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Long-Term and Short-Term Period and Amplitude Perturbation Measurements: Are They All Needed?

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Abstract

The purpose of this study was to examine the relationship among the various forms of amplitude and period perturbation. Long-term and short-term period and amplitude perturbation measures were obtained using a sustained vowel produced by normal speakers. Short-term measures of period and amplitude perturbation were highly correlated with one another in both men and women. Long-term measures of period perturbation were highly correlated among men, but moderately correlated for smooth pitch period perturbation quotient, and not correlated for fundamental frequency variation, among women. In both males and females, long-term amplitude perturbation measures were moderately correlated. As a result, only one short-term and one long-term measure of period and amplitude perturbation may be necessary for clinical judgments.

ABBREVIATIONS

PPQ: Smoothed Pitch Period Perturbation Quotient; vF0: Fundamental Frequency Variation; sAPQ: Smoothed Amplitude Perturbation Quotient; vAm: Peak Amplitude Variation; Jita: absolute jitter; Jitt: Jitter Percent; rap: Relative Amplitude Perturbation; PPQ: Pitch Period Perturbation Quotient; ShdB: Shimmer In Db; Shim: Shimmer Percent; APQ: Amplitude Perturbation Quotient

INTRODUCTION

Although the assessment and treatment of voice disorders relies heavily on the perception of voice quality, a more objective analysis is necessary to provide a comprehensive examination of laryngeal function. Acoustical measures have been found to be more reliable than perceptual measures [1] and often serve as a way to validate or confirm perceptions of voice quality [2].

The most commonly used quantitative analyses in voice measurement include acoustical measurements of aperiodicity (perturbation) and additive noise [3,4]. Measurements of jitter, or period perturbation, and shimmer, or amplitude perturbation, appear to receive much attention as useful measures of aperiodicity in the literature over the years [4-8] and are easily obtained. Perturbations, more specifically jitter, are best measured during sustained vowel production as fundamental frequency has been shown to affect period perturbation measures [9-11]. Furthermore, only one sustained vowel is necessary as jitter and shimmer values have been shown to remain constant despite tongue placement [12]. Even if clinicians use these measures due to ease and agree with the use of one sustained vowel to consistently obtain measures of perturbation across clients, there are numerous options for jitter and shimmer calculations that may lead to differences in value such as: mean absolute jitter, mean jitter percent, jitter ratio, mean jitter factor, relative amplitude perturbation, mean shimmer in decibels, mean shimmer in percent, and amplitude perturbation quotient to name a few. The above list includes both short term and long term perturbation measures with differing algorithms and ultimately different values. Having multiple options within each domain may leave the clinician wondering how many or which ones to collect and report.

The purpose of this study was to determine which jitter and shimmer measures may be necessary by examining if there is a relationship among the various forms of amplitude and period perturbation. High, significant correlations among measures would indicate redundant information, while low or insignificant correlations would indicate differing information is contained in the measurements.

MATERIALS AND METHODS

Fifty-three sustained vowel /ɑ/ normal voice samples were analyzed from the Voice Disorders Database [13]. Females (n =

32) included in the sample had an age range of 22-52 years (M = 34.15, SD = 7.86) and males (n = 21) had an age range of 26-59 years (M = 38.80, SD = 8.49). Each speaker provided one sample recording. All samples were previously recorded with a sampling rate of 44.1 kHz using a DAT-recorder and input into the Computerized Speech Lab system with sampling rates of 25 kHz or 50 kHz and 16- bit resolution. The classification of normal voice quality was pre-determined by the individuals at the Massachusetts Eye and Ear Infirmary at the time of the recording and labeled as such within the database. The database included both long term and short term perturbation measures for each participant as calculated by the Multidimensional Voice Program, an acoustical analysis software package created by Kay Elemetrics. Algorithms for many of these measures can be found in Baken and Orlikoff (2000). Long term period and amplitude perturbation measurements included: smoothed pitch period perturbation quotient (sPPQ), fundamental frequency variation (vF0), smoothed amplitude perturbation quotient (sAPQ), and peak amplitude variation (vAm) respectively. Short term period and amplitude perturbation measurements included: absolute jitter (Jita), jitter percent (Jitt), relative amplitude perturbation (rap), pitch period perturbation quotient (PPQ), shimmer in dB (ShdB), shimmer percent (Shim), and amplitude perturbation quotient (APQ) respectively.

Pearson product moment correlation coefficients among the short term and long term period and amplitude perturbations were calculated. Due to possible differences in perturbation measurements in regard to gender [14], more specifically the known effect of fundamental frequency on perturbation measures [9,15], the correlation coefficients for men and women were analyzed and reported separately.

RESULTS AND DISCUSSION

For the male normal voice recordings, all period perturbation measures (short term and long term) were highly correlated ($p<0.05$), accounting for over 80% of the variance, with vF0 having the lowest correlation among the group, albeit still a high correlation overall, accounting for 75% of the variance (See Table 1). Female normal voice recordings had a similar pattern but only for short term measures ($p<0.05$), again accounting for over 80% of the variance. Unlike the male voice, sPPQ for female voices was moderately correlated with the other measures ($p<0.05$), only accounting for approximately 50% of the variance, and vF0 was not statistically significant($p>0.05$), and therefore not correlated with measures of period perturbation(See Table 2).

Amplitude perturbation measures for male and female normal voices were similar. For both groups, all short term measures were highly correlated with one another($p<0.05$), accounting for over 80% of the variance, and long term measures were poorly- moderately correlated with short term measures ($p<0.05$), accounting for a range of 30-60% of the variance. A difference was found regarding correlations among sAPQ and the other amplitude perturbation measures as the correlations were slightly higher for males than for females (See Tables 3 and 4). Correlations among vAm and the other measures were the lowest, falling in the poor-moderate range for both men and women.

Correlations also were calculated for both male and female normal voices collectively and similar patterns were revealed. Short term period and amplitude perturbation measures were highly correlated with one another in their respective categories ($p<0.05$), again accounting for over 80% of the variance. Long term measures, sPPQ and sAPQ, were moderately correlated with short term measures ($p<0.05$), accounting for over 50% of the variance, and vF0 (not consistently significant at an alpha of 0.05) and vAm were poorly correlated with short term measures ($p<0.05$). When significant, these measures accounted for less than 20% of the variance(See Tables 5 and 6).

The purpose of this study was to examine the possible relationship among short-term and long-term period and amplitude perturbation measures in an effort to determine if all are needed for evaluation and treatment of voice disorders. Although only examining normal voice, results showed that short-term measures, of both period perturbation and amplitude perturbation, were highly correlated with one another in men and women. As a result, this may suggest that only one short-term measure of jitter and one short-term measure of shimmer will suffice. Statistical software packages only become less reliable at calculating perturbation for disordered voices as periodicity becomes more severely impaired; however, correlations among short term and long term perturbation measures for disordered voices would need to be calculated and compared to definitively state the above.

Based on this possible assumption, a clinician would still need to include one short term measure and one long term measure as a lack of correlation or a poor-moderate correlation may suggest differing information is contained in the measurements. These differences were noted for both period perturbation and amplitude perturbation across men and women. Starting with jitter, as mentioned previously, a relationship between period perturbation and fundamental frequency is well documented in

Table 1: Normal voice male period perturbation truncated Pearson r correlations. All values are significant with a p-value of <0.05.

	Jita	Jitt	RAP	PPQ	sPPQ	vF0
Jita	1.000	0.979	0.974	0.983	0.909	0.878
Jitt	0.979	1.000	0.999	0.997	0.913	0.898
RAP	0.974	0.999	1.000	0.994	0.903	0.890
PPQ	0.983	0.997	0.994	1.000	0.915	0.903
sPPQ	0.909	0.913	0.903	0.915	1.000	0.957
vF0	0.878	0.898	0.890	0.903	0.957	1.000

Table 2: Normal voice female period perturbation truncated Pearson r correlations. All values are significant with a p-value of <0.05.

	Jita	Jitt	RAP	PPQ	sPPQ	vF0
Jita	1.000	0.988	0.986	0.985	0.749	0.106*
Jitt	0.988	1.000	0.997	0.995	0.766	0.071*
RAP	0.986	0.997	1.000	0.990	0.734	0.059*
PPQ	0.985	0.995	0.990	1.000	0.756	0.072*
sPPQ	0.749	0.766	0.734	0.756	1.000	0.081*
vF0	0.106*	0.071*	0.059*	0.072*	0.081*	1.000

*Indicates a correlation with a p-value that was >0.05.

Table 3: Normal voice male amplitude perturbation truncated Pearson r correlations. All values are significant with a p-value of <0.05.

	ShdB	Shim	APQ	sAPQ	vAm
ShdB	1.000	0.999	0.947	0.821	0.585
Shim	0.999	1.000	0.943	0.813	0.591
APQ	0.947	0.943	1.000	0.894	0.559
sAPQ	0.821	0.813	0.894	1.000	0.557
vAm	0.595	0.591	0.559	0.557	1.000

Table 4: Normal voice female amplitude perturbation truncated Pearson r correlations. All values are significant with a p-value of <0.05.

	ShdB	Shim	APQ	sAPQ	vAm
ShdB	1.000	0.998	0.975	0.653	0.582
Shim	0.998	1.000	0.975	0.631	0.553
APQ	0.975	0.975	1.000	0.729	0.587
sAPQ	0.653	0.631	0.729	1.000	0.634
vAm	0.582	0.553	0.587	0.634	1.000

Table 5: Normal voice (male and female) period perturbation truncated Pearson r correlations. All values are significant with a p-value of <0.05.

	Jita	Jitt	RAP	PPQ	sPPQ	vF0
Jita	1.000	0.919	0.914	0.913	0.817	0.256*
Jitt	0.919	1.000	0.998	0.995	0.844	0.276
RAP	0.914	0.998	1.000	0.991	0.825	0.269*
PPQ	0.913	0.995	0.991	1.000	0.839	0.273
sPPQ	0.817	0.844	0.825	0.839	1.000	0.276
vF0	0.256*	0.276	0.269*	0.273	0.276	1.000

*Indicates a correlation with a p-value that was >0.05.

Table 6: Table 6 Normal voice (male and female) amplitude perturbation truncated Pearson r correlations. All values are significant with a p-value of <0.05.

	ShdB	Shim	APQ	sAPQ	vAm
ShdB	1.000	0.998	0.947	0.759	0.447
Shim	0.998	1.000	0.950	0.751	0.422
APQ	0.947	0.950	1.000	0.841	0.355
sAPQ	0.759	0.751	0.841	1.000	0.436
vAm	0.447	0.422	0.355	0.436	1.000

the literature [9-11]. Specifically, research has shown that relative period perturbation measures, or long-term measures, will be greater in higher frequency voices and absolute perturbation measures (short-term), will decrease in higher frequency voices [9,11,16-17]. This means that long-term and short-term measures for females may differ from one another whereas this difference may not be seen with male voices. Consistent with these findings, long-term measures of period perturbation were only highly correlated with the short-term measures for male voices. With female voices, long-term measures were either poorly-moderately correlated or not correlated at all. In regard to sPPQ, this correlation with the short-term period perturbation measures for women only accounted for only approximately half of the variance.

In addition, across men and women, vF0 seemed to differ the most in relation to the short-term measures. For men, it remained highly correlated, although slightly less than some of the other period perturbation correlations. Alternatively, for women, the vF0 correlations to short-term measures lacked statistical significance. However, one must consider the calculation of this measure, which may explain this lack of agreement. vF0 examines the standard deviation of the variation in cycle to cycle period, or the variation of variation. This calculation differs from the other short and long term period perturbation calculations and as a result, should stand-alone. The differences between men and women remained and may be explained by the effect of vocal onset and offset of period perturbation. Generally, vocal onset and offset generate higher period perturbation measures than the steady-state portion of the vowel [9,18].With a noted increase in aspirated noise often found in female voices [19,20] secondary to an increased glottal opening [21], onsets may differ and greater standard deviations in the variation of period perturbation may be found in women as compared to men.

In regard to amplitude perturbation, a similar pattern followed. Short-term measures were highly correlated and although statistically significant, the long-term measure (sAPQ) was moderately correlated with short-term measures in both men and women. Again, the smoothed measure of shimmer (sAPQ), or long-term measure, had a slightly higher correlation for men than for women. On average, men have been found to speak with a greater mean vocal sound pressure level than women [22] and shimmer may be inversely related to vocal intensity [23]. This difference in average vocal intensity for men and woman may result in different measures when comparing long-term and short-term amplitude perturbations as the inclusion of additional cycles may result in larger shimmer values for women than men. Lastly, just as vF0, vAm had the lowest correlation with the other measures. Again, this is a calculation of the standard deviation of peak to peak amplitude, a variation of the variation. Subsequently, just as vF0, differences in vocal onset in addition to differences in vocal intensity, may greatly affect this standard deviation for women more so than men.

CONCLUSION

Overall, a clinician may need only record one short term and one long term measure of period and amplitude perturbation to obtain the necessary information for diagnosis and treatment. If desired, a standard deviation of variation can also be selected as this measure yielded the poorest correlations or complete lack of correlation with all other perturbation measures, suggesting it provides additional information. Although it is not time consuming to record all jitter and shimmer measures, multiple measures simply may not be necessary due to their close relationship.

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