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Review Article

Toward a Consensus Description of Vocal Effort, Vocal Load, Vocal Loading, and Vocal Fatigue

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Purpose: The purpose of this document is threefold: (a) review the uses of the terms "vocal fatigue," "vocal effort," "vocal load," and "vocal loading" (as found in the literature) in order to track the occurrence and the related evolution of research; (b) present a "linguistically modeled" definition of the same from the review of literature on the terms; and (c) propose conceptualized definitions of the concepts.
Method: A comprehensive literature search was conducted using PubMed/MEDLINE, Embase, Cochrane Central Register of Controlled Trials, and Scientific Electronic Library Online. Four terms ("vocal fatigue," "vocal effort," "vocal load," and "vocal loading"), as well as possible variants, were included in the search, and their usages were compiled into conceptual definitions. Finally, a focus group of eight experts in the field (current authors) worked together to make conceptual connections and proposed consensus definitions.
Results: The occurrence and frequency of "vocal load," "vocal loading," "vocal effort," and "vocal fatigue" in the literature are presented, and summary definitions are developed. The results indicate that these terms appear to be often interchanged with blurred distinctions. Therefore, the focus group proposes the use of two new terms, "vocal demand" and "vocal demand response," in place of the terms "vocal load" and "vocal loading." We also propose standardized definitions for all four concepts.
Conclusion: Through a comprehensive literature search, the terms "vocal fatigue," "vocal effort," "vocal load," and "vocal loading" were explored, new terms were proposed, and standardized definitions were presented. Future work should refine these proposed definitions as research continues to address vocal health concerns.

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In the current examination of healthy and unhealthy phonation, the relationship between "vocal load," "vocal loading," "vocal effort," and "vocal fatigue" has been frequently explored. For example, patients with voice problems often report elevated "vocal fatigue" and/or "vocal effort" even during common oral communication situations (Welham & Maclagan, 2003). These elevated reports can be exacerbated (even in vocally healthy individuals) in situations of high vocal demand (e.g., school teachers speaking for long durations, communicating in a noisy room). Thus, even in the absence of a disorder, it is likely that physiology, long durations of voicing, vocal intent, level of vocal exertion, health, environment, and vocal technique contribute to the vocalist experiencing vocal discomfort, reduced vocal quality, or decreased vocal endurance (Chang & Karnell, 2004; Hunter et al., 2019; Koufman & Blalock, 1988; Laukkanen et al., 2008; Solomon, 2008; Titze & Hunter, 2015; Whitling et al., 2017b) and, in extreme cases, even phonotrauma (Doellinger et al., 2009; Whitling et al., 2017b). Much of the research on these topics has been focused on occupational voice users because,

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while most individuals will experience some type of voice problems sometime during their lives, occupational voice users report a significantly higher occurrence of reported voice problems (Åhlander et al., 2012; Cantor-Cutiva, 2018; Cantor-Cutiva & Burdorf, 2016; Carroll et al., 2006; Jones et al., 2002; Kooijman et al., 2006; Roy et al., 2005). Common to these studies is the attempt to describe and/or quantify such concepts as (a) what the vocalist is doing, (b) what the intent of the comunication is, and (c) what the physiological outcome of the voicing is (e.g., epithelial damage, physical discomfort). Describing such concepts has coalesced into the utilization of the following terms: "vocal load," "vocal loading," "vocal effort," and "vocal fatigue."

Despite the quantity and quality of work toward understanding these four terms, there is some inconsistency in how these terms are used, as well as their implied definitions. For example, the term "vocal fatigue" has been used as both a diagnosis and a symptom (Cantor-Cutiva et al., 2018; Welham & Maclagan, 2003). Further adding confusion, other reports have blurred the distinction between "vocal fatigue" and "vocal effort" by describing "vocal effort" in terms of talker symptoms of pain and discomfort (Isetti et al., 2014; Paes & Behlau, 2017). Moreover, "vocal loading" and "vocal load" are at times referred to as unique terms but are often used interchangeably in the literature (Echternach et al., 2014; Solomon, 2008; Titze et al., 2007). Therefore, there is a need for more standardized definitions of the terms.

A valuable first step in developing these definitions is a systematic review of literature, which is a scientific method that helps researchers assimilate large quantities of information into palatable pieces (Mulrow, 1994). From the results of this review, a bibliometric analysis can be conducted, thereby allowing researchers to summarize large quantities of information by means of a mathematical and statistical analysis of patterns in the publication and use of documents (Diodato & Gellatly, 2013). The identification and analysis of patterns through a bibliometric study may help us define an "intellectual structure" within a field of interest. For instance, citation analysis (one of the bibliometric parameters) is based on the hypothesis that authors cite publications that they consider to be relevant in the development of their work; therefore, frequently cited publications are likely to have a greater influence on the discipline than those less frequently cited (Culnan, 1987; Tahai & Meyer, 1999).

Therefore, the purpose of the current publication is threefold: (a) review the definitions and use of "vocal load," "vocal loading," "vocal effort," and "vocal fatigue" (as found in the literature) to trace the evolution of research on these terms; (b) determine a "linguistically modeled" definition and a use summary of the same four terms; and (c) propose conceptualized definitions of the same based on consultation with experts in the field. By proposing standardized definitions and usages of these terms, the translatability of related research studies and interstudy comparison of results could be improved. Furthermore, standardized definitions could improve the effectiveness of future research studies in classifying risk factors, tracking results of prevention programs, and quantifying vocal limitations and enhancements. Finally, standardized definitions and usages would be key to the development of related metrics, which is a necessary component of evidence-based practices.

Method

This section summarizes the exploratory and retrospective analysis conducted by way of a systematic review of literature, specifically bibliometric analysis (details have been presented previously; Cantor-Cutiva et al., 2018). Following this summary is a description of the deliberations, which lead to the proposed standardized definitions.

Literature Review

Comprehensive literature searches were conducted using four computerized databases: PubMed/MEDLINE (National Library of Medicine, Bethesda, MD), covering from 1966 to September 2017; Embase (Elsevier, Amsterdam, the Netherlands), covering from 1984 to September 2017; Cochrane Central Register of Controlled Trials, covering from 1972 to September 2017; and Scientific Electronic Library Online (Sao Paulo, Brazil), covering from 1997 to September 2017. These dates represent the full range offered by the databases. We aimed at inclusion of publications on all possible terms that could be linked with the definitions of "vocal fatigue," "vocal effort," "vocal load," and "vocal loading." Table 1 shows the search strings used in this systematic review. The search was further extended by screening the reference lists of all relevant publications identified.

Publication Selection

The literature search resulted in 971 potentially relevant publications (after exclusion of duplicates). Titles and abstracts of all papers identified were screened. For example, only those publications accessible to the authors and published in peer-reviewed scientific journals written in English, Spanish, or Portuguese were included. Additionally, publications reporting studies on animals were excluded. After this screening, there were 218 papers left to review. An additional 88 were excluded as they were without an explicit definition or description of any of the terms of interest; descriptions included were interpreted broadly and could refer to standardized questionnaires or assessment methods (e.g., the GRBAS [grade, roughness, breathiness, asthenia, strain] scale). A total of 128 publications on "vocal fatigue," "vocal effort," "vocal load," and "vocal loading" met our inclusion criteria and, therefore, were included in the systematic review (see Appendix A).

Data Extraction and Analysis

Data analysis of included publications were conducted in three phases following the data extraction: network analysis, creation of linguistically modeled definitions, and expert discussion for proposed definitions. First, eight readers

Table 1. Search strings used in the systematic review of literature.

Database	Search string
PubMed/MEDLINE	"vocal fatigue" OR "vocal effort" OR "vocal load*" OR "vocal demand*" OR "vocal performance" OR "vocal strain*"
Embase	"vocal fatigue" OR "vocal effort" OR "vocal load*" OR "vocal weak*" OR "vocal tired*" OR "vocal demand*" OR "vocal performance" OR "vocal strain*"
Cochrane Central Register of Controlled Trials	"vocal fatigue" OR "vocal effort" OR "vocal load*" OR "vocal weak*" OR "vocal demand*" OR "vocal tired*" OR "vocal performance" OR "vocal strain*"
Scielo	(vocal fatigue) OR (vocal effort) OR (vocal load*) OR (vocal weak*) OR (vocal tired*) OR (vocal demand*) OR (vocal performance) OR (vocal strain*)

Note. Scielo = Scientific Electronic Library Online.

(graduate and undergraduate students) organized in pairs to read and extract relevant information on the definition of each of the terms of interest; this redundancy was built in to reduce the chance that both readers would miss a term in a paper. A single bibliometric indicator was then defined (key word co-occurrence network; see Figure 2), which was then used to understand co-occurrence of key words in the corpus of definitions. Using the extracted key words, a research network diagram was created to analyze research competency of each definition. This research network contained "items" (circles) that are the objects of interest (key words). The size of the circle is determined by the weight of the item, and the color of the item is determined by the cluster to which the item belongs. "Items" are connected by links (lines between circles), with the width of the link determined by the number of occurrences that publications have in common (the higher this value, the stronger the link). The software VOSviewer version 1.6.13 was used to build the bibliometric map (van Eck & Waltman, 2010).

Second, a latent semantic analysis was performed, in which the most common key words, as well as the key word co-occurrence network results, were included to create "linguistically modeled" definitions of each topic based on how the terms were used in the current literature. "Latent semantic analysis" is a theory and method for extracting "meaning" of words by analyzing word use patterns statistically (Evangelopoulos, 2013; Landauer & Dumais, 1997). For the "linguistically modeled" definitions, the eight readers created a database in Excel where they registered the main concept of the paper (i.e., "vocal load," "vocal loading," "vocal fatigue," and "vocal effort") and the key words from the definitions presented in each included publication. Each "linguistically modeled" definition included the most frequently used words presented in the reviewed publications. The readers consulted often to write the linguistically modeled definitions in a way that represented the key words and usages found in the literature.

As became apparent per the "linguistically modeled" definitions, there was a significant amount of overlap and inconsistent key word use found in the literature. Therefore, the final step in the review analysis was to propose standardized and clarified definitions of the terms to improve use and reduce ambiguity. Starting with the results of the review, particularly with the linguistically modeled definitions, a focus group of eight experts in the voice field (current authors) met multiple times over nearly 6 months to discuss these linguistically modeled definitions and to make conceptual connections for potential future definitions. During the first few meetings, the modeled definitions were discussed, as well as how the experts used the four terms themselves. Assignments were made to pairs of experts to draft a standard definition, which would be proposed to the group. In subsequent meetings over several months, the proposed definitions were regularly discussed and refined. Eventually, proposed definitions were approved by the group, and the final section of the paper was written to present the definitions in a way that both reflected previous work and clarified the concepts for future use.

During these discussions, because it was concluded that there was also much still unknown about the underlying physiology and potential quantities related to the concepts, it was determined that the primary gap was the lack of clarity of the terms and their distinctions. Therefore, it was decided to leave other concepts (e.g., experimental designs and measurable quantities) to future work by the scientific community at large.

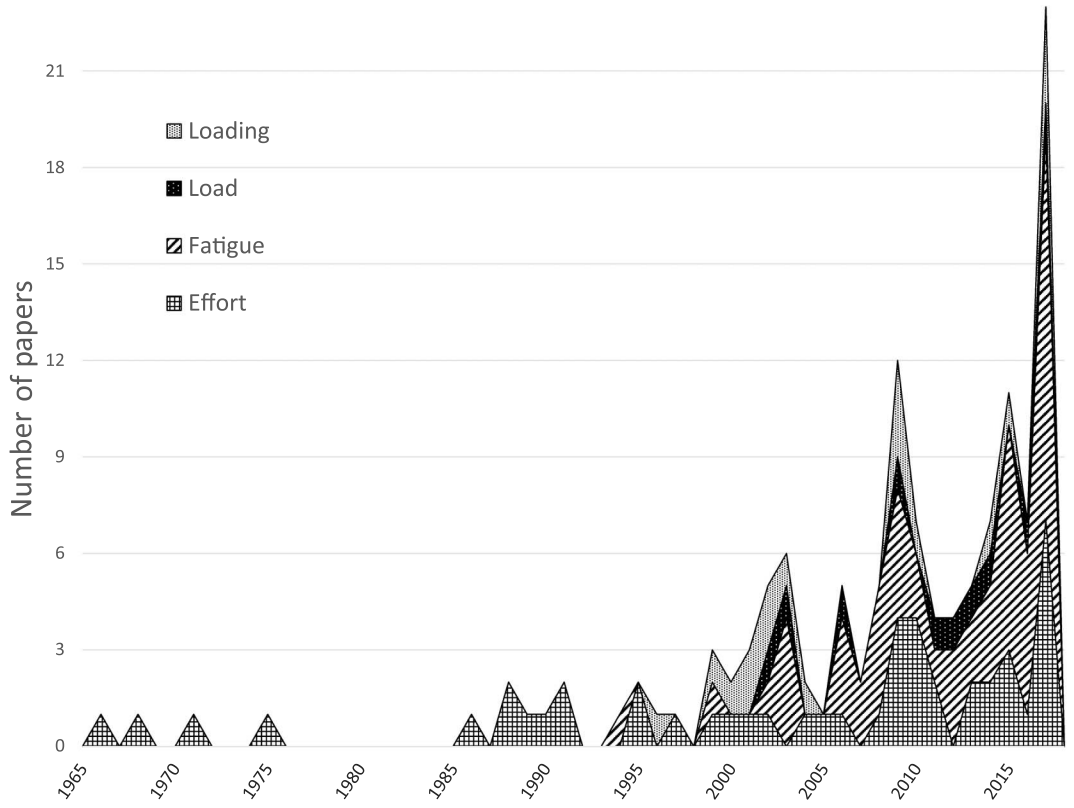
Results and Discussion

This section consists of four subsections reflecting the phases of the data extraction and analysis: (a) evolution of publications per year and topic, (b) analysis of the occurrence and frequency of term usage as found in the literature, (c) summary of the definitions based on how the terms are defined and/or used in the literature, and (d) proposal of definitions for future use.

Part 1: Evolution of Publications per Year and Topic

Based on the literature review, Figure 1 shows the evolution of publications per topic. Before 1990, 100% of the publications reported results on research about vocal effort. This tendency changed during the 90s when research in "vocal fatigue," "vocal load," and "vocal loading" started

Figure 1. Evolution of publications per year and topic.



to be published. From 2000 to 2017, "vocal fatigue" was the leading topic among the four, with about 45% of the published manuscripts on this topic.

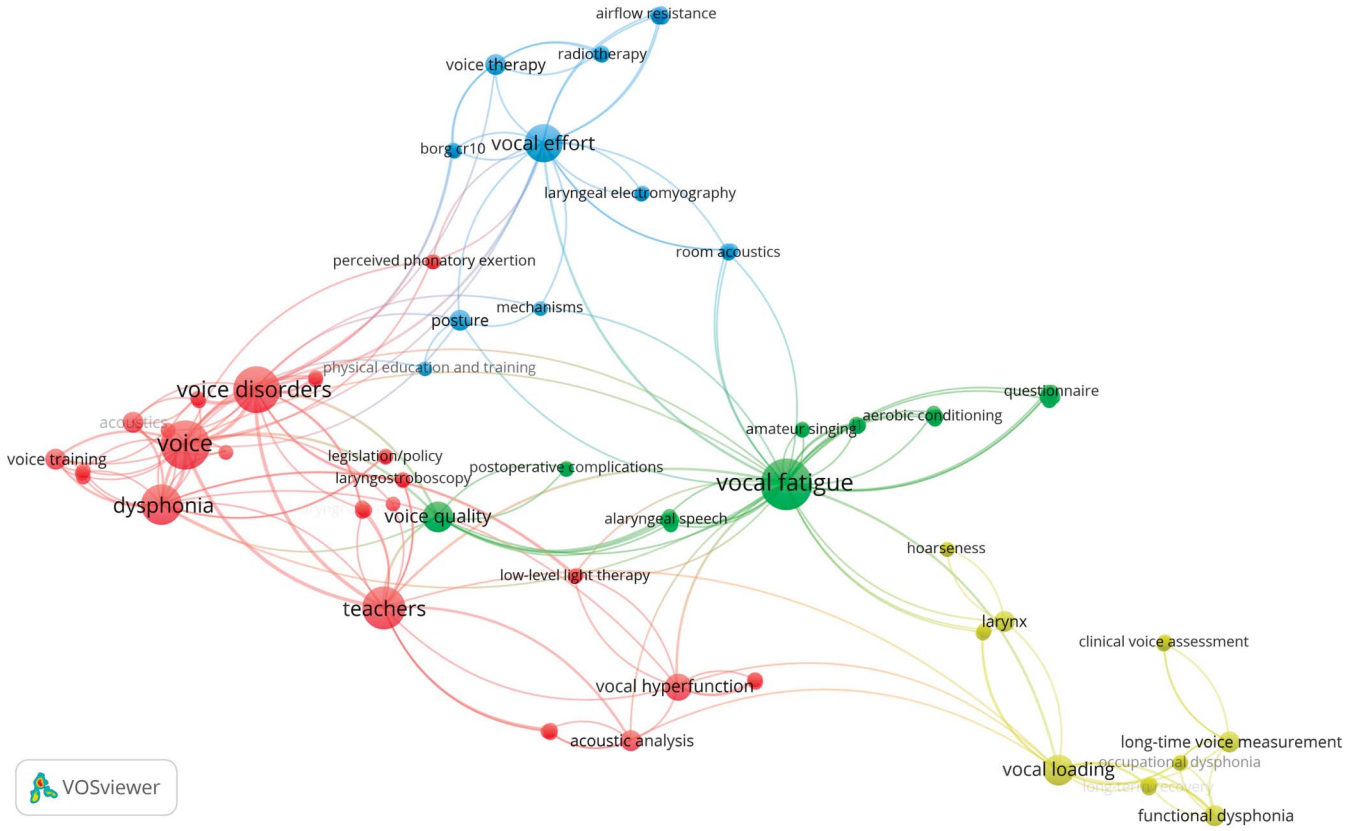
Part 2: Term Occurrence and Use Frequency

Based on the key word search and connecting definitions, key word usage from the literature allows for the foundation of an overall conceptualization of definitions. Appendix B shows the occurrence of the search term key words as they occurred in the definitions of the four terms in the reviewed papers. The two key phrases associated most often with "vocal fatigue" were (a) "vocal symptom/deficit" and (b) "prolonged voice time," with 34 and 27 occurrences, respectively. "Prolonged voice time" was one of the most often used key words included in the definition of "vocal loading," with 14 occurrences. "Prolonged voice time" was a key phrase commonly used to define "vocal effort," "vocal loading," and "vocal fatigue," with 4, 14, and 27, occurrences, respectively. The two phrases most often used to define "vocal effort" were "vocal loudness change" (23 occurrences) and "raise in fundamental frequency" (11 occurrences), both of which were used to describe the effects of "vocal effort."

A co-occurrence network and occurrence frequency graph provide the relationship between key words. Figure 2 shows the key word occurrence frequency and key word co-occurrence network (only those terms with two or more connections are shown). Besides the key words of "voice," "teachers," "voice disorders," and "dysphonia" (all in the red cluster), the most frequent key words were "vocal fatigue" (green), "vocal effort" (blue), and "vocal loading" (yellow). The co-occurrence network also groups the key words with the highest association by color, showing key words with the most links; for example, "vocal loading" (yellow) is clustered with terms such as "functional dysphonia," "long-time measures of voice," and "occupational dysphonia." Connections between clusters indicate that "vocal loading" (yellow) has a strong connection to "vocal fatigue" (green) and several in the red cluster ("teachers," "hyperfunction," "acoustic analysis") but not with "vocal effort" (blue).

As with any review, there are limitations due to research uncertainty and unknowns. In this case, while the protocol attempted to be thorough (data extraction steps included pairs of research personnel working together, reading the papers, and scanning for the extractable content), information could have been missed despite these redundancies. However, the research team met regularly to ensure quality. Also, the study did not include other languages outside English, Portuguese, and Spanish. This inherently neglects potential work in Swedish or other

Figure 2. Key word co-occurrence network.



languages that may represent a significant research presence on the topics.

Part 3: Summary of Definitions, Usage, and Contexts in the Literature

The results of the literature review above demonstrate an increased interest and awareness in these topics. Additionally, these results allowed us to create a descriptive overview of how the concepts of "vocal load," "vocal loading," "vocal effort," and "vocal fatigue" are presented in the literature from various research teams and over multiple decades. Therefore, they represent how the terms have been used and not how they should be defined. Due to this dependence on term use in the literature, there are significant overlaps and redundancies between some of these definitions. Nevertheless, we have compiled an overview of how each term has been defined in the literature, along with usages and contexts.

Vocal Load From the Literature

Definition. "Vocal load" is often described as a perception or phonatory effort. It is consistently described as being "heavy, moderate or light." Physiologically, usage in the literature suggests that "vocal load" is measured in the same way as "vocal loading" (described next). Some correlated descriptions including tiredness, muscular strain, dry throat, fatigue, burning, pain, overall voice quality, and vocal tract discomfort were also obtained from both listeners and speakers. Many authors also described "vocal loading tasks" as "vocal load." Solomon (2008) described "vocal load" as phonating at higher than normal frequency, intensity, and/or duration levels. Many papers used "vocal load" as the amount of "vocal loading" to which participants were subjected. The amount of "vocal load" required to negatively affect a subject's voice varied but was markedly less for subjects with known voice disorders. In summary, previous reports indicate a general consensus, though not universal, on the use of vocal load, that is, that "vocal load" is affected by increased vocal demand, and the consequence of the increased "vocal load" is associated with an increased likelihood of voice disorders (e.g., vocal fatigue, dysphonia).

Potential quantities. The term "vocal load" was most often described in the reviewed papers in terms of physiological, perceptual, acoustic, and/or aerodynamic metrics resulting from prolonged voice use and/or a task specifically designed to fatigue the voice (called "vocal loading tasks" or "vocally fatiguing tasks"), as well as from existing vocal impairments. "Vocal load" was also described as the

accumulated voicing time of a timed session of the task (Titze et al., 2007), with the amount of load that a talker could handle using the term "vocal loading" capacity (Echternach et al., 2014). "Vocal load" has been quantified using several perceptual questionnaires/surveys including the Vocal Loading Test (Richter et al., 2016) as well as the Vocal Loading Index (Švec et al., 2003). Acoustically, previous quantification of "vocal load" was described in terms of phonation threshold pressures, time dose, distance cycle dose, radiated energy dose, maximum phonation time, jitter, shimmer, relative fundamental frequency, cepstral peak prominence, Vocal Health Index, sound pressure levels (SPLs), and changes in laryngeal appearance.

Vocal Loading From the Literature

Definition. Several phrases in the literature were used interchangeably with "vocal loading," including vocal challenge, prolonged voice use, vocally fatiguing task, and vocal attrition. "Vocal loading" has been distinguished as voicing tasks leading to "vocal load" (Solomon, 2008). Physiologically, "vocal loading" was most often described as increased vocal fold vibration, muscle tension, negative phonatory function, and negative formal physiological evaluation by qualified personnel. The literature is inconclusive regarding whether "vocal loading" is a state caused by excessive "vocal load" or the process leading to vocal overload, as it is mentioned in relation to vocal warm-up, "vocal effort," "vocal fatigue," and vocal recovery. It is, however, neither clearly defined nor distinguished. Another aspect adding to this enigmatic concept is the lack of studies exploring "vocal loading" in parts of the population suffering from a voice pathology related to strain, increased effort, and vocal fatigue. There is a lack of distinction in much of the literature between how "vocal loading" and "vocal load" are used, with many authors often using the terms interchangeably. Several perceptual features were associated with both "vocal loading" and "vocal load" including increased dry throat, hoarseness, and perceived effort. Additionally, "vocal loading" and "vocal load" both have been described in terms of increased vocal strain, vocal stress, vocal demand, loudness, tiredness, and vocal fatigue. However, in some reports, there are distinctions made where "vocal loading" is used to refer to the tasks used to induce "vocal load." In this context, "vocal loading" was more often caused by targeted prolonged "vocal load" (voicing tasks), ranging in duration from 30 to 150 min. Researchers consistently manipulated "vocal load" by manipulating "vocal loading" tasks (i.e., increasing pitch and loudness, increasing background noise during a loading task, and/or decreasing the air quality and room acoustics). Consequences of both "vocal loading" and "vocal load" have been described as affecting voice quality and limiting job performance.

Potential quantities. Increased "vocal loading (along with vocal load)" has been correlated with a consistent decrease in voice quality. For example, an increase in fundamental frequency and a decrease in pitch range were reported after "vocal loading" tasks.

Vocal Effort From the Literature

Definition. "Vocal effort" is a multidimensional concept. After a review of the papers with definitions of "vocal effort," several perspectives could be identified, including external perception of effort with a physiological component, the experience of vocal effort, psychological effort, effort as a speech production level, and effort in terms of the communication environment conditions. From the external perceptual and physiological point of view in the reviewed literature, "vocal effort" is commonly defined as an increase in vocal loudness and strain in voicing (Brandt et al., 1969; Lagier et al., 2010; Lien et al., 2015; Meynadier et al., 2018; Mooshammer, 2010). Less common but also present in the reviewed papers are changes in posture (such as forward bending of the trunk and backward rotation of the head) that were identified among individuals reporting increased "vocal effort" (Lazarus, 1990). From the point of view of the person experiencing or exerting "vocal effort," some of the most common symptoms found are experiencing pain/discomfort while speaking, tight feeling in the throat, and sounding tearful (Isetti et al., 2014; Paes & Behlau, 2017). From the psychological perspective, "vocal effort" has been associated with mood changes, cognitive load, and self-efficacy (Ford Baldner et al., 2015; van Leer & van Mersbergen, 2017; van Mersbergen & Delany, 2014; van Mersbergen et al., 2017, 2008). From the communication environment perspective, "vocal effort" has been known to encompass the environmental components of voicing with three main aspects: distance to the interlocutor, background noise, and time in vocal use (Bermúdez de Alvear et al., 2011; Brinca et al., 2015; Brungart & Scott, 2001; Cheyne et al., 2009; Cipriano et al., 2017; Eriksson & Traunmüller, 2002; Huang et al., 1995; Liénard & Di Benedetto, 1999; Machado et al., 2011; Pelegrín-García et al., 2011; Sliwinska-Kowalska et al., 2006; Traunmüller & Eriksson, 2000). Therefore, as discussed in the voice literature to date, "vocal effort" can be conceptualized as a physiologic or perceptual effort.

Potential quantities. From the external perceptual and physiological point of view in the reviewed literature, "vocal effort" may be linked with an increased subglottal (tracheal) pressure and a higher cervical muscle tension. From the speech acoustic perspective, "vocal effort" is associated with an increase in fundamental frequency, standard deviation of fundamental frequency, first formant, and SPLs and its variation in voice (Bottalico, 2017; Cheyne et al., 2009; Eriksson & Traunmüller, 2002; Hazan et al., 2016; Lagier et al., 2010; Pohjalainen et al., 2013; Primov-Fever et al., 2013).

Vocal Fatigue From the Literature

Definition. "Vocal fatigue" has been commonly defined as a set of self-perceived vocal symptoms, as well as physiologic adaptations following extensive vocalizing. However, there is a division in the etiology of "vocal fatigue." One subset defines "vocal fatigue" as a perceptual condition identified as increased "vocal effort," neck and shoulder tension, reduced control of voice flexibility, increase in

symptoms across the speaking day, poor vocal quality, and/or a weak voice (Nanjundeswaran et al., 2015; Solomon, 2008). The other subset defines "vocal fatigue" as a voice acoustic or physiological consequence resulting from prolonged voice use (Boucher, 2008).

Potential quantities. "Vocal fatigue" appears to be described as laryngeal muscle and tissue fatigue resulting in laryngeal discomfort, reduced range and control of fundamental frequency and intensity, and increased phonation threshold pressure (Chang & Karnell, 2004; Laukkanen & Kankare, 2006), which will improve with rest (Hunter & Titze, 2009).

Part 4: Proposed Definitions and Usages

Definitions and usages (past and present) of the concepts of "vocal load," "vocal loading," "vocal effort," and "vocal fatigue" have overlap and redundancy, resulting in inconsistent use and confusion on explicit concepts. Nevertheless, the results of the literature search and the subsequent literature-based definitions do support that there are four distinct concepts even if the current usages of the terms do not always support those concepts without ambiguity. However, the frequent use of the terms shows a maturity in the concepts within the context of vocal health. As scientific literature is organic with a wide variety of contributing scientists and backgrounds, a range of usages and ambiguities is not unexpected. Nevertheless, the consequence of these ambiguities can hinder the ability to effectively quantify and discuss vocal health. Therefore, a step toward clarity, as well as focused, collaborative, and complementary progress within the field, would be the development of concise term usage and definitions. After the many discussions by the authors about how the terms have been used and how we propose the terms should be used, the following section was written to delineate (with similarities and differences) the primary four concepts. This section, therefore, could be used as a stand-alone guide for voice clinicians, voice scientists, and academic voice students.

To address the ambiguity in the use of the terms "vocal load" and "vocal loading" (as well as the similarity of the terms themselves), we propose that two new terms be subsequently used: "vocal demand" and "vocal demand response." These new terms will allow for a firm step forward to reduce confusion and preserve the impact that the individual concepts can convey. Additionally, it should also be noted that, based on the literature review and the discussion of the terms, "vocal fatigue" emerged as a concept that was so fundamentally different from the other three terms that it could not be approached in the same way; thus, its definition is presented last and contains language commonly found in exercise science.

To begin, the Merriam-Webster Dictionary was consulted to gather pertinent phrases from dictionary entries of concepts related to the four terms (Merriam-Webster, 2019):

- Demand (noun): "requirement of work or the expenditure of a resource"
- Effort: "work or a conscious exertion," "a serious attempt"
- Fatigue: "weariness or exhaustion from work, exertion or stress," "the temporary loss of power to respond [with] …sensory…or motor [components]"
- Load (noun): "quantity…that can be carried at one time," "something that weighs down the mind…"
- Load, Loaded, Loading (verb): "to put a load in or on," "to receive a load"
- Response (noun): "an act of responding," "output… resulting from a given input"

Building on the information from the dictionary definitions, usage in the literature, and experts in the field, we offer the following terms and definitions as the first step toward a more universal set of descriptions that captures the intent of the concepts.

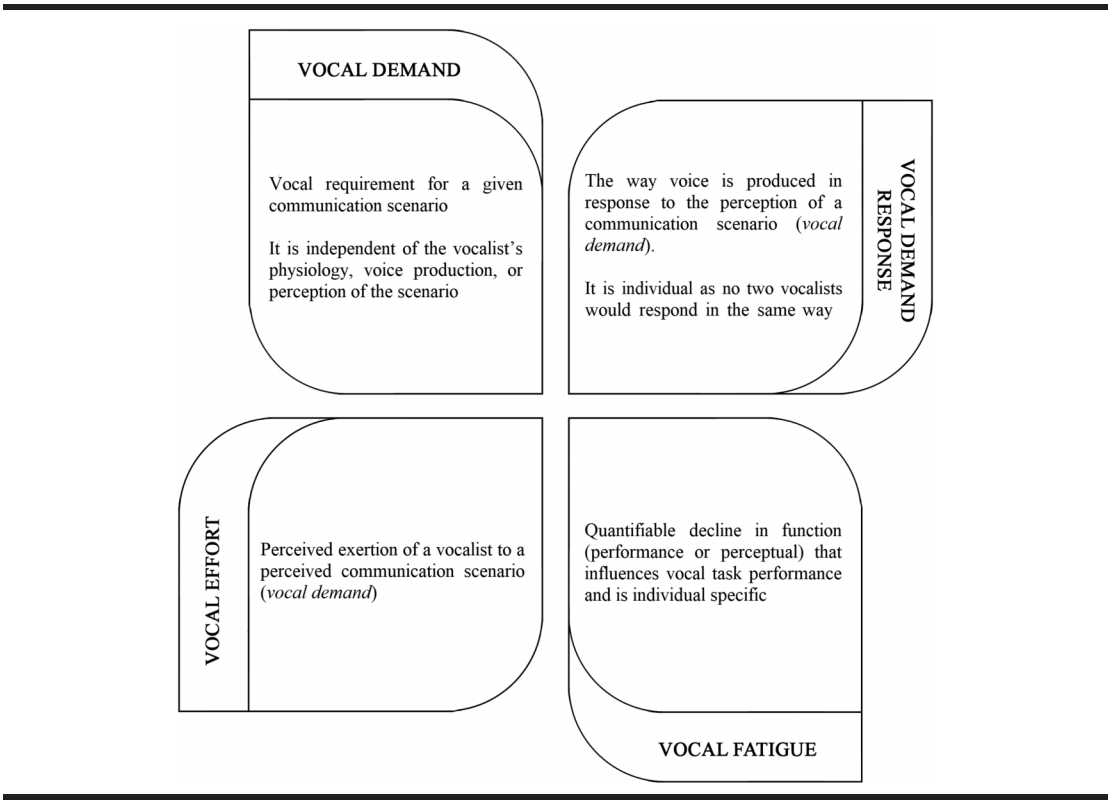
The proposed definitions for "vocal demand," "vocal demand response," "vocal effort," and "vocal fatigue" will be presented below (a summary of the proposed definitions can be found in Figure 3 below). They will be depicted using a common occupational voice use example—that of a schoolteacher intending to lecture orally over some duration of time to a group of students in a classroom with significant background noise. In the presence of noise, a talker commonly responds with elevated vocal loudness, elevated vocal pitch, and a modified voice spectrum (Lombard effect; Egan, 1971; Letowski et al., 1993; Zollinger & Brumm, 2011). This classroom example allows for the identification of several key features of these communicative situations, which are applicable to other communicative situations: vocalist/talker or the source of sound, listener(s) or other receivers, communication goal/intent, and external factors such as noise.

Proposed Definition of Vocal Demand

Definition. "Vocal demand" is the vocal requirement for a given communication scenario, and it is independent of the vocalist's physiology, production technique, or perception of the scenario. The "vocal demand" can be defined in terms of the description of the scenario (e.g., communicative purpose, complexity of material, listeners, environment, social/emotional situation) as well as in terms of the vocal content (propagating vocal acoustic signal) required to satisfy a communicative scenario (e.g., dB SPL, spectral content, accumulation and modulation over time of several voice parameters).

Example. The "vocal demand" of a classroom scenario could include such quantities as the amount of material to convey orally, duration of class periods, complexity of the material, level of the background noise, age and attention/listening ability of the pupils, social/emotional situation, and physical activity requirement. Additional "vocal demand" descriptions related to the actual acoustic voice requirements could include needed voicing time or vocal loudness. These are all independent of the teachers' actual voice production but are the communicative situation

Figure 3. Summary of the definitions.



requirements of the acoustic voice signal. These requirements should be quantifiable. Finally, multiple acoustic voice signal options for satisfying these requirements are possible (e.g., enhanced modulation of the vocal acoustics may reduce the amount of elevated vocal loudness needed). Thus, the "vocal demand" of the classroom may be described in terms of a required vocal signal that could satisfy the demand of a noisy communication situation. "Vocal demand" could include required vocal loudness level to be heard, vocal embellishments to engage students (e.g., modulation, inflection), modification of the vocal spectrum to tune well to the students' ears (e.g., boost in 3–5 kHz), and/or duration or repetition of speech.

Potential quantities. The "vocal demand" could be quantified in terms of the communication scenario quantities and/or acoustic voice quantities that would satisfy the scenario. Communication scenario quantities could include environmental descriptors such as room size and construction, noise type and level, and listener ability. Room acoustic parameters contributing to quantifying "vocal demand" could include such existing quantities as room gain, percentage articulation loss of consonants, Speech Transmission Index, clarity (C50), and definition (D50). Vocal demand quantities in terms of acoustic vocal signals needed to satisfy the communication scenario could include such targeted demand requirements as specific vocal loudness, vocal pitch, and vocal quality. Potential vocal demand parameters related to voice accumulation over time could include equivalent sound level, vocal doses, voicing, and silence accumulations. Vocal demand parameters could be related to modulation over time of voice parameters such as jitter, shimmer, loudness and pitch variability, formant transitions, speaking rate, and articulation rate.

Proposed Definition of Vocal Demand Response

Definition. "Vocal demand response" is the way voicing is produced by an individual in an attempt to respond to a perceived "vocal demand" within a communication scenario. "Vocal demand response" is defined to include the process and product of phonation as determined by individual factors (e.g., physiological and psychological capacity of phonation). "Vocal demand response" would be described in terms of subjective and objective qualities, such as the sense of exertion and effort combined with physiological phonation in the context of a "vocal demand." "Vocal demand response" would be dependent on individual attributes such as vocal health status, vocal capacity and training (baseline vocal aptitude), perceived communicative intent, communicative complexity, social/emotional state, self-auditory perception/feedback, and perceived room acoustics. Its individualized nature may result in one person experiencing a higher physiological demand (mechanical load, potentially overload) on the vocal system, thereby partially explaining a disparity of vocal injury between vocalists given similar "vocal demand."

Example. Given the classroom scenario, "vocal demand response" would be the teacher's specific vocal production to the perceived "vocal demand" of the classroom situation (e.g., noise in classroom, the demand of the material, inattentiveness of the pupils). This individually defined vocal production in a classroom scenario would likely include increased vocal duration, as well as an elevated vocal level and fundamental frequency due to room noise or perceived students' inattention. The teacher may also respond with elevated vocal modulation and speech articulation in order to increase intelligibility. In contrast to "vocal demand," which is external to the individual, the "vocal demand response" is unique to an individual as each teacher may produce voice in a different way to satisfy the communication requirements (e.g., monologue lecture style vs. conversational lecture style, vocal attention cues vs. nonvocal attention cues, increased vocal modulation vs. increased loudness). Additionally, "vocal demand response" may vary given the same "vocal demand" due to the perception of the demand (e.g., awareness of inattentive children, external stressors or distractors). Finally, a teacher's "vocal demand response" to a repeated "vocal demand" could be affected by behavioral changes and vocal habilitation directed at their vocal capacity and vocal resilience.

Potential quantities. Some aspects of "vocal demand response" may be quantifiable in terms of the quality or quantity of common vocal acoustic metrics similar to those presented in "vocal demand" (e.g., dB, fundamental frequency, voicing time, voice modulation) but would also include vocal production quantities (e.g., subglottic pressure, maximum flow declination rate, nasalance), physiological variables (e.g., lung volume, vocal fold length, lamina propria elasticity, hydration), and some functional/behavioral elements (e.g., laryngeal hyperfunction, whole-body stress). The physiological component of "vocal demand response" is akin to the mechanical load on the tissue due to the vibration. Because of the psychological component of "vocal demand response," topics such as personality traits or situational awareness could directly affect how a person realizes "vocal demand response" given a "vocal demand." Therefore, psychological quantities could be part of the "vocal demand response" quantities.

Proposed Definition of Vocal Effort

Definition. "Vocal effort" is the perceived exertion of a vocalist's response ("vocal demand response") to a perceived communication scenario ("vocal demand"). The "vocal effort" is defined as a perceptual phenomenon (as opposed to a physiological phenomenon) experienced by the speaker and not the listener (Abbiss et al., 2015; Banister, 1979; E. Borg, 2007; E. Borg & Kaijser, 2006; G. Borg, 1982, 1990, 2005; Morgan, 1994; Pageaux, 2016; Pageaux et al., 2015; Tenenbaum et al., 2012; Tenenbaum & Hutchinson, 2007). This definition will be consistent with other literature on physical effort. By defining "vocal effort" as the vocalists' perception of exertion and work associated with voice production, it is by definition measured via self-report. Furthermore, given that effort is a multidimensional, global perception (G. Borg, 1990; Tenenbaum et al., 2012), many additional psychological factors may influence an individual's sense of "vocal effort."

Example. Given the scenario of a teacher in a classroom with noise, there are several conditions that could elicit a higher "vocal effort" report from the teacher. Consider the case where the background noise elevates (increasing the "vocal demand") and the teacher's accommodation ("vocal demand response") is to increase his or her loudness level. The increased exertion the teacher feels and subsequently reports in order to produce increased vocal loudness would be increased "vocal effort." Another scenario could be the increase of "vocal effort" of a teacher in maintaining oral communication due to an extended speaking obligation (e.g., long lecture) or the onset of an illness (e.g., upper respiratory infection). The "vocal response" to the prolonged speaking requirement could be to alter a phonatory technique in order to compensate for physiological changes (e.g., fatiguing laryngeal muscles, slight inflammation of the vocal folds). The elevated "vocal effort" would be the perception of elevated exertion to maintain oral communication due to a changing voice system. Despite the origin of the situational demand or the physiological response to that demand, the teacher's "vocal effort" and the perception of work could change drastically even if with little or no change in the "vocal demand" or "vocal demand response" quantities.

Potential quantities. As reviewed above, the most commonly employed focus on "vocal effort" in the literature has been to describe the physiological conditions in vocal production that lead individuals to experience "vocal effort." However, these physiological conditions are not themselves measures of effort. As a perceptual phenomenon, "vocal effort" is highly individual and can vary greatly given the same physical and physiological parameters. Whereas "vocal demand" and the subsequent "vocal demand response" have some direct physical and physiological parameters, respectively, "vocal effort" is measured solely via psychophysical parameters (Banister, 1979; E. Borg & Kaijser, 2006; G. Borg, 1990, 2005). Therefore, to investigate the perception of "vocal effort" resulting from a change in physical or physiological conditions, effort ratings should follow sound psychophysical principles and be made immediately following the vocal activity. This tight temporal relation will avoid exposure to additional factors that might influence these ratings. Self-report measures such as magnitude estimation (Banister, 1979; Tenenbaum et al., 2012), a visual analog scale (G. Borg, 1990), Likert and Likert-type scales such as the NASA Task Load Index (Morgan, 1994), or the Borg effort scales (E. Borg, 2007; E. Borg & Kaijser, 2006; G. Borg, 1982, 1990, 2005) are the most frequently employed measures of effort in other fields of physical exertion. Indeed, many "vocal effort" studies have employed these scales to capture aspects of the perception of effort (Ford Baldner et al., 2015; Solomon, 2008; Solomon et al., 2003; van Leer & van Mersbergen, 2017). Additionally, because effort is a perceptual phenomenon, it is subject to a myriad of psychological states that affect

its measurement level. Mood, emotion, temperament, attention, concentration, self-regulation, and memory have all been known to affect "vocal effort" ratings (Ford Baldner et al., 2015; van Leer & van Mersbergen, 2017; van Mersbergen & Delany, 2014; van Mersbergen et al., 2017; Vinney et al., 2016). Therefore, in addition to reporting on physical and physiological parameters of "vocal demand response," controlling for and reporting on these other variables will allow for a clearer picture of an individual's perceived phenomena. Using a multimeasure approach, "vocal effort" measures may lead to a deeper understanding of how effort ties into the physical, physiological, psychological, and social domains.

Proposed Definition of Vocal Fatigue

Definition. "Vocal fatigue" is the perceived measurable symptom that influences vocal task performance and is individual specific; it is a multifaceted concept integrating self-perceived vocal symptoms and/or physiologic deficit, which may be a result of high "vocal demand response," high "vocal effort," or neuromuscular deficit. Due to the multifaceted nature of vocal fatigue, terms from exercise physiology will be incorporated in the discussion. First, fatigue in exercise physiology literature has been defined by "performance fatigue" and "perceived fatigue" (Enoka & Duchateau, 2016). "Performance fatigue" is a measurable outcome and is defined as changes in performance ability (i.e., decreased power, increased time taken to complete a task, decreased force production). It is determined by the contractile properties of the muscles, bioenergetic substrate availability, and the ability of the nervous system to provide adequate activation signal for the given task. Therefore, performance fatigue in voice production could be due to central and peripheral aspects of laryngeal muscle fatigue. Material fatigue of the vocal fold cover has also been proposed as a component of performance fatigue (Welham & Maclagan, 2003); however, this is not yet evidence supported. "Perceived fatigue," or the perception of fatigue in relation to a task, is derived from sensations regulated by a vocalist to maintain homeostasis and their psychological state. It is influenced by many modulating factors including an individual's current mood, motivation, pain, expectations, and performance feedback. In other words, an individual with the same amount of vocal response and physiological response may not experience the same intensity of perceived fatigue. While fatigue cannot be completely mitigated with conditioning training, both perceived fatigue and performance fatigue can be delayed with careful training to improve performance and protect against injury. Nevertheless, the concept of fatigue resistance training has been a little-considered aspect of vocal function. Finally, fatigue in the realm of vocal performance could be addressed as something to manage and train for instead of a condition to be avoided.

Fatigue has also been described in terms of state fatigue and trait fatigue. "State fatigue" captures the change in perception of fatigue during an ongoing activity, whereas "trait fatigue" is the average amount of perceived fatigue over a period of time. An individual may present with "trait fatigue" prior to the measurement of an ongoing task, which is measured at the baseline of a task as this may influence the performance and state fatigue. While state fatigue is influenced by physiological performance and success of the ongoing activity, it should not be confused with "vocal effort," which is a perception of work or exertion.

Example. Assume that the teacher is now using a loud voice for extended periods while engaging in physical activity with the students. Symptoms and reports of "vocal fatigue" may present as the respiratory and phonatory systems are no longer able to maintain the sound level required without significant exertion or physical straining and pushing ("vocal effort"). Such limitations in completion of the task might be examples of "performance fatigue." Perceived "vocal fatigue" is an important signaling mechanism for taking a voice break. The tipping point for perception of fatigue is idiosyncratic and may be triggered by a variety of reasons, which may include but is not limited to fatigue, illness, motivation, dehydration, or classroom noise. Assuming our teacher performed this activity repeatedly every day, the overall accumulating fatigue ("trait fatigue") of the teacher may slowly increase over the school year. If adequate recovery does not occur after work or on weekends, it places an impact on "state fatigue" during the actual activity. Over time, however, this teacher may be better conditioned to tolerate this activity and experience less "trait fatigue." Tolerance to the imposed "vocal demand" (state fatigue) may be more characteristic of the teacher at the end of a school year.

Potential quantities. Quantification of "vocal fatigue" will require acknowledgment of performance versus perceived components and, specifically, state versus trait fatigue. Measurement of "performance fatigue" is usually measured by a decline in force, but there are no specific means to measure a decline in force related to voice use. Some aspects in the literature of "vocal fatigue" have quantified performance fatigue using a phonation task where vocal performance becomes limited (e.g., inability to produce soft voice, vocal onset measures, phonation threshold pressure). However, these outcome measures could be a "vocal demand response" and not necessarily an indication of "vocal fatigue." Performance components need to be physiologic/metabolic changes and will require a careful derivation from the exercise physiology literature to study vocal fatigue. "Perceived fatigue" is measured using a self-reported symptom description. "Trait fatigue" is measured using a psychophysical scale, such as the Vocal Fatigue Index, that measures the experience of fatigue over the past month. "State fatigue" is often used interchangeably with perceived exertion and may be related to perceived "vocal effort." Perceived exertion is measured using the Borg scale but has also been measured using a visual analog scale in response to the question: "How fatigued are you now?" Because of the psychological component of "vocal fatigue," modulating factors need to be considered in the evaluation of "perceived fatigue."

Individual Differences and External Influences

Individual differences that are unchangeable (i.e., immutable) personal characteristics might affect research and treatment, such as intelligence, height, and personality traits. Individuals bring to the research laboratory and clinic a host of factors that are known to affect the awareness and acuity of vocal demand, vocal demand response, vocal effort, and vocal fatigue. Strictly speaking, individual differences are the unique cognitive aptitudes, perceptual capabilities, and temperamental predispositions that may explain or strengthen the values of vocal demand, demand response, effort, and fatigue. Although it seems unlikely that an external construct such as vocal demand would be influenced by an individual's personal makeup, there is evidence that internal factors such as personality interact with external environment in such a way that causes certain individuals to seek out situations that may present increased vocal demand (Krueger, 2000). For example, extroverts are more likely to be drawn to professions that require increased amounts of talking and leisure activities that occur in louder environments. Additionally, perceptual attention has been found to influence what an individual does during a prolonged vocal production task. In a study by Whitling et al. (2017b), individuals who presented with functional dysphonia continued to speak in a prolonged vocal task despite reporting fatigue. The continuation of an activity in the presence of fatigue suggests that these individuals have prioritized their internal sensations differently during this task than others who stopped after feeling fatigued. Moreover, individuals who possess fewer cognitive resources to manage communication situations may report an increased sense of vocal effort due to their increased cognitive load because cognitive effort and vocal effort are difficult to differentiate (van Mersbergen et al., 2019). Numerous studies have reported that transient mood and personality also affect the sensation of vocal effort (van Mersbergen et al., 2017, 2008), presenting an important concept in the study of these constructs. Thus, a variety of person-specific factors may need to be accounted for when examining these constructs.

External factors also influence vocal demand, vocal demand response, vocal effort, and vocal fatigue. In a study by Nanjundeswaran et al. (2017), individuals with higher levels of physical fitness (specifically cardiovascular fitness) reported reduced vocal fatigue despite having no formal voice therapy (Nanjundeswaran et al., 2017). In a series of additional studies by Solomon et al. (2003), dehydration in the presence of elevated vocal demand response intensified the perception of fatigue. The list of additional factors that might affect these constructs (e.g., various medications, amount and quality of sleep, previous vocal or physical activity, warm-ups, illness) has yet to be fully investigated. However, these influences are present and should be included in the interpretation of any reported value. Factors such as self-efficacy or confidence, a construct that relies on both internal predispositions and external experiences, may influence vocal effort but have yet to be studied. Future efforts to study these constructs will require researchers and clinicians to accommodate for differences that individuals bring to these measures by quantifying them prior to measurement to establish a reasonable baseline, modifying research design and clinical protocols to control for the variability of these differences, and employing proper power estimations to account for the potential difference in research. Indeed, these caveats are true for any research involving humans, but for vocal demand, vocal demand response, vocal effort, and vocal fatigue, these variables need to be further investigated to avoid conflation of these constructs.

Conclusions

In reviewing the terms "vocal load," "vocal loading," "vocal effort," and "vocal fatigue" in the literature, it is our desire to further enhance coordinated discussions of these important concepts. Our proposed evolution of terms (adding "vocal demand" and "vocal demand response") and the proposed definitions above will help the voice science and clinical voice community to continue to press forward in studying voice production. We do not suggest that these definitions are the final verdict but instead an important next step in our evolution to better understand and care for the voice. Future work should further explore the quantification of and relationship between these terms, which should include individual differences and external influences.

In summary, the following outlines the universal definitions proposed above (see Figure 3). "Vocal demand" is an independent variable (a requirement of the vocal communication environment). "Vocal effort" and "vocal demand response" are dependent variables in response to the perception of the "vocal demand," while "vocal fatigue" is a dependent variable in response to "vocal effort" and "vocal demand response" and is only indirectly related to "vocal demand." In other words, given a "vocal demand," the goal of vocal training or vocal therapy is finding a vocalist's optimal "vocal demand response" and optimal "vocal effort" in response to that "demand." Interventions to address "vocal response" and "vocal effort" may include counseling on how to reduce the external "vocal demand" but cannot ignore how to balance "vocal effort" and "vocal response." Optimization of "vocal response" may then occur even when the "vocal demand" does not change. "Vocal fatigue" is more related to the symptoms a vocalist would describe (e.g., discomfort, recovery) or lack of vocal ability (performance) due to a given "vocal effort" and "vocal demand response."

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Characteristics of the Included Publications

Topic	Title	Authors	Year	Journal
Effort	Intraoral Pressure and Rate of Flow During Speech	Subtelny et al.	1966	*Journal of Speech and Hearing Research*
Effort	Postural Habits and Vocal Behavior of Physical Education Professionals in the Hydro-Gymnastics Modality	Machado et al.	2011	*Revista CEFAC*
Effort	Acoustic Level and Vocal Effort as Cues for the Loudness of Speech	Allen	1971	*The Journal of the Acoustical Society of America*
Effort	Changes in Brain Activity Following Intensive Voice Treatment in Children With Cerebral Palsy	Bakhtiari et al.	2017	*Human Brain Mapping*
Effort	School Teachers' Vocal Use, Risk Factors, and Voice Disorder Prevalence: Guidelines to Detect Teachers With Current Voice Problems	Bermúdez de Alvear et al.	2011	*Folia Phoniatrica et Logopaedica*
Effort	The Sound Level of the Singer's Formant in Professional Singing	Bloothooft & Plomp	1986	*The Journal of the Acoustical Society of America*
Effort	Speech Adjustments for Room Acoustics and Their Effects on Vocal Effort	Bottalico	2017	*Journal of Voice*
Effort	Vocal Loudness and Effort in Continuous Speech	Brandt et al.	1969	*The Journal of the Acoustical Society of America*
Effort	The Prevalence of Laryngeal Pathologies in an Academic Population	Brinca et al.	2015	*Journal of Voice*
Effort	Spectrographic Analysis of Divers' Speech During Decompression	Brubaker & Wurst	1968	*The Journal of the Acoustical Society of America*
Effort	The Effects of Production and Presentation Level on the Auditory Distance Perception of Speech	Brungart & Scott	2001	*The Journal of the Acoustical Society of America*
Effort	Long-Term Results of Type II Thyroplasty for Adductor Spasmodic Dysphonia	Chan et al.	2004	*The Laryngoscope*
Effort	Talker-to-Listener Distance Effects on Speech Production and Perception	Cheyne et al.	2009	*The Journal of the Acoustical Society of America*
Effort	Combined Effect of Noise and Room Acoustics on Vocal Effort in Simulated Classrooms	Cipriano et al.	2017	*The Journal of the Acoustical Society of America*
Effort	The Role of Experience of Judgments of Dysphonia	Eadie et al.	2010	*Journal of Voice*
Effort	Perception of Vocal Effort and Distance From the Speaker on the Basis of Vowel Utterances	Eriksson & Traunmüller	2002	*Attention, Perception, & Psychophysics*
Effort	Effects of Noise on Speech Production: Acoustic and Perceptual Analyses	Van Summers et al.	1988	*The Journal of the Acoustical Society of America*
Effort	A Review of Measures of Vocal Effort With a Preliminary Study on the Establishment of a Vocal Effort Measure	Ford Baldner et al.	2015	*Journal of Voice*
Effort	Is the Effort Dependence of Speech Loudness Explicable on the Basis of Acoustical Cues?	Glave & Rietveld	1975	*The Journal of the Acoustical Society of America*
Effort	Analysis of Human Scream and Its Impact on Text-Independent Speaker Verification	Hansen et al.	2017	*The Journal of the Acoustical Society of America*
Effort	Suprasegmental Characteristics of Spontaneous Speech Produced in Good and Challenging Communicative Conditions by Talkers Aged 9–14 Years	Hazan et al.	2016	*Journal of Speech, Language, and Hearing Research*
Effort	Comparisons Among Aerodynamic, Electroglottographic, and Acoustic Spectral Measures of Female Voice	Holmberg et al.	1995	*Journal of Speech and Hearing Research*
Effort	Delivering the Lee Silverman Voice Treatment (LSVT) by Web Camera: A Feasibility Study	Howell et al.	2009	*International Journal of Language & Communication Disorders*
Effort	Measures of Vocal Function During Changes in Vocal Effort Level	Huang et al.	1995	*Journal of Voice*
Effort	Strain Modulations as a Mechanism to Reduce Stress Relaxation in Laryngeal Tissues	Hunter et al.	2014	*PLOS ONE*

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Characteristics of the Included Publications

Topic	Title	Authors	Year	Journal
Effort	Inferring Speaker Attributes in Adductor Spasmodic Dysphonia: Ratings From Unfamiliar Listeners	Isetti et al.	2014	*American Journal of Speech-Language Pathology*
Effort	Coordination Between Posture and Phonation in Vocal Effort Behavior	Lagier et al.	2010	*Folia Phoniatrica et Logopaedica*
Effort	New Methods for Describing and Assessing Direct Speech Communication Under Disturbing Conditions	Lazarus	1990	*Environment International*
Effort	Individual Monitoring of Vocal Effort With Relative Fundamental Frequency: Relationships With Aerodynamics and Listener Perception	Lien et al.	2015	*Journal of Speech, Language, and Hearing Research*
Effort	Effect of Vocal Effort on Spectral Properties of Vowels	Liénard & Di Benedetto	1999	*The Journal of the Acoustical Society of America*
Effort	Speech Production Modifications Produced in the Presence of Low-Pass and High-Pass Filtered Noise	Lu & Cooke	2009	*The Journal of the Acoustical Society of America*
Effort	Estimating Vocal Effort from the Aerodynamics of Labial Fricatives: A Feasibility Study	Meynadier et al.	2018	*Journal of Voice*
Effort	Acoustic and Laryngographic Measures of the Laryngeal Reflexes of Linguistic Prominence and Vocal Effort in German	Mooshammer	2010	*The Journal of the Acoustical Society of America*
Effort	Dosage Dependent Effect of High-Resistance Straw Exercise in Dysphonic and Non-Dysphonic Women	Paes & Behlau	2017	*CoDAS*
Effort	Acoustic Conditions for Speech Communication in Classrooms	Pekkarinen & Viljancn	1991	*Scandinavian Audiology*
Effort	Vocal Effort With Changing Talker-to-Listener Distance in Different Acoustic Environments	Pelegrin Garcia et al.	2011	*The Journal of the Acoustical Society of America*
Effort	Influence of Asymmetric Stiffness on the Structural and Aerodynamic Response of Synthetic Vocal Fold Models	Pickup & Thomson	2009	*Journal of Biomechanics*
Effort	Detection of Shouted Speech in Noise: Human and Machine	Pohjalainen et al.	2013	*The Journal of the Acoustical Society of America*
Effort	The Effect of Physical Effort on Voice Characteristics	Primov-Fever et al.	2013	*Folia Phoniatrica et Logopaedica*
Effort	Audiovisual Investigation of the Loudness-Effort Effect for Speech and Nonspeech Events	Rosenblum & Fowler	1991	*Journal of Experimental Psychology: Human Perception and Performance*
Effort	Speech Recognition at Simulated Soft, Conversational, and Raised-to-Loud Vocal Efforts by Adults With Cochlear Implants	Skinner et al.	1997	*The Journal of the Acoustical Society of America*
Effort	The Prevalence and Risk Factors for Occupational Voice Disorders in Teachers	Sliwinska-Kowalska et al.	2006	*Folia Phoniatrica et Logopaedica*
Effort	Harsh Voice: Vocal Effort Perceptual Ratings and Spectral Noise Levels of Hearing-Impaired Children	Thomas-Kersting & Casteel	1989	*Journal of Communication Disorders*
Effort	Paralinguistic Variation and Invariance in the Characteristic Frequencies of Vowels	Traunmüller	1988	*Phonetica*
Effort	Acoustic Effects of Variation in Vocal Effort by Men, Women, and Children	Traunmüller & Eriksson	2000	*The Journal of the Acoustical Society of America*
Effort	Using the Borg CR10 Physical Exertion Scale to Measure Patient-perceived Vocal Effort Pre and Post Treatment	van Leer & van Mersbergen	2017	*Journal of Voice*
Effort	Functional Dysphonia During Mental Imagery: Testing the Trait Theory of Voice Disorders	van Mersbergen et al.	2008	*Journal of Speech, Language, and Hearing Research*

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Characteristics of the Included Publications

Topic	Title	Authors	Year	Journal
Fatigue	The Effectiveness of Low-Level Light Therapy in Attenuating Vocal Fatigue	Kagan & Heaton	2017	*Journal of Voice*
Fatigue	Sensory Symptoms in Patients Undergoing Thyroidectomy	Fernandes de Araújo et al.	2017	*CoDAS*
Fatigue	Some Vocal Consequences of Sleep Deprivation and the Possibility of "Fatigue Proofing" the Voice With Voice Craft Voice Training	Bagnall et al.	2011	*Journal of Voice*
Fatigue	Hoarseness of Voice: Clinicopathological Profile of 100 Cases	Bajwa & Jalil	2012	*Pakistan Journal of Medical and Health Sciences*
Fatigue	Voice Rehabilitation for Laryngeal Cancer Patients: Functional Outcomes and Patient Perceptions	Bergström et al.	2016	*The Laryngoscope*
Fatigue	Cricothyroid Joint Abnormalities in Patients With Rheumatoid Arthritis	Berjawi et al.	2010	*Journal of Voice*
Fatigue	Teachers' Voicing and Silence Periods During Continuous Speech in Classrooms With Different Reverberation Times	Bottalico et al.	2017	*The Journal of the Acoustical Society of America*
Fatigue	Effects of Voice Style, Noise Level, and Acoustic Feedback on Objective and Subjective Voice Evaluations	Bottalico et al.	2015	*The Journal of the Acoustical Society of America*
Fatigue	Effects of Speech Style, Room Acoustics, and Vocal Fatigue on Vocal Effort	Bottalico et al.	2016	*The Journal of the Acoustical Society of America*
Fatigue	Acoustic Correlates of Fatigue in Laryngeal Muscles: Findings for a Criterion-Based Prevention of Acquired Voice Pathologies	Boucher	2008	*Journal of Speech, Language, and Hearing Research*
Fatigue	Physiologic Features of Vocal Fatigue: Electromyographic Spectral-Compression in Laryngeal Muscles	Boucher et al.	2006	*The Laryngoscope*
Fatigue	Physiological Attributes of Vocal Fatigue and Their Acoustic Effects: A Synthesis of Findings for a Criterion-Based Prevention of Prevention of Acquired Voice Disorders	Boucher and Ayad	2010	*Journal of Voice*
Fatigue	Glottal Function Self-Perception and Auditory–Perceptual Analysis of Municipal School Teachers	Santos Carregosa et al.	2016	*Revista CEFAC*
Fatigue	Objective Measurement of Vocal Fatigue in Classical Singers: A Vocal Dosimetry Pilot Study	Carroll et al.	2006	*Otolaryngology—Head & Neck Surgery*
Fatigue	Voice Disorder in Systemic Lupus Erythematosus	de Macedo et al.	2017	*PLOS ONE*
Fatigue	Relationship Between Voice Complaints and Subjective and Objective Measures of Vocal Function in Iranian Female Teachers	Faham et al.	2017	*Journal of Voice*
Fatigue	The Effect of Head Position and/or Stance on the Self-Perception of Phonatory Effort	Gilman & Johns	2017	*Journal of Voice*
Fatigue	Acoustic Changes of the Voice as Signs of Vocal Fatigue in Radio Broadcasters: Preliminary Findings	Guzmán et al.	2013	*Acta Otorrinolaringológica Española*
Fatigue	Effect of Pregnancy on the Speaking Voice	Hamdan et al.	2009	*Journal of Voice*
Fatigue	Effect of Weight Loss on Voice After Bariatric Surgery	Hamdan et al.	2014	*Journal of Voice*
Fatigue	A Randomized Controlled Trial of Two Semi-Occluded Vocal Tract Voice Therapy Protocols	Kapsner-Smith et al.	2015	*Journal of Speech, Language, and Hearing Research*
Fatigue	The Perceptual Features of Vocal Fatigue as Self-Reported by a Group of Actors and Singers	Kitch & Oates	1994	*Journal of Voice*

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Characteristics of the Included Publications

Topic	Title	Authors	Year	Journal
Fatigue	Electroglottogram-Based Estimation of Vocal Economy: 'Quasi-Output-Cost Ratio'	Laukkanen et al.	2009	*Folia Phoniatrica et Logopaedica*
Fatigue	Occupational Voice Complaints and Objective Acoustic Measurements—Do They Correlate?	Lehto et al.	2006	*Logopedics Phoniatrics Vocology*
Fatigue	Assessment of Vocal Capacity of Finnish University Students	Leino et al.	2008	*Folia Phoniatrica et Logopaedica*
Fatigue	A Comparison of the Effects of Voice Massage™ and Voice Hygiene Lecture on Self-Reported Vocal Well-Being and Acoustic and Perceptual Speech Parameters in Female Teachers	Leppänen et al.	2009	*Folia Phoniatrica et Logopaedica*
Fatigue	Reducing the Negative Vocal Effects of Superficial Laryngeal Dehydration With Humidification	Levendoski et al.	2014	*Annals of Otology, Rhinology & Laryngology*
Fatigue	The Prevalence and Impact of Voice Problems in Primary School Teachers	Munier & Kinsella	2008	*Occupational Medicine*
Fatigue	Vocal Fatigue Index (VFI): Development and Validation	Nanjundeswaran et al.	2015	*Journal of Voice*
Fatigue	Metabolic Mechanisms of Vocal Fatigue	Nanjundeswaran et al.	2017	*Journal of Voice*
Fatigue	Does Postthyroidectomy Syndrome Really Exist Following Thyroidectomy? Prospective Comparative Analysis of Open vs. Endoscopic Thyroidectomy	Park et al.	2015	*Clinical and Experimental Otorhinolaryngology*
Fatigue	Phonatory Function After Prolonged Voice Use in Brazilian Woman	Pellicani et al.	2015	*CoDAS*
Fatigue	Effect of the Tracheoesophageal Voice Resistance Test in Total Laryngectomees	Pellicani et al.	2017	*The Laryngoscope*
Fatigue	Relationship Between Vocal Symptoms in College Students and Their Possible Causes	Ferreira et al.	2012	*International Archives of Otorhinolaryngology*
Fatigue	Comparison of Effects Produced by Physiological Versus Traditional Vocal Warm-up in Contemporary Commercial Music Singers	Portillo et al.	2018	*Journal of Voice*
Fatigue	Work-Related Voice Disorder	Przysiezny & Przysiezny	2015	*Brazilian Journal of Otorhinolaryngology*
Fatigue	Vocal Impact of a Prolonged Reading Task at Two Intensity Levels: Objective Measurements and Subjective Self-Ratings	Remacle et al.	2012	*Journal of Voice*
Fatigue	Vocal Change Patterns During a Teaching Day: Inter- and Intra-Subject Variability	Remacle et al.	2018	*Journal of Voice*
Fatigue	Effects of Sound-Field Frequency Modulation Amplification on Reducing Teachers' Sound Pressure Level in the Classroom	Sapienza et al.	1999	*Journal of Voice*
Fatigue	Conhecimento Vocal e a Importância da voz Como Recurso Pedagógico na Perspectiva de Professores Universitários	Merlin Servilha & da Costa	2015	*Revista CEFAC*
Fatigue	Effects of Vocal Fatigue on Voice Parameters of Indian Teachers	Sivasankar	2002	*Indian Journal of Otolaryngology and Head & Neck Surgery*
Fatigue	Vocal Fatigue and Its Relation to Vocal Hyperfunction Dagger	Solomon	2008	*International Journal of Speech-Language Pathology*
Fatigue	Perceived Vocal Fatigue and Effort in Relation to Laryngeal Functional Measures in Paresis Patients	Stager & Bielamowicz	2014	*The Laryngoscope*
Fatigue	Arytenoid Subluxation After a Difficult Intubation Treated Successfully With Voice Therapy	Tan & Seevanayagam	2009	*Anaesthesia and Intensive Care*

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Characteristics of the Included Publications

Topic	Title	Authors	Year	Journal
Fatigue	Vocal Hyperfunction in Parents of Children with Attention Deficit Hyperactivity Disorder	García-Real & Díaz-Román	2016	*Journal of Voice*
Fatigue	Vocal Hygiene in Radio Students and in Radio Professionals	Timmermans et al.	2003	*Logopedics Phoniatrics Vocology*
Fatigue	Voicing and Silence Periods in Daily and Weekly Vocalizations of Teachers	Titze et al.	2007	*The Journal of the Acoustical Society of America*
Fatigue	Phonatory Symptoms and Acoustic Findings in Patients With Asthma: A Cross-Sectional Controlled Study	Hamdan et al.	2017	*Indian Journal of Otolaryngology and Head & Neck Surgery*
Fatigue	Sintomas Vocais Auditivos e Proprioceptivos pré e Pós-terapia de Grupo de Pacientes com Disfonia	Medeiros Costa Vital et al.	2016	*Revista CEFAC*
Fatigue	Vocal Fatigue: Current Knowledge and Future Directions	Welham & Maclagan	2003	*Journal of Voice*
Fatigue	Treatment Outcomes for Professional Voice Users	Wingate et al.	2007	*Journal of Voice*
Fatigue	Effect of Hydration and Vocal Rest on the Vocal Fatigue in Amateur Karaoke Singers	Yiu & Chan	2003	*Journal of Voice*
Fatigue	Quantitative High-Speed Laryngoscopic Analysis of Vocal Fold Vibration in Fatigued Voice of Young Karaoke Singers	Yiu et al.	2013	*Journal of Voice*
Fatigue	Cross-Cultural Adaptation of the Brazilian Version of the Vocal Fatigue Index - VFI	Zambon et al.	2017	*CoDAS*
Fatigue	Effects of a Vocally Fatiguing Task and Systemic Hydration on Men's Voices	Solomon et al.	2003	*Journal of Voice*
Loading	Voice Quality Assessment Before and After Social and Professional Voice Use	Aragão et al.	2014	*Audiology Communication Research*
Loading	Change in Voice During a Day in Normal Voices Without Vocal Loading	Artkoski et al.	2002	*Logopedics Phoniatrics Vocology*
Loading	Variability of Normal Vocal Fold Dynamics for Different Vocal Loading in One Healthy Subject Investigated by Phonovibrograms	Doellinger et al.	2009	Journal of Voice
Loading	Investigating the Effects of Caffeine on Phonation	Erickson-Levendoski & Sivasankar	2011	*Journal of Voice*
Loading	A Review of Vocal Loading Tasks in the Voice Literature	Fujiki & Sivasankar	2017	*Journal of Voice*
Loading	Exploring the Effect of Laryngeal Neuromuscular Electrical Stimulation on Voice	Gorham-Rowan & Morris	2016	*The Journal of Laryngology & Otology*
Loading	Prevalence and Risk Factors for Voice Problems in Priests	Hočevar-Boltežar	2009	*Wiener Klinische Wochenschrift*
Loading	Is an Occupation With Vocal Load a Risk Factor for Laryngopharyngeal Reflux: A Prospective, Multicentre, Multivariate Comparative Study	Hočevar-Boltežar et al.	2012	*Clinical Otolaryngology*
Loading	Quantifying Vocal Fatigue Recovery: Dynamic Vocal Recovery Trajectories After a Vocal Loading Exercise	Hunter & Titze	2009	*Annals of Otology, Rhinology & Laryngology*
Loading	Voice Quality in Native and Foreign Languages Investigated by Inverse Filtering and Perceptual Analyses	Järvinen et al.	2017	*Journal of Voice*
Loading	Effects of Sound Amplification on Teachers' Speech While Teaching	Jónsdottir et al.	2001	*Logopedics Phoniatrics Vocology*
Loading	Changes in Teachers' Speech During a Working Day With and Without Electric Sound Amplification	Jónsdottir et al.	2003	*Folia Phoniatrica et Logopaedica*

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Characteristics of the Included Publications

Topic	Title	Authors	Year	Journal
Loading	Effects of Prolonged Loud Reading on Normal Adolescent Male Voices	Kelchner et al.	2006	*Language, Speech, and Hearing Services in Schools*
Loading	Benefits of the Fiber Optic Versus the Electret Microphone in Voice Amplification	Kyriakou & Fisher	2013	*International Journal of Language & Communication Disorders*
Loading	Mean F0 Values Obtained Through Standard Phrase Pronunciation Compared With Values Obtained From the Normal Work Environment: A Study on Teacher and Child Voices Performed in a Preschool Environment	Lindstorm et al.	2010	*Journal of Voice*
Loading	Voice Disorders in Primary School Teachers	Lira Luce et al.	2014	*Acta Otorhinolaryngologica Italica*
Loading	Sound Level Variation Findings for Pianissimo and Fortissimo Phonations in Repeated Measurements	Sihvo & Sala	1996	*Journal of Voice*
Loading	Vocal Dose Measures: Quantifying Accumulated Vibration Exposure in Vocal Fold Tissues	Titze et al.	2003	*Journal of Speech, Language, and Hearing Research*
Loading	Voice Problems at Work: A Challenge for Occupational Safety and Health Arrangement	Vilkman	2000	*Folia Phoniatrica et Logopaedica*
Loading	Occupational Safety and Health Aspects of Voice and Speech Professions	Vilkman	2004	*Folia Phoniatrica et Logopaedica*
Loading	Effects of Prolonged Oral Reading on F0, SPL, Subglottal Pressure and Amplitude Characteristics of Glottal Flow Waveforms	Vilkman et al.	1999	*Journal of Voice*
Loading	The Effects of Post-Loading Rest on Acoustic Parameters With Special Reference to Gender and Ergonomic Factors	Vintturi et al.	2001a	*Folia Phoniatrica et Logopaedica*
Loading	Objective Analysis of Vocal Warm-Up With Special Reference to Ergonomic Factors	Vintturi et al.	2001b	*Journal of Voice*
Loading	Loading-Related Subjective Symptoms During a Vocal Loading Test With Special Reference to Gender and Some Ergonomic Factors	Vintturi et al.	2003	*Folia Phoniatrica et Logopaedica*
Loading	Long-Time Voice Accumulation During Work, Leisure, and a Vocal Loading Task in Groups With Different Levels of Functional Voice Problems	Whitling et al.	2017a	*Journal of Voice*
Loading	Recovery From Heavy Vocal Loading in Women With Different Degrees of Functional Voice Problems	Whitling et al.	2017b	*Journal of Voice*
Loading	Design of a Clinical Vocal Loading Test With Long-Time Measurement of Voice	Whitling et al.	2015	*Journal of Voice*
Loading	Cancellation of Simulated Environmental Noise as a Tool for Measuring Vocal Performance During Noise Exposure	Ternström et al.	2002	*Journal of Voice*

Appendix B

Occurrence of Key Words Included in Definitions of Vocal Fatigue, Vocal Effort, Vocal Load, and Vocal Loading

Key words	Vocal effort	Vocal load(ing)	Vocal fatigue
Vocal symptom/deficit			34
Prolonged voicing time	4	14	27
Increased effort			19
Vocal loading		28	11
Tiring of voice			11
Neck strap muscle involvement (throat or cervical muscle tension)	3	2	9
Laryngeal/vocal discomfort			9
Physiological condition			9
Improvement after vocal rest			7
Reduced pitch range and flexibility			7
Reduced control of voice quality			6
Changes in intensity			4
Weak voice			4
Increased risk for voice disorders			3
Negative vocal adaptation			3
Vocal loudness change	23	11	
Raise in F0	11		
Distance to the interlocutor	9		
Strain in voicing	6	6	
Increase sound level (loudness)	6	4	
Related with background noise	5	6	
Increase first format frequency	5		
Increase subglottal (tracheal) pressure	5		
Perceived effort during phonation	2	5	
Mood induction	2	2	
Pitch changes		14	
Professional related		10	
Poor room acoustics		9	
Lack/increase of vibration		7	
Vocal fatigue		7	
Aerodynamics		6	
Air quality		6	
More common in women		6	
Noise		6	
Self-assessed		6	
Vocal demand		6	
Acoustic analysis		5	
Voice quality affected		5	
Disorder		4	
Singing/theater		4	
Stroboscopy		4	
Dysphonia		3	
Hoarseness		3	
Inflammation		3	
Nodules		3	
Nonhabitual voice use		3	