

LEXICAL STRESS CONTRASTIVITY IN TYPICALLY DEVELOPING ITALIAN CHILDREN

Joanne Arciuli¹ and Lucia Colombo²

¹ The University of Sydney, Australia, joanne.arciuli@sydney.edu.au

² The University of Padova, Italy, lucia.colombo@unipd.it

ABSTRACT

There has been substantial progress in understanding the production of individual speech sounds. Much less is known about prosodic aspects of speech production. Lexical stress is the prosodic contrast between strong and weak syllables within single words (compare ‘INcense’ with ‘inCENSE’ in English). The ability to achieve stress contrastivity during speech production shows a protracted developmental trajectory in healthy children and can be atypical in some individuals within certain populations (e.g., autism spectrum disorders). Almost all previous research in this area has examined speakers of English. One important gap in our understanding is whether lexical stress production seen in typically developing children is similar across languages. Here we provide new data regarding lexical stress production in typically developing Italian children (3-5 years), and a comparison with published data from English speaking children.

Keywords: speech production, lexical stress, prosody, acoustic, pairwise variability index, PVI.

1. INTRODUCTION

Neither English nor Italian have a fixed pattern of lexical stress. However, the dominant pattern of lexical stress in Italian is different from the dominant pattern of lexical stress in English. In Italian stress tends to be placed on the penultimate syllable of words. Thus, unlike English, the majority of Italian trisyllabic words begin with a weak syllable (‘coTOne’). A recent corpus analysis indicated that only 15% of trisyllabic Italian word types start with a strong syllable (‘CUpola’) [1]. Other estimates are slightly higher, around 20% [2].

In normal speech strong syllables can be realized acoustically in terms of vowel duration (ms), vowel intensity (peak amplitude in dB), and vowel fundamental frequency (f_0 : peak fundamental frequency in Hz). When it comes to examining stress contrastivity the focus is on the acoustic changes across adjacent syllables. A measure of *relative change* (contrastivity) in stress across adjacent

syllables, such as the Pairwise Variability Index (PVI: [3]), is more robust than absolute measures in terms of accommodating the ambient recording environment and individual differences amongst speakers (e.g., speaking rate; emotional state). The PVI is preferable to other relative measures, such as the lexical stress ratio (LSR: [4]) because it allows analysis of the 3 key acoustic variables separately.

An acoustic study of typically developing English speaking Australian children that used PVIs revealed that production of trisyllabic words beginning with a strong syllable (e.g., ‘BUtterfly’) is mastered in early childhood. By contrast, adult-like mastery of words beginning with a weak syllable (e.g., ‘poTAto’) continues beyond 7 years [5]. It was hypothesised that this could reflect cognitive-linguistic processes (it is far more common for words to begin with a strong syllable than a weak syllable in English) and/or the constraints of the maturing speech motor system (e.g., due to increases in subglottic pressure the physiological demand to produce a rising contour is greater).

If cognitive-linguistic processes influence mastery of stress production then young Italian children might show less contrastivity with the non dominant pattern of lexical stress (i.e., words that begin with a strong syllable). However, if there are physiological demands associated with producing a rising contour they might show less contrastivity with words beginning with a weak syllable. Thus, data on lexical stress production in Italian children provides an ideal cross-linguistic point of comparison that can assist in delineating between these different developmental constraints.

We note that while there have been cross-linguistic acoustic studies of children’s speech production [6], as far as we are aware, no previous acoustic study has focused on the developmental trajectory of stress contrastivity in Italian versus English.

2. METHOD

2.1. Participants

A total of 27 Italian children living near Trento took part in the research (20 females and 7 males). Participants ranged in age from 3 to 5 years (mean =

4.85 years, $sd = .80$). All had normal hearing acuity, no known developmental, language or genetic diagnosis, and Italian as their only language (via teacher report).

2.2. Materials

Stimuli were selected with the following constraints: (1) all were picturable words that are familiar to young Italian children, (2) all followed the same phonological structure (e.g., began with a consonant and ended with a vowel), (3) all contained consonants that have been found in the consonant inventories of Italian children as young as 3 years of age [7], (4) all of the stimuli had easily demarcated vowel onsets and offsets in the acoustic signal (e.g., no liquids or semivowels). Disyllabic stimuli were not used so as to avoid syllable-final vowel-lengthening effects which might affect the first 2 syllables being analysed acoustically [8].

Stimuli were 10 trisyllabic Italian words. Of these target words, 5 had stress on the penultimate syllable (i.e., weak-strong: WS): ‘patata’, ‘matita’, ‘cucina’, ‘banana’, ‘tacchino’. The other 5 had stress on the initial syllable (i.e., strong-weak: SW): ‘pattino’, ‘macchina’, ‘gomito’, ‘sedano’, ‘pettine’.

Stimuli were presented via powerpoint displayed on a laptop. Two orders of presentation of pictures were used for each participant – so that two productions for each target word could be collected. A head-mounted microphone was used in combination with Audacity software to collect recordings. Responses were sampled at a rate of 48 kHz with 16 bit quantization.

2.3. Data analysis

Preliminary perceptual analysis was conducted in order to determine the correct productions that would be analysed acoustically. Productions were rated by two individuals, one of whom (the second author) is a native speaker of Italian.

Acoustic measurements of correct productions were made with PRAAT software, Version 5.2.0.1 [9]. Waveforms and wide-band spectrograms with a 300-Hz bandwidth were generated for each sound file. For each correct word production, 3 measurements were made for the first 2 syllables of each word: (1) vowel duration (ms) from onset to offset of glottal pulsing for vowel 1 (V1) and vowel 2 (V2), (2) peak vocal intensity (dB) for the nucleus of V1 and V2, and (3) peak f_0 (Hz) for the nucleus of V1 and V2. These measures were used to calculate PVIs for duration (PVI_duration), intensity (PVI_intensity), and f_0 (PVI_ f_0).

The PVI represents the normalised

difference between the first 2 vowels of each stimulus for each measure: $PVI_a = 100 \times \{(a_1 - a_2) / [(a_1 + a_2) / 2]\}$ where a_1 and a_2 are measures of duration, peak intensity, or peak f_0 of the first and second vowels, respectively. A positive PVI signifies greater stress on the first syllable, a negative PVI signifies greater stress on the second syllable.

3. RESULTS

The study was designed to collect 540 word productions (27 participants x 10 targets x 2 productions of each target). However, the second round of productions were not recorded for one of the participants due to equipment failure – leaving the potential for 530 correct productions.

The two raters made perceptual judgements regarding whether each production could be considered to be a correct production of the target. Where productions varied slightly only in terms of the final vowel (which was not measured acoustically in this study), but were clearly semantically related to the target, they were considered to be correct (this affected a very small number of productions, for example, a handful of cases of singular/plural cases: pattino/pattini or noun/verb cases: pettine/pettino).

Overall agreement between raters was high (> 90%). Where there was disagreement the rating of the native speaker of Italian was chosen. Productions were missing (because the child did not know the target) or incorrect (child produced a word that was clearly different from the target) in 15 cases (2.83%). Of the remaining 515 correct productions the raters agreed that 9 productions (1.75%) had very low contrastivity in terms of lexical stress (productions that sounded like they might be bordering on ‘equal stress’ across the first two syllables included 4 instances of ‘matita’, 2 instances of ‘tacchino’, 1 instance of ‘patata’, 1 instance of ‘gomito’, and 1 instance of ‘sedano’). As these productions were still considered to be intelligible correct productions of the targets we retained them for acoustic analysis.

3.1. Acoustic measures

For each participant, PVIs for duration, intensity and fundamental frequency were averaged across the two productions of each target. Then, for each participant, PVIs were averaged across all weak-strong, WS, targets and across all strong-weak, SW, targets. The resulting data were inspected and any means that were 2SD from the mean for that condition were replaced with the mean value for that condition (5.6% of data).

Means and standard deviations for

PVI_duration, PVI_intensity, and PVI_ f_0 for WS and SW words, collapsed across all 27 child participants are presented in Table 1.

As can be seen from the table, PVI_duration was negative for WS words (indicating greater stress on second syllable) and positive for SW words (greater stress on first syllable). All remaining PVI values were positive. The data revealed that PVI_intensity was close to zero for WS words and was smaller when compared to SW words, however, this pattern was reversed for PVI_ f_0 . These results suggest that vowel duration is the strongest marker of lexical stress in Italian children’s speech production.

Table 1: Means and standard deviations (in parentheses) for PVIs for WS and SW words.

| | Dur | Int | f_0 |
|----|----------------|-------------|-------------|
| WS | -44.49 (12.95) | .71 (4.05) | 3.51 (3.46) |
| SW | 52.51 (17.76) | 5.39 (3.54) | .11 (6.21) |

Table 2 displays the mean PVIs for WS and also SW words, broken down by the age of child participants. Included in the table are corresponding means from English speaking Australian children reported in Ballard et al. (2012). Italian speaking children at 3, 4, and also 5 years of age appear to exhibit comparable levels of contrastivity in their WS versus SW productions. By contrast, it seems that English speaking children exhibit far greater contrastivity in their WS productions when compared with their SW productions. Although we were not able to analyse the statistical significance and effect sizes relating to these differences (because we do not have access to the Ballard et al. dataset), the differences appear to be quite striking.

Table 2: Cross-linguistic comparison of mean PVIs at 3, 4, and 5 years in Italian (I) and English data (E). English data from Ballard et al. (2012).

| | | WS | | | SW | | |
|---|---|--------|------|-------|------|-----|-------|
| | | Dur | Int | f_0 | Dur | Int | f_0 |
| I | 3 | -43.2 | 0.2 | 3.7 | 59.1 | 7.4 | -0.4 |
| | 4 | -44.4 | 0.5 | 4.3 | 51.9 | 5.2 | -0.5 |
| | 5 | -45.0 | 1.0 | 3.1 | 50.1 | 4.7 | 0.6 |
| E | 3 | -107.3 | -5.1 | 3.8 | 36.0 | 5.5 | 1.0 |
| | 4 | -115.2 | -9.3 | -4.7 | 32.9 | 6.8 | 5.6 |
| | 5 | -116.2 | -9.4 | -1.2 | 35.3 | 4.8 | 6.6 |

Note: Values are rounded to a single decimal place because that is the way the data was reported in Ballard et al. (2012).

4. DISCUSSION

Here we report on lexical stress contrastivity in typically developing Italian children in an effort to shed light on this fundamental, but largely neglected, aspect of speech production. We found that vowel duration was the most prominent marker of lexical stress in Italian children’s speech. This finding is in line with early perceptual research noting the importance of vowel duration in marking lexical stress in Italian [10].

Importantly, we sought to distinguish between cognitive-linguistic vs. physiological constraints that may affect the developmental trajectory of speech production. We hypothesised that if cognitive-linguistic processes influence mastery of stress production then young Italian children might show less stress contrastivity in words with the non dominant pattern of lexical stress (words beginning with a strong syllable). By contrast, if there are physiological demands associated with producing a rising contour Italian children might show less stress contrastivity in words beginning with a weak syllable. Our findings were not in line with one or other of these hypotheses. Typically developing Italian children appeared to show similar levels of contrastivity across WS and SW words. It may be that the additive effect of cognitive-linguistic effects (specific to Italian) and physiological demands results in similar levels of stress contrastivity across WS and SW words in the speech of Italian speaking children.

We are currently collecting data from Italian speaking adult participants. We intend to compare that new data with the data reported here so that we can ascertain whether Italian children aged 3-5 years are producing adult-like levels of contrastivity.

4.1. Limitations and future directions

Our sample size may be considered modest. However, it compares favourably with recent studies of Italian children’s speech production. For example, Majorano and D’Odorico [11] examined babbling and first words in 11 Italian children aged 1-2 years. Another study assessed 30 Italian children aged between 36 and 42 months [7]. Note that neither of the previous studies of Italian children utilised acoustic analyses. A recent study of English speaking Australian children reported by Ballard et al. used the same acoustic techniques that we used in the current study [5]. Although that study assessed children from a wider age range, and also adults, that study included 40 children in the same age range as we report here (3-5 years). Moreover, it is important

to note that the study by Ballard et al. included productions of only 2 SW words ('butterfly' and 'caterpillar') and 2 WS words ('potato' and 'tomato'). In the current study we had 2.5 times the number of target words (5 SW words and 5 WS words). This increase to 10 targets meant we had more data points for children aged 3-5 years in the current study than in the study by Ballard et al.

Cross-linguistic comparisons are difficult because it can be challenging to identify target words in different languages that are equivalent in every way. There may be some differences concerning vowel quality in the stressed syllables of the stimuli used in the Italian and English studies reported here. For example, the presence of long vs. short vowels in the stressed syllable could be explored in future research. Also, there are differences in the way that English and Italian utilise schwa that could be investigated more fully. Having said this we don't think that vowel quality can fully explain the striking differences in degree of contrastivity exhibited by Italian vs. English speaking Australian children for SW words (especially given there appears to be much less difference in contrast when it comes to WS words).

The data reported here suggest that there are a variety of factors that affect lexical stress contrastivity in children's speech production. They demonstrate that cross-linguistic comparisons are critical for a better understanding of the complexities of speech development beyond the production of individual sounds. We hope that our findings might trigger additional cross-linguistic research of stress contrastivity, using a range of methodologies, in order to explore cognitive-linguistic and physiological influences on children's speech production.

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