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The Initial teaching of intonation in the brass wind instruments and music reading in Spain. An exploratory study with music school teachers[1]

Jesús Tejada[2]; Adolf Murillo[2]; Borja Mateu-Luján[3]

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Abstract. Intonation is probably the most important component of good training on instruments with variable intonation, such as brass wind instruments. It is a complex skill that involves perceptual and productive aspects as well as the coordination of both. Due to a variety of factors, experts confirm that there is no specific and systematic approach to teaching intonation in this family of instruments, at least compared to other aspects of performance. This exploratory study is part of a larger research project which aims to identify the praxis of brass instruments and musical theory teachers in the process of teaching intonation at the initial level in the context of 8 music schools. Several focus groups were carried out in Spain with a total of 32 teachers who had at least 20 years of teaching experience at the beginning level of music education. A recursive analysis was carried out using the previous categories: perceptions of intonation, contents, methodology, assessment and ICT resources. The results reveal inconsistencies in the teaching of intonation, the prevalence of intuitive forms based on the teachers' experience and training, but with a lack of theoretical systematisation to support it, the lack of coordination between teachers of music theory and instrumental specialists, and furthermore, the absence of a generalised framework or model for evaluating the initial teaching of brass wind instruments.
Keywords: intonation teaching; brass wind instruments; music schools; teacher praxis.

[es] La enseñanza inicial de la entonación en instrumentos de viento-metal y lenguaje musical en España. Un estudio exploratorio con profesorado de escuelas de música

Resumen. La entonación es probablemente el factor más importante de una buena formación en instrumentos de entonación variable, como los de viento metal. Es una habilidad compleja que compromete aspectos perceptivos y productivos, así como a su coordinación. Debido a diferentes factores, los expertos confirman que no existe una aproximación específica y sistemática a la enseñanza de la entonación en esta familia de instrumentos, al menos comparado con otros aspectos de la interpretación. Este estudio exploratorio es parte de un trabajo de mayor alcance. Su objetivo ha sido identificar la praxis del profesorado de instrumentos de viento-metal y lenguaje musical en los procesos de enseñanza de la entonación en el nivel inicial en el ámbito de 8 escuelas de música. Fueron realizados varios grupos de discusión en España con un total de 32 docentes con al menos 20 años de experiencia docente en el nivel inicial de enseñanzas musicales. Se realizó un análisis recursivo utilizando las categorías previas: percepciones sobre la entonación, contenidos, metodología, evaluación y recursos TIC. Los resultados visibilizan inconsistencias en la enseñanza de la entonación, la prevalencia de formas intuitivas basadas en la experiencia y formación del profesorado pero que carecen de una sistematización teórica que la sustente, la falta de coordinación entre el profesorado de lenguaje musical y el de especialidades instrumentales y, además, la ausencia de un marco o modelo generalizado de evaluación en las enseñanzas iniciales de las especialidades instrumentales.
Palabras clave: enseñanza de la entonación; instrumentos de viento-metal; escuelas de música; praxis del profesorado.

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[2] Institute of Creativity and Educational Innovation. University of Valencia (Spain).
E-mail: jesus.tejada@uv.es
ORCID: https://orcid.org/0000-0003-0532-3960
E-mail: adolf.murillo@uv.es
ORCID: https://orcid.org/0000-0002-3445-7856
[3] Department of Comparative Education and History of Education. University of Valencia (Spain)
E-mail: borja.mateu@uv.es
ORCID: https://orcid.org/0000-0003-0961-9435

1. Introduction

Learning a musical instrument involves the building of knowledge along with the development of numerous skills. For brass instruments and voice, intonation is probably the most important component of good training. Intonation is a complex skill that engages different brain areas and motor structures (Morrison, 2000). "Intonation" may be an imprecise term for a complex skill that engages different sub-skills, e.g. "pitch discrimination", which is the ability to distinguish between two different sounds in the perceptual domain (Morrison and Fyk, 2002). Furthermore, if production is taken into account, pitch matching is another sub-skill that allows for the reproduction of a previous sound (Morrison and Fyk, 2002). For these authors, intonation is a set of discrete skills that provides experience with pitches and intervals within a real musical context, "the acoustic and artistic accuracy of sound" (p. 184). However, intonation is not accurate in real contexts, as deliberate deviations from intonation occur for expressive purposes (Gardner, 2020; Garzoli, 2020; Kanno, 2003; Leedy and Haynes, 2001).

Thus, intonation is not an absolute value and depends on other factors reported in the literature, such as melodic-harmonic context, presence or absence of accompaniment, register, timbre, type of instrument, vibrato or even portamento (Geringer, MacLeod, Madsen et al., 2015; Kanno, 2003; Larrouy-Maestri and Pfordresher, 2018). For these and other reasons, intonation is a very complex activity for novice learners, as they do not have a cognitive-motor schema for sound production, so learning the instrument comes with a high cognitive load or mental effort. This is not the case for professional musicians, who have built up a schema for sound production throughout their apprenticeship (Stambaugh, 2016).

One of the reasons for undertaking this research is the general lack of knowledge about the teaching praxis of intonation in brass instruments and music theory in Spanish music schools. The specific literature in the Spanish field is non-existent and in the English speaking field it is very scarce, with the exception of work by Flunker (2010). There are some partial studies on the effect of some parameters on intonation in wind bands in American secondary schools, as well as some other hypotheses (see a summary in Bernhard, 2002; Morantz, 2016). Given the great differences between the educational goals of music schools (in amateur and or pre-professional training) and conservatories (to train professionals), it is important to understand how teachers actually carry this out in the classroom. With these objectives in mind, an exploratory qualitative study was designed using panels of experts. Information on intonation in initial learning has been collected and analysed from brass instrument teachers (tuba, trumpet, horn, trombone, euphonium) and music theory teachers in different Spanish music schools through expert panels: their ideas on intonation competence, the contents programmed, the teaching methodology, their assessment methods, and the technology and resources they use to work on this central aspect of instrumental training.

2. Teaching intonation on brass wind instruments

There is some consensus that there is no specific and systematic approach to teaching intonation in this family of instruments, at least compared to other aspects of playing. This is due to three factors: 1) the way the instruments are built; 2) the ways in which intonation interacts with and influences other aspects that contribute to accuracy in playing; and 3) the perception of intonation as a scientific and technical element rather than an artistic one (Flunker, 2010). To deal with all these difficulties, students need instrument-specific strategies (compensating with embouchure, improving breathing, using alternative fingerings, correcting the position of the slide in the case of the trombone, and the like) (Latten, 2003; Powell, 2010). It can be inferred from this that, although wind instruments share many intonation problems, the solution to each of them requires precise guidelines, techniques and methods which are specific to each instrument and situation.

In the literature review, three methods of intonation development have been identified: traditional, auditory and audio-visual. The traditional method consists of the student understanding intonation from a theoretical point of view and following the teacher's advice or corrections through verbal instructions (Cavitt, 2003; Springer, 2020). It has been suggested that this is the least effective (Powell, 2010), due to several problems regarding the meaning of verbal instructions. These are mostly metaphors of movement or direction ("high", "low", "up", "down") (Johnson and Larson, 2003), which may not be entirely effective in instrumental training due to ambiguity or confusion. For example, the expression "lower" (to indicate a lower intonation according to the staff) and the spatially lower position on stringed instruments (high range of the instrument), could be contradictory and disorienting for the student.

The auditory method has been widely used in conservatoires and is a precursor to learning by imitation or modelling (Rumjaun and Narod, 2020). It includes several techniques, such as the imitation of a sound model that may come from the teacher himself or from a recording. There are also other methods such as analysis of one's own recordings, co-assessment among students (Geringer, MacLeod y Lofdahl, 2015; Ha, 2015; Springer, 2020) or an electronic guidance system that accompanies the learner during practice with a musical instrument with sensors placed on the learner's body (Pardue and McPherson, 2019).

The audio-visual method involves the use of hardware or software, which can complementarily integrate different modalities of presenting musical information. Typical actions of the learner are to listen to the model and their own input, to view the on-screen representation of the model and the input, and to check whether their own performance

corresponds to the model. The latter constitutes audio-visual feedback, an element of learning that has been studied extensively, but with inconclusive results (Blanco and Ramírez, 2019; Blanco et al., 2021; Galera et al., 2013; Lim and Raphael, 2010; Owens and Sweller, 2008; Pardue and McPherson, 2019; Pérez-Gil et al., 2016; Springer, 2020; Wilson et al., 2008). Citing one of the latest studies, Pardue and McPherson (2019) developed a system for visual feedback of intonation. Beginning instrumentalists, both children and adults, received 4 face-to-face 20-30 minute lessons. In each lesson, one of the intonation feedback methods was used, along with a control lesson without feedback. There was no effect of visual or aural feedback, nor of their combination. The feedback methods improved intonation for some people but were distracting for others.

Thus, the combined presentation of different kinds of perceptual information in instrumental or vocal training yields negative results in some studies and positive results in others. This disparity could be due to the factors of attentional partitioning and modality specificity of information, both of which are addressed in Multimedia Learning Theory (Ayres and Cierniak, 2012) and Cognitive Load Theory (Low and Sweller, 2014). Multimedia Learning Theory proposes that: 1) auditory and visual information is processed in different information channels; 2) the capacity of each channel is limited; 3) learning is an active process; 4) task difficulty is a critical factor in learning, as it sets the amount of processing for a person to complete a task. Task difficulty is currently referred to as "cognitive load" and reflects the limitations of cognitive processing in working memory (Castro-Alonso and Sweller, 2020). Cognitive Load Theory suggests that cognitive overexertion (extrinsic cognitive load) added to the cognitive load of the learning materials themselves (intrinsic cognitive load) could slow down the speed and quality of information processing, which would have a negative effect on learning. However, this would depend on the mode in which the information is presented, the cognitive style of the learner and whether the presentation of information forces the user to divide their attention between concurrent media (Ayres and Cierniak, 2012).

It should be noted that the differences between perception tasks and music production tasks are very large, not only in terms of the cognitive effort required, but also in terms of the processes involved. While the former is developed in the cognitive domain, performative tasks also require proprioceptive knowledge and motor intervention. In other words, the development of a sense of pitch is needed to recognise the correct intonation, proprioceptive knowledge to manipulate the muscles of emission, physical reaction to execute the actions and an internal monitoring loop to adjust the intonation to the correct pattern (Pardue and McPherson, 2019).

Regarding brass instruments, there are several factors that affect their intonation: their construction design (Flunker, 2010; Latten, 2003; Powell, 2010; Schlegel and Springer, 2018), mouthpiece variations (Dalmont et al., 1995); and temperature (Zendri et al. 2015). Likewise, the sound is also highly conditioned by the instrumentalists. Thus, the position of the tongue (Heyne and Derrick, 2015; Heyne et al., 2019) and the air column (Bucur, 2019) are key to obtaining correct intonation. Due to the multiple factors that can affect sound intonation, its teaching to beginners has been and continues to be the subject of much research. According to Powell's (2010) review, the most effective methods are dissociation of rhythm and pitch (Anvari et al., 2002; Bengtsson and Ullen, 2006), vocalisations (Bernhard, 2002) and singing intervals before playing them on the instrument. However, there is no conclusive evidence of whether vocalising and/or humming before performing on the instrument improves intonation skills, with either negative (Silvey et al., 2019) and positive (Bernhard, 2002) results.

Other research suggests wind players use a harmonic accompaniment during practice (a drone) (Puangsamlee and Fyr, 2018) or a "pedal note" (a continuous sound, usually the tonic note) (Springer et al., 2020). However, the study by Zabanal (2019) does not confirm positive results from the use of drones, although this work has been limited and exploratory. It should also be noted that timbre plays a fundamental role in wind instruments, as students must not only be able to intonate with other instruments like their own, but also with instruments belonging to other families and registers (Latten, 2003; Powell, 2010). Moreover, in some timbres such as the trumpet, "out-of-tune" is perceived with lower margins of error than in other instruments, such as the voice or violin (Geringer, MacLeod y Sasanfar, 2015).

3. Objectives

This work is the first phase of a larger research project focused on the development of a real-time intonation assessment software. It aims at understanding the teaching practices of brass instrument (tuba, trumpet, horn, trombone, euphonium) and music theory teachers in some Spanish music schools along with the competences, contents, methodology, assessment systems and technology used by teachers in the teaching of intonation.

4. Method

4.1. Design

This research has adopted a descriptive-exploratory qualitative design, based on expert panels on the teaching practice of teachers at the initial level of teaching brass instruments and music theory.

4.2. Techniques and instruments

In this study, the expert panel technique has been used, a special type of focus group that allows for information to be obtained from people with considerable knowledge in a specific field (Bloor et al., 2001). The expert panel technique was adopted in order to understand the peculiarities of teaching intonation in brass instruments and in the music theory subject. In the expert panel, it is not necessary to reach a consensus on the object of enquiry, but to investigate collaboratively on a prior problem or question (Heron, 1996). In this article, the data have been conveniently reduced by means of a recursive content analysis to extract, interpret and relate the different beliefs, conceptions and practices of the experts on the topics discussed. The themes corresponded to the categories of information related to the objective of the study and constituted the analytical categories.

4.3. Participants

Fourteen active teachers from music schools in Madrid, Catalonia, Valencia, Andalusia and Melilla took part in 8 panels of experts. The selection was made according to convenience, teacher availability and specialisation (Fig. 1). First they had to fulfil two specific conditions for participation: 1) have 20 years or more professional teaching experience in specialised music education institutions; 2) be active or have worked at the initial level of teaching brass instruments and music theory.

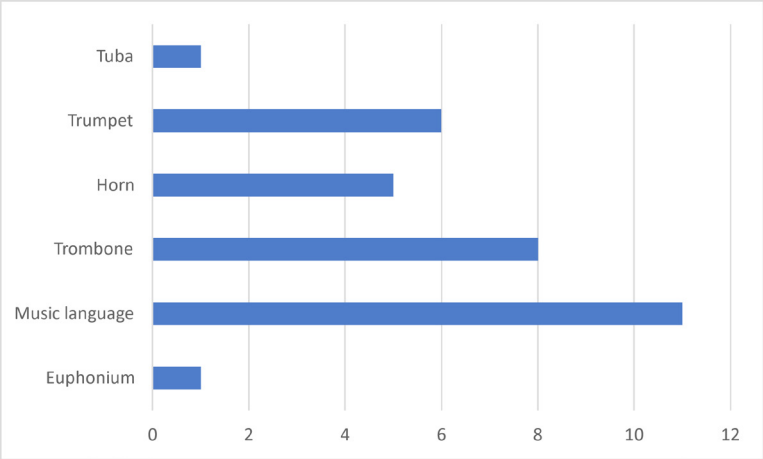

Figure 1. Specialization and number of participating teachers

4.4. Analysis categories

The analysis was carried out using predefined categories defined by the research objective itself (Fig. 2). The information obtained was organized according to codes, which were then sorted under the different categories.

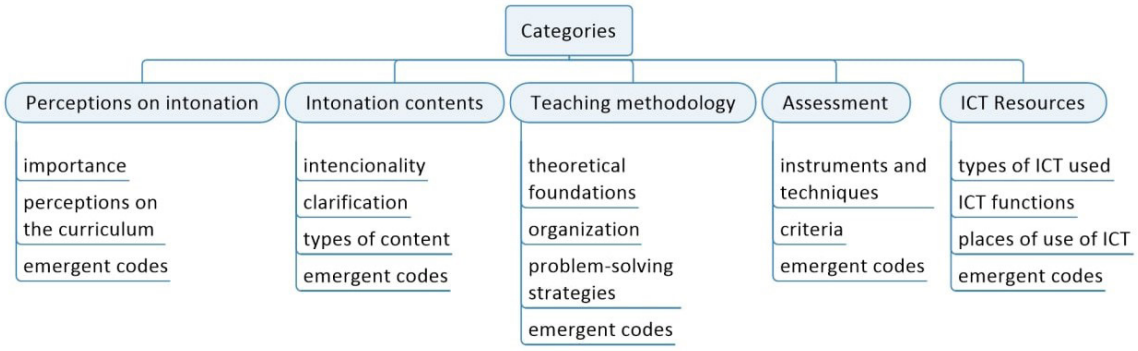

Figure 2. Table of codes and categories used in the expert panel data analysis.

4.5. Procedure

Prior to initiating each expert panel, the researchers sent participants the list of general topics to be discussed (coinciding with the analytical categories) and an informed consent document to participate in the research. The panels followed a basic structure: 1) the consent form was read and signed if applicable; 2) participants briefly introduced themselves; 3) the moderator asked a few warm-up questions; 4) the panel topics were presented and

discussed; and 5) if necessary information on some topics was not covered, the moderator addressed the topic after all topics had been covered. All panels consumed the maximum scheduled time (60 minutes). The panels were recorded by video camera (7 panels) and audio recorder (1 panel). The information obtained was transcribed into text manually. The transcriptions were checked for errors. The resulting text documents were imported as primary documents into the Atlas.ti v.8 software programme and analysed.

5. Results and discussion

5.1. Perceptions of intonation competence

In general, the participants mention that intonation is very important in learning both music and the instrument, alluding to the official educational curriculum, or justifying it in the need for playing the instrument itself:

> *At an elementary or intermediate level* […] *I think they should be more aware of intonation. Not that they should tune perfectly, because you can't tune perfectly, but it is important that they control the feeling of when they are in tune* (trumpet teacher, 6:8).

However, this importance is specifically defined by some teachers who do not consider the learning of intonation so important in the initial stage, either due to the difficulty for very young people (mostly between 8 and 15 years old; see below) or because there are other higher priority learning steps such as posture or breathing. They consider that the elementary level of teaching should be used for tuning, which they will need to know at the intermediate level, i.e., four years later:

> *In the first years, and more so with children at the age of six, seven or eight years, you can do very little with tuning: know the notes in the first year and tell them here is the note, this is the first position, this is the second position, etc…. as far as we can go. In the second year, they are already looking for strategies to listen to each other so that the note sounds the same. But, until we get to the professional level, we don't really find the intonation, we are looking for* (trombone teacher, 35:5).

> *I don't get involved yet in making sure that the tuning is very precise, that's when they start playing the instrument. When they get older we both play together and try not to make it sound out of tune, but of course that requires a bit of technique* (horn teacher 1, 5:2).

These ideas are confirmed by the evaluation systems adopted by the participants (see below), in which the most important thing is generally not the exact intonation.

Music Theory teachers see intonation as a tool for decoding representations with the voice and bringing the sound to the instrument:

> *I think this is where perhaps we have to be a little bit more careful in the sense of assuming that our subject* [Music Theory, M.T.] *is fundamentally a tool* (M.T. teacher, 18:65) *which is inseparable from aural sensation, from learning to listen* (M.T. teacher, 18:16).

They consider that there have been improvements in the teaching of intonation compared to previous plans, where intonation was not addressed and was learned intuitively, through practice and time. They state that there now seems to be a greater awareness among teachers of the need to specifically address intonation. However, this does not seem to be a widespread reality in classrooms due to the lack of coordination between instrumental and musical theory teachers (Cañizares et al., 2015).

5.2. Intonation contents

There is no consensus on intonation content for brass instruments. Some teachers use an interval and harmony-based approach, starting with the tonic chord sounds and then the dominant chord sounds, very much in line with Gordon (2007) and other enthusiasts of Music Learning Theory. Other teachers consider the intonation of intervals as a relevant component of music theory. Teachers do not usually programme specific intonation content at the initial level because it is worked on through repertoire, which is mostly composed of children's film soundtrack songs, popular urban music, and songs accessed on the Internet, as well as technical studies. Activities related to intonation consist of playing and matching long teacher sounds, playing specific intervals to understand and achieve correct intonation, playing scales and arpeggios, playing to the accompaniment of a "pedal-note" (sustained sound), a drone (a harmonic interval) or an ostinato (repeated pattern of sounds). These activities are in line with studies that recommend such activities and strategies (Springer et al., 2020), although there is controversy regarding the effectiveness of drone use (e.g. Zabanal, 2019).

Teachers seek to relate their content to what is taught in music theory. In this respect, music theory teachers generally prefer to work with learning manuals as an almost exclusive way of approaching music theory, but they are

aware that students must learn to intonate with the voice, in order for it to become an effective tool for the instrument. This is sometimes a problem because music theory teachers do not include the activities and ideas necessary for students to cope successfully with instrumental lessons, or at least not to the extent that instrumental teachers need for teaching to play the instrument.

The heterogeneity of the stated intonation content is not surprising, as the official documents are deliberately ambiguous in their determination and are left to the choice of the educational institution that implements the school's educational project, which in turn delegates to the teachers. Thus, the following are mentioned as teaching contents for brass instruments: "Strengthening of facial muscles for embouchure. Study of sound emission. Basic principles of fingering. Practice of the different articulations. Work on dynamics. Development of the flexibility of the lips, with the practice of linked intervals and fixed positions. Study of the mouthpiece for the specific embouchure […]". (Generalitat Valenciana, 2007, p. 37108).

Finally, and as suggested above, mention is made of the lack of coordination between the teachers of this subject and the instrumental teachers in relation to the contents, an important problem of music education institutions already analysed by Cañizares et al. (2015) in Andalusian music schools. This is a major problem for learning, as it can lead to heterogeneous performance among students for each specific instrument.

5.3. Intonation teaching methodology

In general, it is considered that the student must have mental representations of the sounds to be able to intonate correctly:

> *If the student does not identify the interval well, he can get the right position, but it is impossible for him to get the note right if the pitch in his head is not adjusted* (trombone teacher, 5:6).

This idea links the concept of auditory imagery and the ability to imitate (vocal or instrumental) (Pfordresher and Halpern, 2013), which is also present in the concept of audiation (Gordon, 2007). Perhaps this is why instrumental teachers do not prioritise intonation in elementary studies. The construction of internal auditory images is something that is achieved through continuous practice, requiring time, which students do not have in class. Nor do they have much time at home due to the necessary compatibility that should exist between music studies and compulsory education.

According to some participants, this process of constructing sound representations should be done through singing and then transferred to the instrument. Many participants state that they use it to build the pupils' sound imagery, mentioning that it is a fundamental tool and should be used frequently:

> *One should sing more than play, because whoever sings well, then plays well* (trumpet teacher, 6:15).

This is in line with Bernhard's (2002) findings, although they are not consistent with the results of other studies (Bennett, 1994; Coveyduck, 1998; Morantz, 2016; Silvey et al., 2019). However, the latter studies tested hypotheses using discrete-extent stimuli (single sounds, paired or small-extent patterns) in quantitative single-session designs, not with extended treatments or complete patterns and drills, which are typical processes in teaching environments. The relationship between auditory imagery (modality-dependent mental imagery) and short-term memory structures needs to be supported by further research (Schaefer, 2017).

Finally, one panel mentioned that some intonation problems are not solved by singing, e.g., the inability to imitate pitches or melodic patterns with the voice. As to the cause of this poor-pitch-singing phenomenon, it has been suggested that it is not strictly due to individual perceptual or motor factors, but to the relationship between these two factors (Pfordresher and Mantell, 2009).

In relation to singing, buzzing is used as an intermediary between singing and instrument:

> *When working with the mouthpiece you start from scratch, you have to look for everything: air control, pitch, sound quality* (trumpet teacher, 6:24).

> *I like to use the mouthpiece without the instrument and it's like singing; we can also start by singing a note. Then look for that note on the mouthpiece, and then proceed to producing it on the instrument, try to get it and continue on with all notes that are challenging* (french horn teacher 1, 5:14).

There are consistent didactic reasons for the use of instrumental buzzing (MacKay, 2012) and its positive effects on intonation and timbral quality (Beghtol, 2017). However, this should be taken with caution, due to the paucity of research related to the effectiveness of its use.

Instrumental teachers often work with the imitation method, because

> *the student* […] *learns by imitation; therefore, it is necessary for the teacher to be constantly giving a good example* (M.T. teacher 3, 17:10).

Some use tuners, but this is a controversial issue. On the one hand, it is claimed that the novice student has not yet built up internal mental representations of pitches and needs visual information to consolidate his or her ability to discriminate correct intonation. Furthermore, at this stage

it is important that they control the feeling of being in tune (trumpet teacher, 6:8).

Some teachers ask their students to close their eyes and not to look at the tuner until they have made the sound. On the contrary, some teachers claim that the tuner is too accurate and that they should work with ear, not the eye. Those who use it employ mobile applications that evaluate intonation with colours (red and green, e.g., Tunable) instead of an indicator needle. This indicator colour constitutes de facto visual feedback. Its use is in line with the findings of some studies suggesting the usefulness of visual feedback on intonation during early voice and instrument learning (Blanco et al., 2021; Zaki-Azat, 2016). However, these results are not consistent with those of other studies (Pardue and McPherson, 2019; White, 2020; Wilson et al., 2008).

Some teachers advocate the interrelation of technique with harmony from the very beginning, in accordance with certain methodological postulates that point out that tonal functions are an important basis for instrument learning (Gordon, 2007). This allows them to work by intervals, to systematise the teaching and to direct the student towards group instrumental practice, while allowing them to work on the flexibility of intonation in groupings (the use of the system of just tuning and the system of equal temperament). To facilitate intonation, the teachers use well-known songs that have characteristic intervals and that due to their cultural diffusion, could be available in the students' memory as auditory images:

It is easier to explain a fifth with Superman soundtrack music (M.T. teacher 3, 17:10).

This could corroborate the relationship between these images, information in long-term memory, and vocal or instrumental imitation (Pfordresher and Halpern, 2013). However, this relationship between sound mental images and memory structures requires further investigation (see Schaefer, 2017, for further discussion on mental representations or auditory images).

It is mentioned that learners are often better at discriminating intonation quality in others than in themselves. This could be explained by the fact that performative activities are more resource-intensive (motor and cognitive) than purely perceptual (cognitive) activities, being more prone to a division of attention (Ayres and Cierniak, 2012). Perhaps this could be the reason for the lack of effect from visual aids on instrumental intonation, as in the studies mentioned above (e.g., Pardue and McPherson, 2019).

Finally, the importance of group lessons as opposed to individual lessons is highlighted, as pupils of this age are more receptive and open when they are with other children. This social factor could enhance learning from a socio-constructivist theory of learning through peer-to-peer interaction.

5.4. Evaluation

Teachers pay attention to a series of assessment criteria generally included in rubrics: whether they intonate in general; whether the sounds of the melody have been produced; whether they reproduce the melodic profile; instrument positioning and body posture; breathing; phrasing; expression; tempo; continuity of speech. They consider it positive that pupils feel annoyed when they intonate incorrectly, as it indicates that they are beginning to notice deviations.

Intonation is not often seen as the only evaluative factor because many teachers consider music holistically. This may also be due to the inability of novice students to intone correctly because of one or more of the cognitive or motor control factors mentioned by Pfordresher and Mantell (2009). In general, relative intonation is not negatively assessed. If the student starts with a lower or higher pitched sound and performs the melodic profile of the exercise correctly, the task is positively assessed. It is mentioned that this problem is not difficult to correct and is not prevalent.

Despite this more holistic attitude to assessment, some of the teaching staff maintain deep-rooted teaching traditions:

Play the scales over and over again, until the sound is burnt in there (horn teacher 2, 18:86).

This idea could stem from the teaching styles prevalent in higher level conservatoires, but is inappropriate for teaching in music schools, since the two types of institutions have different educational objectives. While conservatoires are institutions that aim at preparing professional musicians (MEC, 2006), music schools prepare music amateurs (MEC, 1992).

In general, it can be stated that teachers are laxer in the assessment of intonation in the first years of the elementary level than in the last years and, of course are more demanding at the intermediate level. This attitude could also be due to the lack of a generalised model of assessment of these teachings at the elementary level (Cañizares et al., 2015).

5.5. Technological resources for intonation

In general, as will be seen, instrument teachers do not use technology extensively in class. This is not the case for music theory teachers. A small number of teachers prefer to use audio recording as a resource. It is used in different ways, e.g. to record lessons and send them to pupils; to record instrumental lessons and listen to them, sing them or have them played by pupils afterwards. This issue is called into question in some panels (see below). It is also used to record accompaniments (also known as *Minus-one* or *Karaoke*) of certain pieces and for pupils to practise

certain solo lines, in class or at home. To do this, they use simple recording applications such as *Audacity*, use free sequencers such as *Cakewalk*, or use score editors such as *Musescore* to produce the recordings. They arrange class assignments to generate accompaniments and then play the audio in class as accompaniment or it is given to students so they can practice.

However, student recording, as a didactic resource, is not a habitual activity in class:

> *During the pandemic lockdown experience* [due to COVID-19] *it was very surprising to see that, as it was compulsory the students had to record themselves some lessons, the result was positive because, for the first time, they were obliged to listen to what they were going to send to the teacher. And, well, it was a surprise because their level of demand went up* (french horn teacher 3, 22:26).

This same teacher mentioned that

> *it is very paradoxical in the mastery of new technologies that young people have nowadays, how little they use it for music. Sometimes, you even have to force them to record themselves or to watch* [video] *versions when it is an important tool* (french horn teacher 3, 22:29).

This opinion is qualified in other panels by statements about the problem of lack of time. These children simultaneously attend the primary and music education curriculum. There is a problem of time and also a lack of coordination to harmonize studies, social life and leisure. Technology has an important role to play here, according to one of the teachers:

> *One of the great disadvantages they [students] have today, in my opinion, is the lack of time. So, well, maybe from there it can help; but, really, what there is a problem of coordination between compulsory and special* [music] *teaching* (viola teacher, 22:32).

This coordination problem has been described and studied by different authors (Berbel and Díaz, 2014; Díaz, 2004) and does not seem to have an easy solution, although it points towards the establishment of policies that allow for the creation of a greater number of integrated educational centres.

In line with the use of rhythmic and intonation guides, some teachers use applications (*Tabla Pro*) for mobile devices that generate "pedal notes" or "drones" that make it easier for the learner to place his or her intonation in the key, also providing a basis for improvisation. Others use applications that generate harmonic progressions as accompaniment for playing (*IReal Pro*, *Audio Chord*) or generate structures in certain hip hop, jazz, funky styles so that students can invent structures, generate a sound base and play in that style:

> *In this way, by playing with improvisation, they analyse and deepen their understanding of harmony* (trumpet teacher, 6:29).

Finally, the teachers mention the use of manuals that include accompaniment for the lessons in the form of *MIDI* files.

Another important application of technology is video recordings. It is used by some teachers, particularly for postural aspects of performance, which could affect intonation. However, this use is not general, probably due to the time constraints of the classes:

> *For us, intonation failure is a postural issue. Record yourself on video and look at yourself. Look how I do it… with my mobile phone* (horn teacher 3, 22:31).

Some teachers use screen projection of scores exclusively or in combination with audio accompaniment.

A few music theory teachers recommend the use of ear training programmes for home practice. They also recommend some mobile applications that allow the control of timbral mixing, recording, looping and other tasks that are easily done with online programmes. A few other teachers use non-music-specific assistive technologies (Google Classroom) to organise content, materials, tests and assignments, and also use blogs as repositories of links to digital resources, such as videos on certain instrumental techniques.

The classroom technology common to most teachers is the tuner, even if it is not the teachers themselves who tune the instruments one by one "so as not to waste class time". A few teachers within this group who use technology sparingly are of the opinion that it should be incorporated into their classes, either because they are teaching "in the 21st century" or pupils find some resources such as *Minus-one* or *karaoke* to be motivating. Furthermore, children practising alone at home need these resources or materials as support. However, some teachers do not even mention this possibility. Finally, a large number of teachers are not inclined to use technology in class, perhaps due to technophobia:

> *I refuse this application, because in three or four years or ten years we would all be unemployed* (M.T. teacher 4, 18:148).

or because limited classtime may not be conducive to use of technology, as mentioned above.

To analyse the results regarding teachers' use of technology, it is necessary to study their educational profile in Spain. If their qualification is the highest level (Advanced Teacher Degree), this implies that they have completed 4 academic courses of 60 ECTS credits at a higher level conservatory. These institutions teach among other specialisations, instrumental performance, a requisite for graduates to be able to teach an instrument, and Music Pedagogy a requisite for teaching Music Theory. In all the music curricula of these conservatories in the different Spanish autonomous communities, there are training subjects on music technology with a load that ranges from between 6 and 12 ECTS credits, depending on the community (which has full educational competences), but actually ranges between 3 and 11 ECTS (Díez, 2018). This teaching load in a 240 ECTS credit course may well be insufficient for teachers who have to integrate technology in the training of novice instrumental or musical theory students (Díez, 2018). Finally, music schools only require their teaching staff to have an intermediate level qualification, i.e. the professional degree. If this is the level of teacher training, their initial technological training is probably non-existent. Some content integration models could help to structure technology-related subjects taught in conservatories. Moreover, the TPACK framework facilitates the integration of disciplinary, methodological and technological content, facilitating its application in higher education training contexts (Tejada & Thayer, 2019).

In the case of instrument specialisation, this insufficient technological training is combined with the scarcity of continuous training courses:

> *Courses are offered, but very few and very basic; for example, courses are offered that involve pressing a key on the computer and turning it on, in other words, there are no specific courses that work on this offer that we are talking about* (tuba teacher, 22:37).

The instrument teaching methods course is not so motivating for those learning to play an instrument, as they tend to be more interested in the performance or interpretive parts. This could partly explain the scarce use of technology in the classroom in instrumental subjects, as well as the differences in the use of technology between instrumental and musical theory teachers.

Finally, the teachers were asked about their opinion on the creation of software for intonation on brass instruments and for voice, as well as the characteristics it should have. Most of the teaching staff do not express an opinion. The rest of the teaching staff are in favour of similar software and mention some characteristics: 1) it can be worked on at home; 2) it be open (with exercises that can be configured by the teaching staff or the students); 3) the exercise can be listened to before it is actually performed; 4) it generates a detailed evaluation report.

6. Conclusions

The results of this exploratory study have revealed certain inconsistencies in the teaching of intonation, which indicate the prevalence of intuitive practices based on experience and teacher training, as well as a relative absence of theoretical pedagogical foundations to support practice. There is also a lack of uniformity in the sequencing of content, a problem which becomes even more complex if we consider a certain laxity on the part of teachers in the approach to intonation in the initial stages. This occurs especially for complex musical instruments such as the brass family, which tend to postpone the consolidation of this very important skill in the development of specific instrumental competences in children to the professional teaching stage. However, it would be highly recommendable that it be carried out systematically and gradually from the beginning of instrumental and musical training.

There is a notable absence of a generalised assessment model and of effective coordination between music theory teachers and instrumental specialists, which would allow pupils from all instruments to fulfil the same objectives. This is an aspect that would require the work of the management team for each centre or, as Díaz (2004) points out, the creation of regional music education policies.

Music theory teachers are more systematic in their work with intonation than instrumental teachers, perhaps because progress in instrumental training depends on them. The greater use of technology, audio and recreational resources in this subject would enhance the progressive construction of auditory images in pupils and furthermore facilitate the construction of a cognitive-motor scheme for instrumental intonation.

The use of a hypothetical ad hoc software could be an important tool for the improvement and systematisation of the daily work with intonation in initial training: "it seems axiomatic that the more instructional tools the teacher has for teaching intonation, the greater the possibility that the students can learn to perform with good intonation" (Silvey et al., 2019, p. 393). In this sense, their use could provide certain unifying criteria for teachers that would help to generate more consistent pedagogical forms in intonation work with brass instruments and in music theory. In addition, it could provide reinforcement and provide greater autonomy in students' daily work on intonation, as it would facilitate work at home and provide sites for practice and evaluative feedback without the need for the physical presence of the teacher. In this respect, a software solution is already being worked on and is expected to be validated in the near future.

Another question that deserves investigation is whether the lack of coordination between music theory and instrumental teachers is a widespread phenomenon in music schools all over the country and, if so, to investigate its causes and possible solutions.

Finally, and due to the exploratory nature of this work, some limitations should be considered. The findings obtained in this work describe the methods and practice of 32 teachers from 8 Spanish music schools, and these results are not generalisable: what has been described here may not representative practices of all the teaching staff of these institutions in Spain, so it would be necessary to undertake a more in-depth study of the issues dealt with here and with a larger number of experts. This would make it possible to validate the claims made in this paper about intonation teaching practice.

4. References

Anvari, S., Trainor, L., Woodside, J., & Levy, B. (2002). Relations among musical skills, phonological processing and early reading ability in preschool children. *Journal of Experimental Child Psychology, 83*(2), 111-130. 7TUhttps://doi.org/10.1016/s0022-0965(02)00124-8U7T

Ayres, P., & Cierniak, G. (2012) Split-Attention Effect. In N. M. Seel (Ed.), *Encyclopedia of the Sciences of Learning.* (pp. 3172-3175). Springer. http://doi.org.https.jxnydx.proxy.chaoxing.com/10.1007/978-1-4419-1428-6_19

Beghtol, J. W. (2017). *The Effect of a Researcher Composed Mouthpiece Buzzing Routine on the Intonation and Tone Quality of Beginning Band Brass Students.* [Doctoral dissertation, University of Mississippi] *Electronic Theses and Dissertations*. https://egrove.olemiss.edu/etd/714

Bengtsson, S., & Ullen, F. (2006). Dissociation between melodic and rhythmic processing during piano performance from musical scores. *NeuroImage, 30*(1), 272-284. https://doi.org/10.1016/j.neuroimage.2005.09.019

Bennett, S. J. (1994). *Can simple vocalization help improve the intonation of wind players?* (Order No. 9514867) [Doctoral dissertation, Arizona State University]. ProQuest Dissertations Publishing. https://www.proquest.com/dissertations-theses/can-simple-vocalization-help-improve-intonation/docview/304112186/se-2?accountid=14777

Berbel, N., & Díaz, M. (2014). Educación formal y no formal. Un punto de encuentro en educación musical. *Aula Abierta, 42*(1), 47-52. https://doi.org/10.1016/S0210-2773(14)70008-3

Bernhard, H. (2002). Singing in Instrumental Music Education: Research and Implications. *Update: Applications of Research in Music Education, 22*(1), 28-35. https://doi.org/10.1177/87551233020220010501

Blanco, A. D., & Ramírez, R. (2019). Evaluation of a sound quality visual feedback system for bow learning technique in violin beginners: An EEG study. *Frontiers in Psychology*, *10*:165. https://doi.org/10.3389/fpsyg.2019.00165

Blanco A. D., Tassani, S., & Ramírez R. (2021). Effects of Visual and Auditory Feedback in Violin and Singing Voice Pitch Matching Tasks. *Frontiers in Psychology*, *12*:684693. https://doi.org/10.3389/fpsyg.2021.684693

Bloor, M., Frankland, J., Thomas, M., & Robson, K., (2001). *Focus groups in social research.* Sage.

Bucur, V. (2019). Resonant Air Column in Wind Instruments. In *Handbook of Materials for Wind Musical Instruments* (pp. 337-358). Springer. https://doi.org/10.1007/978-3-030-19175-7_8

Cañizares, A., Pomares, B., & González, E. (2015). Profesorado de enseñanzas básicas de música de Andalucía: ¿mejoramos la coordinación docente? *Eufonía,* (63), 47-58.

Castro-Alonso J.C., & Sweller J. (2020) The Modality Effect of Cognitive Load Theory. In W. Karwowski, T. Ahram, & S. Nazir (Eds.), *Advances in Human Factors in Training, Education, and Learning Sciences.* A*HFE 2019. Advances in Intelligent Systems and Computing,* vol. 963 (pp. 75-84). Springer. https://doi.org/10.1007/978-3-030-20135-7_7

Cavitt, M. E. (2003). A descriptive analysis of error correction in instrumental music rehearsals. *Journal of Research in Music Education*, *51*(3), 218-230. https://doi.org/10.2307/3345375

Coveyduck, S. (1998). *Vocalization and its effect on the intonation of a beginning instrumentalist* [Unpublished master's thesis, University of Calgary]. http://hdl.handle.net/1880/25950

Dalmont, J. P., Gazengel, B., Gilbert, J., & Kergomard, J. (1995). Some aspects of tuning and clean intonation in reed instruments. *Applied Acoustics*, *46*(1), 19-60. https://doi.org/10.1016/0003-682X(95)93950-M

Díaz, M. (2004). La música en la educación primaria y en las escuelas de música: la necesaria coordinación. *Revista Electrónica Complutense de Investigación en Educación Musical, 1*(2), 1-14. https://revistas.ucm.es/index.php/RECI/article/view/RECI0404110002A

Díez, N. (2018). La formación en TIC de los pedagogos de música. Análisis de la situación en las Enseñanzas Superiores de Música. *Revista Electrónica de LEEME,* (42), 31-51. https://doi.org/10.7203/LEEME.42.13067

Flunker, J. (2010). *Trumpet intonation pedagogy in the United States at the beginning of the twenty-first century* (Order No. 3428898) [Doctoral dissertation, University of Connecticut]. ProQuest Dissertations Publishing. https://www.proquest.com/dissertations-theses/trumpet-intonation-pedagogy-united-states-at/docview/759506379/se-2?accountid=14777

Galera, M., Tejada, J., & Trigo, E. (2013) Music Notation Software as a Means to Facilitate the Study of Singing Musical Scores. *Electronic Journal of Research in Educational Psychology*, *11*(1), 215-238. https://roderic.uv.es/handle/10550/70448

Gardner, R. D. (2020). Extending the Discussion: Intonation Pedagogy for Bowed Stringed Instruments, Part 1. *Update: Applications of Research in Music Education*, *38*(2), 55-58. https://doi.org/10.1177/8755123319893219

Garzoli, J. (2020). Competing Epistemologies of Tuning, Intonation and Melody in the Performance of Thai Classical Music on Non-Fixed-Pitch Instruments. *SOJOURN: Journal of Social Issues in Southeast Asia*, *35*(3), 407-436. https://doi.org/10.1355/sj35-3a

Generalitat Valenciana (2007). *DECRETO 159/2007, de 21 de septiembre, del Consell, por el que se establece el currículo de las enseñanzas elementales de música y se regula el acceso a estas enseñanzas*. (Diari Oficial de la Generalitat Valenciana n.º 5606, 25-09-2007). http://www.docv.gva.es/datos/2007/09/25/pdf/2007_11701.pdf

Geringer, J. M., Macleod, R. B., & Lofdahl, H. (2015). A survey of practice behaviors among middle and high school string players. *String Research Journal*, *6*(1), 55-69. https://doi.org/10.1177/194849921500600004

Geringer, J. M., MacLeod, R. B., & Sasanfar, J. K. (2015). In tune or out of tune: Are different instruments and voice heard differently? *Journal of Research in Music Education*, *63*(1), 89-101. https://doi.org/10.1177/0022429415572025

Geringer, J. M., MacLeod, R. B., Madsen, C. K., & Nápoles, J. (2015). Perception of melodic intonation in performances with and without vibrato. *Psychology of Music*, *43*(5), 675-685. https://doi.org/10.1177/0305735614534004

Gordon, E. (2007). *Learning Sequences in Music: A Contemporary Learning Theory.* GIA Publications.

Ha, J. (2015). Teaching intonation in violin playing: A study of expert string teaching. *Australian Journal of Music Education*, (2), 224-236. https://www.proquest.com/scholarly-journals/teaching-intonation-violin-playing-study-expert/docview/1788572311/se-2?accountid=14777

Heron, J. (1996). *Co-operative inquiry. Research into the human condition.* Sage.

Heyne, M., & Derrick, D. (2015) The influence of tongue position on trombone sound: A likely area of language influence. *Proceedings of the 18th International Congress of Phonetic Sciences* (ICPhs 2015). http://hdl.handle.net/10092/11122

Heyne, M, Derrick, D., & Al-Tamimi J. (2019). Native Language Influence on Brass Instrument Performance: An Application of Generalized Additive Mixed Models (GAMMs) to Midsagittal Ultrasound Images of the Tongue. *Frontiers in Psychology, 10:*2597. https://doi.org/10.3389/fpsyg.2019.02597

Johnson, M., & Larson, S. (2003). 'Something in the Way She Moves' Metaphors of Musical Motion. *Metaphor and Symbol, 18*(2), 63-84. https://doi.org/10.1207/S15327868MS1802_1

Kanno, M. (2003). Thoughts on how to play in tune: Pitch and intonation. *Contemporary Music Review*, *22*(1-2), 35-52. https://doi.org/10.1080/0749446032000134733

Larrouy-Maestri, P., & Pfordresher, P. Q. (2018). Pitch perception in music: Do scoops matter? *Journal of Experimental Psychology: Human Perception and Performance*, *44*(10), 1523-1541. https://doi.org/10.1037/xhp0000550

Latten, J. E. (2003). *Exploration of a sequence for teaching intonation skills and concepts to wind instrumentalists* (Order No. 3096999) [Doctoral dissertation, The Pennsylvania State University]. ProQuest Dissertations Publishing. https://www.proquest.com/docview/287992058?pq-origsite=gscholar&fromopenview=true

Leedy, D., & Haynes, B. (2001). Intonation (ii). *The New Grove Dictionary of Music and Musicians*, *12*, 503-504.

Lim, K., & Raphael, C. (2010). InTune: A System to Support an Instrumentalist's Visualization of Intonation. *Computer Music Journal, 34*(3), 45-55. https://doi.org/10.1162/COMJ_a_00005

Low, R., & Sweller, J. (2014). The modality principle in multimedia learning. In R.E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning,* 2nd ed. (pp. 227–246). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.012

MacKay, G. (2012). Mouthpiece buzzing. *Canadian Winds: The Journal of the Canadian Band Association, 10*(2), 21-23. https://www.proquest.com/scholarly-journals/mouthpiece-buzzing/docview/1013474811/se-2?accountid=14777

MEC-Ministerio de Educación y Ciencia (1992). *Orden de 30 de julio de 1992 por la que se regulan las condiciones de creación y funcionamiento de las Escuelas de Música y Danza* (Boletín Oficial del Estado n.º 202, de 26-08-1992). https://www.boe.es/boe/dias/1992/08/22/pdfs/A29396-29399.pdf

MEC-Ministerio de Educación y Ciencia (2006). *Real Decreto 1577/2006, de 22 de diciembre, por el que se fijan los aspectos básicos del currículo de las enseñanzas profesionales de música reguladas por la Ley Orgánica 2/2006 de Educación* (Boletín Oficial del Estado n.º 8, de 20-01-2007). https://www.boe.es/boe/dias/2007/01/20/pdfs/A02853-02900.pdf

Morantz, C. (2016). *Effect of singing instruction on the tone quality and intonation of beginning brass players* [Doctoral dissertation, University of Georgia]. Athenaeum. https://getd.libs.uga.edu/pdfs/morantz_cara_a_201608_edd.pdf

Morrison, S. J. (2000). Effect of melodic context, tuning behaviors, and experience on the intonation accuracy of wind players. *Journal of Research in Music Education*, *48*(1), 39-51. https://doi.org/10.2307/3345455

Morrison, S. J., & Fyk, J. (2002). Intonation. In R. Parncutt y G. McPherson (Eds.), *The Science & Psychology of Music Performance: Creative Strategies for Teaching and Learning* (pp. 182-197). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195138108.003.0012

Owens, P., & Sweller, J. (2008). Cognitive load theory and music instruction. *Educational Psychology: An International Journal of Experimental Educational Psychology, 28*:1. 29-45. https://doi.org/10.1080/01443410701369146

Pardue, L. S., & McPherson, A. (2019). Real-time aural and visual feedback for improving violin intonation. *Frontiers in Psychology*, *10*:627. https://doi.org/10.3389/fpsyg.2019.00627

Pérez-Gil, M., Tejada, J., Morant, R., & Pérez, A. (2016). Cantus. Construction and evaluation of a software for real-time vocal music training and musical intonation assessment for music education. Journal of Music, Technology and Education *9*:2, 125-144. https://doi.org/10.1386/jmte.9.2.125_1

Pfordresher, P., & Halpern, A. (2013). Auditory imagery and the poor-pitch singer. *Psychonomic Bulletin Review, 20*, 747-753. https://doi.org/10.3758/s13423-013-0401-8

Pfordresher, P., & Mantell, J. (2009). Singing as a Form of Vocal Imitation: Mechanisms and Deficits. In J. Louhivuori, T. Eerola, S. Saarikallio, T. Himberg, P. Eerola (Eds.), *Proceedings of the 7th Triennial Conference of European Society for the Cognitive Sciences of Music* (ESCOM 2009), Finland. https://jyx.jyu.fi/bitstream/handle/123456789/20911/1/urn_nbn_fi_jyu-2009411309.pdf

Powell, S. R. (2010). Wind instrument intonation: A research synthesis. *Bulletin of the Council for Research in Music Education*, *184,* 79-96. https://www.jstor.org/stable/27861484

Puangsamlee, P., & Fyr, K. (2018). Benefits of listening for harmony on the performance of wind instrument beginners. *Malaysian Journal of Music*, *7*, 100-116. https://doi.org/10.37134/mjm.vol7.6.2018

Rumjaun, A., & Narod, F. (2020). Social Learning Theory–Albert Bandura. In B. Akpan & T. J. Kennedy (Eds.), *Education in Theory and Practice. An Introductory Guide to Learning Theory* (pp. 85-100). Springer. https://doi.org/10.1007/978-3-030-43620-9_7

Schaefer, R. S. (2017). Music in the brain. In R. Ashley y R. Timmers (Eds.), *The Routledge Companion to Music Cognition* (pp. 25-35). Routledge. https://doi.org/10.4324/9781315194738.ch3

Schlegel, A., & Springer, D. (2018). Effects of accurate and inaccurate visual feedback on the tuning accuracy of high school and college trombonists. *International Journal of Music Education, 36*(3), 394-406. https://doi.org/10.1177/0255761418763914

Silvey, B., Nápoles, J., & Springer, G. (2019). Effects of Pre-Tuning Vocalization Behaviors on the Tuning Accuracy of College Instrumentalists. *Journal of Research in Music Education, 66*(4), 392-407. https://doi.org/10.1177/0022429418806304

Springer, D. G. (2020). Research to Resource: Evidence-Based Strategies for Improving Wind Intonation. *Update: Applications of Research in Music Education*, *39*(1), 4-7. https://doi.org/10.1177/8755123320930483

Springer, D. G., Silvey, B. A., Nápoles, J., & Warnet, V. (2020). Effects of Tonic Drone Accompaniments on the Intonation of Collegiate Wind Instrumentalists. *Journal of Research in Music Education*, *69*(3), 343-359. https://doi.org/10.1177/0022429420974389

Stambaugh, L. A. (2016). Implications of extrinsic cognitive load on three levels of adult woodwind players. *Psychology of Music*, *44*(6), 1318-1330. https://doi.org/10.1177%2F0305735615627206

Tejada, J., & Thayer, J. (2019). Design and validation of a music technology course for initial music teacher education based on the TPACK Model and the Project-Based Learning approach. *Journal of Music, Technology, and Education, 12*(3), 225-246 https://doi.org/10.1386/jmte_00008_1

White, A. (2020). *The Effects of Feedback on Sight-singing Achievement* (Order No. 28156770) [Doctoral dissertation, Northwestern University]. ProQuest Dissertation Publishing. https://www.proquest.com/dissertations-theses/effects-feedback-on-sight-singing-achievement/docview/2469533799/se-2?accountid=14777

Wilson, P., Lee, K., Callaghan, J., & Thorpe, W. (2008). Learning to sing in tune: Does real-time visual feedback help? *Journal of Interdisciplinary Music Studies, 2*(1&2), 157-172.http://musicstudies.org/wp-content/uploads/2017/01/Wilson_JIMS_0821210.pdf

Zabanal, J. R. A. (2019). Effects of short-term practice with a tonic drone accompaniment on middle and high school violin and viola intonation. *String Research Journal*, *9*(1), 51-61. https://doi.org/10.1177/1948499219851407

Zaki-Azat, J. N. (2016). *The Influence of Real-Time Visual Feedback Training on Vocal Control* [Master dissertation, Wilfrid Laurier University]. http://doi.org/10.13140/RG.2.1.1214.3123

Zendri, G., Valdan, M., Gratton, L. M., & Oss, S. (2015). Musical intonation of wind instruments and temperature. *Physics Education*, *50*(3), 348-351. http://doi.org/10.1088/0031-9120/50/3/348