The difference between predictable and non-predictable stress has also been shown to account for “stress deafness.” While speakers of languages with non-predictable stress readily perceive stress, speakers of languages with fixed stress [12, 13], or more generally predictable stress [25], do not accurately perceive stress.

In the present study, we have more closely examined the manifestation of stress in three languages considered to have fixed stress, but which may also have exceptions. The goal was to determine whether, within a given language, stress in the canonical position is manifested in the same way as stress in a non-canonical, exceptional position. We hypothesized (Hypothesis 1) that the latter, being less usual, and less frequent, would exhibit clearer acoustic cues than the former. The statistical analyses did not, however, confirm this hypothesis, revealing that there was not a high rate of distinction between the final (canonical) and penultimate (non-

canonical) stresses in the fixed stress languages. That is, the acoustic manifestation of stress is not very different in the two positions. A similar rate of distinction was also observed between the default penultimate and the less common final stresses in Portuguese, even though stress is non-predictable, a further indication that canonical position itself does not constitute sufficient redundancy in a language to alter the stress properties.

When we compared the distinction between stressed and unstressed vowels in the canonical position, we found fairly similar, moderate, distinction rates (71% - 81%) across the languages, again, including Portuguese. Where we did observe a difference among the languages, however, was in the distinction between stressed and unstressed vowels in predictable vs. non-predictable positions, confirming Hypothesis 2. It will be recalled that in the stimuli used in the present investigation, the non-canonical stress patterns were predictable in Turkish (morphologically) and Armenian (phonologically). In these languages, the overall stress classification rates actually show a slight decrease in the non-canonical, but nevertheless predictable, penultimate position (5% and 4%). By contrast, in French, where the non-canonical stress was not similarly predictable, arising only in very limited phonological contexts, and additionally being subject to individual variability, there was an increase (8%) in distinguishability in the non-canonical penultimate position. In this respect, French is similar to Portuguese, where stress position is not predictable, and there is also an increase in stress classification (7%) in the non-canonical (i.e., less common) final position. While the specific percentage rates cannot be compared across the languages, what these patterns reveal is that it is the overall predictability of stress in a particular position that affects the clarity of its manifestation. Simply appearing in the canonical position in a (mostly) fixed-stress language does not lead to less clarity in the manifestation of stress, when compared to stress in a non-canonical, but otherwise predictable position.

7. Conclusions

In sum, our investigation of the effect of predictability on the manifestation of stress properties, specifically the role of the canonical position in languages with fixed stress, shows that while predictability does result in less clarity in the distinction between stressed and unstressed vowels, it is not the canonical position of stress *per se* that accounts for the predictability effect. That is, while non-canonical, but predictable, stress does not result in enhancement of the stress distinction, as seen in Turkish and Armenian, the lack of predictability of non-canonical stress, as seen in French, does result in an increase in the distinction. In fact, the unpredictability of penultimate stress in French results in a similar increase in clarity to the unpredictability of the relatively uncommon final stress in Portuguese, a language with non-predictable stress in general. These findings are, moreover, consistent with the previously observed low stress classification rate in Hungarian, where there are no exceptions to initial stress [24]. Finally, with regard to stress deafness, our findings suggest that it is the overall predictability of stress [25], not having a fixed stress position [12, 13], that results in speakers being stress deaf, since Turkish speakers have been found to be similar to French speakers in this regard, although Turkish has notable, but largely predictable, exceptions to its canonical final stress pattern.

8. References

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