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CHORAL REPERTOIRE SELECTION:
an auxiliary device proposal for grading works by difficulty

São Paulo
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Dissertation submitted to the Music Graduate Program in the concentration field of "Music: processes, practices, and theorizations in dialogs", at the Institute of Arts, São Paulo State University (UNESP), in partial fulfillment of the requirements for the degree of PhD in Music.

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Advisor: Prof. Dr. Marcos José Cruz Mesquita (UNESP)
Co-advisor: Prof. Dr. Márcio Luís Moreira de Souza (UFJF)

São Paulo
2025

To the memory of my great-grandparents,
Fióvo Trere' (1901-1990, gold panner, police officer, bicycle mechanic) and
Sílvia de Lourdes Coelho (1908-2008, traditional cook, amateur harpist),
and my grandfathers,
Wilson Coelho (1931-2020, textile worker, tailor, amateur mandolinist) and
Darcy Sottani (1935-2010, textile worker, fisherman, itinerant merchant, amateur guitarist), with gratitude and longing, I dedicate this work.

À memória de meus bisavós,
Fióvo Trere' *(1901-1990, garimpeiro, policial, mecânico de bicicletas) e*
Sílvia de Lourdes Coelho *(1908-2008, quitandeira, harpista amadora)*
e de meus avôs,
Wilson Coelho *(1931-2020, operário têxtil, alfaiate, bandolinista amador) e*
Darcy Sottani *(1935-2010, operário têxtil, pescador, comerciante itinerante, violonista amador), com gratidão e saudade, dedico este trabalho.*

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To Whom hath established the Algorithm of All Things and set the World in the human heart (Colossians 1:16; Ecclesiastes 3:11). To the Creator and Redeemer of the Cosmos, for granting so many mysteries to be scrutinized. To the Messiah, under Whose Light those escaping from their pride shall find shelter. To the Spirit of Life, Who continually kindles humankind's curiosity toward the Infinite.

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Nova Coral at the UFMG (2008); *Coro VivaVoz* (2007-2010); *Coro Hallel*, AMES (2008-2012); *Coro de Câmara*, the School of Music at the UEMG (2013-2014); and *Coro Acadêmico* at the UFJF (2014-2020).

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[...] when God created the world,
he sprinkled around a little bit of logics (and procedures)
to act as spice and bonding for his creation.
Logics and algorithms are everywhere.

D. Gabbay

(Gabbay; Siekmann, 2010, p. 767)

ABSTRACT

This investigation started from the problem of the scarcity of devices to evaluate the difficulty degree of choral pieces in the process of repertoire selection apart from ready-made catalogs provided by publishers, institutions, and composers. The objective was to develop a partial formulation of an algorithm inherent to the difficulty process, implement and deploy the model as a software prototype, and test it. As delimitation, a conceptual model was specified for mixed adult amateur choirs seeking artistical excellence in preparing *a cappella* repertoire. Mendelssohn's opuses 41, 48, 59, 88, and 100 were elected as the target repertoire due to their archetypical nature and pedagogical potential in the delimited context. Premises in programming were introduced as ground for the development of the algorithm model, and the need for work-choir relation for determining the difficulty degree was established. The literature review demonstrated that, although the difficulty assessment is not regarded as one of the most important criteria for repertoire choice, it is relevant enough for being mentioned in most titles. The target repertoire was analyzed following Jan LaRue's SHMRG structure, generating a comprehensive dataset, of which the analysis included variables selection and aggregation, as well as heatmaps and PCA. The analysis unraveled, in the context of the target repertoire, the pieces with highest, intermediate, and lowest global complexity, respectively: Op. 59, No. 2; Op. 48, No. 6; and Op. 41, No. 2. The analysis results led to the development of the algorithm input data structure, which is divided into two data categories: compositional parameters and choir's competencies. Next, an expert survey was conducted with highly qualified conductors, in which a comprehensive online questionnaire was adopted as the data-collection instrument. The data analysis of the expert survey resorted to PCA, Kendall Tau-b correlation, median analysis, line graphs, heatmaps, interrater reliability within-group index, and generalizability coefficient. Despite structural inconsistencies in the questionnaire, its effectiveness as a data-collection instrument was confirmed by the data analysis, which also validated the judgment sampling method. Several algorithm initial models were tested against the participants' opinions, regarding the estimates of mean difficulty and of rehearsal time demand, for the three previously selected songs to be prepared by each respondent's choir. The KC1.1 model was the most aligned with the participants' evaluations. The difference between the model outputs and the participants' estimates yielded, with 95% confidence, an interval of ±4.23 points on the difficulty scale (0-100). The KC1.1 model, now available at the

Choral Calculator (www.choralcalculator.com), supplies resources – such as technical registration of choirs, for longitudinal learning assessment, and of works, for difficulty, rehearsal demand, and feasibility estimates, or for analysis – for choral conductors, teachers, students, researchers, and composers interested in the choral music field, providing statistically reliable outputs for most situations, thereby addressing the research problem.

Keywords: choral music; repertoire selection; difficulty evaluation; Mendelssohn's partsongs; mixed adult amateur choir.

RESUMO

Esta investigação partiu do problema da escassez de dispositivos para avaliar o grau de dificuldade de peças corais no processo de seleção de repertório, para além dos catálogos prontos fornecidos por editoras, instituições e compositores. O objetivo foi desenvolver uma formulação parcial de um algoritmo inerente ao processo da dificuldade, implementar o modelo como um protótipo de *software* e testá-lo. Como delimitação, estabeleceu-se um modelo conceitual para coros amadores adultos mistos em busca de excelência artística na preparação de repertório *a cappella*. Os opus 41, 48, 59, 88 e 100 de Mendelssohn foram escolhidos como repertório-alvo, devido a seu caráter arquetípico e a seu potencial pedagógico no contexto delimitado. Premissas em programação foram introduzidas como base para o desenvolvimento do modelo de algoritmo, e foi estabelecida a necessidade de uma relação obra-coro a fim de se determinar o grau de dificuldade. A revisão de literatura demonstrou que, embora a avaliação da dificuldade não seja considerada um dos critérios mais importantes na escolha de repertório, ela é relevante o suficiente para ser mencionada na maioria das publicações. O repertório-alvo foi analisado seguindo-se a estrutura SHMRG de Jan LaRue, gerando-se um extenso banco de dados, cuja análise incluiu seleção e agregação de variáveis, mapas de calor e ACP. A análise revelou, no contexto do repertório-alvo, as peças com maior, média e menor complexidade global, respectivamente: Op. 59, No. 2; Op. 48, No. 6; e Op. 41, No. 2. Os resultados da análise levaram ao desenvolvimento da estrutura de dados de entrada do algoritmo, dividida em duas categorias de dados: parâmetros composicionais e competências do coro. Em seguida, foi conduzido um *expert survey* com regentes altamente qualificados, no qual foi adotado um extenso questionário *online* como instrumento de coleta de dados. A análise desses dados recorreu a ACP, correlação de Kendall Tau-b, análise de medianas, gráficos de linha, mapas de calor, índice de confiabilidade entre avaliadores intragrupo e coeficiente de generalizabilidade. Apesar de inconsistências estruturais no questionário, sua eficácia como instrumento de coleta de dados foi confirmada pela análise de dados, que também validou o método de amostragem por julgamento. Vários modelos iniciais de algoritmo foram testados, em relação às opiniões dos participantes acerca das estimativas de dificuldade média e de demanda de tempo de ensaio, para as três canções anteriormente selecionadas serem preparadas pelo coro de cada respondente. O modelo KC1.1 foi o que apresentou maior alinhamento com as avaliações dos participantes. A diferença

entre os resultados do modelo e as estimativas dos participantes apresentou, com 95% de confiança, um intervalo de ±4,23 pontos na escala de dificuldade (0-100). O modelo KC1.1, já disponível na Calculadora Coral (www.calculadoracoral.com.br), oferece recursos – tais como registro técnico de coros, para avaliação longitudinal da aprendizagem, e de obras, para estimativas de dificuldade, demanda de ensaio e viabilidade, ou para análise – para regentes de coros, professores, estudantes, pesquisadores e compositores interessados no campo da música coral, fornecendo resultados estatisticamente confiáveis para a maioria das situações e contribuindo, portanto, no enfrentamento ao problema de pesquisa.

Palavras-chave: música coral; escolha de repertório; avaliação de dificuldade; canções polifônicas de Mendelssohn; coro amador adulto misto.

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LIST OF ABBREVIATIONS AND ACRONYMS

AbCalc	Abilities Calculation
AbCalcLang	Abilities Calculation of Languages
ACF	Abilities Calculation Form
CI	Confidence Interval
CRF	Choir's Registration Form
CRV	Choir's Registration Viewer
IQR	Interquartile Range
MCF	Main Calculation Form
ME	Margin of error
No.	Number
Op.	Opus or Opuses
PCA	Principal Component Analysis
PrevKnowl	Previous Knowledge
QICF	Q Indices Calculation Form
QRelevances	Question about relevance
Qrt	Quartile
RehDem	Rehearsal Demand
RehDemNorm	Rehearsal Demand Normalization
SHMRG	Sound, Harmony, Melody, Rhythm, and Growth
SpecDiff	Specific Difficulties
SVRF	Selected Variables Registration Form
SVRV	Selected Variables Registration Viewer
v.	Variable or variables
WComp	Works Comparison
WCont	Work Context
WRF	Work Registration Form
WRV	Work Registration Viewer

LIST OF SYMBOLS

$\tilde{x}$	Sample median
x_i	Each individual observation
$\bar{x}$	Sample mean
Σ	Summation
i	The position of an observation in the series
μ	Population mean
n	Number of observations in a column
N	Total number of observations in the population
s	Sample standard deviation
s^2	Sample variance
σ	Population standard deviation
σ^2	Population variance
z	Z-score
H_0	Null hypothesis
τ	Kendall Tau correlation coefficient
A_C	The number of available categories in a variable or question
G	Generalizability coefficient
r_{wg}	Interrater reliability within group index
$s_{\bar{x}}$	Sample standard error
σ_{μ}	Population standard error
t	Student's critical value
$\bar{x}_{corr}$	Correlated estimates mean

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1 INTRODUCTION

When a choral conductor – especially a conductor of amateur choirs – moves from country, city, or even rehearsal room, he is very likely also changing choirs. If but he does not move to another place and remains with the same choir for several years, it is almost certain that there will be a turnover in the body of singers and that, as a result, the musical possibilities of the group will undergo several transformations. The choral conductor, therefore, must always be prepared to "play" a new "instrument", an "instrument" with different sounds, "fingering",… and ability. Part of such condition is always being able to choose a repertoire which corresponds to the idiom of his "instrument" – a choir in general and his current choir in particular. It is, therefore, mainly the technical-expressive skills of the "instrument", the choir, and not of the "instrumentalist", the conductor, which will determine the limit to be respected or challenged for repertoire selection. Moreover, respecting or challenging the limit means being aware of how difficult or easy a choral work is for the group.

In order to facilitate the conductor's work, it is possible to find repertoire lists organized by difficulty levels in catalogs of publishers, of institutions related to choral music, of composers, and in choral anthologies. However, substantial inconsistency has been observed when relating the classification methods adopted by various sources, as previously pointed out by Mehaffey (2005, p. 84) and as will be seen further in this investigation. It should be noted that few devices provide the choral conductor with an objective and auxiliary means to grade, by difficulty, the repertoire apart from such lists – Mehaffey is a notable exception. On that account, when the conductor does not intend to assemble the entire repertoire from ready-made lists, he is often left to make a subjective classification – which, by its nature, may demand significant time for reflection, as well as a great deal of knowledge and practical experience. Consequently, an awareness of the limit to be respected or challenged in choosing repertoire may be somewhat blurred for young conductors or conducting students.

Given the languages which have emerged in the digital age, the current easiness of access to a virtually infinite profusion of choral repertoire, and the increasingly multiple demands placed on the conductor's role, it is urgent to develop devices which allow a conductor – especially the less experienced – to evaluate new works for his choir in a faster and more accurate way, while contributing to an effective growth of the group.

This doctoral investigation started in 2021, during the COVID-19 pandemic. In those times, thousands of choirs worldwide – and Brazil was not different – had to reinvent themselves to survive social distancing. Contact with new technological resources became urgent, and many singers and conductors had to learn to deal with tools and software which had not even appeared in the history of choral music until then. Thousands of choirs went on to produce multitrack videos, rediscovering their repertoire and exploring both the new expressive possibilities and the numerous limitations of the new normal – as exemplified by the Academic Choir of UFJF (Sottani; Magalhães; Arriel, 2021). Assuming that the contingencies generated by the pandemic were temporary, there was, on the other hand, the expectation that the knowledge and techniques constructed in such time were perennial.

The fact is that choral singing was – as it should never cease to be – always very fond of the concreteness of the paper with staffs and of the bibliography, of the pencil and the eraser, of the chair and the acoustics of the rehearsal room, of the physical contact between singers, conductors, pianists, and voice teachers. Nevertheless, the avalanche of innovations in the current century certainly drives an adaptation, or rather, an aggregation of new perspectives. Therefore, this study contributes to such aggregation by offering a novel methodological resource for conductors, one which introduces technological innovation and holds the potential to yield accurate results.

1.1 Problem, hypothesis, and objective

As already mentioned, few devices are able to assist the conductor – or the editors – with grading the choral repertoire by difficulty and which may be applied directly to choral works apart from the available lists. In addition, throughout the literature review (Chapter 3), it will be explained that most parameters associated with difficulty in the literature are merely alluded to, without explanations of how much or in what manner they contribute to the construction of the sense of difficulty. The discrepancy between the importance attributed to difficulty and the level of depth in the subject points to the need for more thorough exploration of the topic in the context of choral music. Even beyond the musical context, more broadly, Gallego-Durán, Molina-Carmona, and Llorens-Largo (2018) state that difficulty is rarely addressed to as a specific object of study.

The hypothesis is adopted throughout this study that there is an algorithm inherent to the difficulty process, in which the input data structure is based on the compositional elements of a score and the competencies of a choir, while the output data are the mean difficulty level of the work and a predicted rehearsal demand for the group to prepare it. Beyond investigating this hypothesis, **the objective** of this work is to develop a formulation of such algorithm – even if partial – implement and deploy it as a software prototype and test it.

Attentive to the previously referred lack of discussion, the present investigation explores the nature of the difficulty perceived by a choir in relation to a piece and describes part of the logic behind such perception of difficulty, unraveling the input data structure – that is, the parameters – for an algorithm of the difficulty. The study isolates the work-choir relation and highlights compositional elements (Appendix C) and choir's competencies (Appendix E) as parameters of difficulty. For the sake of discussion objectivity, any external factors beyond these two groups of parameters – such as rehearsal room lighting or temperature and everyday setbacks experienced by the singers – are disregarded, although they may certainly and actually influence the sense of difficulty.

Since the investigation intended to yield a product and since such product bears applicability, this study may be categorized as **applied developmental research** (Thomas, 2021, p. 59). The reasoning does justice to the **hypothetico-deductive method** (p. 26-29), and the hypothesis draws primarily on a diffuse choral theory partially codified in Chapter 2 and which has been both cultural and scientific, in Zbikowski's terms (2002, p. 114-117). Hence, the hypothesis may be approached with systematized concepts and tested by analyzing data collected through musical analysis (Chapter 5) and an expert survey (Chapter 6).

Indeed, a prototypical algorithm has been achieved and implemented as a web application, namely, the Choral Calculator. The software is expected to improve the processes of repertoire selection, rehearsal planning, and even concert programming. At the same time, the use of the software may favor the systematic improvement of the musical and vocal abilities of the individual singers and the choir as a whole, as well as their learning assessment. As will be stated in section 5.5, even if a conductor does not trust the algorithm results, the forms of the Choral Calculator still hold pedagogical value as diagnostic snapshots of the choir's current state within a longitudinal assessment process.

1.2 Scope

The Choral Calculator will under no circumstances replace the conductor in the process of repertoire choice or even in the classification of works by difficulty degrees. Even if an inexperienced conductor uses it, the software will only help in one of the stages of the repertoire selection process. However, it has the potential to optimize and even improve the quality of such process significantly. The conductor will still be the judge of the repertoire in the phase prior to the first rehearsal and, through musical analysis, must be able to appropriate each work chosen in all its intricacies. Here, Picchi's definition of analysis is valid:

> In a greater depth, analyzing may mean unraveling a functioning, revealing a creation in its constructive essence, in the most intimate of its mechanism of existence. [...] analyzing is for understanding how something is done, as much as it is for how something works, how it is structured, realized, developed.[1] (Picchi, 2019, p. 59, our translation)

The analysis applied to repertoire choice requires less depth than the analysis applied to interpretation. After all, both sorts of analysis may have performance in mind, but the first case requires a look at feasibility, while the second at communication. However, even deeming such difference, the conductor, in both cases, will need to know compositional resources and analytical techniques. For the less experienced conductor, the Choral Calculator will act as a sort of accelerator of the analysis applied to the repertoire choice.

Picchi (2019, p. 132) proposes a process for the art song[2] rendition, in which singer and pianist go all the way together, from the initial reading, through the analysis, up to the performance. In the case of choral music, such a detailed path, involving all the participants, would be highly time-consuming if carried out for every piece, might lead to logistical problems, and might unpleasantly highlight gaps in theoretical and practical training among singers, in addition to possible divergences of interest. Consequently, the person ultimately responsible for the analytical-interpretative process should be the conductor, who is to be followed by both the choir and the collaborative pianist or the ensemble of instrumentalists. Nevertheless, the Choral Calculator will not reflect difficulties posed by the work to the

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[1] "Em maior profundidade, analisar pode significar desvendar um funcionamento, revelar uma criação em sua essência construtiva, no mais íntimo de seu mecanismo de existência. [...] analisar está para compreender como é feito, tanto quanto está para como funciona, como está estruturado, realizado, desenvolvido."

[2] "*Canção de câmara*", in Portuguese.

conductor, as he is expected to have an in-depth understanding of the work before the first rehearsal.

This study is carried out in the context of Brazilian mixed adult amateur choirs which seek to prepare original *a cappella* repertoire for choir in the soprano-alto-tenor-bass (SATB) formation, a conceptual model of a basic-level category – for explanation, see Chapter 2. The lexeme "choir" refers immediately and simply to a group of people singing, likely distributed among female and male voices. In the case of the basic-level category "choir", the attributes of a conceptual model might be: voices of individuals of both sexes, especially adults, and only their voices; mandatory distribution into soprano, alto, tenor, and bass; and participation more by the desire than by the obligation to sing. Section 2.1.3 brings a more detailed specification of such conceptual model.

This study also focuses on the repertoire represented by scores in which: the rhythmic figures of sound always indicate defined pitches and durations; the text always involves the formation of syllables with consonants and vowels; the rhythmic figures of sound always correspond to the duration of the vowels and not of the consonants or any other type of sound. Matching such criteria, Felix Mendelssohn's (Bartholdy, 1877a, b, c, d, e) non-sacred *a cappella* soprano-alto-tenor-bass (SATB) partsongs originally published in cycles were elected as the target repertoire, given their archetypical nature concerning the conceptual model of choir delimited above and in section 2.1.3. For more about the importance of Mendelssohn's partsongs in the context of this investigation, see section 2.1.4.

All such specification is merely a delimitation proposal and is not intended to summarily exclude from the universal choral repertoire any other so-called "choral" work which a choir may adequately perform. This study does not either exclude further application to other categories of choirs, and it is intended to be continued in order to make its application more straightforward in other contexts.

This author's background in choral singing was, from the very beginning, equally formed under the leadership of both female and male conductors. These mentors' perspectives regarding musical practice – careful, meticulous, diligent, expressive, creative, eclectic, intense, responsible, deeply knowledgeable, extraordinarily rich in interpretation, powerful – profoundly and decisively shaped the author's point of view. Therefore, it is difficult to imagine a choral world without women participating in every stage of production, from

composition to conducting, and inevitably through singing in the choir sections.

In addition to meeting the delimitation criteria, Felix Mendelssohn's partsongs represent an era when adult women finally began to gain visibility as a collective – or rather, to be heard, even if only through singing in mixed choirs. Significant advances would still be necessary over the next 200 years, as they remain necessary nowadays. Even Fanny Mendelssohn, who originated the genre "Songs without words", herself was encouraged not to publish her works under her own name, upon her brother Felix's recommendation (Taruskin, 2010, p. 183). Nevertheless, the choral repertoire published at the time represents progress concerning the acceptance of a vocal sort of expressiveness which had previously been silenced by society.

1.3 Stages and explanatory notes

Engaging with varied fields such as programming, philosophy of value, musical analysis, vocal technique, and musical cognition, the following stages are reported throughout this dissertation:

a) Chapter 2: Developing a theory which helps to define the concepts of choral music and of difficulty to be approached, as well as delimiting the investigation.
b) Chapter 3: Reviewing the literature to examine how the theme of choral repertoire difficulty has been explored.
c) Chapter 4: Proposing the main methods of data analysis to be applied in the subsequent stages.
d) Chapter 5: Preparing and analyzing a dataset with information from the scores of the target repertoire to determine: the best compositional parameters (Appendix C) for an analysis applied to repertoire selection and their respective parameters of choir's competencies (Appendix E); and the most representative pieces of such repertoire in terms of degrees of compositional complexity.
e) Chapter 6: Conducting an expert survey based on the selected compositional parameters and their respective parameters of choir's ability in order to gather material and arguments to test and validate the Choral Calculator algorithm.
f) Chapter 7: Outlining the Choral Calculator structure and functioning, as well as testing and validating its algorithm against the expert survey data.

In the interest of transparency and clarification, the following notes must be highlighted:

a) Over the course of this work, all mentions to "Choral Calculator" should direct the reader to the website www.choralcalculator.com – or its corresponding translations into Spanish (www.calculadoracoral.com) or Portuguese (www.calculadoracoral.com.br).

b) In this volume, the terms "dissertation" and "thesis" respectively refer to doctoral and master's degree works, following the usage in the United States[3]. An exception is the "References" section, where each term is preserved as it appears in the original publication.

c) Throughout this work, the simple noun "score" will exclusively refer to a musical score and will not be used in any other sense. Additionally, the word "score" will appear as part of the compound noun "z-score", which should be interpreted as a statistical concept.

d) The Excel functions referred across this dissertation correspond to the Brazilian Portuguese version of the software.

e) All VBA scripts and almost all R scripts used across the investigation were written with the assistance of artificial intelligence (ChatGPT, OpenAI), of which the suggestions were analyzed and adjusted by this author according to specific needs. Exception are the R scripts used in section "5.4 Analysis of the Q indices", which were developed by Prof. Dr. Márcio Luís Moreira de Souza, joint advisor of this work.

f) Portions of this dissertation were previously published in Portuguese in the author's papers (Sottani, 2023, 2025) during his doctoral studies, and more is intended to be published in due course.

g) The expert survey (Chapter 6) was conducted after approval by the Committee for Human Subjects Research at the Federal University of Juiz de Fora (UFJF)[4], under CAAE 76870323.6.0000.5147, and was approved by the Committee on March 18, 2024, under Review No. 6.709.957.

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[3] The terminology for academic degrees varies across countries. Most Romance-language countries – e.g., Portuguese-, Spanish-, French-, or Italian-speaking – use cognates of "thesis" to denote "doctoral work". This aligns with the Brazilian usage of "*tese*" for a doctorate and "*dissertação*" for a master's degree. The term "thesis" is also commonly used for a doctoral work in most English-speaking countries, particularly in British and Commonwealth contexts.

[4] https://www2.ufjf.br/comitedeetica/

8 CONCLUSION

This study started from the problem of the scarcity of devices to evaluate the degree of difficulty of the choral repertoire apart from ready-made catalogs provided by publishers, institutions, and composers. The problem is that difficulty is one relevant criterion for choosing repertoire, and its evaluation has been mainly undertaken through subjective or non-systematic procedures. The primary objective of this investigation was to build and test a software for aiding the choral conductor in assessing the difficulty of a piece faster and more accurately. Such objective has been accomplished with the deployment of the Choral Calculator.

Chapter 2 introduces the concepts of "vocality" and "chorality" as voice characteristics. Additionally, the term "**chorability**" was coined, standing for a score characteristic determined by: (1) the condition of a musical part to be suitable for a choir section through peculiar accommodations unifying voice line, verbal text, and text-music relation in a single environment; and, (2) at the same time, in the case of polyphony, the condition of the work includes lines which maintain their chorability while performed together with other lines.

Subsequently, a historical overview made a parallel between the beginnings of the mixed adult amateur choirs from the late 18th- to the early 19th-century Europe with the 20th and 21st-century Brazilian secular amateur choral movement. It was demonstrated that, in terms of style, the latter was a new musical branch yielding several excellent choirs seeking the same *a cappella* choral ideal constructed by choirs from the Western Northern Hemisphere throughout the 19th century. General specifications of such choirs were listed, defining the **conceptual model** to which this investigation first applies: adult; mixed; amateur; led by specialized conductors; and seeking excellence in *a cappella* SATB repertoire.

It was argued that, with proper vocal training, the contemporary amateur choirs are able to prepare the same repertoire and sound close to the pioneering groups – which implies that such repertoire bears a pedagogical potential to drive the current choirs to the excellence ideal addressed above. Besides bearing chorability, one genre comprised in such repertoire was described as matching the possibilities of the conceptual model of choir specified: the *a cappella* SATB secular partsong. Given their **archetypical nature**, Mendelssohn's opuses 41, 48, 59, 88, and 100 (Bartholdy, 1877a, b, c, d, e), were elected as representing the genre and

the style, becoming the **target repertoire** of this investigation.

In addition, Chapter 2 explored the nature of difficulty in choral music aiming at representing the input data partial structure of an algorithm which captures the process through which the sense of difficulty develops in the **work-choir relation**. Hence, a piece is not difficult or easy in itself: it should be analyzed as a function of the abilities and traits of a choir and the choristers. Programming and philosophy of value literature support the idea that the difficulty process may be considered an entity intrinsically containing the referred algorithm. Therefore, the written representation of the algorithm may be used to predict the degree of difficulty of a piece for a choir and the ideal rehearsal time for the choir to prepare the piece.

The concepts of instant, global, and **mean difficulty** were established. For the latter two, basic mathematical formulations were developed following an accumulative model, for which a **predictive model** was proposed as an alternative. In other words, a model which treats the time needed by a choir to prepare a piece as an output rather than an input. It was clarified that such time estimate refers to an ideal timeframe for maintaining the group's interest. Gradual **measurement scales** were established from 0 to 100 degrees for mean difficulty and from 0 to 11 months for rehearsal time demand. Any value above should be considered unfeasible. It means that, while difficulty may be represented within a gradual scale, feasibility is binary, having only two possible values: yes, or not.

In Chapter 3, an exploratory search on the internet confirmed a substantial inconsistency in relating the methods adopted by the various sources for classifying choral repertoire by degree of difficulty, which supported the urgency of developing the subject. A bibliographic search was conducted in academic databases, focusing on criteria for choosing choral repertoire for adult amateur choirs. The selected literature demonstrates that the process of choosing repertoire should be organic and that several criteria beyond the difficulty might and should be adopted, with emphasis on the artistic merit and the pedagogical merit of the works. The bibliography attests that difficulty is **not** the most important criterion of all. Still, several authors give special attention to the difficulty as a criterion, mentioning that a balance is necessary to not overload the choir, either in rehearsal planning or concert programming.

Some authors suggest ways to guide the process of choosing repertoire, such as orientation by: predefined lists; elements of musical structure; existing genres and forms; sonority likely to be achieved; choristers' strengths and weaknesses; diverse traditions of choral practice;

choristers' participation in the choice process; choristers' sociocultural context; and audience's appeal. Several authors offer models or checklists to aid the selection process but not necessarily to assess the degree of difficulty of the works.

A systematic review of the works studied in Chapter 3 confirmed a need for more research on adult amateur choirs concerning the process of choosing repertoire. The review also revealed that the vast majority of works which specify criteria for such process cite difficulty as a criterion. Of these studies, three-quarters relate different parameters to the problem of difficulty. Thus, even if difficulty is not the most important criterion, it is noticed that it is important enough to be addressed in more than half of the selected works.

Ending Chapter 3, a theory-based review unraveled parameters associated with the idea of difficulty by the selected authors. The parameters related to composition were organized according to LaRue's (1992) contributing and combining elements in the following categories: sound; harmony; melody; rhythm; and growth. LaRue addresses such structure by **the acronym SHMRG**, which was also adopted in this investigation. The distribution of the parameters of ability was oriented by Heffernan's (1982) principle of separation between vocal and choral techniques in addition to Davids and LaTour's (2012) order of approaching vocal techniques.

It was noticed that some parameters appear with a wording sometimes more general, sometimes more specific, and that some other parameters appear only in a general way. As a rule, the parameters are only mentioned by the authors, without very detailed explanations about the extent or the manner in which they influence the difficulty process. It was still detected in the literature the absence of also relevant parameters to evaluate the repertoire difficulty, such as "metric" and "harmonic rhythm".

Chapter 4 introduced the **subsequent stages** of the investigation: analysis of the target repertoire; expert survey; algorithm modeling; and algorithm testing. The expert survey and the algorithm modeling would unfold in parallel, both based on the repertoire analysis. Finally, the algorithm would be tested against the expert survey data. Chapter 4 followed presenting the statistical resources which would pervade the data analysis in the subsequent chapters. Having presented classifications of qualitative and quantitative data types, the chapter describes technically the calculation of quartiles, median, outliers, variance, standard deviation and z-score. Next, the importance is detailed of principal component analysis,

heatmaps, and Kendall Tau-b correlation test. Finally, the concepts and basic calculations are explained of interrater reliability within-group index, generalizability coefficient and margin of error.

In order to list parameters for the input data structure of an algorithm of the difficulty, Chapter 5 then analyzed the target repertoire defined in Chapter 2, that is, the five cycles of Mendelssohn's partsongs. The data were collected following LaRue's (1992) SHMRG structure. A worksheet was prepared for gathering data and was named "SHMRG instrument", resulting in the "SHMRG dataset" (Appendix A).

The data gathered were analyzed from the perspective of their **feasibility and effectiveness** in the process of repertoire selection and in the expert survey. Many variables were found to be very time-consuming and were disregarded for the subsequent stages of the investigation. The remaining 74 variables comprised the set of **SHMRG selected variables** (Appendix B) and brought balance to the category "rhythm" in relation to the category "sound" – contrasting the lack of detail about "rhythm" in the literature studied.

Relations observed among the SHMRG selected variables induced their aggregation into 28 **Q variables**, the verbal manifestation of which are the **Q instructions** (Appendix C). Due to their nature, the Q variables implicitly preserve the property of the SHMRG selected variables of balancing the approach to the category "rhythm" compared to "sound". It is worth noting that the mathematical formulation of the Q variables is entirely free of nominal data. When such data are present in the set of the SHMRG selected variables, they are merely counted and thus derived into ratio data. Once data from the SHMRG dataset were combined in the Q variables, they yielded the **Q indices** (Appendix D).

The Q indices passed by a principal component analysis (PCA) in order to yield two-dimensional plots. Analyses of the plots allowed for establishing a relation between most Q variables and tempo. Indeed, tempo was found so connected with many other variables that it would be unnecessary to ask about its complexity separately in a process aiming at the mean difficulty calculation. Therefore, the algorithm will need tempo information input solely for rehearsal demand estimation.

Another finding was that the Q variables relating to voice registers and transitions do not align with each other, nor with tempo, nor is there any other alignment pattern. Which confirmed the need to ask about them separately and not grouping the choral parts or the choir sections

into one question in the process of repertoire difficulty assessment related to voice registers. Once validated, the 28 Q variables were used to deduce 35 corresponding choir's **C competencies** (Appendix E).

Additionally, the repertoire analysis revealed its best three pieces for representing the diversity of complexity profiles, pieces which would be addressed to in the subsequent expert survey. Namely, Op. 59, No. 2, was found to be the piece with greater variability in standard deviation; Op. 41, No. 2, the one with the least variability; and Op. 48, No. 6, the intermediate piece.

Chapter 6 reported the **expert survey** conduction, according to the project approved by the Ethics Committee for Human Subjects Research at the Federal University of Juiz de Fora (UFJF)[62]. The purpose was to record highly qualified choral conductors' perceptions about the difficulty within the relation between a choir and a choral piece. The study resorted to judgment sampling, that is, the participants were individually chosen from the population based on specific criteria (section 6.1.1). The data-collection instrument, i.e., the questionnaire (Appendix G) incorporated the C competencies and the Q instructions as questions, which were organized in three blocks: the first, about a non-identified actual choir which the participant had conducted; the second, about each of the three pieces selected from the target repertoire; and the third, about the relevance of the Q instructions in determining the difficulty degree of a choral piece.

After outlining the expert survey design, Chapter 6 exposed a series of structural problems observed in the questionnaire during data analysis, especially concerning the diversity of scales among the question blocks. Subsequently, the only open-ended question was addressed. In their answers, several participants offered additional elements to be considered in the repertoire selection process. Nevertheless, the analysis emphasized that this investigation focused on technical factors to specifically estimate, in such process, the difficulty of a work for a choir. Thus, more subjective aesthetic or interpretative aspects, while indeed relevant, were intentionally left out due to the **deterministic nature** of the algorithm developed.

In the analysis of the remaining questions of the expert survey, the findings were presented according to each analytical resource utilized, chiefly: PCA; Kendall Tau-b correlation; the

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[62] https://www2.ufjf.br/comitedeetica/

median; and line graphs. The very low correlation between each participant's prior knowledge and the other variables indicated that, overall, whether or not the participant was acquainted with the piece did not systematically affect the assignment of difficulty or rehearsal time, contributing to **validating the sample quality**. Even in face of sporadic discrepancies in application of different scales and potential inconsistencies in the questionnaire responses, there was remarkable convergence regarding the difficulty order of the three songs: **Op. 41, No. 2 < Op. 48, No. 6 < Op. 59, No. 2** – which aligns with their complexity order established after the repertoire analysis.

The expert survey responses support such progression in a statistically significant way, indicating that most participants indeed considered the choir abilities when evaluating the demands of each piece, rather than other factors which might be deemed universal. The estimated rehearsal time follows the same pattern, although some correlations showed lower significance due to the open-ended and potentially infinite nature of the scale in minutes. Still, the overall alignment suggests that the conductors consistently interpreted the concepts involved.

Regarding the compositional elements and the choirs' abilities, the correlation analyses revealed an inverse trend: for the most part, when a technical-compositional aspect was well mastered by the choir, the participant tended to assign lower relevance to that aspect in determining the difficulty degree of the work. Some exceptions emerged but, in most cases, they were attributed to sporadic differences in interpretation or to situations in which the conductor, instead of focusing on "difficulty", might have considered "relevance", that is, a criterion to explore the group's potential. Overall, it became clear that there are no fixed weights applicable to all choirs for each compositional element: each variable must be weighted according to the competencies actually present in the group.

The concept of **Δ variations** was established, which indirectly captures the participant's opinion on the inherent complexity of each score, instead of the degree of difficulty which relates the score to the choir. The analysis of the medians of the Δ variations reinforced the perception of an **almost linear increase** in complexity among the three songs. As a result, the analysis validated the selection of the songs for the expert survey, as well as the method adopted to choose them, from the SHMRG instrument through the Q variables, to the PCA of the Q indices. Furthermore, the analysis confirmed the conductors' ability to consistently assess the relative difficulty of the works, validating the methods for selecting the sample of

participants.

Finally, the line graphs made visible both the cases of internal consistency – in which the difficulty and rehearsal time estimates keep a clear proportion for the same participant – and the sporadic discrepancies of specific participants. Overall, the analysis highlighted the conceptual soundness of the proposal to assess the difficulty of a work based on the choir's abilities. In addition, it revealed where future adjustments to the questionnaire might enhance the reliability and clarity of the responses – for instance, by standardizing scales and instructions to minimize interpretative confusion and reduce outliers.

Chapter 7 described the **Choral Calculator** and reported its algorithm testing. After a chronology of the development process, the scope of the application was explained, as well as its functioning was outlined, while divided into the Main Module and the Researcher Module. The input data structure draws directly on the findings from the repertoire analysis in Chapter 5. The Main Module is grounded in the Q instructions (Appendix C) and the C competencies (Appendix E), and its process returns the mean difficulty degree of a work for a choir and the estimate of the rehearsal time demand for the choir to prepare the work. The Researcher Module, in turn, follows two paths. One is based on the SHMRG selected variables (Appendix B) and returns the Q indices of a work. The other is based on the C competencies and returns the ability degrees of a choir in each Q variable.

The algorithm was then tested against the expert survey data. Out of the several initial models, the **KC1.1 model** was the most aligned with the participants' evaluations about mean difficulty degree and rehearsal demand estimate for the three selected partsongs and their respective choirs. All tests of the initial models and the KC1.1 showed discrepancies for the choirs of two specific participants. Statistical analysis indicated that, when such participants were excluded, the **median of the Δ variations** of the KC1.1 model results matched the median of the Δ variations found for the participants' opinions. In other words, for most of the sample, the distribution of the KC1.1 model results is quite close to the distribution of the participants' opinions in relation to the difficulty of the works and the rehearsal demand.

Specifically regarding rehearsal demand, there were minor divergences in relation to four other participants, given that the model tends to overestimate this aspect. This, however, was considered safer than underestimating and leading to insufficient rehearsal planning. In addition, it was noticed that the tests resorted to the RIAS Kammerchor (Mendelssohn, 2008)

rendition to specify the tempo of the pieces while the expert survey participants did not. While tempo does not impact the mean difficulty calculation, it does impact the rehearsal demand. Therefore, the Choral Calculator is expected to yield more accurate rehearsal demand estimates in real-world since it will resort to the user's decision on tempo.

To assess the reliability of model KC1.1, the **margin of error** was calculated by comparing the mean difficulty between the participants' opinions and the algorithm results. A margin of ±4.23 points on a scale from 0 to 100 was found for the mean difficulty, which is deemed acceptable given the subjectivity involved. As for rehearsal demand, the margin of error was ±70 minutes, which may be quite impactful when the set of works in the sample is considered very easy and thus requires less rehearsal time. This variation largely reflects how each participant of the expert survey or user of the Choral Calculator inputs the data, possibly adopting personal criteria which diverge from the listed parameters.

Again, the difference between the Choral Calculator and the participants' evaluations regarding rehearsal demand is **not the result of a miscalculation** by the algorithm but rather stems from the source of the tempo data used at the beginning of the process. Had the participants been asked about the metronome in the expert survey, and their responses used as inputs in the Choral Calculator, the margin of error would very likely have been smaller.

In summary, KC1.1 provides a **statistically reliable result for most situations** and proves suitable for estimating the difficulty and rehearsal time of choral repertoire. The main remaining challenge concerns cases in which participants underestimate or overestimate the choir's competencies in ways not anticipated by the algorithm. Pending issues include: comparing the results of the predictive and accumulative models described in section 2.2.4; defining the range of mean difficulty levels which keep the group's interest, as proposed in section 2.2.5; and formulating the notion of repertoire viability as a whole rather than a single piece in isolation. Tests relating choirs to their actual repertoire and comparing the results with the singers' and conductors' opinion might contribute to such developments.

At the moment of this dissertation completion, the KC1.1 model of the Choral Calculator remains limited to the stylistic scope of the target repertoire. Nevertheless, the software functionalities may be applied to repertoire from other periods, provided the compositional characteristics of a piece are broadly aligned with the repertoire addressed in this study.

Beyond estimating difficulty and rehearsal time demand, the application may serve as: a

structured storage of technical information on works and choirs; a diagnostic instrument for capturing snapshots in longitudinal assessments of a choir's learning progress over time; a consistent framework for formative self-evaluation and reflection by choral conductors; an analytical tool for researchers, teachers, and students in the choral music field; and a source of guidance for composers aiming to enhance the chorability of their repertoire.

This investigation provides solid results, although its practical repercussions are only beginning to be explored. Given its consistency, the lists of SHMRG selected variables, Q instructions and C competencies offered here, together with the public availability of the Choral Calculator, make a significant contribution to the field of choral conducting and may be employed by conductors in the processes of repertoire selection, rehearsal planning, concert programming, and evidence-based assessment of learning.

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