# THE ROLE OF STRESS IN SYLLABLE MONITORING

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## ABSTRACT

In a syllable monitoring experiment, Greek and English speakers (N = 20 per language) monitored for [ma] embedded in Greek real and nonce words; [ma] was word-initial, word-medial or word-final, and stressed, unstressed or rhythmically stressed. Both groups spotted stressed [ma] faster than unstressed [ma]; unstressed [ma] was spotted faster by Greek than English participants. Rhythmically stressed [ma] patterned with unstressed [ma] for both groups. Word category (real or nonce) did not affect latencies. These results show that stress played an important role whether participants were responding to unfamiliar (nonce) stimuli (Greeks) or processing in an altogether unfamiliar language with different stress requirements (English). The importance of stress did not depend on rhythm class, as has sometimes been argued, though familiarity with language did affect responses. The results do not support the view that processing is related to rhythm class and confirm that Greek makes only a binary stress distinction.

**Keywords**: syllable monitoring, stress, Greek, English, rhythm class, rhythmic stress

## 1. INTRODUCTION

Performance in syllable monitoring is said to be affected by rhythm class: speakers of languages like English, considered stress-timed, adopt a stress-based strategy, while speakers of languages like French, considered syllable-timed, adopt a syllable-based approach (see [8] and references therein). However, not all results tally with this view. Research on French indicates that CV syllables are not spotted faster in French nonce words than CVC fragments spanning a syllable boundary [14, 20, 21]. On the other hand, research on Spanish indicates that stress does play a part in processing, even though Spanish is said to be syllable-timed [27, 28]. Despite results like these, there is relatively little research examining the role of stress in languages which, like Spanish, are said to be syllable-timed but have stress.

Here we tested Greek and English participants to examine whether stress plays a part in processing in both languages, independently of purported rhythm class affiliation: English is considered the stress-timing prototype [1], while Greek is often classed as syllable-timed [6]. Previous studies [8, 9, 10, 22] have suggested that this difference is crucial during processing, leading English participants to focus on stressed syllables, to which they respond faster. The same would not be expected to apply to Greek participants under this view.

Collecting responses from both Greek and English participants allowed us to also examine the role of different stress cues in syllable monitoring. English stress relies largely on vowel quality distinctions [7], while such differences are minor in Greek which relies mostly on differences in duration and amplitude to encode primary stress [4]. This difference allowed us to test whether previous results from English, such as [9], apply not only with nonce stimuli based on English but also with stimuli that clearly sound different and unfamiliar to English ears; this applies both to the words overall and to the target [ma] which is not an optimal example of a stressed syllable in English as its vowel is close to English [ʌ] in quality.

In addition, Greek has been previously described as having not only primary stress (which is lexically determined [26]) but also *rhythmic stress*. Rhythmic stresses are said to be used postlexically to break up sequences of unstressed syllables and thus remedy lapses that lead to dysrhythmy [18, 23, 24]; cf. [16]. For instance, a word like /siðiˈroðromos/ “train” is said to be produced with a rhythmic stress on its initial syllable, *viz*. [ˌsiðiˈroðromos]. The phonetic and phonological existence of such stresses has been disputed however [2, 3]; see [4] for a review. A second aim of the experiment then was to determine whether rhythmic stresses play any part in processing. If so, this would imply a phonetic presence of rhythmic stress that had previously been undetected; the effect of rhythmic stresses should be evident at least in the responses of the Greek participants.

## 2. METHOD

### 2.1. Participants

Twenty speakers of each language took part in the experiment as volunteers. The Greek participants (16 female) were native speakers of Standard Athenian Greek; their average age was 20. The English participants (14 female) were native speakers of Standard Southern British English; their average age was 22. None of the British speakers had any knowledge of Greek. No participant reported any history of speech or hearing disorders. They were all naïve as to the purposes of the experiment.

### 2.2. Stimuli

The syllable monitored for was [ma] which was embedded in real Greek and nonce words. One set of stimuli (henceforth the *primary stress set*) were three syllables long. The target syllable [ma] was either unstressed or had primary stress; [ma] was in word-initial, word-medial or word-final position (see Table 1). Word-initial and word-medial unstressed syllables were adjacent to a stressed one. There were three stimuli per condition for a total of 36 stimuli.

A second set of stimuli (henceforth the *rhythmic stress set*) was devised to include words said to carry rhythmic stress in addition to their primary lexical stress. These stimuli were either three or four syllables long, with [ma] being in the first or second syllable respectively. Primary stress was on their ultima, leading to the prediction that word-initial [ma] in three-syllable words and antepenultimate [ma] in four-syllable words would carry rhythmic stress [18, 23]; e.g. [ˌmaɣaˈzi], [ziˌmariˈka]. As with the primary stress set, there were three stimuli per condition, for a total of 12 stimuli. All had a CV syllable structure.

The materials from which the stimuli were selected were elicited from a native speaker of Standard Greek who had phonetic training but was not involved in the experiment. She produced two repetitions of each stimulus; the one judged most natural by the first author was selected for the experiment.

### 2.3. Procedure

The experiment was run in a sound-treated room at the University of Kent using DMDX software on a laptop. Participants listened to the stimuli in stereo using a pair of good quality headphones. Written instructions were provided on the screen in the participant's native language. Each session started with a short practice. Participants were instructed to press a dedicated button on an *X-box 360* controller (adjusted to suit participant handedness) as soon as they heard [ma]. Individual randomisation lists were used. Each trial started with a 440 Hz tone of 0.5 s duration; there were 0.5 s of silence between tone and stimulus. Reaction times (RTs) were recorded; the cut-off for responses was set to 4 s.

The instructions to the Greek participants explained they would hear Greek real and nonce words. The instructions to the English participants explained that the stimuli were not English, but did not mention what language they came from or that two types of words were involved.

**Table 1**: Summary of the main experimental design and examples of stimuli.

| **Stress** | **Position** | **Word category** | |
|---|---|---|---|
| | | **real** | **nonce** |
| stressed | initial | ˈmaɣulo “cheek” | ˈmapina |
| | medial | doˈmata “tomato” | vuˈmani |
| | final | lukuˈma “dumpling, ACC.” | vuluˈma |
| unstressed | initial | maˈruli “lettuce” | maˈpani |
| | medial | ˈrimata “verb, PL.” | ˈsumana |
| | final | ˈðoloma “bait” | ˈðokema |

### 2.4. Predictions

Following the rhythm class argument, we predicted that Greeks would respond equally fast to both stressed and unstressed [ma], while English listeners would detect stressed [ma] faster than unstressed [ma]. Further, if monitoring for syllables is lexically facilitated, we would expect to find an interaction of language and word category such that English participants would respond more slowly overall and Greeks would show an effect of word category and respond faster to real than nonce stimuli. We would not expect to find a real word advantage in Greek if the task tapped a prelexical, acoustically guided process. In this case, we might find a main effect of language since Greeks were listening to familiar acoustic patterns while English participants were not.

For the rhythmic stress set, RTs to [ma] with rhythmic stress were compared to those of stressed and unstressed [ma]: three-syllable stimuli like [ˌmaɣaˈzi] were compared to stimuli like [ˈmaɣulo] and [maˈruli] in which [ma] is either stressed or unstressed, respectively. If rhythmic stress has phonetic reality, the [ma] of [ˌmaɣaˈzi] should be detected as fast as the stressed [ma] of [ˈmaɣulo] or at least faster than the unstressed [ma] of [maˈruli]. The same hypothesis applied to stimuli like [ziˌmariˈka] with respect to stimuli like [doˈmata] and [ˈrimata] in which [ma] is in second position from word onset and stressed or unstressed respectively.

### 2.5. Statistical analysis

Reaction times were measured in ms from the onset of [ma], and non-responses, premature responses and outliers (± two standard deviations) were removed. Preliminary inspection of the results indicated that there was a positive correlation between RTs and the duration of [ma] which varied depending on stress and position (cf. [13]). To address this issue, the RT values were normalized and expressed as ratios of time with reference to [ma] onset (set to 0) and offset (set to 1).

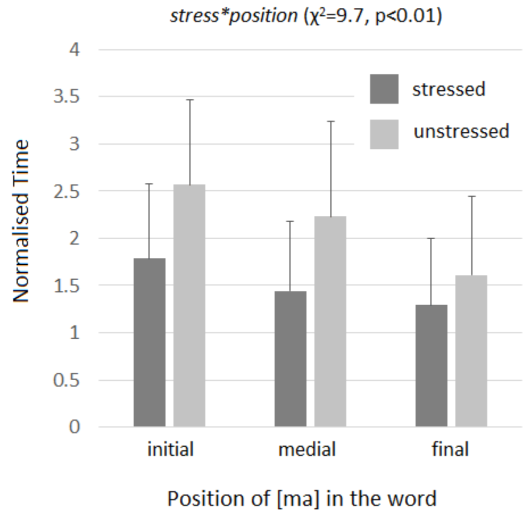
Linear mixed-effects models were fitted to the data in R 3.1.0. For the primary stress set, *participant language* (Greek, English) and the three experimental manipulations – *word category* (real, nonce), *position* (initial, medial, final) and *stress* (stressed, unstressed) – were fitted as predictors; *stimulus* and *participant* were random effects.

To test the relevance of rhythmic stress, additional models were fitted to RTs in response to the stimuli with rhythmic stress and their counterparts with stressed and unstressed [ma] (see 2.4). The same predictors and random effects were used except that *stress* now had three levels, stressed, unstressed, and rhythmically stressed.

## 3. RESULTS

For the primary stress set, we found two significant interactions: *stress*position* [$\chi^2 = 9.7$, $p < 0.01$; Figure 1] and *language*stress* [$\chi^2 = 10.7$, $p < 0.01$; Figure 2]. Contrary to our hypothesis, *word category* (real vs. nonce) did not have an effect on RTs.

**Figure 1**: Means and standard deviations of normalised RTs for the interaction of lexical stress and position of the syllable within the word.




As shown in Figure 1, both Greek and English participants were slower to monitor for unstressed than stressed [ma] regardless of its position in the word [$t > 3.3$; $p < 0.01$]. Position did affect RTs in slightly different ways depending on stress. Word-initial *stressed* [ma] was processed particularly slowly compared to medial and final position [$t > 3.1$, $p < 0.01$], but there was no difference between medial and final [ma] [$t = 1.2$, *n.s.*]. Unstressed [ma] was spotted most slowly word-initially [$t = 3.1$, $p < 0.01$] and fastest word-finally [$t = 5.2$, $p < 0.001$].

Figure 2 displays the interaction of listeners' native language and stress, showing that Greek participants were slightly faster to monitor for unstressed [ma] than English participants [$t = 3.1$, $p < 0.01$]. There was no difference for stressed syllables.

**Figure 2**: Means and standard deviations of normalised RTs illustrating the interaction of listeners' native language and lexical stress.

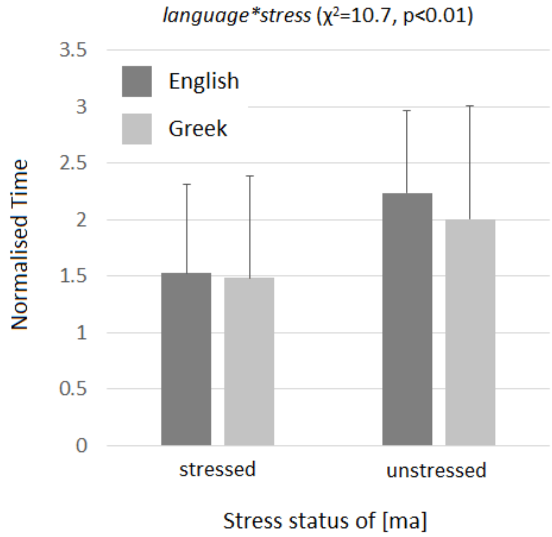
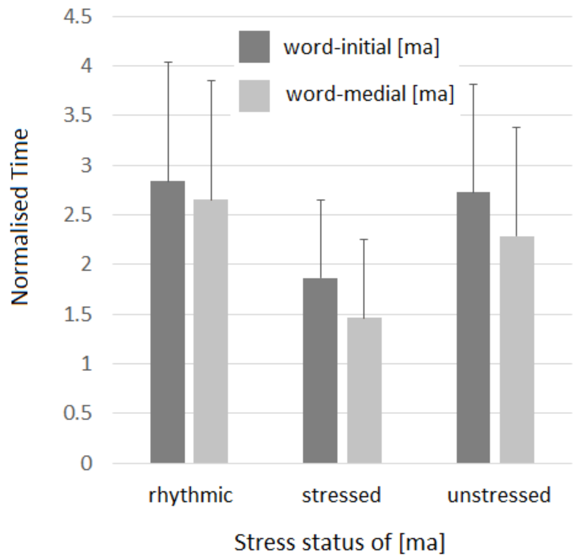



**Figure 3**: Means and standard deviations of normalised RTs for the main effect of stress status in stimuli with word-initial and word-medial [ma].



The models testing for a three-way distinction of stress (stressed, unstressed and rhythmic stress) produced only a main effect of stress for both word-initial and word-medial rhythmically stressed [ma] [$\chi^2 = 18.8$, $p < 0.001$, and $\chi^2 = 32.5$, $p < 0.001$ respectively]. In word-initial position, rhythmically stressed [ma] was processed more slowly than stressed [ma] [$t = 4.4$, $p < 0.001$], but not differently from unstressed [ma] [$t = 0.5$, *n.s.*]. See Figure 3. A very similar effect was observed for words with word-medial rhythmically stressed targets. In this case, RTs were slower for rhythmically stressed [ma] in comparison to both stressed and unstressed [ma] [$t = 8.9$, $p < 0.001$, and $t = 2.8$, $p < 0.05$ respectively].

## 4. DISCUSSION

These results show that stress played an important role in the processing of both groups of participants. Both English participants, who were processing in an altogether unfamiliar language, and Greek participants, who were responding to both real and nonce stimuli, responded faster to stressed than unstressed targets. This result supports the original prediction that stress is crucial for processing in all languages that have it regardless of putative rhythm class; cf. [5, 11, 27]. These results add to a host of studies showing that despite some evidence linking fragment monitoring responses to rhythm class ([9, 10, 22, 29]), such results do not hold for all studies and all types of stimuli. This suggests that the explanation for previous findings has to be sought elsewhere, not in rhythm class affiliation. The lack of word category effect found here (real vs. nonce) was also reported in other studies (cf. [14]) and indicates that processing in this task is bottom-up and thus relies mostly on phonetic cues.

Possibly for that same reason, the results did not support the prediction that English participants would respond more slowly overall in comparison to Greek participants. By comparison to related studies such as [14], both groups had short and similar latencies: English participants' average RT was 398 ms and that of Greek participants 372 ms. This is an interesting result as it shows that English participants responded fast even to stimuli that, based on their experience, should be suboptimal. There was only a small effect of language, in that Greek participants spotted unstressed syllables faster than English participants (but still more slowly than stressed syllables). This could be seen as *prima facie* evidence of the greater role of stress in English. However, alternative interpretations are also possible. First, since the stimuli were citation forms, F0 cues to stress were strong; this could have facilitated processing by the English participants (cf. [15]). Second, language knowledge may have been an advantage to the Greek participants. Additional experiments, e.g. with F0 cues removed and additional types of targets, could be used to test these alternative explanations.

In addition to the stress effect, the results also showed an effect of position of the target syllable, such that [ma] was detected most slowly in initial position for both stressed and unstressed syllables. This result, which does not appear to be affected by language or stress, is in line with predictions of the dynamic attending theory according to which listeners' attention is strongly locked to more salient events [17, 22]. As early events are less expected than late events, the former receive less attention and this, in turn, negatively affects their processing (cf. [19]).

The responses to the stimuli with purported rhythmic stress, on the other hand, clearly show that this type of stress does not have any phonetic reality that can help participants during processing. Phonetic cues to rhythmic stress have not been detected in previous acoustic studies (see [2, 3]). If there were any in the present stimuli, they were clearly not salient enough to be used by either Greek or English participants. This result indicates that syllables said to be rhythmically stressed in Greek are processed no differently than unstressed syllables, casting further doubt on the notion of rhythmic stress in Greek (cf. [2, 3, 4]).

## 5. CONCLUSION

In conclusion, the results show that speakers of a language said to be syllable-timed do use stress as a cue in processing and so do as effectively as speakers of English, the prototypical stress-timed language. These results strongly indicate that this putative distinction into rhythm classes does not have an effect on processing. Further, the results on rhythmic stress, by showing that it is not used for processing in Greek, lend further support to the view that, contrary to phonological analyses, Greek makes only a binary distinction between lexically stressed and unstressed syllables.

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