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Can Orchestration Teaching Be Improved?

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The fundamentals of mastering orchestration are a well-grounded knowledge of the instruments, their mechanics, techniques, and their phenomenology. To succeed in instrumentation and orchestration praxis, students must commonly 1) massively memorize examples of successful orchestration available in treatises on orchestration; 2) analyze as many as possible orchestral scores, and 3) orchestrate excerpts proposed by their instrumentation teachers. We aimed to conduct an exploratory study to detect possible voids in orchestration teaching. For this purpose we recruited 16 participants for this aim. Eight were Music Pedagogy students in their senior academic year, and the other eight were Composition undergraduates. The participants of the Pedagogy group completed one course in instrumentology, while the composers-students had a background of at least one course in instrumentation. Due to the differences in training, Pedagogy students instrumented an excerpt from a song by Ibert, and Composition students orchestrated an excerpt transcribed for piano from "Romeo and Juliet" (overture-fantasia) composed by Tchaikovsky. Also, we asked the participants to write down all their decisions and choice-making during the task to obtain more information for a deeper insight. As a result, we observed that the participants of both groups showed poor performance and low-quality products, except for those who conducted large ensembles. Both groups presented relevant similarities concerning orchestration-related concepts and procedures. Therefore, we can conclude that the general trend of the handbooks on instrumentation and orchestration is to work from a prescriptive model. We attribute the low-quality results of the composers' group (comparable to non-composers) to the quantity of information to be integrated into the frame of such a model. Rimsky-Korsakov inaugurated the transition to a nomothetic model concerning the tembrotechnonic musical structure. But still, major understanding must be achieved regarding the timbre.

Keywords: general rules, instrumentology, instrumentation, orchestration, pedagogy, Gestalt, musical analysis, prescriptive model, nomothetic model, polytimbral texture.

Introduction

Almost one century and a half ago, Rimsky-Korsakov [1, p. 150–1] wrote these prophetic words addressing the study of orchestration: "After consulting Tyndall and Helmholtz, I wrote an introduction to my opus, trying to explain the laws of the acoustics governing the functioning of the musical instruments. The opus was to begin with detailed monographs on the instruments grouped by families, with sketches and tables, and describe the fingering that the instrumentalists actually use in the present days. In the second part, I would address the combinations of different instruments. But I soon realized that I had gone too far. <…> Such a massive description would, actually, require an enormous effort; and, in fact, what benefit would my manual bring to the reader? All of these monographs on the instruments, their descriptions, technical possibilities, and limitations would not but confuse the apprentice".

This Rimsky-Korsakov quotation reflects the status quo of orchestration pedagogy. It is necessary to have extensive knowledge about musical instruments, their technical possibilities, and phenomenology (the sound resulting from playing in different registers with different techniques). On the other hand, integrating all this information does not necessarily imply its appropriate use in orchestration and instrumentation tasks. Their performance also demands a great dose of refined technique and talent, according to Rimsky-Korsakov [1, p. 8].

Today, the question posed by Rimsky-Korsakov is still to be solved. Though there is a plethora of orchestration treatises and handbooks, scientific research on orchestration pedagogy is absent. We searched for the terms with the boolean operator "orchestration" AND "pedagogy" in Web of Science and Scopus, obtaining only one result. It was Reymore's work [2], where the author presented Timbre Trait Profiles that resulted from rating timbres of 34 individual instruments on 20 semantic descriptors from "1 = does not describe at all" to "7 = describes extremely well". She used semantic descriptors from a previous study by Reymore and Huron [3]. The peculiarity of Reymore's work [2] is that her participants performed judgment on imagined timbres of listed instruments, not on their actual sound. We must observe that Reymore's participants were professional and nonprofessional musicians, and topics on timbres of some instruments are frequent among musicians. For instance, the oboe usually receives the qualification of "nasal", and the character of the flute is frequently described as "airy" or "sweet". It is not surprising to find these topics in Reymore's work, as the evoked features of imagined instruments include the representation of a prototypical sound (a kind of token) linked to a semantic description, which is highly dependent on the instrumental family. Though semantic descriptions of timbre may be useful in analysis aiming to link musical content to semiotic meaning, they still do not enable students to solve concrete and practical orchestration problems.

Given that we retrieved only one result, we expanded our search criteria to "orchestration" AND "music". We obtained three types of articles: computer-aided composition systems [4], descriptions of frequent orchestral combinations [5; 6], and those linking timbre perception to grouping mechanisms [7–10]. All of these authors coincide in one point: there is no formalized theory of orchestration because of its complexity. At best, there are descriptive and prescriptive models whose nature is semantic, mathematical or both. For instance, Carpentier et al. [4] worked with the software Orchidea, developed by Cella (2008–2020). This software enables the following sequence: 1) the researchers input

the parameters of the signal to be obtained; 2) the algorithm of the program searches among thousands of sound samples from its database; 3) the software generates several outputs of sample combinations that allow obtaining the desired signal. Carpentier and other researchers linked to the Institut de recherche et coordination acoustique/musique [IRCAM, Institute of Acoustics/Music Research and Coordination], through various works, showed the performance of the software Orchidea. One of their strongest arguments is that working in a computer-assisted environment helps to come up with unintuitive combinations. From our point of view, this model is prescriptive and resistant to predictions as its pedagogical potential is not very different from the prescriptive treatises of orchestration of the nineteenth century. We may establish an easy comparison with the following quotation from Berlioz's *Grand Traité d'Instrumentation et d'Orchestration modernes* [11, p. 125]: "La mélange des sons graves du Cor Anglais avec les notes basses des Clarinettes et des Cors pendant un tremolo de Contre-Basses, donne un sonorité spéciale autant que nouvelle, propre a colorer de ses reflets menaçant les idées musicales oú dominent la crainte, l'anxiété"[1].

Chon, Huron, and DeVlieger [5] summarized the most frequent combinations found in orchestral repertoire from 1700 to 2000. This information can be very useful in music analysis to generate expectations and distinguish between the normative and the extraordinary use of instruments. Though, if applied to the orchestration pedagogy, it is rather prescriptive and idiographic than nomothetic. That is, the statistics of the most frequent combinations addresses "what" questions, but not "why" and "how" [6].

The most promising path to the further development of the art of orchestration seems to be the one proposed by McAdams and colleagues [7–10]. Their works draw important conclusions on how timbre similarities or dissimilarities can enhance or modify the perception of the compound elements of musical tissue. Insight into the art of orchestration made from the perspective of the timbre psychoacoustics has the potential to elaborate a new pedagogical approach, where not only the "what-to-do" questions but also the "why" and "how" underlying rationale would be addressed. The main issue of this kind of studies is their echological validity: the stimuli used in the experiments and the performed tasks do not find parallelisms in real life contexts (listening to live music performed by acoustic instruments).

We have indicated earlier there is no formalized theory of orchestration because of its complexity (see, for example, McAdams' discussion [8]). It is logical to pose the following question: how the orchestration is taught? For the present work, we do not consider composition with virtual instruments, nor computer-assisted composition or orchestration software, for several reasons. Acoustic instruments present idiosyncrasies and limitations that virtual instruments can override with an appropriate parameter manipulation. For instance, an oboe cannot play triple tonguing, while it is possible to program a virtual instrument to simulate this technique in any register and dynamics. The piccolo flute in its highest register can pierce the whole orchestra, but playing soft is impossible in this register, which is easily changeable in a computer-assisted environment. That is why we reject recordings or music based on virtual instruments as a source of nurturing the auditive experience in the orchestration domain. The recording, production, and post-production

[1] Translation from French: The combination of the low sounds of the English Horn with the low sounds of the Clarinets and Horns during a Double Bass *tremolo* yields a special and new sonority, that is appropriate to color the musical ideas with menacing hues, where fear and anxiety reign.

processes corrupt the real interrelationships among instruments and orchestral masses. For instance, the live performance of the *Concierto de Aranjuez* for guitar and orchestra composed by Joaquín Rodrigo in 1939 has nothing to do with its recordings, where the guitar's sound is significantly potentiated. Also, apprentices may configure an unreal image of technical and dynamic possibilities of orchestral instruments, especially in the case of virtual instrument usage.

Another reason is the problem of professional intrusion, which is especially visible in multimedia platforms (YouTube and others) and production. People with basic musical formation or no formation can "compose" and "orchestrate" assisted by that technology. One more powerful reason is that it seems technology is synonymous with progress. Nevertheless, lately, we have seen how it has jeopardized the art of music in several domains: 1) the use of virtual instruments saves costs of hiring musicians; 2) instead of hiring professional composers or orchestrators whose services are expensive due to their high qualification and specialty, it became possible to recur to amateurs and dilettantes; 3) discredit of the profession of composer-orchestrator; 4) loss of the essence of the art of orchestration in favor of industrialization; 5) production of standardized objects devoted to easy consumption instead of art-works; 6) illegitimate claiming of all these dilettantes they make art; 7) pretension of these dilettantes to general validation of their products as artistic works. It is reasonable to suspect the hidden aim is to save time and costs while dressing this aim up with pretended artistry and progress. Any questioning of its value triggers multiple accusations of possessing retrograde and anti-technology perspectives that restrain progress.

We must make clear our point in this respect. The technological revolution has changed our lives irrevocably: many tasks assumed by technological gadgets simplified and alleviated our day-to-day and increased our life quality. This utilitarianism is contrary to the same essence of arts. The throes of arts are never simple but are made of intricate esthetic experiences which are subtle and resistant to mathematization, semantic description, and objectivation [12, p. 17]. Consequently, arts can only emerge from human interactions [12, p. 18]. YouTube or other online resources are not valid for learning such a complex human function.

In the anterior paragraphs, we discarded the computer-assisted orchestration path. We want to state clearly that the scope of the present paper considers live and paper-and-pencil-based orchestration. That does not discard the use of synthetic instruments or musical text processing software, but we insist this art cannot lose its human soul. We must repeat here that we have not retrieved scientific literature on orchestration pedagogy, although there is literature concerning different orchestration issues.

Brief history of orchestration teaching

If there is no formalization of live orchestration, how is it taught? Can orchestration teaching be improved? Let us make a very brief historical review of the literature on orchestration and instrumentation. In this paper, we understand *orchestration* refers to scoring for an orchestra, while *instrumentation* implies scoring for smaller ensembles (chamber music). Both of them can be a part of the process of composing an original piece or be an arrangement of an existing piece (for the piano, string quartet, different duos, etc.). The aim of orchestration and instrumentation is not just to obtain some kind of colorful

sound, but to highlight the musical structure, emphasize musical ideas to make them understandable to the audience, and provide the necessary balance between uniformity and variety to preserve the *Gestalt* of the piece of art.

The evolution of the art of orchestration is linked to the composers' social and professional profiles. In the 17th century, music masters were typically servants at European courts and noble houses. They were multi-faceted professionals who reunited in one person a virtuoso player (typically of a violin and different keyboard instruments), a teacher, a composer, a rehearsal master, and a conductor (who conducted playing among the musicians). If a music master had an apprentice, the latter followed the former in his quotidian chores and learned hands-on. It is reasonable to think that there was no need to write and publish instrumentation textbooks because the master directly and constantly supervised the progress of his apprentice. Notwithstanding, treatises dating from that period contain musical theory and instrument vademecums[2], such as Agricola [13], Praetorius [14], and Mersenne [15; 16].

The orchestra, as a reasonably standardized entity, was not established until Lully under Louis XIV (with a very loose definition of "orchestra" [17, p. 70–1]) or even much later, with Haydn and Mozart [17, p. 167]. These masters and other minor composers, following the uses of the Baroque and Classical periods, were extraordinary violin players. Their apprentices were required to practice enough to become virtuoso players, apart from acquiring composition skills. In this scenario, music masters and their apprentices scoring for the bowed instruments was very advanced, but they needed help to deal with the other orchestra instruments. Three possible solutions to this problem were: 1) learning to play some of the other instruments, at least the basics, for appropriate scoring; 2) interviewing the players to collect as much useful data as possible for correct scoring; 3) reading a book describing the other instruments, their mechanics and technical possibilities. This last option belongs to the domain of vicarious learning. Humanity took advantage of vicarious learning. Instead of conducting a study or learning to play an instrument, it is possible to save time and resources by reading a book or a publication. In concordance with that profile of composers-violinists, early books on Intrumentology[3] appeared. Those books aimed to meet the necessity of composers to get familiarized with wind instruments. In 1772, Francœur published a book with a meaningful title, *Diapason Général de tous les Instrumens à Vent*, and the following foreword: "The Experience made me aware that it is impossible to score correctly for the wind instruments, without having performed a detailed study on them, I believe that to save the long-term apprenticeship and derived difficulties it was mandatory to write down some basic principles" [18, p. iii].

In the same vein, the treatise published by Vandenbrock in 1793 [19] was focused only on wind instruments. Besides describing them, the author illustrated easy and difficult passages for different winds. Since then, three formats have been adopted for the instrument vademecums: 1) hyper-reduced format, where only the essential information is provided and typically one page or less is allotted to each instrument, for instance, the

[2] Here, we use the term *instrument vademecum* to refer to handbooks that contain monographs on musical instruments. The purpose of such handbooks is to provide basic information on the technical possibilities and limitations of different instruments.

[3] We borrowed the term *instrumentology* from the Russian word инструментоведение as it is more accurate in describing the nature of this brand of knowledge. As it is obvious, it cannot be confounded with instrumentation (scoring for ensembles) nor with organology (that deals with the physics of sound and instrument construction).

encyclopedia of LeDhuy from 1833 [20]; 2) hyperextended format, where very detailed information is provided, including *solo* excerpts to illustrate the limits of the technical possibilities of each instrument, such as widely used *Technique* of Casella and Mortari of 1970 [21]; 3) hyper-specialized vademecums focused on only one instrument where a detailed description of its techniques is provided, and, in some cases, only one technique is extensively discussed. A recent representative exemplar of this type of handbook is *Instrumentology* by Popov [22]. The author provides general information on each instrument group (organological, technical, and mechanical aspects) at the beginning of the corresponding part and then proceeds to the individual instrument descriptions. This format is especially appropriate for apprenticeship stage as it comprehends information synthesized from the composer's perspective and contains evaluation activities that highlight essential aspects to be retained.

Towards the 19th century, with the appearance of the first conservatories all over Europe [23, p. 270], the music teaching paradigm and the profile of composers changed drastically. First, increased the number of disciples per teacher, so the constant follow-up was not possible anymore because the teaching time decreased to one session a week. Second, the tonal music and its vertical conception found better resonance among players of polyphonic instruments, particularly the piano. Due to this, the biggest part of composers of the 19th century were pianists. Third, the hands-on learning paradigm shifted to a theoretical approach. We can easily observe the parallel evolution of handbooks and treatises on the instrumentation of the 19th century to meet the new demands of composition teachers and disciples. The growing tendency for composers to be pianists made it necessary to extend the instrumentation vademecums with descriptions of string instruments.

On the other hand, since composition disciples could not have regular access to the orchestra, their auditive experience of orchestral forces' interactions was seriously handicapped. Kastner was among the first pedagogues and composers to point out that instrumentology was not enough to score properly for the orchestra [24, p. i], and his response to meet this new demand (how to score for the orchestra) consisted of offering lists of the most frequent instrument combinations. Kastner divided his textbook into three parts. In the first place, he offered an illustrated thesaurus of the most frequent instrumental combinations, for example, the first oboe, or the first clarinet, or the first flute, or altogether, usually doubled the first violin, and the second of these woodwinds doubled the second violin. The second part included an analysis of the excerpts selected by Kastner, who highlighted interesting instrumental combinations and briefly described their resultant timbre. Band or military music occupied the third part. In sum, the basis of orchestration teaching throughout the nineteenth century was 1) to memorize semantic descriptions of technical and sound possibilities of different instruments and 2) to learn by heart the most successful combinations discovered by the previous music masters. Berlioz (1855), Gevaert (1890), and others followed the example of Kastner with the noble aim of introducing novices into the art of orchestration. Throughout the nineteenth century, many instrumentology vademecums and thesauruses of orchestral combinations appeared.

At the beginning of the 19th century, the orchestra established its bowed core, the quartet (though actually, it was a quintet, as the double bass frequently doubled the violoncello, virtually, four-part writing was common). By the mid-19th century, a fully chromatic and self-contained woodwind family became complete. Towards the end of the 19th century, the orchestra integrated a fully chromatic and self-contained brass family. That

posed more and more demands on the memoiristic resources of composers and their disciples.

Towards the end of the 19th century, some authors tried to alleviate the burden of the memoiristic load. They recurred to a simple and effective metacognitive strategy of generalization. This way, the configuration of the learning program acquired the following sequencing:

Students, following the handbooks, began by studying bowed instruments and their intragroup combinations.

The study of wind instruments (typically, woodwinds plus French horn) followed the bowed instruments.

Combinations of bows and wind instruments or *le petit orchestre [the small orchestra]* was the third target of the learning program.

Then, the students proceeded to the studying of brass (natural and chromatic) instruments, as well as their mélange with the small orchestra.

The full orchestra (combinations of *arci*, woodwinds, brass, and percussion) was the colophon of the learning program[4].

Specific training tasks proposed for the students to acquire and develop orchestration skills were: 1) instrumentation/orchestration of piano excerpts [25, p. 235–42; 26, p. 45]; 2) reorchestration of piano reductions and comparison with the original orchestration [26, p. 114; 27, p. 1]; 3) reduction from the orchestra score to piano score; and 4) reduction of orchestral scores to a smaller ensemble or piano [28, p. 42–9].

* * *

The pedagogical method of Rimsky-Korsakov published in 1913 by his disciple Steinberg can be considered a breakthrough in instrumentation and orchestration teaching and learning. The structure of his treatise is as follows: the first part addresses a brief review of the four orchestral families. The remaining parts of the book are devoted to examination, explanation, and illustration of orchestral gestures: melody duplications, varieties of accompaniment, harmonic sustain, orchestral crescendo and diminuendo, echoes, antiphons, orchestral accents, etc. We can say it is a higher lever metacognitive strategy because the grouping concerns orchestral families and their contribution to the structure of the music.

Rimsky-Korsakov was not the first author to address this issue. We can find commentaries on some orchestral gestures (crescendo, diminuendo, balance, color) in previous treatises, for instance, Prout's [25, p. 136–45]. The novelty of Rimsky-Korsakov's treatise was his *Gestalt* conception concerning the musical structure. So, Chapter II provides examples of orchestral operativization of Melody; Chapter III deals with Accompaniment; Chapter IV addresses the general orchestral fabric of music, including echoes, *tutti*, *soli*, dialogues, *crescendo*, and *diminuendo*, accents, ornaments, etc. Rimsky-Korsakov forwarded a big step in the orchestration pedagogy: he formalized general rules concerning the structure of the musical fabric. Notwithstanding, the basis still was the memorization of instrumental descriptions and combinations. The difference resided in that Rimsky-Korsakov provided context and tonal function to different instrumental combinations, which allowed for a more comprehensive analysis of orchestral scores. Nevertheless, the orches-

[4] This sequence reflects the historical development of the orchestra.

tration practice still had to be memory-based. Consider how Rimsky-Korsakov operatives the orchestral accent: "When the chord is attacked by the woodwinds in *piano*, the same cord must be reinforced by the shot of strings, preferably in double, triple quadruple stops" [29, p. 130]. It sounds logical to an experienced orchestrator, and this combination is easily identifiable in the score. Nevertheless, it may be difficult for an apprentice to produce this gesture without copying from the model, and, fortunately, Rimsky-Korsakov provides plenty of them.

The progress foreseen by Rimsky-Korsakov seems to paralyze for almost one century. In 1921 Florence Fidler published her *A handbook of Orchestration* [30] with her method consisting of the following activities: 1) memorizing descriptions of individual instruments and successful instrumental combinations; 2) analyzing a set of scores the author selected (guiding the analysis by the learned assertions; this would prime the following activity); 3) scoring many piano pieces for strings, then for a woodwind instrument *solo* accompanied by strings and the remaining woods, then for the small orchestra and, finally, for the full orchestra. The pieces considered by Fidler for orchestration contained plenty of orchestral gestures, such as *crescendi*, accents, phrasing, *tutti*, etc.

Piston's treatise from 1969/1980 [31] is similar in its conception to those of French authors from the end of the 19th century. Almost two-thirds of the book is devoted to instrumentology, which is very detailed and well-illustrated. Once memorized the first part, Piston proposes to pre-analyze orchestral scores in the following manner: the student must examine each voice from the perspective of the player (the memorization of characteristics of different instruments should facilitate this task); attention must be paid to the difficulties, time allotted to play, idiomatic gestures, etc. Afterward, the score analysis can take place, proceeding to identify the major compound elements of the musical structure. Also, notes must be taken on the most frequent orchestral solutions. Such a detailed process, tacitly understood by Piston, should nurture the orchestral imagination and thinking.

The process of orchestration is inverse to the analysis. Here, the first step would be to segment the structure into melody, accompaniment, contrapuntal lines, etc. [31, p. 356]. The second step would consist of assigning instruments to the identified structures. Once the general framework is sketched, it would be necessary to go into detail about fixing the excessive spacing, highlighting the accents, redistributing instruments for a better balance, etc.

A plethora of new treatises on instrumentology, instrumentation, and orchestration appeared in the last fifty years. Some of them presented vademecum format and were specialized only in instrumentology, like Del Mar (1981, 1987), Casella and Mortari (1970), providing very detailed descriptions; or, on the contrary, were concise and schematic, like Agafonnikov (1981), Ficher and Siccardi (1983), and Malter (1966), among others. Treatises such as Blatter (1995), Adler (2002, 2016), Sevsay (2013), and Peters (2018) are widely used in pedagogical practice for three reasons: 1) they reunite instrumental vademecum and thesaurus in one book, 2) they provide information on orchestral gestures in a format that is very close to pedagogical positivism [32], i. e., trying out every possible instrument combination and commenting on its phenomenology, 3) they offer instrumentation and orchestration exercises whose difficulty increases with the number of implied instruments and instrument families. Finally, some treatises have resumed the throe opened by Rimsky-Korsakov by addressing an effective treatment of orchestral gestures [33–35].

The aim of the present study

When the composition teaching paradigm shifted from a hands-on to a theoretical model, semantic learning became the most important component in acquiring instrumentation and orchestration skills. In this study, we want to explore the impact of the semantic approach. Our interest is motivated by the mismatch between the input (verbal learning) and the required output (procedural tasks). Our baseline will be the degree of proficiency in the instrumentation task of students who had undertaken one course of instrumentology and had no instrumentation/orchestration training. The performance of this group will be compared to the performance on the orchestration task of students of Composition Degree with at least one course of instrumentation and orchestration. Since it is an exploratory study, we do not have previous expectations. We will assess the quality of the task, considering the sound balance, the timbral treatment of musical structures, and the *Gestalt* of the overall sonority. Also, we will analyze the internal strategies used by the participants in the instrumentation/orchestration task.

Materials and methods

The study was conducted at the Royal Conservatory of Music of Granada (Spain). The management team received an oral and written briefing, where the main guidelines of the research to be conducted were pointed out. Also, written informed consent was signed by the institution chairman.

Participants

Sixteen participants were recruited through word-of-mouth and online advertising. All of them were provided with informed consent. Eight of them were pursuing a Composition Degree (composers group), while the remaining eight were pursuing a Musical Pedagogy Degree (non-composers group). All of them were surveyed to explore their musical background (see the Table below for relevant demographic information).

The sample of the Table above roughly represents the demographic situation of two different Degrees: whereas there are more women in Pedagogy, the number of female composers is drastically lower. Regarding the age, it is higher among the non-composers

Table. **Participants' demographic data**

Group	N (f; m)	Age (years)	Conducts N (f; m)	Years of instrumentation training
Composers	8 (1; 7)	22 (SD = 1.1)	2 (0; 2)	2.9 (SD = 0.8)
Non-composers	8 (5; 3)	25.1 (SD = 6.4)	1 (0; 1)	0*

Note 1: The group of non-composers was made up of the Pedagogy senior students. Students from different courses, except freshmen, were admitted to the composers' group.

Note 2: The reference textbook for the courses of instrumentation taken by the Composition students was Adler (2002).

*Specific note: The group of non-composers took one course in instrumentology (their reference textbooks were Casella and Mortari [21], and Berg and Stork [36]).

group (Pedagogy) because some of them were pursuing their second Degree after having completed a Degree in Music performance. One of the most important questions of the survey was whether they conducted any ensemble. The conduction allows the exposition to live music. This frequent behavior of approximation to live music can influence the decision-making in instrumentation tasks. When conducting, we heuristically learn the most frequent and successful combinations, different models of accompaniment, the most frequent use of instruments, bass models, the use of the brass instruments models, etc.

Materials and task

The inquiry was carried out at the Royal Conservatory of Music of Granada (Spain). The participants undertook the task individually. The administration was paper-and-pencil based. They were allotted one hour and a half to complete the task. All of them finished before the time was out. The participants were not allowed to refer to any support material. They were invited to clarify doubts about the order of the instruments in the template, the number of instruments per voice, and whether it was mandatory to use all the disposable instruments. Previously to the instrumentation/orchestration task, all participants were provided with written informed consent. Also, they completed a survey in which they were asked about their experience in conducting any ensemble, playing in any ensemble, years of formal training in instrumentation, the instrument(s) they played, and their reference textbook of the course(s) of instrumentology (non-composers group) and instrumentation/orchestration (composers group).

Materials. Since the non-composers completed only one course of instrumentology and were not explicitly taught to orchestrate, it was necessary to be sensitive to the degree of difficulty of the task assigned to this group. The beginning of *Melodie* No. 2 by Ibert (the first four measures for piano) was selected for the non-composers group. Ibert's fragment is originally scored for piano and voice, and it is horizontally oriented.

A piano reduction of "Romeo and Juliet" (overture-fantasia, mm. 185–190) by Tchaikovsky was selected for the composers' group (see the Figure below).

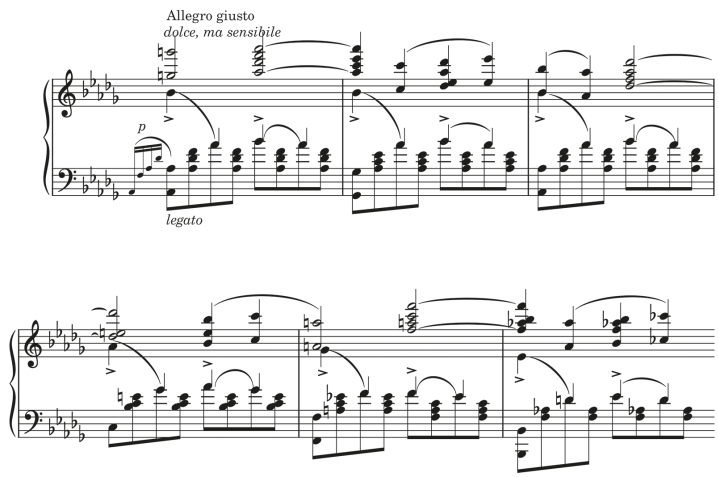

Figure. Fragment proposed to the composers' group. Tchaikovsky, Pyotr. Romeo and Juliet (Overture-Fantasia), TH 42. Author arrangement

The reduction of the Tchaikovsky excerpt was made by the author of the present paper. This excerpt is more vertical (harmonic) than Ibert's excerpt and presents clear segmentation in different layers. Its main difficulty consists in identifying the layer functions to instrument them effectively. This excerpt was chosen because it admits different functional instrumentations and levels of timbric complexity.

Task. All participants were asked to instrumentate (non-composers) or orchestrate (composers) the given excerpt. The non-composers were invited to instrumentate their fragment (Ibert, Melodie No. 2, mm. 1–4, piano part) for a woodwind quintet. The composers were invited to orchestrate their excerpt for a symphonic orchestra (2 flutes, 2 oboes, 2 clarinets, 2 bassoons; 4 French horns, 2 trumpets, 3 trombones, and tuba; timpani; 12 violins I, 10 violins II, 8 violas, 4 violoncellos, and 3 double basses). As they were doing the task of instrumentation/orchestration, they were asked to write down (verbalize) all their choice-making regarding the use of timbre, instruments, their considerations, possible difficulties, analysis, the management of dynamics, agogics, etc. Both instrumentation/orchestration and verbalization tasks were performed in pen-and-pencil format.

Results

The content analysis revealed the most relevant linguistic codes ("best register", "melody", "bass", "layer", "accompaniment", "timbre mixture", "avoid leaps", and "timbre coloring") and the sequence analysis yielded the most frequent tokens or mental categories the participants recurred to during the task. Among the non-composers emerged two main categories: *idiomaticity* and *voicing*. Also, proto-division in layers (polarization melody-bass) and concern about the instrumentation of discrete gestures were noted (resolving the chromatic opening of the F4, measure 3, 3rd crotchet (m. 3), right hand, to the vertical major second F4-G4, m. 34, right hand; the resolution of the octave leap to an impossible for the bassoon note, omit an "unnecessary" octave doubling in m. 2 to solve the appearance of an intruder — C3, left hand — among otherwise 4-voiced texture).

Among the composers, the most relevant category was the *segmentation in layers*. The category *idiomaticity* followed it. Also, the sequence analysis revealed the concern about *voicing* (the continuity of a horizontal line with the same timbre(s) from the beginning to the end of the fragment). The category *timbre coloring* is more complex and is further elaborated in the paragraph devoted to the composers' group.

Non-composers

All participants examined the piece to check whether the natural distribution of the woodwind quintet fitted the horizontal lines from the beginning to the end of the fragment. No reference to harmonic or contrapuntal processes was detected. All of them operated under the precepts of instrumentology, as judged from their written down utterances: "best register [of the flute]", "transpose F1 one octave higher because it is not included in the docile register of the bassoon", "the horn will sing the upper voice of the bass clef because it is the only instrument whose diapason enables it to play this line from the beginning to the end", "the clarinet will sing the lowest voice of the treble clef because it can reach the lower notes and because of its timbre plenitude in the low register", "I transposed the bass an octave higher to allow the final octave leap in the bassoon". We encompassed

all these quotations under the category of voicing because they are related to the possibility of assigning one instrument to a given line from its beginning to the end.

Another relevant category was *idiomaticity*. The solutions ranged from simple transcription to the natural five-instrument distribution with minor adjustments (scoring one note an octave higher or transcribing the upper voice an octave higher to make it suited to the best register of the flute) to the intricate interplay of transferring the melodic line from one instrument to another to keep remain in the best register of the used instruments. One of the participants reached the extreme of changing the vertical order of instruments every beat. Another participant truncated the vertical order of the voices "for the sake of novelty". Also, he discontinued the timbral horizontality of the voices. Surprisingly, he achieved a well-sounding and balanced result because every assigned instrument played in its best register.

Even though the fragment was contrapuntal, three participants verbalized the importance of the polarization melody-bass: "I will score the melody an octave higher for the flute to have it playing in its best register"; "being marked mezzo-forte, I think it is a good option to score the flute doubling the oboe at unison for the melody voice… their timbres will compensate each other's imperfections"; "I prefer to begin the bass with the oboe for its full sonority… and then continue with the bassoon scored one octave higher to make it sound more prominent".

Only two out of eight exercises were satisfactory, rounded, and balanced. The two participants who conducted an ensemble were responsible for them. The remaining exercises were loaded heavily in the intermediate voices because of the oboe use.

Composers

Here, the participants began by analyzing the score and segmenting it into vertical layers. They annotated possible voicing difficulties and proposed a tentative solution for each detected case. Since the vertical construction was clear, the biggest part of the commentaries addressed the treatment of the layers. The segmentation they established was (listed according to the frequency of direct and indirect mentions): melody, accompaniment, under-voice, bass, and pedal.

Idiomaticity also emerged as an important category. All participants scored the first arpeggio for cello because they considered it an "idiomatic" gesture precisely for this instrument. The instrumentation of the melody differed from one participant to another: first and second violins in octave doubling; flutes; upper arci in octave doubling in the first semi-phrase, then flutes and clarinets in the second semi-phrase "for timbre interplay" (this participant understood the fragment as a phrase divided into two semi-phrases, so he implemented a timber-based question-answer orchestral gesture); flutes and clarinets with the first violins in *divisi*; muted trumpets doubling the violins an octave lower; etc. All of these solutions for the melody were idiomatically correct for the proposed instruments (good register, possibility to sing the assigned voice from the beginning to the end, correct dynamics). The problem in all cases, but one, was the lack of balance because of heavy-bottom orchestration.

It is very interesting to observe the differences in the instrumentation of the under-voice, the *suspiratio* layer (Bb4–Ab4). Two of the participants opted for the cello in its high register. What attracts the attention is that they departed from different

reasoning to use this instrument. One of them wrote he "scored it in the high register looking for a flute-like sound… and keeping up with piano marking dynamic". Another one preferred the cello in this register because "something inspired" him for "the violoncello employment" as he believed that "it could sound rather expressive". Otherwise, there was no consensus on the instrumentation of this layer (violas and clarinets "because they have similar function"; one trumpet; one horn; two horns; trumpet and horn "because their timbre is similar in this register"; trumpet, horn, and "viola to uniform the discourse").

One of the participants changed the quavers of the accompaniment by quarter notes to simulate the piano pedaling. Another participant preferred to make the same accompaniment pointillist using horns and trombones. Brass instruments were the preferred ones for the accompaniment. However, there was no consensus among the participants regarding their number or combination, nor for the bass instrumentation.

The vocabulary related to the timbre was more complex and rich among the composers as compared to the non-composers. Some examples are: "velvety sound" of horns, horn as a timbral bridge, "[the timbre of the bassoon] unifies the discourse between woodwinds and arci", "the flute in its low register does not present projection", etc. All these utterances can be found in Fidler [30], Koechlin [37], Adler [38], and others. That indicates two facts: 1) timbre topics are repeated and inherited from generation to generation, and 2) memorization of timbre descriptions was effective among our sample of composers. The *voicing* category (timbre continuity throughout the same voice) emerged, but the composers were eager for using mixed timbres. The narrative products of composers reflect their doubts about the effect of the mixture they proposed.

Discussion

We will use the results of the non-composers as a baseline, whose description follows. It was interesting to observe the emergence of a stronger category, *idiomaticity* (docile register, dynamics), and a feebler *voicing* category (avoid leaps, lead the line from the beginning to the end with the same timber). Generally, when it was necessary to choose between the idiomatic approach and the voice continuity, the students favored the former. In all cases but two, the resulting sound of the instrumentation task was unbalanced due to heavily loaded intermediate voices because of the oboe used in its lower register. In two cases, the *Gestalt* of the excerpt was disturbed because of the capricious timbral interplay. Only one participant achieved a round and balanced sound without altering the original score. This participant usually conducted the band of his native town.

We presume the explanation for favoring the idiomaticity rather than other aspects resides in the nature of the instrumentology course they completed. These participants studied verbal descriptions of mechanics, diapasons, and techniques of individual instruments. Two of the most stressed aspects during the instrumentology course were the diapason of different instruments and their best registers. The narrative of the participants of this group evidenced their main guidance to assign one instrument or another to the voices was the lower and the upper limits of different instruments' diapason.

After analyzing instrumentation exercises of non-composers, the general impression was they were unaware of the relative strength of different instrumental registers. They did not consider the basic rule to preserve the overall balance, which consists of placing

wider intervals at the bottom and narrower intervals at the top. The reason is simple: they studied this rule applied to harmony exercises, but they did not relate it to the instrumentation. Also, they were not taught explicitly to use it in this context. On the other hand, we observed a very optimistic use of instruments: for example, five of them asked the flute to play forte and oboe to play softly in their lower registers. Here, we can adduce two possible explanations. One of them was that they worked with Casella and Mortari's textbook [21], which offered plenty of examples of individual scoring, some demanding a high degree of virtuosic playing. Second, this group of participants was never taught any basic concept of instrumentation. The balance, the roundness of sound, and the formal uniformity were simply out of their cognition.

Finally, we must remark that all the participants of this group mentioned the words "melody" and "bass" indicating their presence among their linguistic codes linked to the musical structural functions. Notwithstanding, only three participants (two of them conducted) made it to offer an effective instrumentation solution reflecting this polarization. We deduce from these results that, though this group was not explicitly taught instrumentation, the exposure to music and general musical training in analysis, harmony, instrument playing, etc., led them to intuitively establish and oppose vertically two main strata: outer voices (main voices) and inner voices (*ripieno*). The practical experience acquired through conduction helped two of them in achieving a satisfactory solution.

The analysis of the composers' products also revealed that the most relevant categories were *idiomaticity* and *voicing*. The procedure they followed to orchestrate their excerpt was very similar to the suggested one by Piston [31]. We described it in the Introduction section of this paper. The first step was to analyze the excerpt to identify the compound elements, the second step was to outline the leading instruments for each identified element, and finally, they went on to fix the details of orchestration.

It is worth saying that important parallelism may be traced between the general procedure described by both groups, though the degree of sophistication is higher among the composers. The main result of the analysis performed by the participants of both groups was the segmentation of the excerpt in layers whose salience was unequal in their contribution to the musical texture. In the group of non-composers, it was rather a basic segmentation, which in the majority of the cases did not find an appropriate operatization nor was linked verbally to the necessity of concrete timbral solution. Among the composers, this segmentation was sophisticated and there was an explicit intention of linking the relative importance of different layers to the timbre salience (though the timbre choice was not always satisfactory).

During the drafting phase, the participants of both groups evidenced they were guided by the diapason of individual instruments, though the composers were more sensitive to and more consequent with their knowledge of the best register of individual instruments. Among the non-composer, the best register was present at the verbal level, but it was not pervasive to the procedural level.

The final step was the most critical for both groups. The composers expressed more doubts than non-composers about the final sonorous result, whether some instruments would blend or whether some combinations are successful. That is not surprising due to 1) non-composers were not trained to achieve balanced sound; 2) the level of difficulty in terms of the number of instruments to manage was higher for the composers. On the other hand, these doubts and generally unbalanced solutions were surprising, as composition

students have been exposed to different models (visual and musical analysis of scores) and had to learn different successful combinations of instruments.

A more detailed analysis of composers' narrative products revealed that semantic input of information on combinations gave the corresponding output in the semantic domain. For instance, utterances such as following "inclusion of clarinets", "concatenation of flutes and oboes", "I scored for the cello bow-up and then bow-down after the first gesture to keep the player in tension"; "I used bassoons and tuba for the bass, reinforcing the half notes of the measures 2, 3, 6 with cellos and double basses playing pizz." reflected the memorization of some instrumental combinations. Nevertheless, this semantic knowledge was unlinked to the orchestration procedures and the comprehension of the context of these combinations.

It is worth noting two cases from the composers' group. The most functional orchestration was accompanied by really illogical reasoning (one of the participants of the composers' group). On the contrary, the outcome of the best structured and correct reasoning was an imbalanced orchestration (another participant from the composers' group). This could be explained by the fact that the former had experience conducting large ensembles (the band of his native town) and the latter had not. That is, the former somehow knew what combinations functioned (from the experience of conducting and exposing himself to live music) and implemented tried-and-true solutions, probably extracted heuristically from the observation of the band he conducted. His verbalization evidenced that this implicit and statistical knowledge was not embodied in general rules, even though he had completed at least one course of instrumentation. His procedural knowledge was disconnected from the declarative memory, despite formal training in orchestration. We have to point out that among the non-composers, the most balanced and sound-rounded exercise was performed by one of the students who conducted an ensemble. The other non-composer who conducted an ensemble handed in the exercise where the voices were scrambled "for the sake of novelty". This latter exercise, though unconventional and lacking uniformity, still could be graded as satisfactory in balance and roundness.

Conclusions

Before proceeding to the conclusion, let us summarize the main point of the obtained result. Semantic learning of individual instruments' characteristics and techniques, accompanied by training in composing idiomatic pieces, led to reasonable success in managing these instruments' scoring. The received feedback in the format of commentaries, corrections, and suggestions, made by an expert (the instrumentology teacher or professor), proved to have the potential to shape the idiomatic scoring for individual instruments. All participants from the non-composers group were aware of the limits of the diapason of different instruments. On the other hand, they had semantic knowledge of the best register of the instruments (according to their verbalization) that configured the template of their exercise (woodwind quintet), though not all of them applied this knowledge during the task.

We found more sophisticated behavior among the composers. Their musical and narrative products led us to conclude that the following four learning activities prevailed in the instrumentation training they received: 1) instrumentology; 2) memorization of successful instrumental combinations with very variable casuistic; 3) analysis of orchestral scores

aiming to recognize idiomatic use of instruments and learned successful combinations; 4) instrumentation and orchestration of piano excerpts aiming to apply their semantic knowledge of different instruments and the most successful instrumental combinations. The feedback on their exercises was oral, as in the case of non-composers. Their teachers or professors offered them commentaries, suggestions, and corrections. We presume the participants of this group, compared to their non-composers peers, presented more sophisticated behavior related to instrumentation partly because the feedback they received was more complex due to a higher number of implied instruments.

The final point of this summary has to do with the structure of the music. We know that timbre interacts with other musical parameters and influences the perceived overall structure [8]. The participants of both groups performed structural analysis of the excerpt (melody-bass among the non-composers; different functional layers, such as melody, accompaniment, bass, and under-voice among the composers). Regarding the interrelationship between the timbre and the structure, we detected three approximations: 1) six of eight non-composers, though being aware of different structural elements, did not verbalize the necessity to link the timber to the structure; 2) seven of eight composers were aware of the structural segmentation and verbalized their intention to differentiate the foreground from the background employing different timbres, though the operatization of this aim was not successful; 3) two non-composers and one composer (all three conducted) differentiated verbally the background from the foreground and succeeded in its timbral expression.

Overviewing the results of both groups, there is no doubt that vicarious learning allows impressive results. Only one course of instrumentology enables students to score idiomatically for a high number of individual instruments. On the other hand, instrumentation and orchestration courses raise more concerns. The institutionalized model of teaching that emerged as a consequence of introducing composition in conservatories became necessarily semantics-based. We have seen that its main benefit was learning acceleration. Its counterpart was a serious handicap concerning the management of multiple timbres: the transference of semantic information to procedural memory is somehow jeopardized. This is congruent with the findings of the classical experiments by Dodson [39] about the impairment of acquisition of a procedure because of the intrusion of semantic descriptions.

The case of the participant who conducted an ensemble is especially relevant to this point. With the same semantic training as their group colleagues, the quality of exercises of students-conductors was substantially higher than compared to the mean performance of their group. It confirms that it still holds that the way to gain good knowledge about timbre combinations "is only by training the ear to recognize the sound of each combination — to know, how, for instance, the Flute and Oboe in unison sound" [30, p. 41]. In line with this point, Blatter [40, p. 300] wrote "the final test as to whether a chord has been voiced [properly] is the ear, not the eye, of the orchestrator". It seems the only way to teach and learn orchestration effectively is to guarantee that students can have regular access to large ensembles. In the actual model of teaching, where optimization of resources is prioritized, is impossible. That could make us conform to the esoteric nature of orchestration teaching, or expressed in simple words: "…orchestration, being an art and not a science, one must ever be prepared to find no good reason. Some questions are never answered" [31, p. 356].

Here we would like to make a reflection that begins with the following idea: the ears are the doors to the mechanical signals, and the sound comes into being within the brain. Consequently, we establish three levels of listening (not hearing, because we are interested in how this signal is interpreted by the brain). The basic one, sensual listening, makes us enjoy combinations of sounds and timbres. This type of listening is excellent to enhance the behaviors of approximation to the music. Its main limitation is its peripheral nature of the processing, it impels us to go over and over again our favorite pieces and very rarely, if ever, engages central thinking. The second or intermediate level, experiential or associative thinking, is culturally acquired. The musical uses sediment a series of topics (f. i. major modes are associated with emotions of positive valence; the contra ire is true for the minor modes) that can be learned throughout general musical training and education. The recognition of these topics enhances the understanding and the appreciation of the music. The third and highest level of listening is analytical. It arises from technical knowledge and engages our central processing. The reflection here is that we must know what we have to recognize through listening to maximally benefit our orchestration skills from the exposure to music. Nevertheless, as we have seen, even a mere exposition, without previous specific knowledge of instrumentation and orchestration, allows for extracting functional patterns (both participants-conductors from the non-composers group). The participant-conductor from the composers' group presented a significantly more effective orchestration product than his group peers did. Even though he did not connect the procedure with the declarative knowledge, we consider his results impressive and presume that the visible acceleration of his learning compared to his peers and the participant conductor from the non-composers group was because the previous semantic learning of successful combinations made him more sensitive to the recognition and appreciation of these combinations, and compare them with others. These processes do not necessarily have to develop at a conscious level to benefit from them, we can be unaware of them and still operate from the previous semantic knowledge.

The actual conditions of formal composition training impair regular access of composition students to an orchestra, except for occasional premiers. Ordinarily, the students are provided with verbal feedback on their orchestration exercises and timbre management they display in their original compositions. The main concern this feedback raises is, once again, the difficulty of transferring semantic information to procedural memory. Another difficulty is the consensus on the message. Do we share the same meaning of a token? Normally, our understanding is nuanced by our experience, context, perceptual idiosyncrasies, etc. It follows that it is difficult to establish consensus on semantic descriptors of individual timbres of instruments. On the other hand, even if a consensus is established because several people used the term "nasal" to qualify oboe, "ridiculous" for the bassoon, and "shrill" for the piccolo, this does not necessarily include everybody understands the same set of features under these terms. There are even more difficulties in memorizing instrumental combinations since they are capricious and elusive to generalization. Also, their application is very restricted, because any change in the register, dynamics, or instrumental configuration corrupts the initial balance.

Learning conditions of instrumentation and orchestration are extremely demanding due to a high degree of uncertainty. Nevertheless, we have observed an important qualitative distance between the non-composers and the composers. Let us examine its underlying reasons because these could show the way for further development.

We have detected two regularities. The composers were trained to recognize different compounding elements of musical structure, and they were explicitly taught these elements must be highlighted by some mechanism of segregation. The non-composers, instead, recognized different structural elements, but they did not verbalize the importance of the differentiation by the means of timbre, pitch, rhythm, etc. We deduce from this observation that the progress of composers, even with only one course of instrumentation and a huge memoiristic burden, gave them a significant advantage with the establishment and explicit expression of some general rules concerning the structure. We understand that the main tool here is musical analysis, as it allows for extracting patterns and regularities more easily, faster, and accurately.

When it came up to assigning different instruments to different voices or structural elements, the non-composers were unaware of timbral relationships and the composers were uncertain about timbral combinations. In either case, we observed poor performance in timbre management. Comparing both situations, musical analysis and timbre management, it seems evident that it is possible to improve the latter as the former has been improved through the years.

Regarding the musical structure, in the section devoted to the Brief history of orchestration literature, we saw a gradual movement from descriptive to nomothetic model. One of the most proximate exemplars of the latter is Banshchikov's handbook [33], where the author tries to draw some general principles out of concrete excerpts of orchestral scores. Through the analysis of this reference, we noted that his general (or functional) principles are akin to some *Gestalt* heuristics (though we do not think Banshchikov is aware of this fact as there is no mention of this parallelism in his handbook). Despite the attractiveness of Banshchikov's approach to the issue, there are three problems. The first one is that the formulated general principles are accessible through musical analysis of the excerpts but are hardly usable in orchestration tasks. It is mainly due to the lack of a systematized approach to low-level phenomena issues. That is, there is no solid rationale to reliably predict the outcome of concrete instrument combinations, which concrete instruments are better suited for a given function in the orchestral fabric, which instruments can be used as melodists and under what conditions, etc. The second problem has to do with the language. Though the author [33] is very systematic in his explanations, it is still difficult to transfer this semantic knowledge to the acquisition and development of orchestration competencies. Our position here is that music is a special kind of knowledge about sound, and this knowledge is characterized by its own semiotics, making it difficult to put this rhizomatic, highly specialized musical knowledge in words. That leads us to the third problematic issue: musical knowledge is accessible only through music, which demands a high degree of expertise acquired through intensive and extensive learning. That makes handbooks on high-level phenomena (such as Banshchikov's *Functional principles*) cognitively inaccessible to apprentices: words poorly reflect musical knowledge, and low-level phenomena are not understood. Therefore, we state that after studying instrumentology and before reaching functional principles of instrumentation, further research is needed to establish and make some general rules for timbre management explicit.

This exploratory study, though working with a very reduced sample, confirmed what some researchers intuited and claimed years ago: for efficient orchestration, there must be timbre management rules [8; 41, p. 458; 42; 43] before going into orchestral texture management. Here we would like to add not only timbre management rules are needed,

but also these have to interweave with general rules concerning the musical structure. Without this higher metacognitive level of material control, the orchestration will keep its status as esoteric art and will be poorly understood [9].

Afterword

Concerning timbre management, it is urgent to forward steps from the reigning descriptive and prescriptive to nomothetic model. We must take into account that throughout the last century more and more instruments (including synthetic ones) were introduced into the orchestral template and more satisfactory combinations were discovered. Also, some combinations that before were considered unsuccessful gained appreciation due to the shift in esthetic trends. The logical consequence of this growth is the increasing uncertainty. We postulate that general rules must be developed to allow a higher degree of control in this ocean of information.

Different domains could get the advantage of these tools. For example, the musical analysis of orchestral scores could be more informative if the timbre use rationale is comprehensible. Music listening would engage higher levels of processing if there were previous expectations regarding timbre employment.

One of the most interesting domains related to timbre management is timbral dramaturgy. There is much scientific and artistic research, but its nature is more descriptive. For instance, for Mahler, the horns personify the romantic hero [44]; Prokofiev recurs to the topic of fanfare music to create an epic atmosphere, which is later dissolved by the pathetic *chant* of the first violins retrieving the first movement diatonic theme [45]. The flute is frequently employed to symbolize sorrow [46], or on the contrary, pastoral idyll. The introduction of the "Prélude à l'après-midi d'un faune" composed by Debussy, the flute timbre also acquired magical-mystical properties [47]. Many great composers recurred successfully to the inherited topics on timbral dramaturgy guided by their intuition. The growth of the number of sonorities admissible in a musical scenario made contemporary composers rethink the links between timbre and its semiotic meaning [48–50]. It is fascinating how great composers from the past and the present are able to use timbre to transmit the valence of the emotions, the finest emotional changes, the personality and the mood of a character, the social contexts, etc. Right now, it is a mystery. But the deduction of general rules of timbre management could cast some light on this intricate world.

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