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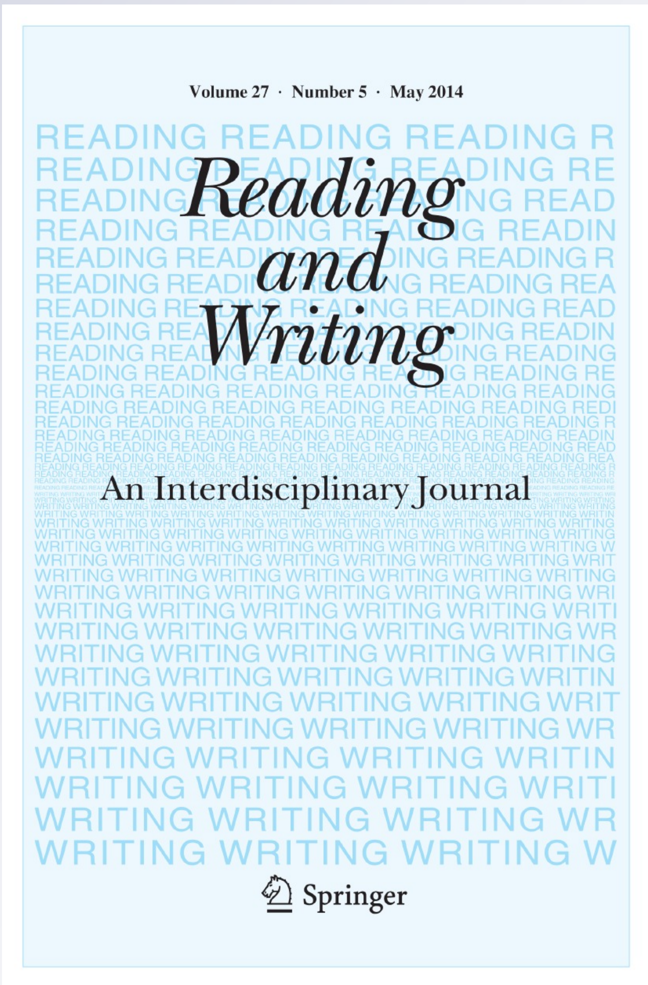

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Stress priming and statistical learning in Italian nonword reading: evidence from children

Lucia Colombo · Chizuru Deguchi · Magali Boureux

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Abstract Italian has regular spelling-sound correspondences; however, assignment of lexical stress is unpredictable. Sensitivity to stress neighborhood information was investigated by constructing three types of three-syllabic nonwords: nonwords with word-endings characterized by a strong neighborhood of dominant stress words (dominant), nonwords with word-endings characterized by a strong neighborhood of non-dominant stress words (non-dominant), and nonwords with word-endings characterized by weak and/or inconsistent stress neighborhoods (ambivalent). Examples of these three types of nonwords were used as targets in a priming experiment. Examples of two of these types of nonwords (dominant and non-dominant) were used as primes. Adults (Experiment 1) and second and fourth-grade children (Experiment 2) were tested in a reading aloud task, and percentage of responses with dominant stress was measured. Children were sensitive to item-specific stress neighborhood information, but less so than adults. Children demonstrated more marked effects of dominant stress, effects that appear to decrease with age. Children also showed smaller effects of prosodic priming compared to adults. The results are in line with a statistical approach to learning.

Keywords Reading acquisition · Prosodic priming · Lexical stress representation · Statistical learning

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Introduction

Stress assignment is a neglected subfield of word reading research. Major models of reading (e.g., Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Harm & Seidenberg, 2004; Perry, Ziegler, & Zorzi, 2007; Plaut, Patterson, McClelland, & Seidenberg, 1996; Seidenberg & McClelland, 1989; Zorzi, Houghton, & Butterworth, 1998) have been mainly concerned with how segmental components are processed. These models focus on how graphemes are converted into phonemes in regular and irregular spellings in English, and are based on findings from reading experiments with monosyllabic words. However, a complete model of word reading must take into account polysyllabic words and describe how segmental and supra-segmental information are combined to produce a correct phonological realization from a written input.

There are in the literature some attempts to account for stress assignment in word naming. By assigning stress with a morphologically rule-based system, Rastle and Coltheart (2000) constructed an algorithm within the dual route model that simulated the reading aloud of disyllabic nonwords in adults. The algorithm scanned the word to be named in search of a morpheme, and assigned stress in agreement with a stress-specified morphemic database. This system worked relatively well with nonwords containing morphemes, but relatively poorly with non-morphemic nonwords, and did not provide information on statistical regularities, or on their acquisition. In contrast, Seva, Monaghan, and Arciuli (2009) simulated the mapping of orthography to stress position for disyllabic English words with a connectionist model that did not use a set of pre-defined rules, but rather exploited statistical regularities in the input, and that was able to simulate nonword reading performance independently of morphemic information.

More recent work containing corpus analyses, behavioural testing, and computational modelling has investigated how children learn to assign stress during reading aloud, specifically whether children exploit probabilistic orthographic cues to stress (Arciuli, Monaghan, & Seva, 2010). The authors investigated the extent to which children of different ages exploit cues present in both the beginnings and endings of disyllabic words. Using carefully constructed nonwords that contained beginnings and endings that were probabilistically associated with particular stress patterns, Arciuli, Monaghan, and Seva (2010) found that younger children tended to assign initial syllable stress when reading aloud disyllabic nonwords. In contrast, older children appeared to be more sensitive to probabilistic orthographic cues. In particular, children's reliance on cues to stress present in endings appeared to increase with age. This study clearly demonstrates the influence of distributional properties that are reflected in orthography and children's increasing reliance on specific probabilistic cues, which is in line with their increasing exposure, with their own increasing age, to a greater volume of reading materials.

Perry, Ziegler, and Zorzi (2010) proposed a recent version of the connectionist dual process (CDP++) model that investigated stress assignment in monosyllabic and disyllabic words. The authors were able to simulate the stress regularity effect on low-frequency words in the pattern of errors (Brown, Lupker, & Colombo, 1994; Colombo, 1992; Monsell, Doyle, & Haggard, 1989). Moreover, after training the model tended to assign nonwords the most frequent stress pattern. As found by Arciuli and Cupples (2006), the network was also able to differentiate the stress pattern of nouns (mostly initial syllable) from that of verbs (mostly second syllable).

Finally, Pagliuca and Monaghan (2010) proposed a parallel distributed processing (PDP) model of reading polysyllabic Italian words. This model, based on Harm and Seidenberg's (1999) model of word naming, is composed of an orthographic (O) and a phonological (P) layer, connected by a hidden layer. The network, exposed to a corpus of about 9,000 two- and three-syllable Italian words with different stress patterns, attempted first to test the idea that units larger than graphemes (large-grain size) are used also in transparent languages, and secondarily to test for effects related to the unpredictable stress pattern in Italian. The model was able to simulate the most important effects found in the literature on Italian word reading, such as morphological and neighbourhood effects (Arduino & Burani, 2004; Burani, Marcolini, De Luca, & Zoccolotti, 2008), supporting the idea that Italian readers effectively exploit large-grain size units. Most importantly for the present study, the network was able to simulate stress consistency effects.

Information used in assigning stress patterns

Several studies suggest that readers use different sources of information, such as sub-lexical and lexical information, diacritics, and stress neighbourhood consistency, to assign stress (Arciuli & Cupples, 2006; Arciuli, Monaghan, & Seva, 2010; Burani & Arduino, 2004; Colombo, 1992; Protopapas, Gerakaki, & Alexandri, 2006; Protopapas & Gerakaki, 2009). This type of information may be implicitly acquired and may not be present yet in younger children. For example, the fact that (English) nouns tend to have a trochaic and verbs an iambic stress is relatively specific, as it describes stress distribution within grammatical categories, and implies a wider knowledge of the lexicon. Likely, information that is more general, such as the dominance of one particular stress pattern type in the language, might be acquired earlier than more specific information.

One of the aims of the present study was to investigate this hypothesis of a developmental trend in the acquisition of statistical information about stress, going from more general to more specific. With an increase in age—and a corresponding increase in exposure to different and more specific distributional properties of language (e.g., stress neighbourhood)—implicit knowledge about these characteristics should also increase. As noted above, this prediction is consistent with the work of Arciuli, Monaghan, and Seva (2010; see also Arciuli & Simpson, 2011, 2012). In general, it is consistent with connectionist models that take a statistical learning approach (Harm & Seidenberg, 2004; Zevin & Seidenberg, 2006).

Lexical stress in Italian

Italian is a language with a regular spelling–sound correspondence, and most of the words are polysyllabic. However, lexical stress is unpredictable and stress position is not indicated with a diacritic, except when stress falls on the last syllable. Colombo's (1992) study suggested the existence of a language's bias in Italian participants toward the most common stress pattern type in Italian (on the penultimate syllable), which was mainly exploited with nonwords. Most words in Italian are pronounced with stress on the penultimate syllable: disyllabic words are almost always stressed on the penultimate syllable, and about 70 % of multisyllabic words are stressed on the penultimate syllable while 20–30 % are stressed on the antepenultimate syllable.

Another important variable regarding Italian stress is the size of stress neighbourhood. Stress neighbourhood has been defined by Colombo (1992) as formed by the group of words sharing the same word ending (i.e., the nucleus of the penultimate syllable and the last syllable). In the word *bam-BI-no* (child), the ending *-INO* is the key element that defines its stress neighbours. The word *caMIno* (fireplace) is neighbourhood consistent because a large majority of its word neighbours (i.e., words ending in *-INO*) have the same stress pattern. Similarly, the neighbourhood of *-OLO* is formed by a majority of neighbours with non-dominant stress. Accordingly, neighbours stressed on the antepenultimate syllable such as *TAvolo* (table) are consistent, while a few words with dominant stress such as *spaGNOlo* (Spanish) are inconsistent with the majority of their neighbourhood. The effect of stress neighbourhood in word reading has been reflected in participants' longer response times in reading words with inconsistent stress neighbours compared to consistent stress neighbours (Burani & Arduino, 2004; Colombo, 1992; Sulpizio, Arduino, Paizi, & Burani, 2013). Further, the number of word neighbours, not their cumulative frequency, is what affects the speed at which words are read aloud (Burani & Arduino, 2004).

The size of the stress neighbourhood effect may depend on the number of neighbours and on their consistency (proportion of stress "friends" and "enemies"). For example, *-INO* has a large-sized stress neighbourhood (1,137 words ending with *-INO* in the COLFIS corpus) (Bertinetto et al., 2005). However, considering more generally the corpus of Italian three-syllabic words, stress neighbourhoods are not only formed by large-sized neighbourhoods. A number of word endings have quite few neighbours (e.g., *-UGE*) or include both stress "friends" and "enemies" in balanced proportion (e.g., *-OGA*). These endings do not help readers to determine stress position according to neighbourhood. Thus, an important issue that can be raised is how stress is assigned when neighbourhood information does not provide sufficient cues. More importantly, this type of knowledge would be acquired through increasing exposure to words, and may be less developed in younger children.

Although nonwords do not have a conventional stress pronunciation, they receive stress when speakers pronounce them, so it is theoretically important to determine where stress is most often assigned in a nonword depending on relevant factors, and how stress information is computed. Colombo (1992, Experiment 5) and Colombo and Zevin (2009) found evidence for a tendency to assign the dominant stress to nonwords congruently with its most frequent distribution. However, this tendency was modified in correspondence with the increase in the number of stress-consistent neighbours: the more neighbours in which the stress was on the antepenultimate syllable, the less likely that the nonword was stressed on the penultimate syllable. Thus, a nonword like *pifone* is much more likely to be assigned dominant stress (*piFOne*), while a nonword like *rolica* will be assigned non-dominant stress (*ROlica*) by the majority of readers.

Sulpizio et al. (2013) found no evidence that nonwords tend to be assigned the dominant stress. However, this finding may have been influenced by their selection of nonwords, with neighbourhoods of non-dominant stress nonwords more consistent on the average (Experiment 1) and also more numerous (Experiment 2) than those of dominant stress nonwords. It remains to be seen whether this selection reflects the characteristics of the lexicon, where dominant stress neighbourhoods are definitely more numerous.

As noted, small or balanced neighbourhoods may not provide clear cues for stress, thus, in order to further specify the effects of the neighbourhood in the present study, nonword stimuli were created using typical word-endings that differed in size and consistency of neighbourhood. Three types of nonwords were constructed: dominant (with strong neighbourhoods containing many neighbours with stress on the penultimate syllable), non-dominant (with strong neighbourhoods containing many neighbours with stress on the antepenultimate syllable), and ambivalent (small-sized or inconsistent neighbourhoods). We expected dominant stress to prevail, except with non-dominant stress nonwords, thus showing that the most frequent stress is assigned, besides with dominant, with ambivalent stress nonwords.

But how do these stress statistical regularities develop? Given the overall high type frequency of penultimate syllable stress in Italian, this stress pattern should be learned earlier by children. However, as children's lexical knowledge and reading ability increase, information about stress neighbourhood should also affect reading performance.

In the present study we also investigated the role of stress priming as a form of contextual information that may modify the effect of learned information, and whether this effect is present in young children. Thus, we assessed the relative influence of two factors potentially relevant to stress assignment in sub-lexical reading: (a) the role of statistical information acquired through language exposure at a specific (stress neighbourhood consistency) and general level (dominant vs. non-dominant stress) and how it develops; and (b) prosodic priming of the metrical frame and whether children are sensitive to this contextual information. To maximize sub-lexical involvement, we used only nonwords, as words tend to induce rapid and automatic lexical access.

We expected that both the general tendency to assign dominant stress and the stress neighbourhood effect would be altered by priming (Colombo & Zevin, 2009; Sulpizio, Job, & Burani, 2012). That is, a non-dominant prime context would diminish the probability of a nonword to be assigned dominant stress. Moreover, if a nonword's neighbourhood favours the non-dominant reading, this effect might be decreased by the presence of primes with dominant stress, suggesting that contextual information can modify not only the effect of general learned information, but also the effect of neighbourhood, which is specific to each nonword. In addition, we expected the effect of priming to be larger for nonwords whose stress neighbourhood is sparse or ambivalent compared to the other two conditions.

We report on two experiments, one on adults and one on children, in which the dependent variable of interest was the proportion of dominant stress assigned to nonwords, and how it varied depending on nonword characteristics (stress neighbourhood) and priming context.

Experiment 1

In Experiment 1 we investigated whether general (dominant stress pattern) and specific (neighbourhood) distributional information, reflected in the endings of the three nonword types, were affected by the context in which nonwords were included, in adults' reading aloud. Primes were nonwords with dominant or non-dominant stress. An effect of priming would be given by a difference in the proportion of dominant response rates in the two conditions. When general and specific statistical information is effectively exploited, there should be less room for other cues. Thus, we expected the priming effect on nonwords with a weak or balanced neighbourhood to be larger than on those with a strong dominant or non-dominant neighbourhood.

Method

Participants

A total of 60 volunteer students of the University of Padua (age range 19–25) participated in Experiment 1. All were native Italian speakers with normal vision and reading ability.

Materials

A total of 240 three-syllable phonologically legal Italian nonwords were constructed, by including word-endings selected on the basis of Barcelona Corpus (Istituto di Linguistica Computazionale, 1989; unpublished manuscript) and classified into three categories according to stress neighbourhood consistency. Nonwords that ended with the nucleus of the penultimate syllable and the last syllable included in words stressed with the dominant stress pattern were likely to receive the dominant stress pattern. For example, the ending -*ato* that is present in words like *geLAto* (ice cream) was used to construct the nonword *piFAto*. In contrast, stress assignment is unpredictable on nonwords with a weak (with a small number of word neighbours) or inconsistent neighbourhood (containing both neighbours stressed on the penultimate and neighbours stressed on the antepenultimate syllables in a balanced proportion).

Pre-test

To test the efficacy of word-endings as a cue in determining the stress pattern and to select nonwords to be used as targets or as primes, we first carried out a pre-test. To this end we selected 105 nonwords having 29 word-endings characterized by strong neighbourhood with dominant stress words ("dominant nonwords"), 105 having 22 word-endings characterized by strong neighbourhood with non-dominant stress words ("non-dominant nonwords"), and 30 having 8 word-endings characterized by weak and/or inconsistent neighbourhood ("ambivalent nonwords"). All nonword types were controlled for length and number of consonant clusters. The mean length of dominant, non-dominant, and ambivalent nonwords was 6.26 letters (SD = 0.57), 6.32 letters (SD = 0.61) and 6.24 letters (SD = 0.61), respectively. The mean number of consonant clusters of these nonword categories was 0.31 (SD = 0.49), 0.37 (SD = 0.50), and 0.30 (SD = 0.47), respectively.

We carried out the pre-test (N = 20 participants) by presenting these nonwords in a random order in a reading aloud paradigm and counted the proportion of types with dominant stress pattern in the three nonword conditions. The mean dominant response rates for dominant, ambivalent, and non-dominant nonwords were 72 % (SD = 0.45), 43 % (SD = 0.50), and 22 % (SD = 0.42), respectively.

Stimuli selection

Selection of primes and targets was based both on results of the pre-test and on stress neighbourhood count. As in former studies, the latter was based on number of types, that is, all words in the Barcelona Corpus database sharing the ending. Based on the results of the pre-test, we selected 90 stimuli comprising 30 dominant ("D-targets"), 30 non-dominant ("ND-targets") and 30 ambivalent ("A-targets") nonwords to be used as targets. In order to create two stress priming contexts, the remaining 150 nonwords, comprising 75 dominant and 75 non-dominant nonwords, were used as primes: ("dominant primes" and "non-dominant primes," respectively). (Note that the abbreviations "D-," "A-," and "ND-" are used only for targets, and not for primes, to distinguish these stimulus categories).

Targets

ND-targets included 30 nonwords that had obtained the lowest rates of dominant stress responses in the pre-test (mean 20.97 %, SD = 5.68, range 8.33–33.33) and had a non-dominant neighbourhood (mean percentage of dominant stress neighbourhood: 17 %). D-targets were selected among nonwords that had received the highest range of dominant response rates (mean 93.86 %, SD = 13.54 %, range 79.17–100 %) and had a dominant neighbourhood (mean percentage of dominant stress neighbourhood: 93 %). Finally, A-targets were those with intermediate range of dominant response rate (mean 55.61 %, SD = 5.94 %, range 29.17–79.17 %) and a balanced neighbourhood (mean percentage of dominant stress neighbourhood: 47 %). D-, A-, and ND-targets shared the initial phonemes. The mean length of D-, ND-, and A-targets was 6.33 letters (SD = 0.61), 6.37 letters (SD = 0.56) and 6.23 letters (SD = 0.57), and the mean number of consonant clusters was 0.33 (SD = 0.61), 0.30 (SD = 0.47), and 0.37 (SD = 0.49), respectively.

Primes

The mean percentage of dominant stress responses to these primes in the pre-test was 82.28 % (SD = 11.36 %, range 54.17–100 %) for dominant primes and 45.44 % (SD = 13.34 %, range 21.74–70.83 %) for non-dominant primes. The selection of non-dominant primes was constrained by the smaller number of endings consistent with antepenultimate stress in the language, and by the fact that the "best" nonwords (those with the highest proportion of non-dominant responses) were included in the target lists.

Procedure

Two priming lists were created, including dominant and non-dominant primes, respectively. For each target type half of the targets were inserted in the dominant priming list and the other half in the non-dominant priming list. In this way, each target was preceded by five primes with the same stress pattern, as in Colombo and Zevin (2009; see also Zevin & Balota, 2000). Thus, each list included 15 targets of the same type and 75 primes. Each of the three target types was presented to different subject groups (thus, target type was a between-subjects variable), whereas the same prime lists were used for all groups (thus, prime type was a within-subjects variable). Four different orders, counterbalanced among subjects, were created for each prime/target set. Each participant received the two priming lists in separate blocks in counterbalanced order; half of the participants received the dominant prime list first, while the other half was presented the non-dominant prime list first.

A voice key connected to the PC's real-time clock was used to collect response latencies and response durations to the nearest millisecond. The experiment was run using E-Prime software. Stimuli were presented on a computer screen. In each trial, a fixation point ("+") was presented for 300 ms, followed by a black stimulus on a white background. At the start of articulation the letter string turned red when the voice key responded, to signal to the experimenter the end of the trial. Response time for each trial was measured from the onset of the stimulus to the onset of articulation. Each stimulus remained on the screen until the experimenter coded the stress position assigned by the reader by pressing one of two keyboard keys. When the letter string disappeared, the next trial started immediately. The experimental blocks were preceded by a practice session with eight nonwords, not included in the experimental trials. Participants were instructed to read aloud each nonword quickly and accurately.

Results and discussion

As we were interested in evaluating the distribution of stress types, data were formed by the mean dominant response rates for the three target types in each priming condition (Table 1). The proportion of mispronunciation errors such as omissions, substitutions, and insertions (removed form further analyses) was very low (0.003). Generalized linear mixed-effects models were fit to the data by Laplace approximation with response dominance (binary data indicating the stress pattern

Table 1 Mean dominant stress response rates (SD in brackets) for the target nonwords in each priming condition obtained from adult participants in Experiment 2

Target	Prime	
	Dominant	Non dominant
Dominant	0.93 (0.25)	0.82 (0.38)
Ambivalent	0.76 (0.43)	0.46 (0.50)
Non-dominant	0.18 (0.39)	0.09 (0.28)

assigned in each trial) as a dependent variable, and including target type (between-subjects factor coding the three categories of nonword targets), prime (within-subjects factor coding the two prime types) and their interaction as fixed effects, and subject and item as random effects.

Mean dominant response rate varied among the three target types, with higher dominant response rate for D-targets than for A-targets and the lowest rate for ND-targets. Multiple comparisons showed significant differences among the three target types (between D- and A-targets (dominant prime condition: estimate = 1.941, SE = 0.704, z = 2.760, $p < .001$; non-dominant prime condition: estimate = 2.675, SE = 0.658, z = 4.064, $p < .001$); between D- and ND-targets (dominant prime condition: estimate = 6.008, SE = 0.705, z = 8.526, $p < .001$; non-dominant prime condition: estimate = 5.710, SE = 0.693, z = 8.242, $p < .001$) and, more importantly, between A- and ND-targets (dominant prime condition: estimate = 4.067, SE = 0.666, z = 6.108, $p < .001$; non-dominant prime condition: estimate = 5.036, SE = 0.678, z = 4.474, $p < .001$). The effect of priming was significant, with higher dominant response rate in the dominant priming than in the non-dominant priming condition for all the target types (for D-targets: estimate = 1.428, SE = 0.317, z = 4.509, $p < .001$; for A-targets: estimate = 2.161, SE = 0.249, z = 8.684, $p < .001$; for ND-targets: estimate = 1.129, SE = 0.285, z = 3.963, $p < .001$).

More interestingly, the priming effect was larger for A-targets (0.30 priming effect) than for ND-targets (0.11 priming effect; estimate = 1.03, SE = 0.38, z = 2.73, $p < .01$) and marginally than for D-targets (0.09 priming effect; estimate = 0.73, SE = 0.40, z = 1.82, $p < .07$), but the contrast between D- and ND-targets was not significant ($p = .43$).

The results showed a gradual decrease in the percentage of dominant stress assigned, depending on how reliably dominant stress was cued by the neighbourhood: ambivalent nonwords received a higher dominant stress rate than non-dominant nonwords, suggesting that when neighbourhood does not strongly cue either stress, the dominant stress is applied.

The results are in partial contrast to those obtained by Sulpizio et al. (2013) with unprimed nonwords. They found that neighbourhood consistency was strong for non-dominant nonwords, but less strong for dominant stress nonwords. In their Experiment 2, for example, only about 60 % of dominant nonwords were assigned dominant stress, and about 75 % of non-dominant nonwords were assigned non-dominant stress. Our data showed strong effects of neighbourhood consistency for both dominant and non-dominant types of nonwords: the average rate of dominant stress through the priming conditions was 87.5 % for D-targets and 86.5 %for ND-targets. One reason for this difference may be that we selected dominant targets with a higher proportion of consistent neighbours than Sulpizio et al. (2013). Moreover, not only the endings, but also the initial part of the nonwords may differently cue stress. For this reason we partially based our selection of nonword targets on the results of the pre-test.

A further important finding of the present study is that there was a significantly larger priming effect for targets whose neighbourhood is sparse or inconsistent, suggesting that when stress neighbourhood information is not strong, information from the context is more likely to be exploited. In general, the main implication is consistent with the findings of previous studies: the selection of endings, number of endings for each stress type, and the relative proportion of stress types within each neighbourhood are critical determinants of the assigned stress.

Experiment 2

Experiment 2 examined children's sensitivity to stress neighbourhood and priming in nonword stress assignment. Due to the much greater frequency of dominant stress in the lexicon, children might prefer to assign dominant stress to nonwords. However, when knowledge about the different distributional characteristics and the relative proportion of stress types is acquired, children may deploy stress neighbourhood as well. To investigate the relative developmental trend of these effects we examined children of two age levels, the second (7–8 years) and fourth (9–10 years) grades of primary school. We predicted that neighbourhood information, being item specific and more dependent on the increase in the size of the lexicon, should be acquired more gradually by children, and fully mastered only in adults.

Method

Participants

Ninety-six children attending primary school, including 48 second graders (age range 7–8 years old; 24 females and 24 males) and 48 fourth graders (age range 9–10 years old; 24 females and 24 males) were enrolled in Experiment 2. To insure that the participants did not have reading difficulties, a standardized test in which words and nonwords were presented in a list, and a text ("Il dente di Anna," from Bisiacchi, Cendron, Gugliotta, Tressoldi, & Vio, 2005) were administered to all children prior to the experimental test. All the children were well within the norms except one child who had difficulties, but only in text reading. All children were tested near the end of the school year.

Materials and procedure

Sixty target nonwords (20 D-, 20 ND-, and 20 A-targets) were selected from those used in the experiment with adults, in order to avoid tiredness in children. Two stress-priming lists were constructed, including 50 dominant and 50 non-dominant primes, respectively. Ten targets for each target type (D, ND, or A) were included in each priming list. Each child was presented with 10 targets of the same type and 50 dominant and 50 non-dominant primes. Each list included 60 items for each prime/target set, for a total of 120 experimental stimuli assigned to each participant. Each of the three target types was presented to different subject groups (thus, target type was a between-subjects variable; sixteen children from each grade were assigned to each of the target types), whereas the same prime lists were used for all groups (thus, prime type was a within-subjects variable). Four different orders were created for each prime/target set and counterbalanced among subjects. Each participant received the two priming lists in separate blocks in counterbalanced order; half of the participants received the dominant prime list first, while the other half was presented the non-dominant prime list first. Practice trials (eight trials for each list) were administered before the experimental trials.

The experiment was performed separately for each participant in a quiet room of the school. The experimenter explained the procedure to each child and ran some practice trials first. The remaining procedure was the same as for Experiment 1, except that no deadline was set for responses, and no pressure for fast latencies was made on children, as our interest was in the description of the distribution of stress types and its development, not in the processing course. The experiment was audio-recorded for later analysis.

Results and discussion

The data were formed by dominant response rates for the three target types in each priming condition (see Table 2). The proportion of mispronunciation errors (omissions, substitutions and insertions; discarded from further analyses) was very low (0.001).[1] Generalized linear mixed-effects models were fit to the data by Laplace approximation, first including dominant response rate as a dependent variable, and target type (between-subjects factor coding the three categories of nonword targets), prime (within-subjects factor coding the two prime types), grade (second and fourth grades), and their interactions as fixed effects. Subject and item were included as crossed random effects.

Stress neighbourhood information was used by children in naming nonwords aloud: dominant response rate varied among the different target types, with higher dominant response rate for D-targets than for A-targets, and lowest rate for ND-targets (Table 2). Differences for all comparisons were significant, except those between D- and A-targets in the Dominant prime condition (see Table 3).

Fourth grade children showed a significant effect of prime for all the target types, with overall higher dominant response rate in the dominant prime than in the non-

[1] The very low proportion of errors compared to other studies with children (see, for example, Marcolini, Burani, & Colombo, 2009; Sulpizio & Colombo, 2013) can be attributed to the fact that no time pressure was made on children, and the aim of the experiment was in the distribution of stress in the three nonword types. Thus, the experimenter induced the children to give as accurate a response as possible. Moreover, the absence of words in the experimental context did not encourage lexicalization errors, which occurred often in Marcolini, Burani, and Colombo (2009). Hesitations and false starts were not considered errors.

Table 2 Mean dominant stress response rates (SD in brackets) for the target nonwords in each priming condition obtained from second and fourth grade children in Experiment 2

Target	2nd grade		4th grade	
	Prime			
	Dominant	Non dominant	Dominant	Non dominant
Dominant	0.96 (0.19)	0.94 (0.23)	0.95 (0.22)	0.89 (0.32)
Ambivalent	0.88 (0.33)	0.76 (0.43)	0.88 (0.33)	0.74 (0.44)
Non-dominant	0.56 (0.50)	0.51 (0.50)	0.41 (0.49)	0.29 (0.45)

Table 3 Comparison between different target types in dominant and non-dominant priming conditions for second and fourth grade children in Experiment 2

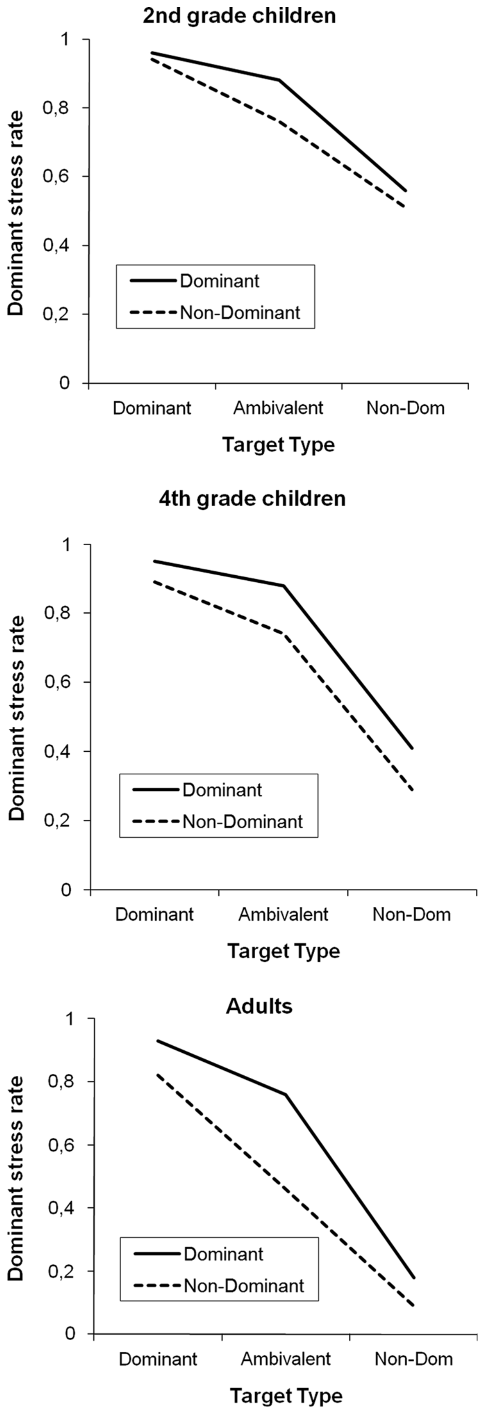
Prime	Contrast	2nd graders	4th graders
Dominant	D- versus A-targets	z = 1.858, $p = .06$	z = 1.930, $p = .05$
	D- versus ND-targets	z = 4.841, $p < .001$	z = 5.726, $p < .001$
	A- versus ND-targets	z = 3.449, $p < .001$	z = 4.254, $p < .001$
Non-dominant	D- versus A-targets	z = 2.762, $p < .01$	z = 2.379, $p < .05$
	D- versus ND-targets	z = 4.824, $p < .001$	z = 5.985, $p < .001$
	A- versus ND-targets	z = 2.374, $p < .05$	z = 3.983, $p < .001$

dominant prime condition (for D-targets: estimate = 1.077, SE = 0.512, z = 2.103, $p < 05$; for A-targets: estimate = 1.276, SE = 0.361, z = 3.531, $p < .001$; for ND-targets: estimate = 0.988, SE = 0.317, z = 3.115, $p < .005$), while in second grade children the effect of prime was significant only for A-targets (estimate = 1.181, SE = 0.364, z = 3.244, $p < .005$).

The effect of grade was only significant for ND-targets in the non-dominant priming condition, with higher dominant response rates for second graders than for fourth graders (estimate = 1.494, SE = 0.716, z = 2.086, $p < .05$). The interactions of grade with other factors were not significant. Overall, children's rate of dominant stress assignment was higher than adults', and also showed a gradual decrease with the decrease of dominant stress neighbourhood. Children were also influenced by stress priming in assigning stress to nonwords, although young children were less sensitive to the effect of context, and could exploit it mainly with items with a weak neighbourhood.

A further analysis was carried out to statistically compare the pattern of effects in children and adults (Fig. 1). The data from Experiment 1 (adults) and Experiment 2 (children) were combined by selecting items in common between the two experiments, and were analysed using models including dominant stress rate as dependent variable, target type, prime and grade as fixed effects, with their interactions, and subject and item as crossed random effects. The comparison between children of each age group and adults was made by including three levels of the fixed effect grade (i.e., second and fourth grades and adults) and by coding

Fig. 1 Interaction plots of dominant response rate (y) for each target type (x) in the dominant (*dashed line*) and non-dominant (*solid line*) prime conditions as a function of target type (dominant, ambivalent, non-dominant) for second grade children (*top*), fourth grade children (*middle*) and adults (*bottom*)



adults as the reference level. To simplify the description, we present only the effect of grade, and significant interactions involving grade.

Dominant response rates were significantly higher in second grade children (estimate = 2.479, SE = 0.673, z = 3.682, $p < .001$) and fourth grade children (estimate = 1.689, SE = 0.675, z = 2.504, $p < .05$) than in adults for ND-targets in the dominant priming condition and for A-targets (second grade vs. adults: estimate = 2.114, SE = 0.673, z = 3.142, $p < .01$; fourth grade vs. adults: estimate = 1.833, SE = 0.666, z = 2.754, $p < .01$) and ND-targets (second grade vs. adults: estimate = 3.296, SE = 0.694, z = 4.751, $p < .001$; fourth grade vs. adults: estimate = 1.800, SE = 0.705, z = 2.553, $p < .01$) in the non-dominant priming condition. Interestingly, the prime by grade interaction was significant only for A-targets for second graders and adults, but not for fourth graders and adults, (estimate = 0.926, SE = 0.439, z = 2.111, $p < .05$) or for ND-targets (estimate = 0.817, SE = 0.396, z = 2.062, $p < .05$), reflecting smaller priming effects in younger children.

Overall, children were influenced by both neighbourhood information of word-endings and stress priming in assigning stress to nonwords. However, they also showed a greater tendency than adult participants to assign dominant stress to nonwords with inconsistent and dominant stress neighbourhood (Fig. 1). Moreover, while younger children showed sensitivity to the priming effect only on nonwords with weak stress neighbourhood (i.e., A-targets) which were most susceptible to priming in adults (Experiment 1), fourth graders showed significant stress priming effect on all the target types in a similar way as adults. Figure 1 also shows that second graders tended to assign stress on the penultimate syllable to ND-targets more often than fourth graders, and this tendency was statistically confirmed in the priming condition with non-dominant nonwords. These results suggest that younger children depend more on the typical prosodic pattern in their native language and that assignment of non-typical stress patterns based on the neighbourhood information is gradually learned as children's reading expertise increases.

General discussion

In two experiments we found that nonwords created with a decreasing rate of dominant stress neighbourhood, as cued by their endings, were assigned a gradually decreasing rate of dominant stress. In particular, ambivalent nonwords were mostly assigned dominant stress. Moreover, nonwords created with a high probability of being named with dominant or non-dominant stress depending on neighbourhood were effective primes for nonword targets. Primes induced participants to assign dominant stress more often when the prime was dominant than when the prime was non-dominant, in particular when the neighbourhood of the target nonword was weak or inconsistent (A-targets). This difference among targets with differing degrees of consistency between orthography and stress patterns is consistent with other findings on nonword pronunciation, supporting the idea of graded sensitivity to probabilistic constraints of the lexicon and, in general, the idea of consistency as a graded, not a categorical, effect (Arciuli, Monaghan, & Seva, 2010; Burani &

Arduino, 2004; Colombo & Zevin, 2009; Cortese & Simpson, 2000; Harm & Seidenberg, 2004; Treiman, Kessler, & Bick, 2002; Treiman, Kessler, Zevin, Bick, & Davis, 2006; Zevin & Seidenberg, 2006).

Although all three factors—general stress distribution in the language, specific (neighbourhood) information, and priming context—affected the proportion of dominant response rates, the pattern was different in adults and children. Children were sensitive to stress neighbourhood, but less so than adults, and showed more marked effects of general information, gradually decreasing with age. Thus children initially over-generalize, but gradually learn to use more specific information, depending on experience with the words they encounter. Similarly, Arciuli, Monaghan, and Seva (2010) found increasing reliance on probabilistic cues to stress in the orthography of endings. More generally, the data are consistent with other studies on nonword pronunciation showing different effects of probabilistic constraints and their influence on reading development (Treiman, Kessler, Zevin, Bick, & Davis, 2006; Zevin & Seidenberg, 2006). In particular, Treiman, Kessler, Zevin, Bick, and Davis (2006) showed that first grade children increasingly used the vowel context (coda-to-vowel and onset-to-vowel) to assign a pronunciation to nonwords, up to the fifth grade. In their monosyllabic nonwords the coda-vowel association is in fact a rhyme, as is a rhyme the ending on which our stress neighbourhood effects are based.

The results are consistent with the results of Sulpizio and Colombo (2013), who tested second and fourth graders in a naming task with words and nonwords. In that study, stress dominance and stress neighbourhood affected the performance on words for both groups of children, and stress neighbourhood affected older children more than it affected younger children. The study also showed that as readers' age increased they showed a general tendency to assign dominant stress less frequently and use stress neighbourhood more frequently. In that study, nonwords' endings were polarized, with endings belonging to either a strong dominant or a strong non-dominant neighbourhood. In the present study we confirmed that the rate of dominant stress decreased with non-dominant stress nonwords. Interestingly, with ambivalent nonwords the proportion of dominant stress was intermediate between dominant and non-dominant stress nonwords in adults, but it was larger for children.

Stress neighbourhood

The influence of stress neighbours on stress assignment has been explained in two ways (Colombo, 1992; Colombo & Zevin, 2009). Stress can be assigned by analogy to existing words, assuming that the endings activate a number of words containing them. If a specific stress pattern is dominant in the neighbourhood, this will affect stress placement, in particular in nonwords. A special case of this idea would be when there is a specific, high frequency neighbour that is particularly similar to a nonword. Indeed, Marcolini, Burani, and Colombo (2009) in a naming experiment on nonwords differing by just one letter from real words found that third and fifth grade children made more errors on nonwords derived from high than from low frequency words. Moreover, they made a relatively high percentage of lexical errors (10 %), reporting the real word instead of the nonword target. In the present study, the number of neighbours calculated according to the orthographic N size statistics were 50, 9, and 49 for dominant, ambivalent and non-dominant nonwords, respectively, with a mean frequency of 6.5, 8.6, and 19.5. Although the mean frequency of non-dominant nonwords was higher than in the other two conditions ($p < .05$), it was still in the low frequency range, which makes it unlikely that a specific neighbour has contributed to the relative patterns of stress assignment in the three conditions. Moreover, we counted how many highest-frequency neighbours of each nonword (that is, the word with the highest frequency in the nonword's neighbourhood) have the same stress as the nonword's itself, and found that it is exactly the same number for dominant and non-dominant stress nonwords (19). Thus, it is unlikely that the pattern of stress assignment in the three conditions was determined by specific neighbours.

A second way to interpret stress neighbourhood effects is to assume that the probabilistic associations between frequent endings in written words and corresponding prosodic patterns is implicitly learned by exposure. Consequently, typical word endings (i.e., word endings that very frequently are assigned a specific pattern) may be easily chunked as units and act as emerging patterns. These patterns may be orthographically coded, providing valid information about stress. A similar proposal has been made for units such as onset and rhyme in English (Treiman & Kessler, 2006; Treiman, Kessler, Zevin, Bick, & Davis, 2006). On the basis of stress typicality effects found in lexical decision and of corpus analyses, Arciuli and Cupples (2006) argued that the information about word endings, providing predictable cues for stress assignment in English, might be orthographically coded.

Children first acquire general information about the most frequent stress pattern. Specific information about stress neighbourhood, based on formal similarity among words, is necessarily dependent on experience with different words and on the increase in the size of the vocabulary. As children's reading proficiency increases, so does their experience with both lexical and sub-lexical orthographic representations, their ability to segment words into functional units, and their associations with learned phonetic patterns.

Older children's increasing tendency to exploit neighbourhood information may depend, besides on their increasing reading ability, on the corresponding increase in the acquisition of the co-occurrence relation between orthography and phonology, and on actively exploiting orthographic cues to pronunciation, rather than purely on an increase in the spoken vocabulary, consistent with proposals based on the idea of multiple grain size units (Pagliuca & Monaghan, 2010; Treiman & Kessler, 2006; Treiman, Kessler, Zevin, Bick, & Davis, 2006; Zevin & Seidenberg, 2006; Ziegler & Goswami, 2005). Specific support for this view comes from Pagliuca and Monaghan's PDP network, which was able to simulate the effect of stress neighbourhood (on words with the less frequent stress) with no layer of lexical nodes. It remains to be seen whether this network can simulate the pattern of results obtained with children.

Stress priming

Stress assignment by both adults and children reflected the stress pattern of the preceding primes, although the sensitivity to priming was different in the two groups. As noted above, given that targets and primes did not share endings and the overlapping phonemes between primes and targets were as limited as possible, within the many constraints of stimuli selection, priming effects must be based on an abstract metrical coding, suggesting number of syllables (which was the same for all stimuli) and position of stress. Younger children were less likely to use this information, showing a priming effect only on nonwords with weak/inconsistent neighbourhood. If the ending is part of a strong neighbourhood, the phonetic correspondence is easily available as an emergent property of the distributional characteristics of a group of words, already acquired at the level of spoken language (the stress neighbourhoods). Thus, priming might not be effective. With weak/inconsistent neighbourhood, the process of abstraction of metrical information from context primes must be computed on line. Although children have been shown to acquire statistical information from an artificial language very rapidly (Saffran, Aslin, & Newport, 1996), this ability probably lags behind their capacity to exploit already acquired information.

An important point that we underline is the fact that similar principles have been shown to apply, despite differences in the orthographic and phonological characteristics of languages like Italian and English. Information about both beginnings and endings provides reliable cues in English, while endings are more important in Italian. Further, despite the much greater difficulty of learning to read in English compared to Italian, both English and Italian children show an increasing reliance on specific (stress position) information, although English children's use of these cues is probably delayed compared to Italian children, who can read three-syllable words much earlier than their English counterparts. Clearly, these results provide important constraints to models of reading and reading development.

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Appendix

Nonword targets used in Experiment 1

Dominant targets

Adoso, bigheta, calune, camave, cezota, colluta, fedale, folino, forlata, frellata, gorese, incroni, lefata, mascato, mazura, mevino, nelota, nervese, nifato, peroci, pialoso, pidoso, pobana, ribate, riscuta, sentana, tofina, torate, tuposo, zilaso.

Non dominant targets

Bagica, calica, cevulo, costico, cuvule, egule, fedulo, fesimo, fessile, framolo, gortica, ivole, lisico, masole, medulo, mubile, navola, nefolo, nostice, paffero, pagile, parico, posico, recolo, ruspice, stasimo, temola, tifola, trivolo, zalide.

Ambivalent targets

Bettuce, castubo, cenuge, chiroga, corafo, empomi, etuce, faboga, feluge, fispuce, fraboro, gurafo, lutebre, mepuce, mivoro, motafo, nalafo, ninoro, nostubo, panebre, paroga, piedomi, pirtubo, reluge, rudomi, saccubo, tegoro, tenuge, tolebre, zefomi.

Nonword targets used in Experiment 2

Dominant targets

Adoso, bigheta, cezota, colluta, forlata, frellata, gorese, incroni, lefata, mascato, mazura, mevino, nervese, nifato, pidoso, pobana, ribate, sentana, tuposo, zilaso.

Non dominant targets

Bagica, calica, costico, egule, fesimo, fessile, framolo, ivole, lisico, navola, nostice, paffero, posico, recolo, ruspice, stasimo, temola, tifola, trivolo, zalide.

Ambivalent targets

Bettuce, cenuge, corafo, etuce, faboga, fraboro, gurafo, lutebre, motafo, nalafo, ninoro, nostubo, panebre, piedomi, reluge, rudomi, saccubo, tegoro, tenuge, zefomi.

Nonword primes used in Experiment 1

Dominant primes

Aldume, ammino, astone, berino, bildese, biluta, birume, bistone, bodune, camoni, cefune, ceraso, cobota, costore, crimito, delore, denora, derrina, dirloni, dolame, dorreta, dumale, ellate, erale, etaso, fevone, frotona, galave, gambura, ganoci, garede, gecana, gerave, govato, iruta, lemana, lidame, lighena, linata, lirdane, mafona, mavena, mobane, namito, nolura, olina, onese, paghite, polaso, predune, raddame, remoni, ristume, rocede, saloci, scelate, settame, sintura, solume, sorato, starave, stoleta, tevone, tralede, urfina, valona, vamite, vaneta, vernite, vistena, zaloci, zemito, zemora, zilota, zirtona.

Non dominant primes

Adimo, alima, ascimi, astola, ballido, bedule, befela, berice, bollice, bovero, catimi, ceberi, celido, comilo, dediro, defano, derule, dessima, dirtola, dolima, dostera, ellera, eperi, facero, faride, fiocimi, giatero, ginido, gofano, gospilo, gramulo, lagule, lenolo, licero, loride, mavida, miegano, mosteri, mulica, necile, nemera, nerida, oddimo, ofide, pamida, perbera, pivida, rastole, rincolo, rolide, rostimi, sanlice, sbaccole, sperilo, spisida, stipimi, stopera, strimole, stubela, terpico, trofulo, tugile, turnido, umbica, valice, vatiro, velfola, vepela, vibela, visima,zapide, zelido, zifilo, ziltica, zipero.

Nonword primes used in Experiment 2

Dominant primes

Aldume, astone, berino, bildese, biluta, birume, bistone, bodune, camoni, ceraso, cobota, delore, denora, derrina, dirloni, dolame, dorreta, ellate, fevone, gambura, ganoci, garede, gecana, govato, iruta, lemana, lidame, lighena, linata, lirdane, mavena, mobane, olina, onese, paghite, polaso, remoni, saloci, scelate, settame, sintura, sorato, stoleta, tevone, urfina, valona, vistena, zaloci, zilota, zirtona.

Non dominant primes

Adimo, astola, ballido, bedule, berice, bollice, bovero, ceberi, celido, comilo, dediro, derule, dessima, dirtola, eperi, facero, faride, fiocimi, ginido, gofano, gospilo, gramulo, lagule, licero, loride, mulica, necile, oddimo, ofide, pivida, rastole, rincolo, rolide, sbaccole, sperilo, spisida, stipimi, strimole, terpico, trofulo, tugile, umbica, valice, vepela, visima, zapide, zelido, zifilo, ziltica, zipero.

References

Arciuli, J., & Cupples, L. (2006). The processing of lexical stress during visual word recognition: Typicality effects and orthographic correlates. *Quarterly Journal of Experimental Psychology, 59*(5), 920–948.

Arciuli, J., Monaghan, P., & Seva, N. (2010). Learning to assign lexical stress during reading aloud: Corpus, behavioural, and computational investigations. *Journal of Memory and Language, 63*, 180–196.

Arciuli, J., & Simpson, I. (2011). Statistical learning in typically developing children: The role of age and speed of stimulus presentation. *Developmental Science, 14*(3), 464–473.

Arciuli, J., & Simpson, I. (2012). Statistical learning is related to reading ability in children and adults. *Cognitive Science, 36*(2), 286–304.

Arduino, L., & Burani, C. (2004). Neighborhood effects on nonword visual processing in a language with shallow orthography. *Journal of Psycholinguistic Research, 33*, 75–95.

Bertinetto, P. M., Burani, C., Laudanna, A., Marconi, L., Ratti, D., Rolando, C., & Thornton, A. M. (2005). *CoLFIS. Corpus and Frequency Lexicon of Written Italian*. http://www.istc.cnr.it/grouppage/colfisEng.

Bisiacchi, P. S., Cendron, M., Gugliotta, M., Tressoldi, P. E., & Vio, C. (2005). *BVN 5-11 Batteria di valutazione neuropsicologica per l'età evolutiva*. Trento: Erickson.

Brown, P., Lupker, S. J., & Colombo, L. (1994). Interacting sources of information in word naming: A study of individual differences. *Journal of Experimental Psychology: Human Perception and Performance, 20*(3), 537–554.

Burani, C., & Arduino, L. S. (2004). Stress regularity or consistency? Reading aloud Italian polysyllables with different stress patterns. *Brain and Language, 90*, 318–325.

Burani, C., Marcolini, S., De Luca, M., & Zoccolotti, P. (2008). Morpheme-based reading aloud: Evidence from dyslexic and skilled Italian readers. *Cognition, 108*(1), 243–262.

Colombo, L. (1992). Lexical stress effect and its interaction with frequency in word pronunciation. *Journal of Experimental Psychology: Human Perception and Performance, 18*(4), 987–1003.

Colombo, L., & Zevin, J. (2009). Stress priming in reading and the selective modulation of lexical and sub-lexical pathways. *PLoS One, 4*(9), e7219. doi:10.1371/journal.pone.0007219.

Coltheart, M., Curtis, B., Atkins, P., & Haller, M. (1993). Models of reading aloud: Dual-route and parallel-distributed-processing approaches. *Psychological Review, 100*(4), 589–608.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascade model of visual word recognition and reading aloud. *Psychological Review, 108*(1), 204–256.
Cortese, J. M., & Simpson, G. B. (2000). Regularity effects in word naming: What are they? *Memory and Cognition, 28*(8), 1269–1276.
Harm, M. W., & Seidenberg, M. S. (1999). Phonology, reading acquisition, and dyslexia: Insights from connectionist models. *Psychological Review, 106*(3), 491–528.
Harm, M. W., & Seidenberg, M. S. (2004). Computing the meanings of words in reading: Cooperative division of labor between visual and phonological processes. *Psychological Review, 111*(3), 662–720.
Marcolini, S., Burani, C., & Colombo, L. (2009). Lexical effects on children's pseudoword reading in a transparent orthography. *Reading and Writing, 22*(5), 531–544.
Monsell, S., Doyle, M. C., & Haggard, P. N. (1989). Effects of frequency on visual word recognition tasks: Where are they? *Journal of Experimental Psychology: General, 118*, 43–71.
Pagliuca, G., & Monaghan, P. (2010). Discovering large grain-sizes in a transparent orthography: Insights from a connectionist model of reading aloud for Italian. *European Journal of Cognitive Psychology, 22*, 813–835.
Perry, C., Ziegler, J. C., & Zorzi, M. (2007). Nested incremental modeling in the development of computational theories: The CDP+ model of reading aloud. *Psychological Review, 114*(2), 273–315.
Perry, C., Ziegler, J. C., & Zorzi, M. (2010). Beyond single syllables: Large-scale modeling of reading aloud with the Connectionist Dual Process (CDP++) model. *Cognitive Psychology, 61*(2), 106–151.
Plaut, D. C., Patterson, K., McClelland, J. L., & Seidenberg, M. S. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review, 103*(1), 56–115.
Protopapas, A., & Gerakaki, S. (2009). Development of processing stress diacritics in reading Greek. *Scientific Studies of Reading, 13*(6), 453–483.
Protopapas, A., Gerakaki, S., & Alexandri, S. (2006). Lexical and default stress assignment in reading Greek. *Journal of Research in Reading, 29*(4), 418–432.
Rastle, K., & Coltheart, M. (2000). Lexical and nonlexical print-to-sound translation of disyllabic words and nonwords. *Journal of Memory and Language, 42*, 342–364.
Saffran, J. R., Aslin, R. N., & Newport, E. L. (1996). Statistical learning by 8-month-olds. *Science, 274*, 1926–1928.
Seidenberg, M. S., & Mc Clelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review, 96*(4), 523–568.
Seva, N., Monaghan, P., & Arciuli, J. (2009). Stressing what is important: Orthographic cues and lexical stress assignment. *Journal of Neurolinguistics, 22*(3), 237–249.
Sulpizio, S., Arduino, L. S., Paizi, D., & Burani, C. (2013). Stress assignment in reading Italian polysyllabic pseudowords. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 39*(1), 51–68.
Sulpizio, S., & Colombo, L. (2013). Lexical stress, frequency, and stress neighbourhood effects in the early stages of Italian reading development. *The Quarterly Journal of Experimental Psychology,*. doi:10.1080/17470218.2013.785577.
Sulpizio, S., Job, R., & Burani, C. (2012). Priming lexical stress in reading Italian aloud. *Language and Cognitive Processes, 27*(6), 808–820.
Treiman, R., & Kessler, B. (2006). Spelling as statistical learning: Using consonantal context to spell vowels. *Journal of Educational Psychology, 98*, 642–652.
Treiman, R., Kessler, B., & Bick, S. (2002). Context sensitivity in the spelling of English vowels. *Journal of Memory and Language, 47*, 448–468.
Treiman, R., Kessler, B., Zevin, J., Bick, S., & Davis, M. (2006). Influence of consonantal context on the reading of vowels: Evidence from children. *Journal of Experimental Child Psychology, 93*, 1–24.
Zevin, J. D., & Balota, D. A. (2000). Priming and attentional control of lexical and sublexical pathways during naming. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 26*(1), 121–135.
Zevin, J. D., & Seidenberg, M. S. (2006). Simulating consistency effects and individual differences in nonword naming: A comparison of current models. *Journal of Memory and Language, 54*(2), 145–160.
Ziegler, J., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin, 131*(1), 3–29.

Zorzi, M., Houghton, G., & Butterworth, B. (1998). Two routes or one in reading aloud? A connectionist dual-process model. *Journal of Experimental Psychology. Human Perception and Performance, 24*(4), 1131–1161.