

The Vocal Score Profile in Verdi's Characters

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Summary: Objectives. Selecting the appropriate repertoire for an opera singer may be crucial for both the prevention of voice disorders and the career progression. Here, we reviewed the score of 14 Verdi's operas to gain the data for the creation of the vocal score profile of each role.

Materials and Methods. Seven musicians were involved in the analysis process. Notes were counted and reported as absolute and relative frequency. Pitch measurements included pitch range, percentage of high-pitched notes, percentage of medium-pitched notes, percentage of low-pitched notes, high-pitched and low-pitched notes rate, percentage of the notes in the *passaggio*, identification of the prevalent octave, percentage of notes in the prevalent octave, and percentage of notes in a moderate range tessitura. The total phonation time was calculated for each character.

Results. A heterogeneity among pitch and duration measurement was found among roles within the same voice type, leading to highly different vocal efforts required by the performer.

Conclusions. Data on 67 Verdi characters were gained, and the vocal demand of each role was discussed. Potentially, these results may support singers, singing teachers, and vocal coaches in the selection of the repertoire. The data may also assist clinicians in the conduction of counseling and during eventual voice therapy. Future studies must investigate the predictive value of the vocal score profile in appraising the risk of vocal injury.

Key Words: Vocal score profile—Verdi—Opera—Singing—Laryngology.

INTRODUCTION

Voice disorders have been reported with a prevalence ranging from 28.65% to 53% in classical singers,¹ and phonotraumatic lesions are the most common etiology.² Selecting the appropriate repertoire for an opera singer may be crucial for both the success of the performance, the career progression, and the prevention of voice disorders. The story of some eminent opera singers are examples of vocal or careers' decline because of inadequate repertoire selection.^{3,4} Beside consideration of age, gender, personality, preferences, and technical and expressive skills, during last decades several tools have been developed in the field of laryngology to assist singers, singing teachers, and vocal coaches in this choice.

First, the vocal range profile (VRP) or phonetogram, a two-dimensional display of the range of a voice in frequency and in amplitude, was proposed in 1953 by Calvet.⁵ It provides an objective measure of the opera singer voices as a complementary tool to the singing teacher's hearing.^{6,7} In contrast, although voice could be adequately classified, singers may be exposed to the risk of phonotrauma as the role assigned may not suit the performer's vocal characteristics.

Therefore, in 1988, Stefan Thurmer introduced the concept of "tessiturogram."⁸

The tessiturogram is a histogram portraying the frequency of note occurrence within each composition or piece. In other words, it is the equivalent of VRP by the scoring perspective and may be suggestive of the vocal demand of a specific role. Afterward, Titze developed Thurmer's tessiturogram by adding measurements of the duration and the frequency in hertz of each sung pitch.⁹ Further improvements were proposed by Fussi et al who associated several indices of vocal demands to the tessiturogram, that they renamed "vocal score profile" (VSP).¹⁰ Moreover, the same authors proposed to assess vocal economy of a role comparing the VRP of the opera singer with the VSP of the score. Nix analyzed a Mozart composition through Titze's tessiturogram and combined the data with the VRP of a singer and the dosimetry derived from the performance of the same song.¹¹ The author highlighted several limits of the tessiturogram, such as the inaccuracy in estimating the short-term recovery and the inability to address the kind of singing. However, he found a sufficient correspondence between the estimated and the actual values for voicing time dose and cycle dose and concluded that the combination of the three tools may represent a helpful battery to guide repertoire selection. Nevertheless, performing the tessiturogram is highly time-consuming and therefore represents a barrier to its systematic use in daily practice as, nowadays, no automatic extraction process from digital files of musical scores is still available.¹²

Among the opera composers, Giuseppe Verdi's operas have been the most performed over the five seasons, 2011/2012 to 2015/2016, with 3728 productions and 16,265 performances all over the world.¹³ Despite the size of these numbers, no data are yet available to allow singers, teachers, and laryngologists to create VSP of Verdi's roles. Therefore, our study aimed to analyze the scores of 67 characters from 14 Verdi's operas to extract objective information for

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the creation of the VSP of these roles. Knowledge of the magnitude of vocal demand, concerning pitch and duration, required by most performed Verdi's roles is the focus of the study. Singers, singing teachers, and vocal coaches may benefit from the availability of these data in the selection of the repertoire. Moreover, these results may potentially be of clinical utility for phoniatrists, otorhinolaryngologists, and speech and language therapists when conducting periodic evaluations of the singers' voice for the prevention of the onset of laryngeal abnormalities, and, when a voice disorder already occurs, for appraising the role of the repertoire on its development, as well as for the conduction of voice therapy.

MATERIALS AND METHODS

The scores of 14 Verdi's opera were analyzed: 3 operas of the early period (until 1849: *Nabucodonosor*, *Ernani*, and *Macbeth*), 4 operas of the middle period (1850–1857: *Rigoletto*, *Il Trovatore*, *La Traviata*, *Les Vêpres Siciliennes*, and *Simon Boccanegra*), 5 operas of the late period (1859–1871: *Un Ballo in Maschera*, *La Forza del Destino*, *Don Carlos*, and *Aida*), 2 final works (from 1874: *Otello* and *Falstaff*), according to Julian Budden's classification.¹⁴ Overall, 67 roles were examined: 16 soprano roles, 8 mezzo-soprano and contralto roles, 15 tenor roles, 17 baritone roles, 11 bass roles. Seven musicians, pianists or singers, and conservatory graduates were involved in the analysis process after a training session on measurement procedure. Pitch and duration indices were measured for each character's scores, based on the VSP as proposed by Gilardone and Fussi in 1998.¹³

For notes' counting, each note was considered as a unit regardless of its duration. Concerning the grace notes, the *acciaccatura* and the *appoggiatura* were considered as a unit, whereas notes in the trills were not considered. For each character, the frequency of every note in the score was, therefore, computed. Notes were designated according to the International Pitch Notation system.¹⁵

Pitch measurements included pitch range (PR), percentage of high-pitched notes (%Hp), percentage of medium-pitched notes (%Mp), percentage of low-pitched notes (%Lp), high-pitched and low-pitched notes rate, percentage of the notes in the *passaggio*, identification of the prevalent octave (PO), percentage of notes in the PO, and percentage of notes in a moderate range tessitura.

The PR represents the vocal range extension required for a certain character and corresponds to the distance between the highest pitched note and the lowest pitched notes of the score.

The %Hp, %Mp, and %Lp were calculated considering high-pitched notes, those included between the *secondo passaggio* (included) and the highest pitched note, medium-pitched notes, those included between the *primo* and the *secondo passaggio* (excluded), and low-pitched notes, those included between the lowest pitched note and the *primo passaggio* (included). The specific note of the *secondo* and *primo passaggio* varies among singers within the same voice type. However, to allow a generalization of the results, a certain degree of approximation is required. Five different essays defining register's limits were consulted.^{13,16–19} Different register's limits were reported among the five essays; hence, average notes were derived for each voice type (Table 1). The three indices %Hp, %Mp, and %Lp provide information on the vocal effort required by the score, as it is increased when the performer sing in the upper or lower register. Indeed, although medium-pitched notes are the results of a steady contraction of intrinsic laryngeal muscles, the contraction of the thyroarytenoid muscle is prevalent in the production of low-pitched, whereas a higher activity of the cricothyroid muscle is observed in the high-pitched notes. Moreover, the high-pitched and low-pitched notes rate (Hp/Lp) was calculated to highlight a potential imbalance between vocal registers. The closer the Hp/Lp to 0, the more prevalent the notes of the lower register; the greater than 1, the more prevalent the notes of the upper register.

The percentage of notes in the *passaggio* (%P) was calculated. *Passaggio* notes require delicate changes of laryngeal and resonant behavior: in the *secondo passaggio*, the performer must balance the need of lengthening the vocal folds with the action of the thyroarytenoid muscle to keep a complete glottal contact and the vibration of the whole vocal fold. Therefore, %P is another index of vocal effort.

The octave (eight consecutive notes) containing the higher number of notes was identified as the PO, and the percentage of notes belonging to the PO (%PO) was measured. Furthermore, the percentage of notes at a moderate range tessitura (%Mt) was recorded counting the number of notes belonging to the PO and subtracting those of the upper and the lower register. Interesting considerations can arise from

TABLE 1.
Register Distribution in Different Voice Types

	Soprano		Tenor		Mezzo-soprano		Baritone		Contralto		Bass	
	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit
Upper register	Hpn	<i>F4–5</i>	Hpn	<i>F#4–5</i>	Hpn	<i>Eb4–5</i>	Hpn	<i>E4–5</i>	Hpn	<i>C#4–5</i>	Hpn	<i>D4–5</i>
Medium register	<i>E4–5</i>	<i>A3–4</i>	<i>E4–5</i>	<i>A3–4</i>	<i>D4–5</i>	<i>G3–4</i>	<i>A4–5</i>	<i>G3–4</i>	<i>C4–5</i>	<i>F3–4</i>	<i>C4–5</i>	<i>F3–4</i>
Lower register	<i>G3–4</i>	Lpn	<i>G#3–4</i>	Lpn	<i>F3–4</i>	Lpn	<i>F#3–4</i>	Lpn	<i>Eb3–4</i>	Lpn	<i>E3–4</i>	Lpn

Notes: *Primo* and *secondo passaggio* are in italics.

Abbreviations: Hpn, highest pitched note; Lpn, lowest pitched note.

TABLE 2.
Average Metronome Markings and Quarter Note's Duration for Each Tempo or Mood Indication

	Metronome Marking for the Quarter Note	Quarter Note's Duration (s)
Largo	50	1.20
Larghetto	63	0.95
Adagio	71	0.84
Adagietto	74	0.81
Andante	90	0.66
Andantino	97	0.61
Moderato	112	0.53
Allegro	144	0.41
Allegretto	156	0.38
Presto	184	0.32
Prestissimo	204	0.29
Recitativo secco	108	0.55

the comparison between the %Mt and the %PO to measure the vocal comfort of a role.

For the duration analysis, using the metronome marking for the quarter note specified by the composer, the time duration of each rhythmic value indicated in the score was converted into seconds, and the results were afterward summed up. Whether the metronome markings were not indicated, the average time duration of the quarter note for each tempo or mood indication was used as reported in Table 2. The total phonation time (TPT) was calculated for each character.

Data analysis

The number of notes for each character is reported as absolute and relative frequency. The results of notes' counting have also been organized in histograms, reporting notes'

pitch on the horizontal axis and absolute or relative frequency on the vertical axis, as a way to represent and compare pitch distribution of different roles. Characters have been divided into five voice types (bass, baritone, tenor, mezzo-soprano and contralto, soprano), and pitch and duration results have been organized in a single table for each voice type to allow an immediate comparison between the different roles.

RESULTS

Pitch and duration measurements for each character are reported in Table 3–7 on the basis of the voice type. Roles are organized in chronological order.

The PR varied from C#6 to F#3 for sopranos, from C6 to G3 for mezzo-sopranos and contraltos, from D5 to Bb2 for tenors, from B4 to F2 for baritones, and from F#4 to E2 for bass roles. High variability was found for the %Hp and %Lp within each voice category. Concerning sopranos, the %Hp ranges from 9% of Alice and Nanetta to 26% of Elvira, the %Lp ranges from 13% of Oscar to 33% of Desdemona; Hp notes are prevalent over Lp notes in 4 of 16 soprano roles. The %Hp reaches its higher level within the category of mezzo-soprano and contralto with 20% of Preziosilla, whereas it represents only 1% of the notes in Madalena. The roles of Fenena, Azucena, and Preziosilla show a balance between Hp and Lp, whereas the latter is prevalent for the other roles of the category, with the peak of 47% of Lp notes and an Hp/Lp of 0.07 for Quickly. Regarding male voices, %Hp varies from 15% to 35% for tenors, from 2% to 11% for baritones, and from 5% to 14% for basses, whereas %Lp varies from 8% to 18%, from 9% to 35%, and from 16% to 32%, respectively. Two tenor roles have an Hp/Lp value lower than 1, whereas Hp/Lp value was higher than 2 for 5 of 15 roles. The Hp/Lp ratio was lower than 1 for all but 1 of 17 baritone and 1 of 11 bass roles.

TABLE 3.
Pitch and Duration Measurements for Soprano Roles

Role	Opera	PR	%Hp	%Mp	%Lp	Hp/Lp	%P	PO	%PO	%Mt	TPT
<i>Abigaille</i>	<i>Nabucodonosor</i>	B3–C6	20.85	56.75	22.40	1.07	11.27	G4–5	81.16	65.33	20'32"
<i>Elvira</i>	<i>Ernani</i>	G#3–C6	25.96	57.38	16.66	1.55	13.09	G4–5	83.27	63.86	24'12"
<i>Lady Macbeth</i>	<i>Macbeth</i>	Bb3–C#6	20.68	52.71	26.61	0.77	11.13	F4–5	81.39	74.41	25'34"
<i>Gilda</i>	<i>Rigoletto</i>	Bb3–C#6	21.62	63.87	14.05	1.49	10.99	G#4–5	86.10	68.31	21'46"
<i>Leonora</i>	<i>Il Trovatore</i>	G#3–C#6	17.71	57.31	24.98	0.70	10.09	G4–5	84.08	70.08	28'53"
<i>Violetta</i>	<i>La Traviata</i>	B3–C#6	16.31	65.83	17.86	0.91	8.55	G4–5	89.01	76.89	38'51"
<i>Elena</i>	<i>Les Vêpres Siciliennes</i>	F#3–C#6	16.35	55.33	28.32	0.57	8.02	F4–5	77.83	73.07	38'11"
<i>Maria</i>	<i>Simon Boccanegra</i>	Bb3–C6	16.14	61.62	22.24	0.72	9.17	F#4–5	84.71	75.54	16'56"
<i>Amelia</i>	<i>Un Ballo in Maschera</i>	A3–C6	18.17	55.24	26.59	0.68	9.10	F4–5	81.00	74.40	22'07"
<i>Oscar</i>	<i>Un Ballo in Maschera</i>	C4–C6	22.29	64.63	13.09	1.70	12.37	G4–5	88.44	71.39	16'21"
<i>Donna Leonora</i>	<i>La Forza del Destino</i>	Bb3–B5	11.26	61.62	27.12	0.41	6.59	E4–5	84.18	84.18	21'10"
<i>Elisabetta</i>	<i>Don Carlos</i>	Bb3–B5	13.02	57.24	29.74	0.43	7.98	F4–5	85.02	80.14	24'50"
<i>Aida</i>	<i>Aida</i>	B3–C6	15.61	57.18	27.21	0.57	7.82	F4–5	79.63	75.24	21'20"
<i>Desdemona</i>	<i>Otello</i>	Bb3–B5	11.81	55.16	33.03	0.35	7.67	F4–5	80.32	75.20	16'12"
<i>Alice</i>	<i>Falstaff</i>	Bb3–C6	9.05	63.14	27.81	0.32	5.64	F4–5	68.40	62.07	20'45"
<i>Nanetta</i>	<i>Falstaff</i>	Bb3–C6	9.05	67.91	23.04	0.39	4.41	F#4–5	88.88	84.47	12'34"

TABLE 4.
Pitch and Duration Measurements for Mezzo-soprano and Contralto Roles

Role	Opera	PR	%Hp	%Mp	%Lp	Hp/Lp	%P	PO	%PO	%Mt	TPT
<i>Fenena</i>	<i>Nabucodonosor</i>	B3–A5	16.18	64.31	19.61	0.82	12.21	E4–5	89.87	75.15	7'53"
<i>Maddalena</i>	<i>Rigoletto</i>	B3–F#5	1.05	73.52	25.43	0.04	10.54	D4–5	94.72	73.51	6'43"
<i>Azucena</i>	<i>Il Trovatore</i>	A3–C6	14.26	66.69	19.05	0.74	7.86	E4–5	87.94	75.28	18'23"
<i>Ulrica</i>	<i>Un Ballo in Maschera</i>	G3–G#5	9.05	53.66	37.29	0.24	16.83	E4–5	83.80	59.63	9'14"
<i>Preziosilla</i>	<i>La Forza del Destino</i>	A3–C6	19.58	60.24	20.18	0.96	9.02	E4–5	87.56	72.98	12'50"
<i>Eboli</i>	<i>Don Carlos</i>	Bb3–B5	14.05	54.03	31.92	0.44	16.59	E4–5	85.60	61.72	18'34"
<i>Amneris</i>	<i>Aida</i>	Bb3–B5	13.36	54.85	31.79	0.42	12.69	Eb4–5	82.17	58.59	21'24"
<i>Quickly</i>	<i>Falstaff</i>	G3–G5	3.71	49.08	47.21	0.07	12.13	C4–5	85.74	43.40	15'12"

TABLE 5.
Pitch and Duration Measurements for Tenor Roles

Role	Opera	PR	%Hp	%Mp	%Lp	Hp/Lp	%P	PO	%PO	%Mt	TPT
<i>Ismaele</i>	<i>Nabucodonosor</i>	B2–Bb4	28.00	62.98	9.04	3.10	19.29	A3–4	90.88	62.97	9'54"
<i>Ernani</i>	<i>Ernani</i>	Bb2–Bb4	22.72	66.24	10.04	2.36	13.68	G3–4	92.24	71.57	25'51"
<i>Macduff</i>	<i>Macbeth</i>	B2–Bb4	34.25	51.73	14.02	2.44	23.04	G#3–4	90.16	57.29	10'02"
<i>Duca di Mantova</i>	<i>Rigoletto</i>	C3–B4	24.22	64.74	11.04	2.19	15.18	G#3–4	92.82	69.94	22'23"
<i>Manrico</i>	<i>Il Trovatore</i>	C#3–Bb4	23.15	68.40	8.50	2.71	13.65	G3–4	95.49	75.81	22'55"
<i>Alfredo</i>	<i>La Traviata</i>	Eb3–Bb4	19.92	69.85	10.23	1.94	11.69	G3–4	93.75	77.27	23'12"
<i>Arrigo</i>	<i>Les Vêpres Siciliennes</i>	C3–D5	23.10	65.37	11.53	2.00	14.26	G#3–4	90.94	70.21	38'34"
<i>Gabriele</i>	<i>Simon Boccanegra</i>	C3–Bb4	20.02	67.10	12.88	1.55	11.70	G#3–4	89.71	71.62	14'32"
<i>Riccardo</i>	<i>Un Ballo in Maschera</i>	Bb2–Bb4	18.30	64.90	16.80	1.08	11.11	G3–4	89.19	74.40	27'15"
<i>Don Alvaro</i>	<i>La Forza del Destino</i>	Bb2–Bb4	17.98	65.42	16.60	1.08	10.24	G3–4	88.77	74.75	20'43"
<i>Don Carlo</i>	<i>Don Carlos</i>	C3–B4	15.86	65.90	18.24	0.86	9.04	G3–4	90.69	78.53	29'45"
<i>Radames</i>	<i>Aida</i>	Bb2–Bb4	19.93	65.52	14.55	1.37	11.30	G3–4	87.35	71.79	19'51"
<i>Cassio</i>	<i>Otello</i>	C3–B4	19.08	66.94	13.98	1.36	11.84	G3–4	88.38	74.17	6'41"
<i>Otello</i>	<i>Otello</i>	B2–C5	16.62	65.07	18.31	0.90	10.54	G3–4	89.97	76.66	23'58"
<i>Fenton</i>	<i>Falstaff</i>	C#3–B4	17.54	67.09	15.37	1.13	9.66	G3–4	91.05	78.08	8'54"

TABLE 6.
Pitch and Duration Measurements for Baritone Roles

Role	Opera	PR	%Hp	%Mp	%Lp	Hp/Lp	%P	PO	%PO	%Mt	TPT
<i>Nabucodonosor</i>	<i>Nabucodonosor</i>	B2–G4	8.17	81.27	10.56	0.77	6.86	F3–4	96.19	88.09	20'42"
<i>Carlo V</i>	<i>Ernani</i>	A2–G4	11.39	79.09	9.52	1.19	8.79	F3–4	95.26	86.50	21'12"
<i>Macbeth</i>	<i>Macbeth</i>	B2–G4	8.39	77.09	13.98	0.63	7.21	E3–4	94.57	87.35	22'57"
<i>Rigoletto</i>	<i>Rigoletto</i>	Bb2–G4	8.61	71.07	20.32	0.42	6.63	Eb3–4	93.14	88.10	27'18"
<i>Conte di Luna</i>	<i>Il Trovatore</i>	G#2–G4	9.11	72.25	18.64	0.48	6.03	Eb3–4	91.34	87.47	21'16"
<i>Germont</i>	<i>La Traviata</i>	Bb2–F#4	9.04	73.84	17.14	0.52	6.76	Eb3–4	94.32	88.10	15'31"
<i>Monforte</i>	<i>Les Vêpres Siciliennes</i>	G#2–G4	8.98	66.81	24.21	0.37	7.32	Eb3–4	91.55	87.33	23'12"
<i>Simon Boccanegra</i>	<i>Simon Boccanegra</i>	B2–F#4	6.65	77.97	15.38	0.43	5.42	E3–4	95.13	89.71	20'52"
<i>Paolo</i>	<i>Simon Boccanegra</i>	B2–F4	2.51	67.86	29.63	0.08	2.14	Eb3–4	92.92	90.95	8'38"
<i>Renato</i>	<i>Un ballo in Maschera</i>	A2–G4	7.74	67.07	25.19	0.30	5.49	Eb3–4	90.96	87.70	21'50"
<i>Don Carlo</i>	<i>La Forza del Destino</i>	Bb2–F#4	10.61	67.48	21.91	0.48	9.41	E3–4	94.07	84.66	14'39"
<i>Melitone</i>	<i>La Forza del Destino</i>	G2–G4	7.92	68.81	23.27	0.33	6.48	E3–4	91.00	89.52	13'22"
<i>Rodrigo</i>	<i>Don Carlos</i>	G#2–G4	6.44	70.48	23.08	0.27	4.79	Eb3–4	93.33	90.58	21'14"
<i>Amonasro</i>	<i>Aida</i>	A2–F#4	8.75	69.46	21.78	0.41	6.69	Eb3–4	90.57	85.67	7'56"
<i>Iago</i>	<i>Otello</i>	F#2–A4	4.71	65.65	29.64	0.15	3.42	D3–4	90.21	90.21	27'02"
<i>Falstaff</i>	<i>Falstaff</i>	G2–G4	5.41	62.67	31.92	0.16	4.21	D3–4	90.38	90.38	29'13"
<i>Ford</i>	<i>Falstaff</i>	F2–G4	7.31	57.58	35.11	0.20	6.10	D3–4	86.92	86.92	19'23"

TABLE 7.
Pitch and Duration Measurements for Bass Roles

Role	Opera	PR	%Hp	%Mp	%Lp	Hp/Lp	%P	PO	%PO	%Mt	TPT
<i>Zaccaria</i>	<i>Nabucodonosor</i>	F#2–F#4	15.00	68.69	16.31	0.92	11.97	D3–4	92.79	80.82	13'45"
<i>Silva</i>	<i>Ernani</i>	F2–F#4	8.38	68.22	23.40	0.35	5.06	C#3–4	86.61	83.39	21'16"
<i>Banco</i>	<i>Macbeth</i>	F2–E4	4.11	71.06	24.83	1.41	2.90	C3–4	92.00	92.00	6'21"
<i>Sparafucile</i>	<i>Rigoletto</i>	F2–F#4	14.20	57.68	28.12	0.50	12.05	D3–4	88.09	76.04	5'11"
<i>Ferrando</i>	<i>Il Trovatore</i>	G#2–F4	5.63	62.03	32.34	0.17	3.26	C3–4	88.84	88.84	12'20"
<i>Procida</i>	<i>Les Vêpres Siciliennes</i>	E2–F4	9.08	58.72	32.20	0.28	7.02	C#3–4	85.42	80.04	28'41"
<i>Fiesco</i>	<i>Simon Boccanegra</i>	F2–F#4	5.93	65.06	29.01	0.20	4.89	C3–4	92.00	92.00	9'45"
<i>Padre Guardiano</i>	<i>La Forza del Destino</i>	F2–F#4	6.13	54.67	39.20	0.15	4.08	C3–4	86.84	86.84	9'52"
<i>Filippo II</i>	<i>Don Carlos</i>	F2–F#4	8.82	63.18	23.00	0.39	7.13	C3–4	87.26	87.26	12'59"
<i>Inquisitore</i>	<i>Don Carlos</i>	E2–F4	13.55	61.87	24.58	0.55	11.65	D3–4	87.71	76.05	3'40"
<i>Ramfis</i>	<i>Aida</i>	F2–F4	7.87	62.39	29.74	0.26	5.06	C#3–4	87.80	84.45	10'22"

The %P was higher for tenors and mezzo-sopranos or contraltos than for other voice categories. Indeed, a %P higher than 10% was found for 13 of 15 tenor roles, for 6 of 8 mezzo-soprano and contralto roles, for 6 of 16 soprano roles, for 3 of 11 bass roles, and none of the baritone roles. Highest %PO values were found for baritones, whereas lowest values were detected for sopranos. The %Mt was higher than 80% for most of the baritone and bass roles, whereas it was lower than 80% for most of the soprano, mezzo-soprano or contralto, and tenor roles. On average, soprano roles have the longest duration with a mean TPT of 23'8" (range 12'34"–38'51"), followed by tenors (mean 20'18", range 6'41"–38'34"), baritones (mean 19'48", range 7'56"–29'13"), mezzo-sopranos and contraltos (mean 13'46", range 6'43"–21'24"), and bass roles (mean 12'11", range 3'40"–28'41").

Tables reporting the absolute and relative frequency of every note for each character are available as Supplementary material.

Figures 1 and 2 show examples on how the present data can be used to compare different characters' scores and to better understand the vocal effort required by those roles; three tenor roles are compared (Cassio, Otello, and Fenton). Using relative frequency enables one to compare the pitch distribution of the role apart from its duration, whereas the overall vocal demand is immediately visualized using absolute frequency.

DISCUSSION

This paper represents the first and preliminary report of the application of an objective method to gain numerical data for the generation of the VSP of Verdi's roles. Scores of 67 Verdi characters from 14 different operas were analyzed, and information on vocal demand for each role can be deduced from the results. Potentially, appraising vocal demand may be possible, combining information on overall

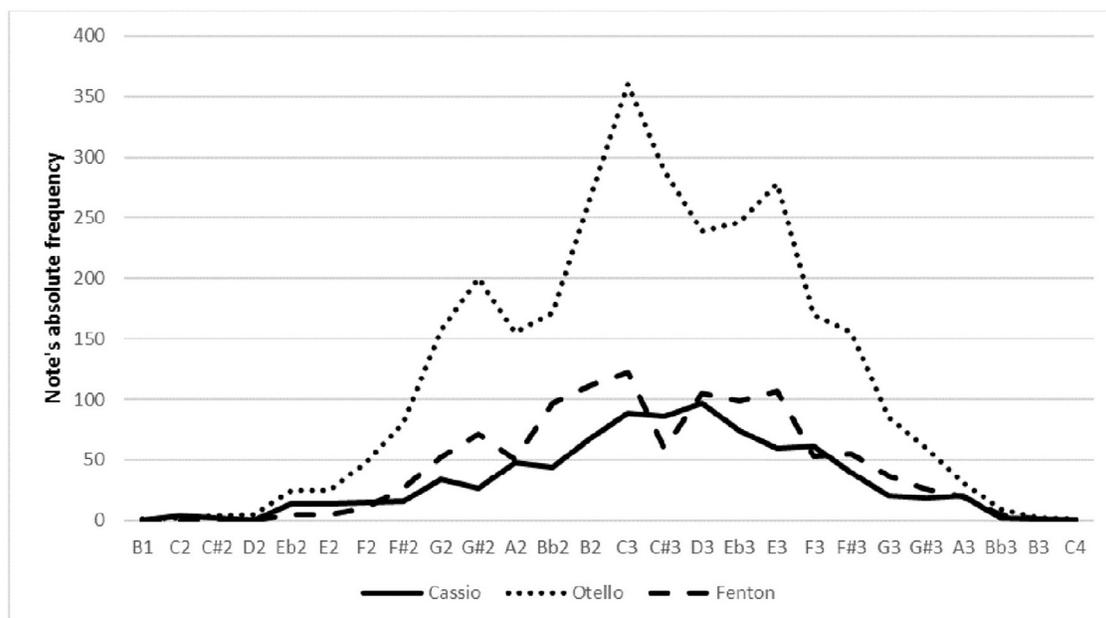


FIGURE 1. Pitch distribution in three tenor roles (absolute frequency).

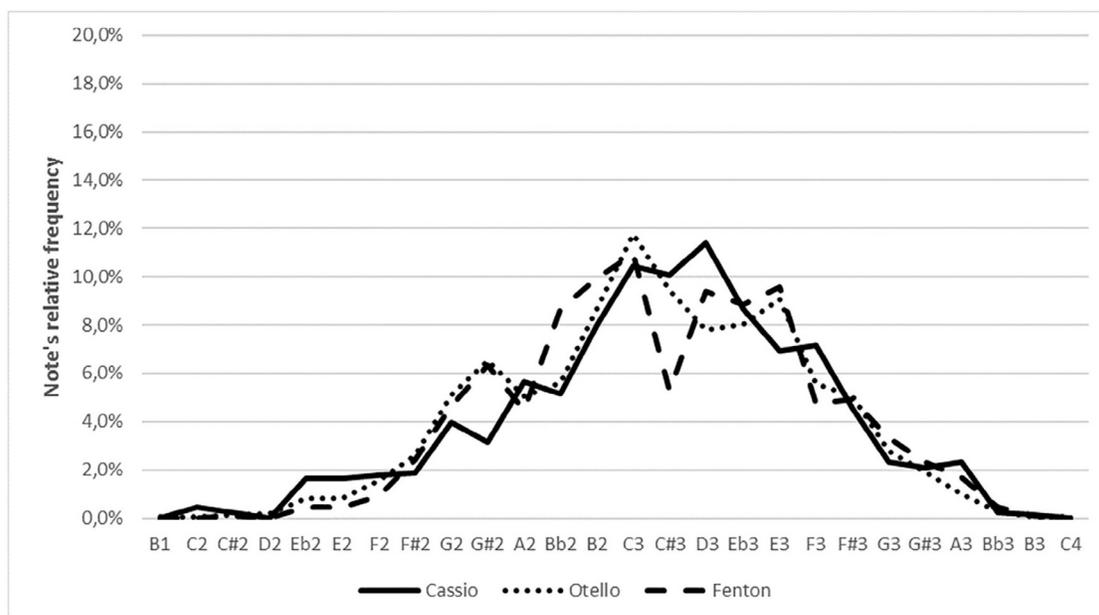


FIGURE 2. Pitch distribution in three tenor roles (relative frequency).

duration and technical difficulty of the role. Data on single pitch measurement should be interpreted together with all the other pitch variables. For instance, the value of %Hp should be weighed based on the higher limit of the PR, whereas the value of %PO should be compared with the value of %Mt to highlight the degree of their overlap. Moreover, the predominance of the action of the thyroarytenoid muscle or of the cricothyroid muscle is represented by the Hp/Lp ratio, but the effort required to each muscle varies depending on the %Mp notes.

Verdi's vocality evolved over the years, moving from the Italian tradition of the beginning of the 19th century to an innovative "conversational" singing. Within this evolution, sopranos gained a more deep vocality. Indeed, the low register became progressively predominant over the high register in these roles, and the %P decreased. High phonation frequencies are associated with greater subglottal pressure²⁰ and greater vocal stiffness.²¹ In the female first *passaggio*, changes in vocal fold oscillation patterns are observed,²² whereas in the second *passaggio*, both laryngeal and resonance adjustments are required²³; therefore, both *passaggio* regions are challenging to maintain steady vocal fold vibrations.²⁴ Hence, when ranking Verdi's soprano roles based on the vocal cost required, the effort required by the operas of the early period is higher than those of the late period. Above all, the roles of Elena and Violetta are the most demanding because of their duration, with nearly 5000 notes and over 38 minutes of TPT. Among the two characters, a greater vocal effort is required for Elena because of the higher %Lp and lower %Mt. Consecutively, the roles of Elvira and Lady Macbeth can be placed with high values of TPT, %Hp, and %P and a low %Mt for the former, whereas a high %Lp and a low %Mp beside a substantial TPT for the latter. A third group is represented by the roles of Abigail and Gilda typified by their limited duration but

low %Mt and high %Hp and %P. The characters of Elisabetta, Amelia, Aida, and Oscar can be grouped together for the presence of critical values in one or two indices but relatively comfortable values on the other measurements. Lastly, the most comfortable soprano roles are Maria, Desdemona, Donna Leonora, and Alice, concluding with Nannetta.

The evolution of female voices in Verdi's opera is also characterized by the gradual decline of contralto voice and a more decisive development of mezzo-soprano voice. Mezzo-sopranos and contraltos were therefore analyzed together as both voice types can perform the roles of the characters included in this category. The roles of Azucena, Fenena, and Preziosilla are characterized by generally high values of %Hp balanced with high %Mt but differed for duration parameters. The %Lp increases in the scores of Eboli and Amneris together with a decrease in the %Mp. Markedly low values of %Mt mark the role of Quickly; moreover, the highest value of %Lp was found for this character compared with the other of the group increasing the vocal demand required from the performer. A notable %Lp was also found for Ulrica. Although a rank based on vocal effort is hard to be established for mezzo-soprano and contralto roles because of their heterogeneity, the role of Maddalena is undoubtedly the most vocally comfortable because of its shortness and the high presence of medium-pitched notes.

As for the sopranos, also Verdi's tenor roles are generally characterized by a limited %Hp in favor of high values of %Mp, with roles of the early operas being more demanding than those of the late operas. Therefore, the typical register of the tenor voice is not emphasized and was progressively reduced over the years of production. The role of Macduff represents an exception to the above-mentioned trend; indeed, the high-pitched notes were 34.25% of the score.

The high %Hp, along with the high %P, makes this role highly costly for the singer, except for its shortness. Overall, the role of Arrigo seems to be the most demanding among tenor characters because of the important TPT, the low %Mt, and the high %P. Proceeding to less challenging roles based on the estimated vocal effort from the VSP, Ernani, Duca, Don Carlo, and Otello can be placed in the second position. Beside an important TPT, the first two characters have significant %Hp and %P together with low %Mt, whereas Don Carlo and Otello exhibit the highest values of %Lp. Consecutively, the remaining roles can be ranked as follows: Riccardo and Manrico, Radames and Alvaro, Alfredo-Ismaele-Macduff, Fenton and Gabriel, and, lastly, Cassio.

Baritones obtained an autonomy from the bass voice type in Verdi's operas, defining their own range and tessitura and becoming the principal male voice type. A gradual transition to a greater predominance of the low register to the detriment of the medium register can be observed from the percentage of low-pitched and medium-pitched notes, as well as from the limits of the PO. Compared with tenors, the baritone roles are distinguished by a lower %P never exceeding 10% and higher %Mt, making these roles generally more comfortable than the previous ones. Rigoletto, Iago, and Falstaff have the longest TPT and wide PR. The roles of Macbeth, Monforte, and Carlo V exhibit high %P beside high TPT. The lowest vocal effort is required when performing the role of Amonasro, Paolo, and Melitone mainly due to their brevity.

Lastly, bass roles are associated with minor characters in the operas analyzed. The role of Procida stands out for the long TPT, the role of Zaccaria for the high %Hp, and the role of Padre Guardiano for the high %Lp. In spite of the markedly reduced duration, the roles of Sparafucile and Inquisitore can be distinguished for the high %Hp and %P. The minimum vocal effort is associated with the role of Banco, in light of the short TPT and high %Mt.

In the present study, the methodology used to gain data for the construction of the VSP and to calculate the pitch indices was the same as that used by the first author (G.M.) in a previous study on Puccini's scores.¹³ However, notes' counting did not differ from Fussi et al's VSP.⁸ Concerning pitch measurements, the authors list five more indices in addition to those used in the present study: the percentage of high-pitched notes excluded the *passaggio* notes for male and soprano roles, the percentage of low-pitched notes excluded the *passaggio* note for mezzo-soprano and contralto roles, the rate between the two previous indices and the %P, the percentage of extreme register notes obtain by summing the %Hp and the %Lp, and the rate between %Mt and %PO. Although these indices were not calculated for the 67 Verdi roles, the reader may compute them by the data collected in the study. Analogously, the estimated cycle dose proposed by Titze could be gained by multiplying the absolute frequency by the hertz frequency of each note in a role.⁹

Several shortcomings of the VSP can be identified. First, as stated in the Materials and Methods section, the allocation of notes to the low, medium, and high register was

based on average register's limit values reported in previous works. However, individual differences in the pitch of *passaggio* notes exist based on anatomy, singing training, technical skills, experience, interpreted character, and environmental factors related to the performance. Moreover, variations within a voice category (eg, bass-baritone, French baritone) were not taken into account in the present study.

Second, the analysis of a role based on the VSP is limited to the information of the score that can be objectively studied. However, the potential suitability of a role to a singer concerning the vocal demand depends also on dynamic indications, particularly the *pianissimo* and *fortissimo*, which require advanced technical skills to finely balance the subglottic pressure and vocal fold closure. Moreover, it is known that the vowels may influence the phonatory stability in the *passaggio* region and therefore its difficulty.²⁵ The size of the orchestra and the acoustics of the auditorium are additional factors influencing vocal demand of a role.

Acknowledging its limits, the VSP provides objective and aggregated data that can be easily and quickly examined by both expert singers and health-care providers who did not undergo a specific music training. Sharing these data between singers, singing teachers, and clinicians may improve the multidisciplinary approach to the care of the singer by creating a common language among different stakeholders. The objective data from the VSP can be used by singers, singing teachers, and vocal coaches in repertoire selection but always along with other information such as age, gender, personality, preferences, technical, and expressive skills. Potentially, from the comparison between the VSP of a role and the performance VRP of a singer, overlaps and gaps may be suggestive of the feasibility of a role and may highlight potential risk to the vocal health of the singer. Addressing this information during counseling may allow greater customization of the recommendation the clinicians give to the opera singer together with general vocal hygiene advice both in physiological and in pathological situations. When laryngeal abnormalities already occur, the analysis of the previous repertoire may highlight possible causal relationships and may afterward guide the conduction of the voice therapy by the speech and language therapists. Nevertheless, the true relationship between performed repertoire and vocal health is still not explored in the literature. The predictive value of the indices used in the study in appraising the risk of vocal injury must be investigated in future studies, together with other factors as mentioned earlier, to understand better the actual benefit derived from the application of the VSP in both educational and clinical practice.

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