participants in the three speaker groups (CAS, CND, AAS) had non-marginal PM+ scores (i.e., met PM criteria for apraxia of speech).

Table 6. Speaking Rate, Articulation Rate, and Pause Time data for participants in three speaker groups classified by PMI level. All participants had non-marginal PM+ scores (i.e., met PM criteria for apraxia of speech).

Table 6 includes speech and pause rate data for participants in three groups (CAS, CND, and AAS) classified by their PMI level of severity. All participants had non-marginal PM+ scores. Speaking Rate includes both pause time and speaking time (syll/sec), whereas Articulation Rate includes only speaking time (i.e., pause times are subtracted). Pause Time/Syllable (ms), is the total pause time divided by the number of syllables.

PART IV. AN ACOUSTIC STUDY OF THE PAUSE MARKER

Part IV describes findings from an initial study towards developing an automated procedure for the Pause Marker. Consistent with study questions and findings in PM III, the focus in these studies was on the pause and speech elements of the Type I inappropriate between-words pause termed *abrupt.*

The significant, but modest effect sizes obtained, using different participant groups, different measures, and different temporal windows (see Table 7), indicated that more developmental work is needed toward the goal of automated scoring of the Pause Marker. Findings from this initial study are included in this technical report for their potential to aid in the development of an automated scoring system for the Pause Marker with the sensitivity and specificity needed for research and clinical applications.

Method

Transcripts from participants positive for apraxia of speech in the CAS and AAS groups, as well as a group termed Complex Neurodevelopmental Disorders (CND) described in PM III, were inspected for occurrences of abrupt inappropriate pauses. For each occurrence of an inappropriate abrupt pause, we attempted to identify an occurrence of one of the other seven types of inappropriate pauses in which the post-pausal word began with the same word, or the same feature in the word-initial sound (e.g., a high vowel), or at least a sound in the same linguistic class (i.e., a monophthong, diphthong, or consonant). For all such within-participant word pairs as originally identified by the acoustic analysts (i.e., a word with an inappropriate abrupt onset and a word with an inappropriate non-abrupt onset), acoustic measures were made of the duration of the pause measured from the waveform and the time aligned spectrogram. Pause duration was measured from the last pre-pausal indication of a speech related event (e.g., glottal pulse for a voiced segment, high frequency noise for a fricative, release burst for a stop) to the first post-pausal indication of a speech related event (e.g., onset of voicing, onset of high frequency noise).

Next, a power plot was calculated for each post-pausal phoneme using the appropriate function in the acoustics software described in PM I, titled TF32 (Milenkovic, 2001). The function averaged amplitude samples over a 5 ms window, initially moving at 1 sample steps (1/44 ms). The power plot was automatically evaluated to determine the point in time (post-Pause) that an amplitude maximum and following plateau was reached, the measure termed “ms-to-peak.” This evaluation examined amplitude values starting at the onset of the post-pausal event and moving in 1/44 ms steps. This step size was considered too small, given that the default step size for most acoustic algorithms that produce power, formant, or pitch plots use

steps sizes as large as 10 ms (e.g. Wavesurfer, Praat). Thus, determination of ms-to-peak was also run using step sizes of 1 and 2 ms. Following this, the derived measure was the slope of the amplitude contour (i.e. dividing the determined amplitude maximum by the ms-to-peak, yielding dB/ms).

Results

Acoustic correlate of the pause element of the PM. Table 7 includes acoustic findings for the duration of pauses perceived by the acoustic analysts as occurring before words with abrupt (AB) speech onsets compared to the durations of inappropriate pauses not classified as having non-abrupt onsets (NAB), which included each of the other seven types of inappropriate between-words pauses, and similarly for the derived dB/ms measure. For each of three participant groups described elsewhere (CAS, AAS, and CND; Shriberg, Strand & Mabie, 2017), Table 7 includes several descriptive statistics, including for each variable and step size, number of tokens, mean and standard deviation for NAB and AB, and columns that provide the difference between the NAB and AB values. The right-most three columns include effect size findings similar to Cohen's d, and confidence intervals around the effect size. Bolded, significant effect sizes have similar algebraic signs for the lower and upper boundaries of the confidence interval.

As shown in Table 7, for the CAS, CND, and CND groups, respectively, the inappropriate between-words pauses preceding words with abrupt onsets were consistently shorter than the inappropriate pauses preceding words with non-abrupt onsets. For CAS the average difference in time was 128 ms, for CND 244 ms, and for AAS 218 ms. The same trend is shown in Table 7 for the derived measure dB/ms. The amplitude at the start of the post pausal speech event rose faster when the pause had been judged to be followed by an abrupt speech

event than it did when followed by a non-abrupt speech event. The averaged differences for the three participant groups were .32 db/ms faster for CAS participants, .31 dB/ms faster for CND participants, and .25/ms faster for AAS participants.

As shown in the last three columns in Table 7, 17 of the 18 effect sizes for non-abrupt (NAB) and abrupt (Abrupt) pauses were statistically significant. Their pattern support the perceptually-based PM distinction between non-abrupt and abrupt inappropriate pauses. The magnitudes of the associated effect sizes, however, ranged from -0.25 to 0.57 with the largest effect size classified at the low end of Cohen's conventional Medium effect size range (.50-.79). We interpret findings as promising, but not sufficient for use in automated procedures to classify speakers as positive or negative for CAS. As described in the introduction, information from this study is included in this technical report for its potential to inform development of an automated PM scoring system.

Summary

The findings reviewed in this section provide some information toward a possible acoustic measure to identify the occurrence of abrupt inappropriate pauses, the most frequent of the four subtypes of inappropriate pauses in the PM. Collaborative research using alternative instrumental methods is needed to automate the PM for increased reliability and efficiency.

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