Stress still affects articulatory planning in reading aloud: A Reply to White and Besner (2016)

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Abstract

In their comment White and Besner (2016) argue against our conclusion that stress assignment may affect polysyllable pseudoword reading and conclude that, currently, we do not know whether the effect of stress position is solid and reliable. White and Besner state that because the experiments reported in Sulpizio, Spinelli and Burani (2015) have methodological problems, our conclusion is grounded on weak evidence. In this reply we present further analyses of our data that overcome the methodological weakness highlighted by White and Besner. The results of these new analyses consistently mirror those reported by Sulpizio and colleagues (2015) and speak in favor of the view that, in reading Italian pseudowords aloud, stress assignment affects articulatory planning of the stimulus.

Statement of the public significance of the work

In a previous study we have demonstrated that, in pseudoword reading, stress has to be assigned before articulation may start. This conclusion was questioned by White and Besner, who argued that our finding was due to a technical flaw in how we measured participants' responses. The present comment replies to White and Besner's criticisms by following their recommendation that vocal responses should be manually checked before statistical analysis. Manually checked results offer further evidence that, at least in Italian, stress assignment affects the starting of articulation. This finding has important implications for understanding how people read written stimuli aloud, as it sheds light on the mechanisms by which abstract-phonological representations are converted into articulatory-motor programs.

In our original article (Sulpizio, Spinelli, & Burani 2015, henceforth SSB) we investigated the effect of stress assignment on pseudoword reading by manipulating the type of stress pseudowords could receive (antepenultimate vs. penultimate) together with the stimulus length (three- vs. four-syllables) and the experimental procedure (immediate reading aloud: participants read pseudowords as soon as they appeared; vs. delayed reading aloud: participants were instructed to wait for a response cue before starting to produce the response). We showed that Italian readers are faster when they read stimuli with antepenultimate (e.g., BA.ni.ro[1]) than penultimate stress (e.g., ba.NI.ro), i.e., when the stressed syllable comes earlier in the to-be-uttered sequence. Since the effect of stress did not depend on the procedure adopted (i.e., same effect in both the immediate and the delayed procedures) we concluded that "stress assignment affects articulatory planning of the stimulus to be read" (Sulpizio et al., 2015, p. 458). In their commentary to our article, White and Besner (2016, hencefort WB) state that the conclusion we drew is questionable since the data we reported are unconvincing. Here we offer further data analyses supporting our previous results; we thus suggest that the available evidence is consistent with the idea that, in reading, stress assignment affects articulatory planning of pseudowords.

In WB's words, "The central problem in all of the experiments revolves around the use of a voice key" (p. 5): Antepenultimate-stress pseudowords would be faster than penultimate-stress pseudowords simply because of "an artifact of the use of the voice key" (p. 5). Specifically, the use of the voice key to record vocal responses is highly prone to error, because it is triggered simply by amplitude and intensity of the sound; therefore, "since unstressed syllables are lower in amplitude and intensity, the voice key is slow at picking them up... The stress effect seen here may therefore be an artifact of the use of the voice key" (p. 5). To overcome this fatal limitation, WB (as well as many other researchers) suggest to use a program that allows to record the waveforms of participants' responses, which can then be inspected and analyzed directly. A software that allows to perform such operations quite easily is DMDX (Forster & Forster, 2003), which we indeed used in

1 Capital letters indicate stressed syllable and dots indicate syllabic boundaries.

our Experiment 3 (p. 458). Waveforms recorded with DMDX can be analyzed with Checkvocal (Protopapas, 2007), which is a program specifically developed to help researchers to check results of naming tasks in terms of proper triggering of the voice key.

Following WB's rule of thumb – i.e., by using the DMDX-CheckVocal combination – we re-analyzed the data of SSB's Experiment 3 in order to verify whether the stress effect we reported passes the critical test after inspecting participants' responses by means of Check Vocal (Protopapas, 2007). Table 1 reports the mean RTs by experimental condition (immediate vs. delayed reading) after the inspection of waveforms.

Table 1. Mean RTS for correct responses by experimental condition after Check Vocal analysis (with standard deviations in parenthesis). Experiment 3 from SSB.

	Immediate reading	
Stress	Three syllables	Four Syllables
Penultimate	619 (140)	766 (237)
Antepenultimate	599 (144)	714 (209)
Difference	**20**	**52**
	Delayed reading	
Penultimate	469 (118)	466 (114)
Antepenultimate	454 (115)	445 (111)
Difference	**15**	**21**

We then analyzed the checked data in the same way WB did, that is by means of a 2 x 2 x 2 ANOVA with RTs as dependent variable and stress type (antepenultimate vs. penultimate stress), stimulus length (three vs. four syllables), and experimental procedure (immediate vs. delayed) as within-participants factors. The use of the same analysis makes our results easily and immediately comparable with those of WB. The RTs were log-transformed in order to reduce the original

skewness of the data and obtain a Gaussian-like distribution (e.g., Baayen, 2008); note that this procedure does not affect the pattern of results, which is exactly the same when raw RTs (instead of log-transformed RTs) are used. The analysis showed main effects of: Experimental procedure ($F(1,34) = 71.06$, $p<.001$), stimulus length ($F(1,34) = 32.45$, $p<.001$), and stress type ($F(1,34) = 11.34$, $p=.001$). The two-way interaction between stimulus length and experimental procedure was also significant ($F(1,34) = 65.31$, $p<.001$); further inspection of the interaction by means of multiple t-test comparisons (with Bonferroni correction) revealed that the effect of stimulus length was significant in the immediate ($t(34) = -7.45$, $p <.001$), but not in the delayed experimental procedure ($t < 1$, $p >.6$): the pattern is identical to that reported by SSB and replicates the well known finding that the effect of stimulus length is cancelled by delayed naming (e.g., Ferrand, 2000; Zoccolotti, De Luca, Judica, & Burani, 2006). No further interaction reached significance (stress type x experimental procedure: $F < 1$, $p >.8$; stress type x stimulus length: $F <1$, $p >.3$; stress type x stimulus length x experimental procedure: $F<1$, $p >.5$). The results clearly speak in favor of a reliable effect of stress type that is not modulated by the experimental procedure. The pattern is identical to that we reported in our original analysis (Sulpizio et al., 2015). Given WB's concerns about four-syllable stimuli in the delayed condition, it is worth nothing that, after the use of CheckVocal, there is an increase in the size of the effect of stress type for them. The effect goes up from the original "unreliable" (because unchecked) 13 ms to the current 21 ms.

Now that we have tackled the specter of the voice key with empirical evidence, we wish to add a further argument, which we believe partially speaks against the logic of the voice-key explanation of the antepenultimate-stress advantage. As correctly noted by WB, the triggering of the voice key is based on voice intensity, which is higher in stressed than unstressed syllables. This issue might have a large impact on our three-syllable stimuli, since their first syllable is either stressed – in the antepenultimate-stress condition (e.g., BA.ni.ro) – or unstressed – in the penultimate-stress condition (e.g., ba.NI.ro); however, the same does not hold for four-syllable

stimuli, in which the first syllable is always unstressed independently of the stress pattern the stimulus receives (e.g., ba.SA.vo.ra vs. ba.sa.VO.ra)[2]. Following on this reasoning, it is worth nothing that, in terms of rhythmic prominence, the first syllable of a four-syllable stimulus may be phonologically more prominent when that stimulus bears stress on the penultimate syllable (swSw, where s = strong, w = weak, S = stressed) than on the antepenultimate syllable (wSws, see, e.g., D'Imperio & Rosenthal, 1999; Lieberman & Prince, 1977)[3]. This entails that antepenultimate-stress four-syllable stimuli would have equal – if not higher – chance to delay voice-key triggering than penultimate-stress four-syllable stimuli. To test whether this insight has any empirical reliability, we have conducted an exploratory acoustic analysis in which we have looked at the intensity of the first syllable of our four-syllable pseudowords when received either penultimate (e.g., ba in ba.sa.VO.ra) or antepenultimate stress (e.g., ba in ba.SA.vo.ra; the measure of intensity was extracted with PRAAT; Boersma & Weenink, 2007). We exploratorily extracted intensity values from the production of 4 female participants and found that the average intensity of the first syllable was higher when the four-syllable pseudowords received penultimate than antepenultimate stress (74.18 dB vs 70.09 dB, $t(19) = 6.64$, $p < 001$). These data suggest that, when four-syllable stimuli are involved, antepenultimate stress stimuli have equal, if not more, chance than penultimate stress stimuli to delay voice-key triggering.

All in all, the new analyses we report here argue against the idea that the antepenultimate stress advantage we reported is simply an artifact of the use of the voice key. White and Besner stated that "The only way to be sure that there is a genuine stress effect when reading aloud is to use DMDX (Forster & Forster, 2003) in combination with the CheckVocal program (Protopapas, 2007) that allows the waveform to be analyzed" (p. 6). This is what we have just done and the results speak in favor of a genuine stress effect.

2 Note that in Italian, unstressed vowels are never reduced to schwa. This means that the first unstressed syllable of four-syllable stimuli is always pronounced with a real vowel, which requires the full realization of the syllable.

3 Other approaches in phonological theory suggest that, within a word, only the stressed syllable is rhythmically strong and all other syllables are equally weak (e.g., Marotta 2003; Nespor & Vogel, 2007). In this case, the first syllable of four-syllable stimuli would be equally weak irrespective of the stimulus stress pattern (wSww vs. wwSw for antepenultimate and penultimate stress, respectively).

Concluding remarks

By analyzing checked RTs we have repeatedly and consistently shown that, in Italian, pseudowords that receive antepenultimate stress (e.g., BAniro, baSAvora) are read faster than those receiving penultimate stress (e.g., baNIro, basaVOra), and this effect is not modulated by the chance participants have to prepare their responses. These results support our previous findings, indicating that the effect of stress type is not a by-product of technical levities.

Where does the antepenultimate stress advantage shown by Italian readers come from? In our view, it has to deal with the articulatory planning of the stimulus to be read, which may proceed rightward incrementally (e.g., Kinoshita, 2000; Schiller, Bles, & Jansma, 2003). Specifically, stress location affects the articulatory planning units; such units would include the stimulus beginning up to the stressed syllable, with readers being able to buffer a partial articulatory representation of the to-be-uttered stimulus (Sulpizio, Arduino, Paizi, & Burani, 2013; Sulpizio et al., 2015; see also, Sternberg, Knoll, Monsell, & Wright, 1988; Sternberg, Monsell, Knoll, & Wright, 1978). Is this the best explanation ever for the phenomenon we discovered? We still don't know. Our proposal is reasonable from both the motor-phonetic perspective – stress determines the rhythmic organization of syllables as well as the identity and coarticulation properties of phonemes – and the cognitive modeling of reading – some current computational models of reading suggest that articulation cannot start until stress has been assigned to the to-be-read stimulus (e.g., Perry, Ziegler, & Zorzi, 2010). Moreover, our introspection suggests that, as readers, we do not have to fully encode a long stimulus (e.g., *supercalifragilisticexpialidocious*) before starting its motor execution. The litmus test for our proposal, however, will be future empirical investigation, which is also needed to better detail the psychological phenomenon under investigation.

For far too long the psychological science of reading has kept the study of the articulatory planning and execution far away from its theories. We hope that stress effects may help to break the ice and be inspiring for future empirical research.

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