Stress assignment in the development of reading aloud: Nonword priming effects on Italian children

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Abstract

Two experiments investigated the development of two aspects related to stress assignment in reading. First, we tested whether the role of distributional knowledge concerning stress changes with the development of the reading system; second, we tested whether stress information is computed independently of phonemic information since the first stages of reading acquisition. We ran two identical experiments in Italian, one with children of two age levels (second and fourth grades) and one with adults. Results showed that older children behave similarly to adults, but younger children do not. Differently from the advanced readers, younger children use more general distributional knowledge about stress and are not able to compute stress information apart from phonemes. Taken together, our results suggest that the stress subsystem, and in particular the mechanisms working at the level of the phonological buffer are not fully developed during the first stages of reading.

Keywords: lexical stress; stress neighborhood; reading development; pathway priming.

Introduction

The process of stress assignment has recently become a central issue in the reading aloud literature. In languages like English, Dutch, or Italian, with a lexicon composed of polysyllabic words and with unpredictable stress, understanding how people read words aloud implies, among other things, understanding how readers assign stress. Research on stress assignment in reading has mainly focused on two issues: First, how readers assign stress to words and nonwords (*e.g.*, Colombo, 1992; Rastle & Coltheart, 2000); Second, how suprasegmental information is represented in the reading system (Colombo & Zevin, 2009; Sulpizio, Job & Burani, in press b).

Let us consider the mechanisms for stress assignment first. Although stress assignment may not cause problems in reading words – readers may retrieve stress information as part of their lexical knowledge – it causes difficulties when stimuli are unknown words or nonwords. Thus, one issue is how readers are able to assign stress with no reference to lexically-stored information (Sulpizio, Arduino, Paizi, & Burani, in press a). Within a connectionist view of reading, studies in English and Italian have highlighted that two different types of distributional knowledge drive readers in stress assignment to unknown stimuli. First, the distribution of the stress patterns in the lexicon – *e.g.*, in Italian, 80% of three-syllabic words bear penultimate stress (maTIta[1], pencil), while 18% bear antepenultimate stress (BIbita 'drink') (Thornton, Iacobini, & Burani, 1997)[2]. This may induce readers, following a default stress bias, to assign the most common pattern to unknown words (Colombo, 1992; Rastle & Coltheart, 2000). Second, some orthographic/phonological units work as cues for stress assignment, with word ending being a strong predictor of the stress pattern (*e.g.*, Arciuli, Monaghan, & Ševa, 2010; Kelly, Morris, & Verrekia, 1998). Consider Italian as an

[1] Capital letters indicate stressed syllable.

[2] The remaining 2% of three-syllabic words bear stress on the final syllable, and in this case stress is graphically marked (*e.g.*, colibrì 'hummingbird')

example: Most of the words ending in -ola bear antepenultimate stress (PENtola, 'pot'; BAMbola, 'doll' *etc.*), that is, -ola has a stress neighborhood composed of many antepenultimate stress friends. Following this statistical tendency, when readers see an unknown word or a nonword ending in -ola, they will be prone to assign antepenultimate stress according to its stress neighborhood (Burani & Arduino, 2004; Colombo, 1992; Sulpizio *et al*., in press a). Thus, readers have two sources of information to assign stress, *i.e*., the lexical knowledge and the distributional information driven by their implicitly acquired statistical knowledge.

The representation of stress within the reading system has been investigated only recently. Two studies on Italian have shown that suprasegmental information may be partially independent from segmental information: Using a priming methodology, both studies found that the word's stress pattern can be primed independently of its segmental level (Colombo & Zevin, 2009, Sulpizio *et al.*, in press b). This finding is in line with the word production literature (Levelt, Roelofs, & Meyer, 1999) – where stress is part of an abstract metrical representation including the number of syllables and stress position – and with the view that speech production and reading aloud may share, at least in part, the last stages of processing, *i.e.*, phonological and phonetic word encoding (Roelofs, 2004). Thus, stress information would be partially independent of phonemic information and readers could compute the former independently from the latter.

But what about young readers? When a child starts to read, her/his reading system is not fully developed, her/ his lexicon may be relatively small, and her/his knowledge of the statistical properties of the language may be relatively limited. How can the development of the stress system be characterized? Does knowledge of stress properties and its application to reading require time to develop? The issue concerning the development of distributional knowledge for stress has received little attention (but see Arciuli *et al.*, 2010, discussed below). To our knowledge, few studies investigated how a metrical representation, autonomous from segmental information, develops in young readers. Colombo, Deguchi and Boureux (submitted) found that young (7-years old) children were little affected by the stress pattern of the priming context nonwords in reading nonword targets, while priming was significant in older children.

In the present paper we further investigated the issue of whether children, when starting to read, are able to use the autonomous representation of stress as adult readers and thus may show stress priming effects. Differently from Colombo *et al*. (submitted), we used real words as targets. Words have a lexical representation which includes stress position. Consequently, if the words' stress pattern is retrieved from lexical memory, this information may be automatically available before information from the prime has any effect, particularly in children whose reading processes are relatively slow. On the other hand, Sulpizio *et al*. (in press b) found significant stress priming for words in adults. Thus the question of whether and in which conditions we may find stress priming for words in adults and children is still open.

We ran two identical experiments, one with children of two age levels (II and IV grade) and one with adults. We adopted the "pathway priming" paradigm (Colombo & Zevin, 2009; Zevin & Balota, 2000) to test the possibility of inducing stress priming not only in adults, but also in young readers. In this paradigm, each target is preceded by five nonword primes with the same stress pattern that act as a small list context for the target. These micro-lists were included in a larger list in which all primes were homogeneous for stress. Participants have to read all stimuli aloud and they are not aware that some stimuli are primes and others are targets. By manipulating the congruency between primes' stress and target's stress – the target could have the same stress as the five preceding primes or a different one – we investigated whether a priming effect would occur, with participants being facilitated when reading a target in the congruent stress condition (when the target had the same stress as its five preceding primes), compared to the incongruent stress condition (when the target had a different stress than its five preceding primes). We expected that the stress priming effect would be stronger in adult readers and (perhaps) in older children, than in younger children.

Colombo and Zevin (2009) showed that stress priming effects are stronger within a sub-lexical context. Consequently, we only used nonwords as primes. In this way, participants were strongly encouraged to rely on sub-lexical reading. The use of nonword stimuli allowed us to further test the second issue: How readers develop distributional knowledge for stress assignment. Arciuli and colleagues (2010) ran a nonword reading experiment with English-speaking children. They found that younger (5/6-year-old) children were more affected by the main distribution of stress patterns in English – they assigned stress to the initial syllable more frequently – and were not affected by the final part of the nonwords. By contrast, in older children (7/8-year-old) the bias toward initial stress became weaker and children were influenced by specific orthographic cues, such as the nonwords' ending. A similar pattern of results was found in Italian. While young children were more prone to assign dominant stress to nonwords and less affected by orthographic neighborhood than older children and adults (Colombo *et al.*, submitted), Italian adults and older children (11 years old) assigned stress to nonwords and low-frequency words on the basis of stress neighborhood, showing very weak evidence for a bias toward the penultimate (dominant) stress in reading words aloud (see also Burani & Arduino, 2004; Colombo & Zevin, 2009; Paizi, Zoccolotti, & Burani, 2011). If these findings reflect cognitive constraints holding for different languages, we might expect similar trajectories in the development of distributional knowledge for stress in English and Italian: Older children and adults should be more affected by stress

neighborhood, while younger children might be more influenced by the distributional bias toward the dominant stress.

In summary, the present study investigated two issues related to the development of stress assignment in reading. First, we investigated whether stress assignment is fully developed already in young readers so that, when reading a word aloud, they are able to exploit the prosodic information available from the context. Second, we investigated whether the trajectory of the development of stress assignment in Italian is similar to what Arciuli *et al*. (2010) found for English, *i.e.*, that distributional knowledge of stress moves from a general distributional bias to more subtle statistical properties, such as stress neighborhood. To test these issues we ran two reading experiments in Italian, a language in which stress is not predictable by rule (Krämer, 2009) and there are two main stress patterns asymmetrically distributed, *i.e*., penultimate stress – which is the dominant pattern and appears in 80% of words – and antepenultimate stress – which appears only in 18% of words. The two experiments were identical, except that one was run with children of different grades and one with adults.

Methods

Experiment 1 - Children

Participants. Two groups of elementary school children took part in the experiment: The first group included 20 second graders (13 males, mean age: 7.1, sd: 0.3); the second group included 18 fourth grade children (10 males, mean age: 9.2, sd: 0.4). All participants were native Italian speakers, with normal or corrected-to-normal vision.

Materials & Method. Thirty three-syllabic antepenultimate-stress words were used as target stimuli. All words had a low frequency (mean frequency: 15.93, sd: 27.96, out of 1.5 million occurrences, Barcelona Corpus, Istituto di Linguistica Computazionale, 1989, unpublished manuscript). The phonological lexical representation of low frequency words is less likely to be automatically retrieved, and thus priming should be easier to obtain. Two sets of three-syllabic phonologically legal Italian nonwords were used in order to create two stress priming contexts. They were constructed in such a way that one set should receive penultimate stress and the other one should receive antepenultimate stress according to the stress neighborhood consistency. Thus, nonwords having the nucleus of the penultimate syllable and the last syllable typical of words stressed with the penultimate (dominant) stress pattern (*e.g.*, -ato in geLAto, "ice cream") were defined as penultimate-stress primes, whereas nonwords having the nucleus of the penultimate syllable and the last syllable typical of words stressed on the antepenultimate syllable (*e.g.*, -olo in TAvolo "table") were defined as penultimate-stress primes. To examine the efficacy of stress neighborhood consistency based on word-ending, we carried out a pre-test, by presenting to adult readers the nonwords in a random order in a word naming paradigm. The pre-test showed that stress was assigned to the nonwords according to their ending: 72% of nonwords with penultimate-stress neighborhood received penultimate stress and 78% of nonwords with antepenultimate-stress neighborhood received antepenultimate stress. Penultimate- and antepenultimate-stress nonwords were matched on: Length in letters (mean: 6.2 [sd: 0.5] *vs*. 6.3 [sd: 0.6]); number of consonant clusters (mean 0.3 [sd: 0.4] *vs*. 0.4 [sd: 0.5]) and initial phonemes.

Fifty penultimate- and 50 antepenultimate-stress nonwords were selected as primes. Target words were divided into 3 sets (10 each). Ten targets were assigned to the penultimate prime list, 10 targets to the antepenultimate prime list, and 10 targets were paired with a set of two simple geometric figures, square and triangle, each repeated 5 times. The latter condition was included to preserve interest and attention to the reading task in children, and was kept similar in the experiment with adults to have a perfectly matched control experiment. Stimuli preceded by figure primes were considered fillers, and not analyzed. Each target was preceded by 5 primes, as in Colombo & Zevin (2009; *cf.* Zevin & Balota, 2000). All target words had antepenultimate stress and they were congruent with the antepenultimate prime list, whereas they were incongruent with the penultimate prime list. The three different target lists were presented between-participants.

Apparatus & Procedure. The monitor was in VGA color. A voice key connected to the PC's real-time clock collected response latencies. The experiment was run using E-Prime software (Psychology Software Tools, Pittsburgh, PA). Participants were tested individually. They were instructed to read aloud each stimulus as fast and as accurately as possible. Stimuli were presented on the computer screen. In each trial, a fixation point was presented for 300 ms, followed by the stimulus in black color. At the start of articulation the letter string turned in red when the voice key responded. Response time was measured from the onset of the stimulus to the onset of articulation. The stimulus remained on the screen until the experimenter coded each trial as correct or as an error (stress or phonemic error) by pressing one of the keys of the keyboard. Advancement of trials was made by the experimenter, as soon as response coding was done. When the letter string disappeared, the next trial started immediately. Participants were audio-recorded to allow a further verification of experimenter's evaluation. Each participant received the two priming lists in separate blocks in a counterbalanced order; half of the participants received the penultimate-stress prime list first, while the other half was presented the antepenultimate-stress prime list first. The experimental blocks were preceded by a practice session with stimuli not included in the experimental trial.

Experiment 2 – Adults

Participants. Twenty-four participants (6 males, mean age: 22.6 sd: 1.3) took part in the experiment. They were all Italian native speakers and had normal or corrected-to-normal vision.

Materials, Method, Apparatus & Procedure. The same as in Experiment 1.

Results

Experiment 1 - Children

Prime analysis. Overall nonword primes were read consistently with their stress neighborhood and this was true for both second graders and fourth graders (Table 1). However, younger children assigned penultimate (dominant) stress significantly more often than older children, especially when reading nonwords with antepenultimate-stress neighborhood (younger children assigned penultimate stress to 56% of the nonwords whereas older children assigned penultimate stress to 52% of the nonwords) and the difference was significant ($\chi^2 = 4.16$, $p < .05$).

Table 1: Children. Percentages of nonwords read with each stress pattern for each class.

	II grade		IV grade	
	Penult. stress	Antepen. stress	Penult. stress	Antepen. stress
Penultimate stress neighborhood	74%	26%	79%	21%
Antepenultimate stress neighborhood	37%	63%	23%	77%

Target analysis.
Responses shorter than 250 ms or longer than 3500 ms (5.8% of all data points) were excluded from the analyses. Naming times and errors were both analyzed using mixed-effects models, with class (II grade *vs*. IV grade) and stress congruency (primes and target sharing the same stress *vs*. primes and target with different stress) as fixed factors. Participants and items were treated as random factors. The models were fitted using the *lmer* function (*languageR* package, Baayen, Davidson, & Bates, 2008) in R software (version 2.11). Results for errors are reported in Table 2.
Naming times. The mixed-effects model was run with naming latencies as dependent variable and class and stress congruency as predictors. The model showed a main effect of class ($\beta = -0.33$, st. err. = 0.11, $t = -2.89$, $p < .01$), with fourth graders faster than second graders. No other effect reached significance (stress congruency: $t = 1.5$, $p > .1$; class by stress congruency interaction: $t < 1$, $p > .5$).
Errors. Two analyses were run, one considering stress errors and the other one considering phonemic errors. Both analyses were performed with accuracy as dependent variable and class and stress congruency as predictors. When considering stress errors, the mixed-effects model showed a significant interaction between class and stress congruency ($\beta = 1.36$, st. err. = 0.4, $z = 3.39$, $p < .01$), with the effect of stress congruency being significant only for fourth graders. No other effect reached significance (both $z_s < 1$). Differently, when considering phonemic errors, only the effect of stress congruency approached significance ($\beta = 0.57$, st. err. = 0.3, $z = 1.89$ $p < .1$), with more errors in the incongruent stress condition. No other effect reached significance (class: $z = 1.3$, $p > .1$; class x prime interaction: $z = -1.4$, $p > .1$). Inspection of means shows that the congruency effect was mainly due to second-graders (Table 2).

Table 2: Children. Mean error percentages for the targets in the two stress-prime conditions.

	Stress errors		Phonemic errors	
	II grade	IV grade	II grade	IV grade
Congruent stress prime	28%	13%	16%	17%
Incongruent stress prime	29%	31%	25%	18%

Experiment 2 – Adults

Prime analysis. Participants read nonword primes according to their stress neighborhood, with no tendency to overuse the penultimate stress (penultimate and antepenultimate stress were assigned 53% and 47% of the times, respectively).

Target analysis.
Responses shorter than 250 ms or longer than 1500 ms (4.1% of all data points) were excluded from the analyses. Naming times and errors were both analyzed using mixed-effects models, with stress congruency (primes and target sharing the same stress *vs*. primes and target with different stress) as fixed factor. Participants and items were treated as random factors.
Naming times. The mixed-effects model was run with naming latencies as dependent variable and stress congruency as predictor. The effect was not significant ($t = -1.1$, $p > .1$).
Errors. Stress errors were few. consequently they were analyzed together with phonemic errors. A mixed-effects model was performed with response accuracy as dependent variable and stress congruency as predictor. The effect of stress congruency (congruent stress prime = 4% errors; incongruent stress prime =10% errors), was significant ($\beta = 1.38$, st. err. = 0.50, $z = 2.76$, $p < .01$): Readers were more accurate when primes and target shared the same stress than when primes and target had a different stress.

Discussion

In two reading experiments, we tested what kind of distributional information younger and older children use

for stress assignment, and whether stress priming affects both children and adults in reading Italian aloud. The results show two main findings: First, while both adults and older children assign stress to non-words (prime stimuli) according to their stress neighborhood, younger children do exploit stress neighborhood, but they also show a tendency to overgeneralize penultimate (dominant) stress in assigning stress. Second, participants were more accurate to read a target when it was preceded by a set of primes with the same stress (both primes and target received antepenultimate stress), than when it was preceded by a set of primes with a different stress (primes received penultimate stress and target antepenultimate stress). This pattern was found with older children and adult readers, but not with younger children. One might argue that reading is a very different task for younger and older children and that this fact might be sufficient to explain the data. Although we do not exclude any effect of task familiarity, we believe that a better explanation may refer to how the reading system develops and what lexical/sub-lexical strategies children adopt (*cf*. Peressotti, Mulatti, & Job, 2010).

In interpreting this pattern of results, we should consider the development of distributional knowledge first. Previous research has shown that stress neighborhood can be considered the main factor able to drive stress assignment in adult readers (Arciuli *et al.*, 2010; Burani & Arduino, 2004; Kelly *et al.*, 1998; Protopapas, Gerakaki, & Alexandri, 2006) and in connectionist simulations of Italian (Pagliuca & Monaghan, 2010). Some studies have suggested that also the bias toward the dominant stress pattern in the language might play a role in stress assignment, but only when readers heavily rely on a sub-lexical procedure (Colombo & Zevin, 2009; but see also Protopapas *et al.*, 2006, for a different perspective in languages other than Italian). Similar to what was found by Arciuli *et al.* (2010) with English-speaking children, our study suggests that readers may use two types of information for stress assignment, but their relative employment changes during the acquisition of reading. Differently from older children and adults, who assign stress on the basis of stress neighborhood alone, Italian young children assign stress to nonwords not only on the basis of stress neighborhood, but also of the distributional bias toward the dominant (penultimate) stress in their native language. This might be due to at least two reasons: First, children are more prone to use sub-lexical reading (Ziegler & Goswami, 2005), thus increasing the chance to apply the distributional general bias. Second, in developing their lexicon and the ability to analyze orthographic and phonological information, children might develop their distributional knowledge by discovering more subtle correspondences between word orthography and stress pattern. Thus, the development of distributional knowledge would follow a trajectory that goes from the more general bias toward the dominant stress to the more specific stress neighborhood, which may require time to develop.

Let us now consider the stress priming effect. Our results are in line with previous research that found stress priming effects in reading (Colombo & Zevin, 2009; Sulpizio *et al.*, in press b). The fact that the stress pattern of a word can be primed confirms the idea suggested in word production models that, when reading a word aloud, participants compute suprasegmental information independently of segmental information (Levelt *et al.*, 1999) instead of retrieving the word's prosodic information from the lexicon. Accordingly, we can assume that these two types of information are first computed separately by means of specific mechanisms, and then assembled together prior to word articulation. However, while both older children and adults show stress priming effects, younger children do not. This difference could be explained by assuming that, although the prosodic system of younger readers is fully developed (Jusczyk, Houston, & Newsome, 1999), it is not yet able to exploit prosodic information from the context, namely, from the primes' stress pattern. A similar interpretation is supported by the pattern of phonemic errors made by young readers, which decrease in the congruent prime condition: This pattern suggests that the prime affects the target's computation, but only at the segmental level; differently, younger readers are not able to use stress information driven by the primes, as no effect of the primes' congruency emerged at the level of stress errors.

The CDP++ model of reading aloud (for English words; Perry, Ziegler, & Zorzi, 2010) can account for our data fairly easily . The model assumes that stress information can be both lexically retrieved and sub-lexically computed. At the sub-lexical level a connectionist network maps graphemes onto phonemes and the orthographic input onto a stress pattern. Moreover, the model assumes that the phonological output buffer includes two different components, namely the *stress output nodes* and the *phonemic output nodes*: The former are responsible for stress assignment and the latter for phoneme activation. During training the network may learn to associate specific orthographic cues with a specific stress (*e.g.*, the final sequence -ola with antepenultimate stress). Thus, the probability that a pseudoword will receive a certain stress depends on the strength of the connections established between the orthographic cues and stress position: The more frequent the association between an orthographic cue and a stress pattern, the stronger the connection between stress and orthography.

The assignment of stress according to stress neighborhood may emerge at the sub-lexical level, with the word final sequence driving stress assignment. This mechanism might work less efficiently in young children who are learning to read, because they have to learn which orthographic sequences may work as a strong cue for stress. Thus, young children might assign stress to nonwords on the basis of a more general distributional tendency such as the bias toward the dominant stress pattern in the language. The stress priming effect may occur at the level of the *stress output nodes*: When planning the target's articulation, readers

might be affected by the repeated pre-activation of the primes' metrical structure, which can be congruent or incongruent with the target. Thus, stress may be primed at the level of the phonological output buffer, when readers assemble the phonological unit that has to be articulated. Finally, the absence of a stress priming effect in younger children might be due to the absence of a fully developed stress system in the first stages of reading.

To conclude, the present study has shown two important aspects of the developmental trajectory of stress assignment in reading. First, when reading a stimulus aloud, readers make use of their distributional knowledge to assign stress and they do it since the first stages of reading development. However, the type of distributional knowledge exploited by readers changes developmentally: While younger readers are more prone to use general knowledge about the dominant stress pattern in the language, older readers are more affected by more specific distributional knowledge, namely stress neighborhood. Second, and more important, stress information can be computed separately from phonemic information, but young children are more likely to use information that has been extensively acquired - (*i.e.*, the dominant pattern in the language), rather than information gathered from the context (*i.e.*, the priming list). Taken together, the present findings suggest a final conclusion: At the early stages of reading, the word stress assignment subsystem appears partially underdeveloped.

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