The Acquisition of Stress-Clash Resolution Strategies in Greek

Angeliki Athanasopoulou

1. Introduction

A stress clash arises when two consecutive syllables are stressed within the same phonological domain (e.g., phonological phrase). For example, the phrase *thirteen balloons* in (1), has no stress clash, since there is an unstressed syllable (marked with “-”) between the two stressed syllables (marked with “*”). The phrase *thirteen sofas* in (2), however, has a stress clash, since the two stressed syllables are next to each other.

(1) Phrase with no stress clash:

\[
\text{- * - *} \\
\text{thirteen balloons}
\]

(2) Phrase with stress clash:

\[
\text{- * * -} \\
\text{thirteen sofas}
\]

Languages tend to avoid stress clashes, but when they arise, two main resolution strategies are used: (a) the Rhythm Rule and (b) Space Insertion (Liberman & Prince, 1977; Nespor & Vogel, 1989; Selkirk, 1984). Each strategy is discussed below in more detail. Both strategies involve above-the-word prosodic domains (e.g., Nespor & Vogel, 1986), since we only have stress clash and the use of clash resolution strategies when the two stresses are within the same phonological phrase (Vogel, Bunnell, & Hoskins, 1995). For example, the word *thirteen* has a stress clash with the following word *clients* in (3), but not with *conned* in (4), even though, in both cases, the two stressed syllables are adjacent. The difference between the two phrases is that the two words belong to the same phonological phrase (PhP) in (3), but they are in a different PhP in (4). The examples are from Vogel and colleagues (1995).

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The question that is relevant for language acquisition is when exactly clash resolution is acquired. Prosody is one of the first language properties that babies are sensitive to (e.g., Jusczyk & Thompson, 1978; Mehler & Christophe, 1995; Nazzi, Bertoncini, & Mehler, 1998; Ramus, 2002; Weber, Hahne, Friedrich, & Friederici, 2004), but not all prosodic patterns are acquired at the same time. Word-level prosody (e.g., word stress) is acquired in the first 2-3 years (e.g., Kehoe, Stoel-Gammon, & Buder, 1995; Schwartz, Petinou, Goffman, Lazowski, & Cartusciello, 1996), but the acquisition of above-the-word prosody may not be complete until the early teenage years (e.g., Athanasopoulou, 2016; Dankovičová, Pigott, Wells, & Peppé, 2004; Shilling, 2010; Vogel & Rainy, 2002; Wells, Peppé, & Goulandris, 2004). We would therefore expect that the acquisition of clash resolution, which involves above-the-word prosodic domains, would be delayed compared to the acquisition of word stress. Indeed, for English, where the Rhythm Rule is the main clash resolution strategy, its acquisition is not complete by the age of 7 years (Goffman, Heisler, & Chakraborty, 2006; Shport & Redford, 2014). Greek, however, differs from English since it primarily uses Space Insertion, and only to a lesser extent the Rhythm Rule as clash resolution strategies (Arvaniti, 1991; 1994; 2000; 2007; Nespor & Vogel, 1989). We do not know, however, when the strategies are acquired in Greek, since there is no study on the acquisition of Greek clash resolution. It is possible, that both develop similarly and Greek too exhibits delayed acquisition, since stress-clash resolution is an above-the-word pattern, in both languages. Since the strategies differ between the languages, however, it is also possible that the developmental trajectories differ as well. The present study tests these possibilities by examining the acquisition of Greek clash resolution between the ages of 6 and 11 years.

2. Stress-clash resolution strategies

The first stress-clash resolution strategy we discuss is the Rhythm Rule. When the Rhythm Rule applies, the left (first) stress of the phrase is reduced, which is often perceived as movement of the stress to the left of the word (Grabe, & Warren, 1995; Vogel et al., 1995). For example, phrase (2) after the application of the Rhythm Rule is produced as in (5). Even though there is no strengthening of the unstressed syllable of the first word (thir in our example), listeners perceive a shift of stress to the left. So, in example (2), thirteen is perceived as THIRteen and not thirTEEN (capital letters = stressed syllable).
The other strategy for stress-clash resolution is Space Insertion. With this strategy, when there is a stress clash, speakers insert space (i.e., time) between the two consecutive stresses. This space can be a pause between the two stresses, or longer duration of the segments between them (Nespor & Vogel, 1989). This is presented schematically in (6).

What is considered stress clash and which clash resolution strategy is used differs depending on the language (Nespor & Vogel, 1989). For example, in English, the clash resolution strategy is the Rhythm Rule and it applies at the phrasal level (Gussenhoven, 1991; Liberman & Prince, 1977; Nespor & Vogel, 1989; Selkirk, 1984). With respect to acquisition, there are two main studies on English clash resolution strategies (Goffman et al., 2006; Shport & Redford, 2014), where a condition with stress clash is compared to a condition with no stress clash, in the productions of 4- to 7-year-old children and adults. In both studies, even the oldest children did not exhibit any stress-clash resolution strategies, since the clash and no-clash phrases did not differ in duration, intensity, or F0. In English, therefore, children as old as 7 years have not yet acquired the Rhythm Rule and do not show evidence of clash resolution. That said, it remains unclear when it is acquired.

It is important to note here, that the adult data were not very clear either, with the adults also showing little difference between the conditions. This could be because the application of clash resolution strategies is optional, at least partially due to speech planning limitations (Tilsen, 2012). So, it is possible that the result of late acquisition of English clash resolution is an artifact of the optionality of clash resolution, and clash resolution is in fact acquired earlier than 7 years of age.

Greek differs from English, since the main clash resolution strategy is Space Insertion and secondarily the Rhythm Rule, but similarly to English, the clash resolution strategy remains a phrasal pattern (Arvaniti, 1991; 1994; 2000; 2007; Nespor & Vogel, 1989). Unfortunately, there are no studies to date that examine the acquisition of clash resolution in Greek, so we do not know when it is acquired and whether the two strategies develop differently. In fact, there are very few studies on the acquisition of Greek prosody, in general (Arvaniti, 2007; Mennen & Okalidou, 2007). Greek word stress, is acquired in the first 3 years of life, like English (Tzakosta, 2004; Kappa, 2000). Above the word, clitic and phrasal stress are acquired before the age of 8 years (Athanasopoulou, 2016).
3. Current Study

The present study is the first to test the acquisition of Greek clash resolution strategies, and one of the few on the acquisition of Greek prosody. We examine the production of phrases by 6- to 11-year-old children and adult speakers of Greek. Based on the phonological structure of Greek phrases and the findings for English clash resolution strategies (Goffman et al., 2006; Shport & Redford, 2014), there are three possibilities for the results of the current study: (i) Since in both, English and Greek, clash resolution involves prosodic constituents above the word, both languages might develop similarly and Greek children might not be able to produce the adult clash resolution strategies at least until the age of 7 years. (ii) If, however, the English result of late acquisition is an artifact of the experimental paradigm used, it is possible that Greek clash resolution strategies are actually acquired before the age of 7 years. (iii) On the other hand, since the two languages differ in the strategies used for clash resolution, it is possible that the developmental trajectories in the two languages differ and Greek children might show early development of Space Insertion, the strategy that English does not use. To investigate the three possibilities, the present study investigates the acquisition of clash resolution in Greek, between the ages of 6 and 11 years.

4. Method
4.1. Participants

Data were collected from 11 adults, eight 6-year-olds (M=6.9 years), eleven 8-year-olds (M=8.7 years), and ten 11-year-olds (M=11.5 years). All speakers were monolingual native speakers of Greek (the standard dialect spoken in Athens). No language, hearing, or cognitive problems were reported.

4.2. Stimuli

The stimuli consisted of ten adjective-noun phrases. The second word (noun) was always stressed on the initial syllable. For half of the phrases, the first word (adjective) was stressed on the final syllable, creating a stress-clash context (7), while for the other half, the first word was stressed on the initial syllable, creating a no-clash context (8). The phrases were produced in a sentence that placed the phrases in the middle of the sentence to avoid sentence-edge prosodic effects (see Table 1 (c) for an example).

(7) Phrase with no stress clash:
    * _ *
    mavro nixi ‘black nail’

(8) Phrase with stress clash:
    _ * *
    xriso daxtilo ‘gold finger’
4.3. Procedure

The experiment was introduced to the participants as a short game. They were asked to help an experimenter complete a poster by correctly matching the (colored) pictures based on what they would see on the screen of the computer. In each trial, there were three steps: (a) The participants would see the target item on the screen, and they would name it; (b) they would see the item on a background picture (a place) and they would name the place; (c) they would say to the experimenter how to complete the poster. An example is given in Table 1. The production from the last step, where the participants produce the target phrase in a sentence is the production that is analyzed. In that last step, the target phrase is not new information (already mentioned in step a) and thus, it is not produced with emphasis or focus, avoiding additional prosodic effects on the targets.

Table 1. Example of the trial for *xriso daxtilo* (‘gold finger’).

<table>
<thead>
<tr>
<th>Trial Steps</th>
<th>Visual Stimuli</th>
<th>Example of productions by participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Name target item</td>
<td>![Hand image]</td>
<td><em>Ena xriso daxtilo.</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>‘A gold finger.’</td>
</tr>
<tr>
<td>(b) Name background</td>
<td>![Bridge image]</td>
<td><em>Ine sti gefira.</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>‘It is on the bridge.’</td>
</tr>
<tr>
<td>(c) How to complete the poster</td>
<td>![Bridge image]</td>
<td><em>Vale to xriso daxtilo sti gefira.</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>‘Put the gold finger on the bridge.’</td>
</tr>
</tbody>
</table>

4.4. Analysis

Acoustic measurements of duration, mean F0, F0 change (F0 vowel end - F0 vowel beginning), and intensity were made with Praat for the stressed vowels of both words in each phrase. For example, for the target phrase *xriso daxtilo* ‘gold finger’ (2), the [o] and [a] are analyzed. An example is given in Figure 1.
Figure 1. The waveform and spectrogram of the phrase *xriso daxtilo* (‘gold finder’) produced by an adult. The target vowels [o, a] are marked on the first line. The white line on the spectrogram is the pitch track.

The data were z-normalized by speaker and analyzed statistically with MANOVA. The dependent variables were the four acoustic measurements and the independent variables were Age (four age groups), Clash (phrase with no clash vs. phrase with clash), and Word (word 1 vs. word 2 of the phrase).

5. Results

The MANOVA revealed no effect of Age ($F(15,2202) = .923, p > .05$), but a main effect of Clash ($F(5,732) = 13.879, p < .01$) and Word ($F(5,732) = 46.141, p < .01$). A follow-up ANOVA shows that three of the four acoustic measurements were significant for those effects: Duration (Clash, $F(1,736) = 5.662, p < .05$; Word, $F(1,736) = 38.472, p < .01$), mean F0 (Clash, $F(1,736) = 22.819, p < .01$; Word, $F(1,736) = 5.847, p < .05$), and F0 change (Clash, $F(1,736) = 34.206, p < .01$; Word, $F(1,736) = 130.393, p < .01$). The MANOVA also revealed two significant interactions between the independent variables: Interaction between Age and Word ($F(15,2202) = 1.77, p < .05$), and between Clash and Word ($F(5,732) = 12.786, p < .01$). A follow-up ANOVA showed significant results for mean F0 ($F(3,736) = 2.743, p < .05$) and F0 change ($F(3,736) = 4.692, p < .01$) for the first interaction and for mean F0 ($F(1,736) = 20.531, p < .01$) and mean Intensity ($F(1,736) = 10.33, p < .01$) for the second interaction. There is no significant interaction between Age and Clash ($F(15,2202) = .639, p > .05$) or between Age, Clash, and Word ($F(15,2202) = .59, p > .05$).

From these results, we see that all the independent variables affect the results. Also, from the four acoustic measurements, it is duration and F0 that play the most important roles, while intensity was also significant. We further discuss only the results for duration and F0 due to space limitations. To better understand the
significant main effects and interactions, simple t-tests were performed for each age group and each acoustic measurement.

5.1. Adults

We start with the adults, which can be considered the target of children’s development. Figures 2 and 3 show that in phrases with no stress clash, the second word’s stressed vowel (V2 henceforth) is longer ($t(107)=-2.967, p < .005$) and with higher F0 ($t(105)=-2.974, p < .005$) than the first word’s stressed vowel (V1 henceforth). In phrases with stress clash, on the other hand, the duration difference between V1 and V2 is eliminated ($t(107)=-1.741, p > .05$), with V1 being lengthened. The F0 difference between the two stresses, however, remains similar ($t(105)=-6.865, p < .001$), but V1 has lower F0 in the clash phrases than in the no clash phrases ($t(105)=3.045, p < .005$).

Overall, we see the two expected stress-clash resolution strategies in the adult phrases: (a) Space Insertion: lengthening of V1, i.e., the insertion of space between the two stresses and (b) Rhythm Rule: V1’s lowering in F0, i.e., the reduction of the phrase’s left stress. Next, we discuss each strategy separately with respect to each child group.

5.2. Clash Resolution Strategy 1: Space Insertion

To test the Space Insertion strategy in children, we look at the duration of the children’s productions, shown in Figure 2. The data from the youngest group (6-year-olds) show that for both no-clash and clash phrases V1 and V2 are equally long (no clash: $t(77)=-1.643, p > .05$; clash: $t(65)=-1.408, p > .05$). So, the 6-year-olds exhibit no manipulation of time with or without clash, which means that they do not exhibit the adult Space Insertion strategy. In the 8- and 11-year-olds’ data, V2 is longer than V1 in the no-clash phrases (8-year-olds: $t(102)=-3.204, p < .005$; 11-year-olds: $t(96)=-3.629, p < .001$), but the two vowels do not differ when there is stress clash (8-year-olds: $t(101)=-1.955, p > .05$; 11-year-olds: $t(98)=-.931, p > .05$). So, the two older groups lengthen V1, exhibiting the adult Space Insertion strategy.
To summarize the results from all the groups of children, we only found the Space Insertion strategy in the 8- and 11-year-olds, while the 6-year-olds exhibited no manipulation of time for clash resolution.

5.3. Clash Resolution Strategy 2: Rhythm Rule

To test the Rhythm Rule strategy in children, we consider the F0 change patterns of their productions, shown in Figure 3. In the 6-year-olds’ productions, V2 has higher F0 than V1 in no-clash phrases ($t(76) = -2.826, p < .01$), but V1 and V2 do not differ in F0 in clash phrases ($t(63) = -0.644, p > .05$). Also, V2 has lower F0 in clash phrases than in no-clash phrases ($t(67) = 2.721, p < .01$). So, V2 and not V1 stress is reduced in stress clash for the 6-year-olds, exhibiting the opposite from the adult Rhythm Rule strategy, what we will call the Reverse Rhythm Rule.

For the 8-year-olds, V2 has higher F0 than V1 in both, no-clash ($t(97) = -6.138, p < .001$) and clash phrases ($t(96) = -3.961, p < .001$), but the two phrases differ in F0. Specifically, V2 has higher F0 in no-clash than clash phrases ($t(94) = 2.881, p < .01$). So, the 8-year-olds, like the younger group, reduce V2 stress and not V1, exhibiting the Reverse Rhythm Rule.

Finally, the 11-year-olds produce a higher F0 in V2 than in V1 for both, no-clash ($t(96) = -6.160, p < .001$) and clash phrases ($t(98) = -6.242, p < .001$). Like the two younger groups, V2 has higher F0 in no-clash than in clash phrases ($t(96) = 2.210, p < .05$), but for the 11-year-olds, V1 has higher F0 in no-clash than clash phrases too ($t(98) = 4.393, p < .001$). So, the 11-year-olds reduce V1 stress,
exhibiting the adult Rhythm Rule strategy, but they also reduce V2 stress, exhibiting the Reverse Rhythm Rule used by younger children.

Figure 3: Normalized (Z-scores) F0 change of the stressed vowels in each word in the phrases in the two clash conditions for each age group: No-Clash Vowel 1 (e.g., mávri míti), No-Clash Vowel 2 (e.g., mávri míti), Clash Vowel 1 (e.g., xrisó dáxtilo), and Clash Vowel 2 (e.g., xrisó dáxtilo). Stars indicate significant differences (p < .05) and the error bars show the standard error of the mean.

To summarize the results from all groups of children, we only found the Rhythm Rule strategy in the 11-year-olds, while the 6-, 8-, and 11-year-olds exhibited the non-adult strategy of reducing the right stressed vowel, the Reverse Rhythm Rule. Note that the 11-year-olds exhibit both the Rhythm Rule and the non-adult strategy.

6. Discussion

The present study investigated the acquisition of Greek clash resolution between the ages of 6 and 11 years by examining the productions of children and adults. We found two clash resolution strategies in adults: (a) Lengthening of the left stressed vowel (Space Insertion) and (b) the reduction of the left stressed vowel (Rhythm Rule). The adult data confirm the use of Space Insertion and the Rhythm Rule in Greek as clash resolution strategies (Arvaniti, 1991; 1994; 2000; 2007; Nespor & Vogel, 1989). This finding confirms that the experiment was successful in eliciting clash resolution strategies.

With respect to the acquisition of clash resolution, since this is the first study to test the acquisition of the strategies in Greek, three possible predictions were a priori identified based on English acquisition and the phonological structure of
Greek phrases: (i) Greek children, at least until the age of 7 years, are not able to produce any clash resolution strategies; (ii) Greek children can produce both clash resolution strategies before the age of 7; (iii) Greek children show early development for Space Insertion, but not for the Rhythm Rule. The results show that both strategies are acquired after the age of 7 years, supporting prediction (i) and not (ii), but the two strategies develop differently, with Space Insertion being acquired earlier than the Rhythm Rule, partially supporting prediction (iii). Specifically, Space Insertion is used by children at the age of 8 years and older, while the Rhythm Rule is only used at 11 years. At the age of 11 years, however, we also find the non-adult Reverse Rhythm Rule strategy that the younger children use. Neither of the two adult strategies is used by the 6-year-olds. Table 2 summarizes the results (✓ = produced; ✗ = not produced).

**Table 2. Summary of results.**

<table>
<thead>
<tr>
<th>ADULT STRATEGIES</th>
<th>6-year-olds</th>
<th>8-year-olds</th>
<th>11-year-olds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Insertion (lengthening of left stress)</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Rhythm Rule (reduction of left stress)</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NON-ADULT STRATEGY</th>
<th>6-year-olds</th>
<th>8-year-olds</th>
<th>11-year-olds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reverse Rhythm Rule (reduction of right stress)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Overall, Greek children do not exhibit the full adult behavior (Space Insertion and the Rhythm Rule) by 11 years. The oldest children in the study (11-year-olds) are the only group that exhibits both adult strategies, but they also exhibit a non-adult strategy found in the younger children. The development of clash resolution in Greek is protracted, similar to the late development of English clash resolution (Goffman et al., 2006; Shport & Redford, 2014). This shows that the English acquisition results are not just an artifact of experimental paradigms due to the optionality of clash resolution, but that indeed, clash resolution strategies are acquired in late childhood. The results, also agree with the acquisition timeline of other above-the-word prosodic patterns, which are acquired late: For instance, English compound prosody (Athanasopoulou, 2016; Dankovičová et al., 2004; Shilling, 2010; Vogel & Raimy, 2002) and Greek clitic prosody (Athanasopoulou, 2016) are acquired around the age of 11 years, while Greek and English phrasal prosody (Athanasopoulou, 2016) are acquired after 11 years, and intonation is acquired at around 13 years (Wells et al., 2004). In contrast, word-level prosody is acquired much earlier: English and Greek word stress are acquired by 3 years (Kappa, 2000; Kehoe et al., 1995; Schwartz et al., 1996; Tzakosta, 2004), and
Greek compound stress is acquired before the age of 6 years (Athanasopoulou, 2016, Tzakosta & Manola, 2012).

The difference in acquisition of word-level and above-the-word level prosodic patterns supports the hypothesis that the phonological structure of the prosodic patterns influences their acquisition (Athanasopoulou, 2016; Demuth & Fee, 1995; Demuth & McCullough, 2009; Demuth & Tremblay, 2008; Vogel & Raimy, 2002). We also see, however, that prosodic patterns with the same phonological structure may develop differently. In the present study, both clash resolution strategies belong to the phrasal level, with the same phonological structure, but they do not develop similarly. Specifically, we found that Space Insertion is acquired at the age of 8 years, while the Rhythm Rule is not completely acquired by 11 years. This difference indicates that it is not only the phonological structure that plays a role in prosodic development, but also the way the phonological structure is realized in the output. In the case of Space Insertion, children have to learn to manipulate the duration of the stressed vowel on the left so that it becomes even longer and in a way further enhanced compared to that in the no-clash phrases. In the case of the Rhythm Rule, children have to learn to manipulate the pitch of the left stressed vowel so that it has lower pitch and become reduced. The difference between the two strategies could be because time manipulation is easier for children to master than pitch manipulation, or it might be easier to enhance a unit than to reduce it.

7. Conclusions

To summarize, Greek children do not exhibit the full adult behavior (Space Insertion and Rhythm Rule) even at the age of 11, showing a protracted development of clash resolution. The same protracted development is also found for English clash resolution. Taken together, the English and Greek results fit in a general pattern of protracted development for prosodies that involve phonological structures that are more complex than single words (e.g., English compound stress, Greek clitic prosody, intonation, etc.). The results support the hypothesis that the phonological structure of prosodic patterns influences their acquisition. Although prosody is one of the first language properties young babies are sensitive to, the internalization of prosody into the phonological system develops gradually and much later than previously thought, likely developing until the early teenage years.

References


