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Research Article

# Individualized Patient Vocal Priorities for Tailored Therapy

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**Purpose:** The purposes of this study are to introduce the concept of vocal priorities based on acoustic correlates, to develop an instrument to determine these vocal priorities, and to analyze the pattern of vocal priorities in patients with voice disorders.
**Method:** Questions probing the importance of 5 vocal attributes (vocal clarity, loudness, mean speaking pitch, pitch range, vocal endurance) were generated from consensus conference involving speech-language pathologists, laryngologists, and voice scientists, as well as patient feedback. The responses to the preliminary items from 213 subjects were subjected to exploratory factor analysis, which confirmed 4 of the predefined domains. The final instrument consisted of a 16-item Vocal Priority Questionnaire probing the relative importance of clarity, loudness, mean speaking pitch, and pitch range.
**Results:** The Vocal Priority Questionnaire had high reliability (Cronbach's $\alpha = .824$) and good construct validity. A majority of the cohort (61%) ranked vocal clarity as their highest vocal priority, and 20%, 12%, and 7% ranked loudness, mean speaking pitch, and pitch range, respectively, as their highest priority. The frequencies of the highest ranked priorities did not differ by voice diagnosis or by sex. Considerable individual variation in vocal priorities existed within these large trends.
**Conclusions:** A patient's vocal priorities can be identified and taken into consideration in planning behavioral or surgical intervention for a voice disorder. Inclusion of vocal priorities in treatment planning empowers the patient in shared decision making, helps the clinician tailor treatment, and may also improve therapy compliance.

Vocal priorities vary according to the vocational and social needs of the individual. The vocal priority for a classroom teacher is the ability to speak and be heard in a large room in a sustained fashion. A construction worker must be able to call out short utterances in a noisy open space to convey instructions or caution. The parent of a young child may wish to sing lullabies at bedtime, which does not require projection but demands a certain range of fundamental frequency and tone color. These different vocal requirements are within the typical vocal capability of the human phonatory mechanism (Titze, 2017). This capability makes it possible to vocalize with a wide sound intensity and fundamental frequency range (Titze, Riede, & Mau, 2016). When the phonatory mechanism is injured or otherwise impaired, the range of vocal capability is reduced. In this work, we define vocal priority as an individual's preference for different domains of vocal capability with respect to acoustic or aerodynamic features.

The current paradigm for the treatment of voice disorders has the generic goal to restore a healthy speaking voice, with the ability to sing targeted in select patients. However, most patients do not need the full range of acoustic capabilities afforded by healthy vocal folds. They just need to fulfill their specific vocal requirements commensurate with their activities. Although the concept of tailoring treatment to the needs of the individual is well-established in the voice therapy literature, customization has not been based on vocal priorities with acoustic or aerodynamic correlates. For example, tailored therapy has been discussed in the context of vocal hygiene programs (Nanjundeswaran et al., 2012; Ziegler, Gillespie, & Verdolini-Abbott, 2010), school-based voice therapy (Ruddy & Sapienza, 2004), voice

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therapy and training for teachers (Niebudek-Bogusz et al., 2008; Timmermans, Coveliers, Wuyts, & Van Looy, 2012), and optimal therapy dosing (Roy, 2012). As these works illustrate, therapy can be tailored based on vocal hygiene risk factors, the specific nature of the voice impairment, and other factors. Another underappreciated dimension to tailoring therapy is the consideration of the individual's vocal priorities.

Priorities can be identified among the common functional attributes of a voice. From the patient's perception, these attributes can include *vocal clarity* (a term used here to combine the phonetic aspects of sonorance, the acoustic concept of periodicity, or the percept of tonality), loudness, pitch (mean speaking pitch), pitch range, and vocal endurance. We use terminology here that stress the positive (desirable) attributes of vocalization rather than the terminology of voice disorders like roughness, breathiness, asthenia, and fatigue. These positive attributes are commonly reflected in negative language, however, in voice patients: "My voice is raspy" (clarity); "My friends can't hear me in a loud restaurant" (loudness); "I sound like a man" from a female patient (pitch); "I can't sing like I used to" (pitch range); and "My voice gets tired by the late afternoon" (vocal endurance/fatigue). Most vocal attributes have clearly defined acoustic correlates, which can serve as the physiologic target for treatment. For example, vocal clarity correlates with the periodicity of the acoustic signal, loudness with sound intensity, pitch with the fundamental frequency, and pitch range with fundamental frequency range. Other vocal attributes are linked to more than one acoustic or physiologic correlate. For example, vocal endurance is correlated with greater glottal efficiency (defined as output acoustic power divided by input aerodynamic power; Schutte, 1980) and with extralaryngeal contributions (Nanjundeswaran, Jacobson, Gartner-Schmidt, & Verdolini Abbott, 2015; Solomon, 2007; Welham & Maclagan, 2003). In any case, the first step is to define a group of vocal attributes among which to set priorities.

A concept closely associated with priority setting is that of trade-offs. A classic example of a trade-off in the treatment of voice disorders is the dose of Botulinum toxin injected into the vocal folds to reduce the symptoms of adductor spasmodic dysphonia. A higher dose generally translates into a longer duration of benefit and longer interval between injections, at the expense of a longer post-injection breathy phase. A smaller dose minimizes the breathy phase but has a shorter duration of benefit and translates into more visits. The trade-offs the patient is willing to make determine the optimal dose for that patient. In a similar fashion, trade-offs can be among various vocal attributes. This is particularly relevant in making treatment decisions when the treatment, for example, voice therapy, may be limited by cost and available time commitment. For example, a sports coach may choose to devote more of his or her therapy time to the ability to project the voice, rather than achieving perfect clarity. The trade-off may also depend on the specific voice disorder. Patients with unilateral vocal fold paralysis may prioritize the ability to project the voice or minimize vocal fatigue over vocal clarity or pitch range. In contrast, patients with adductor spasmodic dysphonia may prioritize vocal clarity over the ability to project. This prioritization of one vocal attribute over another or trade-off brings a new dimension to treatment decision making and treatment planning. For instance, voice therapists often set treatment goals related to typical physiologic and acoustic targets. Although this might be effective in creating a near-normal generic voice, it may or may not be the change the patient desires, especially if uniqueness or identity has already been established.

A tool to help patients set priorities and determine trade-offs among a set of vocal attributes would also empower the patient in shared decision making. Shared decision making is a process in which patients and providers work together to choose care that meets the patients' needs and reflects what is important to them (Légaré et al., 2014). Shared decision making is regarded as a model for clinical practice (Elwyn et al., 2012) and is thought to have the potential to improve the quality of care (Gionfriddo et al., 2014). Examples of health care fields in which shared decision making has been investigated include pediatric otolaryngology (Chorney et al., 2015; Hong, Gorodzinsky, Taylor, & Chorney, 2016; Hong, Maguire, et al., 2016), hearing preservation in acoustic neuroma treatment (Nellis et al., 2017), hearing aid adoption (Amlani, 2016), and elective surgical care (Boss et al., 2016). The Affordable Care Act specifically funded the development of decision aids to facilitate shared decision making as a means to advance patient-centered care (Oshima Lee & Emanuel, 2013). To our knowledge, there has not been a decision aid specific to voice disorders based on vocal priorities.

This study aimed to (a) develop a Vocal Priority Questionnaire (VPQ) as a tool to quantify the relative importance of a set of vocal attributes, (b) determine if these proposed attributes can be reliably measured, and (c) analyze the vocal priorities in a treatment-seeking cohort. Two hypotheses were tested. First, we tested the hypothesis that patients' vocal priorities were associated with the nature of their voice disorder. Second, because behavioral and neurobiological differences in voice perception may exist according to sex and gender (Hancock & Pool, 2017; Junger et al., 2014), we questioned if those differences carried over to vocal priorities. We therefore tested whether vocal priorities differed by sex. The overall goal was to provide voice patients and health care providers a means by which to understand the patient's vocal priorities and to use that knowledge to tailor treatment.

## Method

### *Preliminary Items*

The starting set of five vocal attributes (clarity, loudness, mean speaking pitch, pitch range, and vocal endurance or fatigue) was targeted because they reflect common concerns expressed in our patient population with voice disorders, and most have plausible acoustic correlates. The question items were generated in an iterative process. Starting sample items probing each vocal attribute were created by the authors in group conference. The number of items was then expanded and the wordings refined in conference with three full-time clinical speech-language pathologists (SLPs) at a tertiary care voice center. The SLPs' practice has a clinical emphasis in the assessment and treatment of voice disorders, with 45 years of combined experience. The SLPs refined the items based on common complaints from patients. The items were then again discussed in conference with the authors to ensure they were formulated to probe the desired vocal attributes. Initially, the items directly queried the desired attributes, for example, "On a scale of 1–10, rate the importance of the ability to project your voice." The items were later revamped to be more task- and context-specific, for example, "On a scale of 1–10, rate the importance of the ability to shout to someone across the street." The rationale for using task-specific items is found in high-quality instruments used to assess physical function, such as the National Institutes of Health Patient-Reported Outcomes Measurement Information System Short Form for Physical Function (Broderick, Schneider, Junghaenel, Schwartz, & Stone, 2013; Cella et al., 2010; Gershon, Rothrock, Hanrahan, Bass, & Cella, 2010). Multiple items were employed to probe each vocal attribute. Items pertaining to loudness and pitch range were further formulated to probe varying degrees of vocal need in those domains on a roughly linear scale. For example, the three pitch range questions probed the importance of the ability to "sing in the shower or in the car," "sing in an amateur group," and "sing professionally," which presumably require increasing pitch range from the first to the last. For loudness, six questions were formulated with scenarios on a linear scale of intensity requirement, from "to be heard by the person across the kitchen table in a quiet room" on the low end to "to be loud enough to coach a children's sports team" on the high end. Items were then presented to 20 patients at the Voice Center for feedback on clarity, ease of use, and suggestions for additional and/or alternative items. The items were amended accordingly in conference with the authors and SLPs.

The preliminary VPQ thus generated consisted of 19 items. The items were not marked with the intended vocal attribute to be probed. The six items probing loudness were grouped and listed in ascending order of the perceived loudness required, and the three items probing pitch range were grouped and listed in order of the presumed required pitch range for the particular singing activity. The other items were randomized. The preliminary questionnaire thus generated is shown in Appendix A.

### Reliability Testing

The questionnaire was administered to patients seeking care for various voice disorders at a tertiary care academic voice center. In addition to the item responses, only age, sex, and the voice diagnosis were collected. The study was approved by the Institutional Review Board of University of Texas Southwestern Medical Center.

Statistical analysis was performed using IBM SPSS V24 (IBM Software Group). Because the items were designed to probe five vocal attributes, the VPQ was presumed to have five domains. To examine the reliability of the VPQ, Cronbach's coefficient alpha was calculated for each of the five domains and the total scale. Cronbach's coefficient alpha is a measure of internal consistency reliability. Values of 0 represent no reliability, and 1 indicate high reliability. The association of each item within its designated domain and the total score was evaluated by examining the corrected item-total correlation, as well as by the Cronbach's alpha with the item deleted.

### Exploratory Factor Analysis

Exploratory factor analysis was carried out to determine if the underlying dimensions or factors in the preliminary VPQ corresponded to the predefined domains. It is common practice in statistics to use two different factor extraction methods, because one might represent the data better than the other. Two widely known factor extraction methods were used: principal components and maximum likelihood extraction methods (Dillon & Goldstein, 1984; Nunnally & Bernstein, 1994a, 1994b). Each method was performed with both orthogonal (Varimax) and oblique (Promax with Kaiser Normalization) rotations. Orthogonal rotation would reveal factors that are not correlated with each other, whereas oblique rotation would reveal factors that will be correlated. The rotation that yielded the better fitting model would be used.

In factor analysis, the axes of the underlying factors are rotated to produce a best fit to the data. This rotation consists of a linear transformation represented by a correlation matrix, the scalar components of which are the eigenvalues. The eigenvalue for a given factor measures the variance in all the variables accounted for by that factor. A factor with a high eigenvalue contributes significantly to the variances, whereas a factor with a low eigenvalue contributes little and may be ignored as redundant. It is customary to only retain factors with eigenvalues of 1 or higher (Gorsuch, 1983). A second common approach to determine which factors to retain is to examine a scree plot of the eigenvalues, a plot of the eigenvalues in descending order (Gorsuch, 1983). The typical scree plot has a steep declining slope on the left (consisting of larger eigenvalues) transitioning to a shallow declining slope on the right (consisting of smaller eigenvalues). The point of inflection is used as another benchmark to determine the number of factors to retain. In this study, the following criteria were used to determine the number of factors: inclusion of a factor if it contributed 5% additional variance or greater, eigenvalues greater than 1, point of inflection in the scree plot, interpretability of the rotated factor structure, and simple factor structure.

In the correlation matrix, each VPQ item is represented by a linear combination of component weights and factors (e.g., $\alpha_1 F_1 + \alpha_2 F_2 + \alpha_3 F_3 + \cdots$, where $\alpha$ is a component weight and $F$ is a factor). Component weights of 0.4 or higher were considered important, that is, that particular item loads strongly onto a particular factor (see Appendix B). A typical level of significance in factor analysis is 0.4.

### *Construct Validity*

Construct validity refers to whether a construct, or instrument, measures what it is meant to measure. It is defined as the property of having appropriate relationships with other variables (Bland & Altman, 2002). To have construct validity, the vocal priorities derived from the VPQ should correspond to the subject's intended vocal priorities. To assess construct validity, subjects were asked to independently and explicitly rank the importance of the four vocal attributes to them ("ranking"), after they completed the finalized version of the VPQ, which excluded items pertaining to vocal endurance due to low reliability (see Results section). The instructions included short explanations of the four attributes to make sure the subjects understood their meanings, and their understanding was confirmed verbally by the survey administrators. The mean VPQ scores of the four vocal attributes (clarity, loudness, mean speaking pitch, and pitch range) were compared with explicit rankings of the four attributes. We hypothesized that the rankings should be related to the four domain scores. A within-subject repeated-measures analysis of variance was used. For each subject, the mean VPQ score of the "first-ranked" attribute was placed in the first column of a spreadsheet, the mean VPQ score of the "second-ranked" attribute was placed in the second column, and so on for the third- and fourth- ranked attributes. Good construct validity should be reflected by a linear trend where the first-ranked attribute should have the highest score and the "fourth-ranked" attribute should have the lowest score.

### *Voice Diagnoses*

For the purpose of diagnostic categorization for this work, "benign lesions" broadly encompassed noncancerous growths or aberrations of the vocal fold mucosa, including phonotraumatic lesions and papilloma. "Neurologic" included spasmodic dysphonia, other dystonias, tremor, and Parkinson's disease.

### *Hypothesis Testing*

The Jonckheere–Terpstra test (Daniel, 1990) was used to test the hypothesis that patients' vocal priorities differ based on the nature of their voice disorders and their sex. The Jonckheere–Terpstra test is more appropriate than a chi-squared test in this case because it compares the proportions of responses between groups. The chi-squared test of independence only examines the independence of the rows and columns. Statistical significance was set at $p < .05$ unless otherwise noted.

## Results

### *Demographics*

The preliminary VPQ was administered to 213 patients seeking care for various voice disorders. Female patients were 50.7% (108/213), and male patients were 49.3% (105/213), with a median age of 59 years (range: 19–88). Their diagnoses are listed in Table 1.

### *Reliability of the Preliminary VPQ*

To examine the reliability of the preliminary VPQ, Cronbach's alpha was calculated for each of the five domains and the full scale. Cronbach's $\alpha$ for the full scale was .849, indicating very high reliability when using the full 19 items on the preliminary VPQ. Cronbach's $\alpha$ for the domain scores resulted in three of the five domains with reliability greater than .75. These three domains were clarity ($\alpha$ = .778), loudness ($\alpha$ = .822), and pitch range ($\alpha$ = .824). The item diagnostics for these domains indicated that no items should be recommended for deletion. Reliability for the domain pitch was moderately high ($\alpha$ = .645). Although Item 16 in this domain had the lowest corrected item-total correlation, removing this item from the domain did little to improve the $\alpha$ (.037), so the item was retained. The domain vocal endurance had the lowest reliability ($\alpha$ = .380) and could not be used as a stand-alone domain.

### *Exploratory Factor Analysis and Finalization of Questionnaire*

To examine the interrelationships among the items in the preliminary VPQ, an exploratory factor analysis was performed to examine the underlying structure common among the items and to compare the best fitting result to the predefined domains. The exploratory factor analysis yielded a five-factor solution. Using the principal component analysis extraction method and a Promax with Kaiser Normalization rotation provided the best interpretable results (see Appendix B). The five factors explained 66.5% of the total variance. The items for each of the three domains—clarity, mean speaking pitch, and pitch range—were Factors 4, 5, and 3, respectively. The domains loudness and vocal endurance/fatigue were spread across Factors 1 and 2 with the exception of Item 9, which was found on Factor 5.

**Table 1.** Voice diagnoses of test cohort.

| Diagnosis | % (*N*) |
|---|---|
| Unilateral vocal fold paralysis/paresis | 33.8 (72) |
| Benign lesions | 24.4 (52) |
| Vocal fold atrophy | 9.4 (20) |
| Neurologic | 7.5 (16) |
| Functional | 7.0 (15) |
| Vocal fold cancer | 2.3 (5) |
| Other and unspecified | 15.5 (33) |
| Total | 100 (213) |

The analysis showed that the domain corresponding to vocal endurance had low reliability. In addition, the three items in that domain (Items 9, 15, 18; see Appendix B) were loaded onto three different factors. Because each of those factors was already well-represented by other items, the three items (Items 9, 15, 18) contributed little and were eliminated. Deleting these items reduced Cronbach's α for the full test from .849 to .824, a very small change that did not detract from the high reliability of the overall questionnaire. The final VPQ consisted of 16 items probing the four vocal attributes of clarity, loudness, mean speaking pitch, and pitch range (see Appendix C).

### *Construct Validity*

Construct validity of the final VPQ was assessed with a second cohort of 68 patients. The explicit rankings of the importance of the four vocal attributes were compared with the VPQ scores of the attributes using repeated-measures analysis of variance with a within-subject design (see Methods section). The scores of the top-ranked, second-ranked, third-ranked, and fourth-ranked attributes were tabulated. These four scores were significantly different from each other, $F(2.5, 168.1) = 57.32$, $p < .0001$, with a significant linear trend, $F(1, 67) = 210.4$, $p < .0001$, (see Figure 1). In other words, the highest ranked attribute had the highest average score, and the lowest ranked attribute had the lowest average score. This demonstrated that the VPQ indeed measured what it was meant to measure, indicating good construct validity.

### *VPQ Usage Example*

To illustrate how the VPQ can be utilized to understand vocal priorities, an example is shown in Table 2 using actual responses from a patient. The mean of the item responses for each vocal attribute is used to represent that vocal attribute's priority weight. As the mean scores show, this particular patient clearly prioritized vocal clarity. Figure 2 contrasts the vocal priority of this patient (Patient A) with that of another patient (Patient B). It highlights the advantage of visually representing an individual's vocal priority in histogram format, which makes the relative importance of the attributes immediately obvious. For example, even though Patient B prioritized loudness over other attributes based on the scores, it may be more meaningful clinically to say that loudness and clarity were equally important to her.

### *Vocal Priorities*

To examine the distribution of vocal priorities, data were combined from the initial test cohort ($N = 213$) who completed the 19-item preliminary VPQ and from the second cohort ($N = 68$) who completed the 16-item final VPQ for construct validity assessment. The pooling of data was acceptable because the only difference was the elimination of the three items related to vocal endurance. Vocal clarity was the highest priority for 60.9% (171/281) of subjects, followed by loudness (19.9%, 56/281), mean speaking pitch (12.1%, 34/281), and pitch range (7.1%, 20/281). Conversely, pitch range was ranked as the lowest priority by 73.7% (207/281) of subjects, followed by pitch (14.6%, 41/281), loudness (9.6%, 27/281), and clarity (2.1%, 6/281).

For subjects who ranked clarity as the highest priority, the next highest priority was loudness (48.5%, 83/171), followed by pitch (38.6%, 66/171) and pitch range (12.9%, 22/171). In fact, the most common set of priorities in the entire cohort is 1 = *clarity,* 2 = *loudness,* 3 = *pitch,* 4 = *pitch range,* which was preferred by 26.7% (75/281) of the subjects. The top five most common set of priorities are listed in Table 3. The distribution pattern of the first and second

**Figure 1.** Good construct validity. Within-subject repeated-measures analysis of variance showing that the highest ranked vocal attribute (through explicit query) has the highest mean domain score (from the Vocal Priority Questionnaire), and the four scores follow a linear trend that is consistent with the explicit rankings. Error bars show 95% confidence intervals.

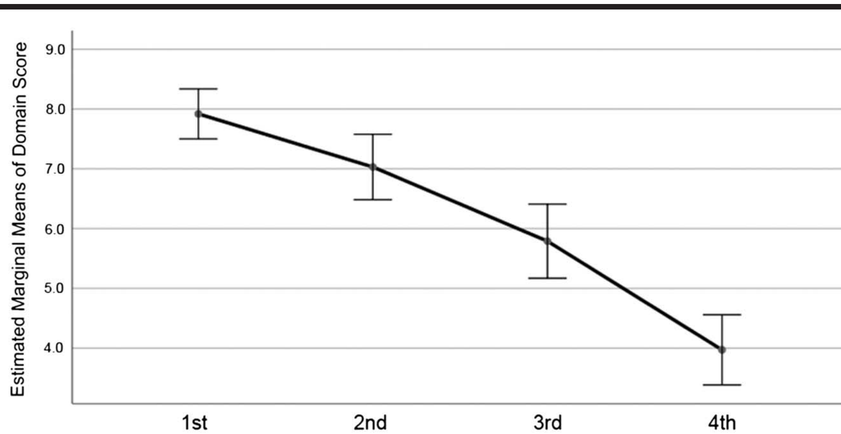


**Table 2.** Example of Vocal Priority Questionnaire (VPQ) response from a single subject.

| Vocal attribute | VPQ item (see Appendix C) | Response | Score (Mean ± *SD*) |
|---|---|---|---|
| Clarity | 1. To have a clear (not raspy or breathy) speaking voice | 10 | 9.8 ± 0.4 |
| | 8. To not have a rough quality to my voice | 10 | |
| | 9. To not have a breathy quality to my voice | 9 | |
| | 15. To not have a gravelly quality to my voice | 10 | |
| Loudness | 2. To be heard by the person across the kitchen table in a quiet room | 10 | 8.0 ± 2.5 |
| | 3. To be heard by people in the back of a classroom of 20–30 students | 7 | |
| | 4. To be loud enough to be heard at the drive-thru | 8 | |
| | 5. To be heard by friends across the table in a noisy restaurant | 10 | |
| | 6. To shout to someone across a busy city street and be heard | 10 | |
| | 7. To be loud enough to coach a children's sports team | 3 | |
| Pitch | 10. Not to be mistaken for another gender on the phone | 6 | 5.7 ± 1.2 |
| | 14. To have my speaking voice not sound too deep/low | 7 | |
| | 16. To have my speaking voice not sound too high/squeaky | 4 | |
| Pitch range | 11. To sing professionally | 1 | 1.7 ± 0.9 |
| | 12. To sing in an amateur group | 1 | |
| | 13. To sing in the shower or in the car | 3 | |

vocal priorities for the entire study population is shown in Figure 3.

## *Effect of Voice Diagnosis and Sex*

Our first hypothesis was that patients' vocal priorities would differ depending on the nature of their voice disorders. For example, a simplistic expectation was that patients with benign lesions would prioritize vocal clarity, whereas those with vocal fold paralysis would prioritize loudness. The Jonckheere–Terpstra test was used to compare the frequencies of the highest ranked vocal attributes in patients with benign lesions against those with unilateral vocal fold paralysis (see Table 4, column A). There was no difference between these two groups ($p$ = .14). However, consistent with the simplistic expectation, the largest difference was in the percentage choosing clarity (61% in benign lesions vs. 46% in vocal fold paralysis), even though it was not statistically significant.

To test the hypothesis that patients' vocal priorities differed by sex, a Jonckheere–Terpstra test was performed on the frequencies of the highest ranked vocal attributes within each sex (see Table 4, column B). The highest ranked vocal attribute did not differ by sex ($p$ = .70).

# Discussion

## *Vocal Priorities*

The most interesting finding from this study was that vocal clarity was the highest vocal priority in a majority of subjects. Among the set of four vocal attributes (clarity, loudness, mean speaking pitch, pitch range), 61% of the cohort prioritized vocal clarity (lack of roughness or raspiness) over other attributes. Consistent with its high prioritization, clarity was also the least common last-ranked priority, by only 2% of the cohort. This overall strong prioritization for clarity was preserved even in the subgroup

**Figure 2.** Vocal priorities of two example patients: Patients A and B. The $y$-axis shows each patient's mean score in each of the four vocal attributes. Response range was 1 = *not at all important* to 10 = *very important*. Error bars show 1 *SD*.

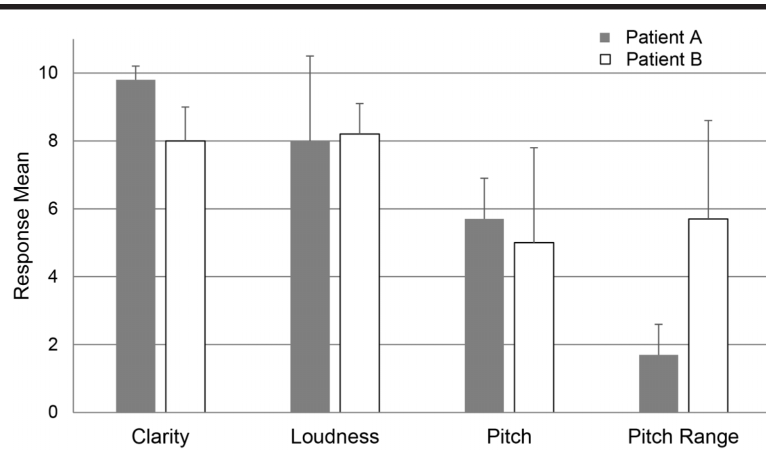


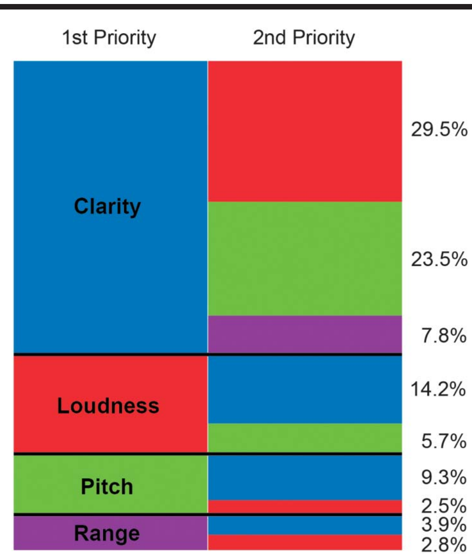
**Table 3.** Top five most common patterns of vocal priorities.

| Vocal priorities | % (*N*/total) |
|---|---|
| Clarity > loudness > mean pitch > pitch range | 26.7 (75/281) |
| Clarity > mean pitch > loudness > pitch range | 20.3 (57/281) |
| Loudness > clarity > mean pitch > pitch range | 10.7 (30/281) |
| Mean pitch > clarity > loudness > pitch range | 8.5 (24/281) |
| Loudness > mean pitch > clarity > pitch range | 5.3 (15/281) |

of subjects with vocal fold paralysis, suggesting that the ability to be heard clearly is more important than just being loud enough. On the other hand, almost 40% of the cohort prioritized other attributes over clarity, indicating substantial variation that highlights the need to understand individual preferences.

Loudness was the second most common top-ranked vocal attribute, but by only about 20% of the cohort. We suspect loudness would be prioritized by those whose vocations require loud vocal projection, such as sport coaches and floor traders in stock exchanges in the days before electronic trading, as well as those involved in cadence calling in sports events, the martial arts or the military, or in artistic performance scream (Ufema & Montequin, 2001). Loudness is also important in certain contexts where the ability to attract attention depends on it, such as calling out for safety at construction sites or in voice vote voting (Titze & Palaparthi, 2014). It is possible that the importance of loudness may be underestimated by the VPQ, because some patients may not relate to some loudness tasks and may score those items lower. Because of this possibility, we advise clinicians to confirm how patients feel about the need for loudness if it is not the top priority.

**Figure 3.** Patterns and proportions of vocal priorities. The left column shows the first priority. The right column shows the second priority. The vertical height of each stack is proportional to the percentage of subjects with that particular set of vocal priorities. In the right column, attributes accounting for less than 0.5% of the total are not shown.




Mean speaking pitch was top ranked by about 12% of the cohort. The inclusion of this vocal attribute in the prioritization list was motivated by patients whose chief complaint was mistaken gender identity by others. A classic example is a woman who is frequently mistaken as male on the phone due to a low mean speaking pitch. Pitch range was ranked as the lowest priority by over 70% of the cohort and as the highest priority by less than 10% of the cohort. This suggests that one of the most remarkable capabilities built into the human vocal apparatus to maximize vocal expression (Titze et al., 2016) is ironically not prized by many humans. The data also support the notion that most people do not fully utilize the range of vocal capabilities afforded by the larynx because human speech has a limited frequency range requirement (Titze, 2017). Although no formal data were collected, anecdotally virtually all subjects who prioritized pitch range in this study sang in one capacity or another. It is likely that singers would rank pitch range higher than the general population.

Vocal endurance (or its converse, vocal fatigue) was included in the initial set of vocal attributes because “my voice tires out” is a common complaint from voice patients. However, it is distinct from the other four attributes in an important way. Whereas clarity, loudness, mean pitch, and pitch range draw from auditory perception of both the speaker and the listener, vocal fatigue is experienced by the speaker alone, and its perception is formed by physiologic inputs beyond audition, such as neck tightness and bodily fatigue. Vocal fatigue has been the subject of multiple inquiries (e.g., McCabe & Titze, 2002; Solomon, 2007; Welham & Maclagan, 2003), and a 19-item instrument has been developed to measure it (Nanjundeswaran et al., 2015). Given the nature of vocal fatigue as a complex, variable phenomenon, it is perhaps not surprising in retrospect that the mere three items designed to probe it in the preliminary VPQ had insufficient reliability as a stand-alone domain. It is also possible that vocal endurance is in part included in vocal clarity. Vocal fatigue often results in roughness or instability of the voice, which may be the auditory cue for speakers and singers. One possible future direction of this work is to reformulate items for vocal fatigue, perhaps with a larger number of items, to achieve sufficient reliability to include it in the ranking of vocal priorities.

## *VPQ: Advantage and Application*

A key advantage of using the VPQ to assess vocal priorities over direct query is that it does not require the patient to understand the nature of the respective vocal attributes. Whereas most people seem to understand the terms *clarity* and *loudness,* the meanings of *pitch* and *pitch range* are often not readily apparent to many nonsingers in the authors’ experience. A second key advantage of using the VPQ is that it does not compel the patient to explicitly rank the vocal attributes. Ranking involves a higher cognitive process and requires a clear understanding of the

**Table 4.** Frequencies of highest ranked vocal attribute by voice diagnosis and by sex.

| Variable | A | | B | |
|---|---|---|---|---|
| | UVFP% (*N*) | Benign lesions% (*N*) | Female% (*N*) | Male% (*N*) |
| Clarity | 46.3 (38) | 61.2 (41) | 62.3 (91) | 59.0 (79) |
| Loudness | 25.6 (21) | 17.9 (12) | 18.5 (27) | 21.6 (29) |
| Mean pitch | 19.5 (16) | 9.0 (6) | 11.0 (16) | 13.4 (18) |
| Pitch range | 8.5 (7) | 11.9 (8) | 8.2 (12) | 6.0 (8) |
| Total | 100 (82) | 100 (67) | 100 (146) | 100 (134) |

*Note.* One patient did not specify sex and was excluded from the analysis by sex. UVFP = unilateral vocal fold paralysis.

items being ranked. During the validation part of this study, the authors observed that some subjects had difficulty ranking the four vocal attributes and were only able to do so with guidance. The VPQ approach of ranking the attributes using domain averages is easily expandable to include a larger number of attributes, whereas direct ranking of a larger number of attributes rapidly becomes cognitively challenging because of the exponentially greater number of pairwise comparisons involved.

Understanding a patient's specific acoustically based vocal priorities before treatment may be advantageous because it provides a personally relevant context to frame treatment goals and gauge success. While current treatment approaches do consider the patient's diagnosis, capabilities of the patient's phonatory system, and self-reported voice production complaints, the VPQ provides additional information for the clinician to tailor voice therapy goals to relate practically to the patient's needs. This will allow for more specific patient education regarding the purpose of the therapy ingredient being applied and how that relates to the top priorities. For example, a patient who prioritizes loudness may not fully appreciate the goal of maximizing resonance in voice therapy but may become more motivated if the exercises are connected to the goal of improving the ability to project. Conversely, a singer who consistently uses amplification may place a much higher priority on pitch range than overall loudness. We anticipate that keeping vocal priorities at the forefront of treatment goals will result in improved patient compliance during therapy and improved generalization of therapy techniques. Furthermore, it is the authors' hope that shifting treatment focus from physiologic targets to vocal priorities may inspire the development of voice therapy approaches that target specific acoustically based vocal attributes.

Similarly, a priori knowledge of vocal priorities can help set appropriate expectations for voice outcomes from phonosurgery. For example, most current surgical options to address vocal fold scarring are unlikely to significantly improve vocal clarity but may increase loudness and reduce vocal fatigue. These expected changes should align with the patient's vocal priorities. If they do not, the discrepancy should be discussed in preoperative counseling. Furthermore, vocal priorities may have the potential to inform surgical planning. Although current phonosurgical techniques do not target specific priorities, it is possible that advances in phonosurgery will lead to a broader slate of options in the future, and vocal priorities can help the patient and surgeon choose among those options. For example, the feasibility of vocal fold lamina propria replacement for the treatment of severe vocal fold scarring has been demonstrated recently (Long, 2018). It is conceivable that lamina propria replacement constructs can be tailored with biomechanical properties to match a patient's specific vocal priorities.

### Limitation and Future Direction

The main limitation of this work lies in the relatively small number of vocal attributes included. The small number was intentional because the goal of this first study was to establish proof of concept. The current work lays the foundation for the inclusion of more attributes in further studies. Another limitation is that the vocal priority profile reported here may not be generalizable to a healthy population, because subjects were recruited from a treatment-seeking population. A future direction is to test the hypothesis that vocal priorities vary according to vocational and social vocal demands. In particular, speakers and singers who routinely use amplification have different priorities from those who sing or speak unamplified. For example, the intentional use of lack of tonal clarity in heavy metal singing should also be considered as a priority, especially in the context of endurance. Generally, clarity of the voice is related to periodicity in vocal signals, which in turn is related to symmetry in vocal fold and airway structure. If the intentional production and control for roughness become priorities, surgical or behavioral intervention may take on a very different form. Thus, a future line of inquiry is to understand the factors that underlie voice patients' vocal priorities. For example, when patients with the same voice diagnosis have divergent vocal priorities, what are the factors that lead to that difference? The answers to this and other questions surrounding vocal priorities should improve our understanding of how individuals relate to their voice and how to best help them when they encounter vocal difficulty.

We also believe that the discussion of vocal priorities remains tightly connected to research into the functional morphology of vocal folds. Comparative research has shown that vocal priorities of different species are supported by their unique vocal fold design (Titze et al., 2016). Among humans, individual differences in the laryngeal cartilaginous framework (Eckel, Sittel, Zorowka, & Jerke, 1994; Storck & Unteregger, 2018) and vocal fold design (Chan, Fu, Young, & Tirunagari, 2007) appear to contribute to diverse vocal abilities. Certain designs may more easily facilitate specific vocal priorities. The better we understand this relationship, the better we may be able to accommodate individual preferences.

## Conclusion

A set of vocal priorities with acoustic correlates have been introduced. Most subjects named vocal clarity as the top priority, but alternative vocal attributes were variably prioritized by others. This work is a first step toward raising awareness of the existence of acoustically based vocal priorities, which can be considered in the treatment and description of healthy and disordered voices. The inclusion of vocal priorities as part of the discussion will empower patients in the process of shared decision making to tailor treatment.

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## Appendix A

Preliminary Vocal Priority Questionnaire

| | **On a scale of 1–10, rate how important the following vocal abilities are to you:** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1 = *Not at all important*** | | | | | | | | **10 = *Very important*** | |
| **The ability:** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| 1. To have a clear (not raspy or breathy) speaking voice | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 2. To be heard by the person across the kitchen table in a quiet room | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 3. To be heard by people in the back of a classroom of 20–30 students | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 4. To be loud enough to be heard at the drive-thru | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 5. To be heard by friends across the table in a noisy restaurant | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 6. To shout to someone across a busy city street and be heard | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 7. To be loud enough to coach a children's sports team | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 8. To not have a rough quality to my voice | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 9. To not run out of air when I talk | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 10. To not have a breathy quality to my voice | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 11. Not to be mistaken for another gender on the phone | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 12. To sing professionally | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 13. To sing in an amateur group | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 14. To sing in the shower or in the car | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 15. To talk on the phone for an hour and not feel vocally tired by the end | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 16. To have my speaking voice not sound too deep/low | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 17. To not have a gravelly quality to my voice | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 18. To talk/lecture to a group of 20–30 people in a room without a microphone for an hour | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 19. To have my speaking voice not sound too high/squeaky | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |

## Appendix B

Exploratory Factor Analysis

| Domain | Items | Component (factor) | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| Clarity | Item1 | 0.219 | 0.143 | –0.212 | **0.786** | –0.202 |
| | Item8 | –0.058 | 0.083 | 0.020 | **0.873** | –0.029 |
| | Item17 | –0.107 | –0.170 | 0.080 | **0.751** | 0.285 |
| | Item10 | –0.009 | 0.134 | 0.001 | **0.434** | 0.381 |
| Loudness | Item6 | **0.463** | **0.442** | –0.015 | –0.125 | 0.137 |
| | Item7 | 0.009 | **0.738** | 0.017 | –0.154 | 0.292 |
| | Item4 | **0.797** | 0.122 | –0.018 | –0.096 | 0.102 |
| | Item5 | **0.845** | 0.037 | –0.020 | 0.064 | –0.062 |
| | Item3 | 0.013 | **0.860** | 0.047 | 0.160 | –0.094 |
| | Item2 | **0.805** | –0.019 | –0.125 | 0.024 | –0.054 |
| Pitch | Item11 | –0.054 | 0.107 | –0.084 | –0.191 | **0.873** |
| | Item16 | –0.054 | –0.028 | 0.146 | 0.245 | **0.540** |
| | Item19 | 0.033 | 0.084 | –0.228 | 0.105 | **0.692** |
| Pitch range | Item12 | –0.254 | 0.158 | **0.788** | –0.047 | 0.041 |
| | Item13 | 0.002 | 0.030 | **0.922** | –0.044 | –0.080 |
| | Item14 | 0.297 | 0.062 | **0.793** | 0.014 | –0.079 |
| Vocal endurance | Item9 | 0.304 | –0.242 | 0.161 | 0.100 | **0.501** |
| | Item18 | –0.091 | **0.800** | 0.188 | 0.129 | –0.100 |
| | Item15 | **0.644** | –0.208 | 0.242 | 0.036 | 0.042 |

*Note.* The table shows the component weights for each factor. Those greater than 0.4 are shown in bold to highlight the important weights, because 0.4 is a typical level of significance in factor analysis. Item numbers correspond to those in the preliminary Vocal Priority Questionnaire as shown in Appendix A. Extraction method: principal component analysis. Rotation method: Promax with Kaiser Normalization.

## Appendix C

Final Vocal Priority Questionnaire

| | On a scale of 1–10, rate how important the following vocal abilities are to you: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 = *Not at all important* | | | | | | | | | 10 = *Very important* |
| **The ability:** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| 1. To have a clear (not raspy or breathy) speaking voice | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 2. To be heard by the person across the kitchen table in a quiet room | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 3. To be loud enough to be heard by people in the back of a classroom of 20–30 students | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 4. To be loud enough to be heard at the drive-thru | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 5. To be heard by friends across the table in a noisy restaurant | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 6. To shout to someone across a busy city street and be heard | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 7. To be loud enough to coach a children's sports team | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 8. To not have a rough quality to my voice | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 9. To not have a breathy quality to my voice | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 10. Not to be mistaken for another gender on the phone | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 11. To sing professionally | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 12. To sing in an amateur group | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 13. To sing in the shower or in the car | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 14. To have my speaking voice not sound too deep/low | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 15. To not have a gravelly quality to my voice | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |
| 16. To have my speaking voice not sound too high/squeaky | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ | ❍ |