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Multi-track recordings of choral singers: Development and validation of a method to identify activities and interaction in the choral voice, based on recordings of the individual singers

Summary

Methods to identify and explore actions of the individual choir singer are scarce and have rarely been systematically described. The aim of this study was to find, develop and evaluate a visual-auditive method for collecting and analysing data from individual choir-singers. Multi-track recordings were performed and analysed. Two voice teachers and singers in a mixed high-school choir with hand-held/head-mounted microphones were recorded on individual tracks. With the help of a computer software, the recordings were transferred for visual analysis. The detailed actions of the singers were possible to identify and thus also actions indicating informal leadership could be identified. This method was concluded to be a useful instrument for collecting, comparing and analysing data from individual singers. Accordingly, the method is found to be valid and productive in choir research, the results of which might provide valuable knowledge of cooperation between choral singers, thus serving as a tool in choir conductors' everyday work.

Keywords*: Choir voices, choir leader, informal leaders, voice recordings*

1 Introduction

In Scandinavia, choir singing is very popular and engages many people: amateurs and professionals, in schools at all levels, in churches and in community choirs. Swedish choral singing has gained worldwide attention for its excellency on professional as well as semi-professional levels. One of the essential factors behind this phenomenon, sometimes referred to as "The Swedish Choral Miracle" (Reimers, 1993 p. 18), is that of preciseness and coordination at many levels, such as vocal blend and staying together with regard to intonation, rhythm and articulation (Hedell, 2009).

In choir-singing voices are commonly meant to blend together. When singing together, singers can sound like one voice even when they are of a greater number. In classical/traditional choral singing this vocal homogeneity entails an ideal of tone quality and vocal blend. Choral conductors need to develop the choir, for example, by placing the singers in the optimal positions in order to make them "sound together" with the aim of monitoring the blend-

ing of voices and for articulation to be alike and united. This is difficult even for the very skilled and experienced choral conductor as it is not always easy to spot which voice comes from which singer. A conductor might listen to the choir and think he or she knows whose voice is heard, but in the mix of all the voices there is a large risk to make a mistake. It is easy to get fooled by the steady eyes of someone, giving the impression of total vocal security, but in the next moment, perhaps during a rest, this person's voice is heard as an undesired solo, and it's clear that the original impression was completely wrong. Further, it is essential that choral singers are socially compatible with their musical neighbours; however, this does not indicate that everyone sings well with their best friend. This can also fool a choral conductor. The combination of voices might even be detrimental to the choir voice as well as for the individual singer's vocal function and voice health. Based on these notions there is a need of tools for choral conductors and researchers, to objectively compare and determine the differences and similarities between each singer and his or her actions in a choral voice.

Moreover, in a previous interview study with experienced Swedish choral conductors the subjects independently stated that in all choirs there are singers who act as leaders, formal or informal (Zadig & Folkestad, 2015). The conductors reported that this leadership emerges when an individual singer takes the musical lead of fellow singers, for example concerning attacks, intonation and phrasing. According to some of the informants this can be noticed also at the level of blend and timbre, so that one voice, or rather the colour of one voice, can spread to the other voices in the specific choral voice, and even to the whole choir. This is an intriguing finding and the present article describes a method to investigate cooperation between the singers in a choir.

1.1 Background

To the best of our knowing, no systematic study has been presented in the area of objectively tracking singers with the aim of following their actions and making it possible to spot processes that might not be aurally or visually perceived. Earlier studies on choral music and choral singing have mostly focused on socialization within the choir (Haugland Balsnes, 2009), the reasons and objectives for singing in a choir (Henningsson, 1996) and health aspects (for example Knight, 2010; Clift, & Hancox, 2001; Grape, Sandgren, Hansson, Ericson, & Theorell, 2003; Kreutz, Bongard, Rohrmann, Hodapp, & Grebe, 2004). The field of studies focusing on cooperation between singers in choirs is so far largely unexplored. However, some studies have through interviews focused on cooperation between choral singers (Einarsdóttir, 2012) and also on leaders and followers in the choir (Einarsdóttir, 2014). Furthermore, Palmer, Spidle, Koopmans and Shubert (2013) have in an adjacent area studied the singers' abilities to coordinate their parts in duet performances (Palmer et al., p. 681).

Some researchers have studied the effects of choral placement, formation, and how the singers perceive their neighbouring singers. The effect on choral blend of the individual vocal production and seating arrangements is, for example, examined in Ekholm (1999, 2000). Also Daugherty (2003) explores choir spacing, both the space between the singers and in different standing formations. A similar study by Aspaas, McCrea, Morris and Fowler (2004) also deals with the choral blend in different choral formations, as well as the choristers' preference and perception of these contrasting choral formations. A similar study was conducted by Ternström, Cabera & Davis (2005) on the self-to-other ratios of the singers' vocal loudness during an

opera performance, but nothing on the cooperation between the singers was analysed. Jers (2007) examines the influence of adjacent singers in a choir, but only on the aspect of sound as a source, not on articulation or blend.

In the choral voice, singers often stand together side by side, shoulder to shoulder. This means that they in fact don't have many possibilities for eye contact or to look at each other's mouths – which could be useful for synchronizing articulation. Thus, singers are bound to listen to each other's singing while simultaneously singing themselves. In order to investigate what happens with the vocal sound between the choir singers, it is essential to understand how the sound propagates within the choir and in the rehearsal room. Ekholm (2000) concludes in her study of choral seating that "arranging choristers so that voices are acoustically matched may enhance blend, dynamic range, phrasing, and overall tone quality" (p. 123). A study of special interest for the present study, in the field of placements in choirs, shows that the sound from one singer is influenced, not so much by the body of a lateral singer, but by a frontal singer (Jers, 2007). These experiments were performed in an anechoic room with a dummy for a singer, with a loudspeaker in its "mouth". Fourteen microphones were picking up sound in a wide circle range around the singing dummy and were moved for each recording into 27 different positions. The result showed that the sound from one singer is influenced, not so much by the body of a lateral singer, but by a frontal singer (Jers, 2007). As a conclusion, Jers strongly emphasized that singers should be placed on different levels on raisers, when performing.

In order to understand cooperation between singers it is of great importance to understand how and when a singer can hear other choral singers. Grell, Sundberg, Ternström, Ptok & Altenmüller (2009) showed how choral singers can react to each other's singing "most singers have a rather quick reaction to a shift in an external auditory pitch reference. In a choir the fellow singers generally provide this reference and it is important that the entire ensemble synchronize their pitch changes" (Grell et al., 2009, p. 412). In the study, singers were given a tone to sing a fifth to. The tone was suddenly shifted, and the time it took for the singer to adapt to the new tone was measured. The investigation showed that highly skilled choir singers reacted faster than moderately skilled singers. A quick reaction could be as fast as 50 ms while the mean reaction for all singers in the study was 223 ms. (range 206-251 ms.).

Choral seating of the singers in the choir is an important issue and has been investigated in a number of studies. It is necessary for the conductor to be aware of the importance of the singers' ability to hear both themselves as well as other singers. Several factors have impact on how the singers experience where they sit or stand in the choir, how they hear the rest of the choir and also how they hear and react to their neighbouring singers Langner (2002) points out that it is important for singers to maintain normal vocal production wherever their location, and that the conductor does not ignore choral problems arising from poor placement (Langner, 2002, p. 10).

In the study Choir Spacing and Formation, Daugherty (2003) examined the differences in sound of choirs, based on different seating/standing formations. A mixed university chamber choir was investigated, its male and female sections, in three varieties of spacing (closed, lateral and circumambient) and two different formations (random block sectional and synergistic). Subsequently, objective evaluations were made by listeners of randomly ordered excerpts, and the singers made subjective evaluations of their preferred formation. The result showed that both groups preferred the spread spacing, but differed in preference on formation: the

singers preferred the spread spacing. They also liked the exercise of trying out different formations and responded that the spread spacing influenced the vocal production in positive ways, both concerning their own vocal tension and the choral sound. The investigation did, however, not focus on informal leaders within the choir. The fact that the singers preferred not to be too close to each other could indicate that they got a better perception on their own sound production when spaced out.

Langner (2002) also suggests a method for the conductor to gain better insight on the individual singers, besides auditions or periodic reviews of the singers. He suggests that, during a rehearsal, "use a small cassette recorder wherein each singer speaks their name, sings their part along with the choir for a minute or two, and then passes it on to the next singer" (Lagner, 2002, p. 9). This method however does not provide information on how to have the singers recorded for direct comparison.

In summary, the research described above deals with the exploration of sound of singers in choirs, and how the sound is propagated and achieved. In choirs, most anything concerning the sound is – for the conductor as well as the singers – based on listening, and by using the ears to place, identify and understand what fellow singers are doing. However, even if the ear is a highly sensitive instrument it has limitations in how to sort and discriminate all heard impressions. There are some studies which have used documentary methods for the identification of the singers' actions (Langner, 2002; Daugherty, 2003; Jers, 2007), but none of the methods have been systematically explored for practical use by a choir conductor. Our conclusion is that in order to be able to identify exactly what the individual singers actually do, an alternate method is required.

All of the above mentioned studies have importance on choral singing and give important clues on cooperation, timing and blend, but none focuses on the leadership within the choir or the choral voice. Also, based on the notions of the conductors in Zadig and Folkestad (2015), there is a need of a means to objectively compare and determine the differences and similarities between each singer and his or her actions in a choral voice.

1.2 Aim

The aim of this research was to design and try out a method giving visually based representations of vocal behaviour in order to make it possible to simultaneously collect and analyse data from singers in a choir: to identify actions and interaction between singers in a choral voice and furthermore in the entire choir. Specific research questions are: (i) is it possible to make objective comparisons between the vocal actions of different singers in one choral voice through individual recordings of a whole group of singers, and (ii) to visualize the vocal actions through graphs of the voices.

2 Methods

This article presents an investigation involving two different experimental settings, covering recordings of two or more singers singing together. The settings were used in three different sub-studies, and will be referred to as Sub-study 1, Sub-study 2, and Sub-study 3.

2.1 Material, equipment and analysis

For Sub-study 1 two dynamic microphones (Shure, SM58) with connections were used. Recordings were made with the program Pro Tools, version 7.4.2 with MacBook Pro 5,4, Intel Core 2 Duo, 2,53 GHz, through the interface Avid Technology, Digidesign Mbox 2, Model No 9100–17246–00 with the capacity to record two voices simultaneously. After recording, the analysis was performed with the software Melodyne 3.2.2.2 where, on the time axis (x) timing and precision is shown, and on the y-axis intonation and true pitches are shown.

For Sub-study 2 and Sub-study 3, each singer wore a head mounted microphone of the type MIPRO MU-53HNS. Its microphone head can be directed straight towards each individual singer's mouth so that it picks up only sparse ambient noise from adjacent singers.

Figure 1: Head mounted, directed microphone MIPRO MU–53HNS

Set-up for these ensemble recordings was done for 6 (Sub-study 2) and 7 (Sub-study 3) separate channels, one for each singer. The recording signal was amplified through M-Audio Fast Track Ultra 8R-USB 2.0 interface which has the capacity to make up to eight simultaneous recordings. The recordings were carried out using MacBook Pro 5,4, Intel Core 2 Duo, 2,53 GHz.

Recordings, analyses of the vocal lines and comparisons of the voices were finally done within Steinberg Cubase 5 with the integrated function Vary Audio. Vary Audio offers possibilities to edit every individually recorded track. The program is initially intended for commercial use and is intended to be used for correcting intonation and timing problems within recordings (Bachmann, Bischoff & Pfeifer, 2009, p. 251). It is possible to trace the timing on the x axis' time line. On the y axis intonation is shown. "the vocal line [voice curb] is analysed and split into segments shown as a graphic representation of the notes sung. After the detection process is complete, the recognized notes can be modified entirely 'non-de-structured' so that any modifications to the audio material can be undone or reverted to the state of the original file" (Bachman et al., 2009, p. 251). The average pitch of a segment is calculated from its micro-pitch curve. Micro-pitch curves represent the progression of the pitch. The analyses of the voice curb are presented in pictures with graphs of pitch and time, towards a coordinate system that can be set up with time direction on the x-axis either according to measures or time in seconds. The latter was chosen in the present study for facile comparison of the voices. The recording program is normally used in recordings where there is a count-down, which gives a fixed starting point. In these recordings the program is running while the choir starts to sing. The time-line can be used as a reference but without synchronized time positions. In order to have the beats of the song or the measures of the music synchronized the choir needs to be started in a certain tempo and with the start paired to the recordings. Measures or bars were not considered applicable since the counting starts from bar number one of a recording (and "expects" the session to start after one or more bars of click-sound/counting down). Pitch is shown in the y-axis. In the coordinate system the pictures can be compared with those from other voices within the

same recording episode. The x-axis will in this presentation be called y *time*, and the y-axis will be referred to as *pitch*.

The words *Voice* and *Voices* are used for the singers as individuals, when they all sing together the term *choral voice* will be used. *Note* is used for the print music while *tone* is used for the sung tone.

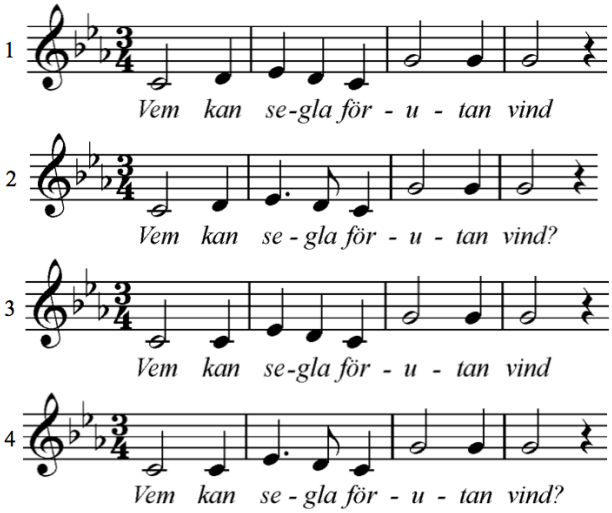
2.2 Subjects

For Sub-study 1, two skilled sopranos, both voice teachers (34 and 36 years old) were recorded. For Sub-study 2 and 3, the choral singers were recruited from an upper secondary school, ages around 16 years old. Choral singing was mandatory in their curriculum. At the time of recording the students had studied choir-singing for about 7 months (Sub-study 2) respectively 1 month (Sub-study 3). Most of the students were previously inexperienced with choir singing. In Sub-study 2 the soprano voice (n=6 female students, 16–17 yrs.) was recorded and in Sub-study 3 the tenor voice (n=8 male students, 16–17 yrs.). For Sub-study 2 the choir was seated in a singular semicircle, sopranos to the far left, then altos, tenors and basses, and for Sub-study 3 in two semicircles with altos to the right of sopranos, as seen from conductor, in the first row. In second row, as seen from the left, basses and to the right of them tenors. For both Sub-study 2 and 3 the conductor was placed centred in front of the semicircle.

2.3 Recording procedures

Sub-study 1. Two recordings were made. Before the first take, the singers were instructed to sing the well know folk tune "Vem kan segla förutan vind" [Who can sail without wind] in unison, a song they knew by heart. The singers held the dynamic microphones (Shure, SM58) in their hands, close to their mouths. In the first recording the singers were not specifically instructed regarding standing position. In the second recording, the singers were asked to face the wall and to stand side-by-side, shoulder-to-shoulder, so that they would not be able to see each other's mouths or eyes. For both recordings, a first note was given from the piano, but no tempo, pulse or cue, with the aim of forcing the singers to take own initiative to start, and to find their common tempo.

Figure 2: Presentation of four different traditions to the start of the tune "Vem kan segla förutan vind".



In this song there are a couple of phrases that by tradition might be sung in different ways. As seen in Figure 2 the notes in the first and second bar can sometimes be sung stepwise, sometimes repeated, and sometimes also punctuated.

In order to be able to compare different recordings with the same choral piece, the same setting and with the same singers, recordings for Sub-study 2 and Sub-study 3 with two choral voices of several singers had to be made during the same choral class. The reason for this was due to the possibility of unwanted changes to the setting in the coming weeks' sessions: someone could be missing or vocal changes due to colds and other circumstances might impact the setting. All singers in the recorded voice were fitted with headset microphones, cables attached to the soundcard and the computer placed behind the choir. To be able to control also whether any of the singers made any visual signs (head, hand or arm movements/gestures or other – conscious or unconscious – presumably making fellow singers react to visual instead of audible cues) all the recorded sessions were simultaneously video filmed. The camera was set up behind and above the conductor, so that the conductor (from behind) as well as the whole choir was in focus. There was no specific instruction given, only to act as though in a normal choral class. The choir in both these studies consisted of four voices: sopranos, altos, tenors and basses. In both studies, the choir singers were seated while singing.

3 Results

3.1 Sub-study 1: Recordings of unison voices

When first introduced to the task to sing in unison, the singers, spontaneously both faced each other to see each other's eyes and mouths in order to sing as similar as possible concerning rhythm and articulation. As being two trained voice teachers they quite easily adapted to the situation. For the second recording they were asked to stand side by side, like they would have in a choral situation. The recordings were analysed with the computer program Melodyne where the vocal line is shown in a graph. When comparing the two graphs of the two sopranos voices, A and B, some distinctive differences emerged concerning timing and pitch. Figure 3 presents the beginning of the song with the two voices shown in separate graphs. As is shown in Figure 3, it is clear that the upper voice starts ahead of the lower on the first note, [A1] and [A2]. It is also possible to see slides in the attacks in both voices, in the upper in hitting the top note [A3] and in the lower at the start [B3]. Concerning the intonation, the graph shows that the melody top note with the text /U-tan vind/, is slightly flat on the vowel "a" in the upper voice [A4]. We can see how the experienced voice teachers quite easily adapted to the situation and took turns being the one who taking initiative in leading the singing. Grell et al. (2009) showed that in both categories of skilled and moderately skilled singers the reaction was quick. Some reacted as fast as after only 50 ms. and a large group of responses were quicker than 150-200 ms. The mean of these two categories was between 206 and 227 ms.

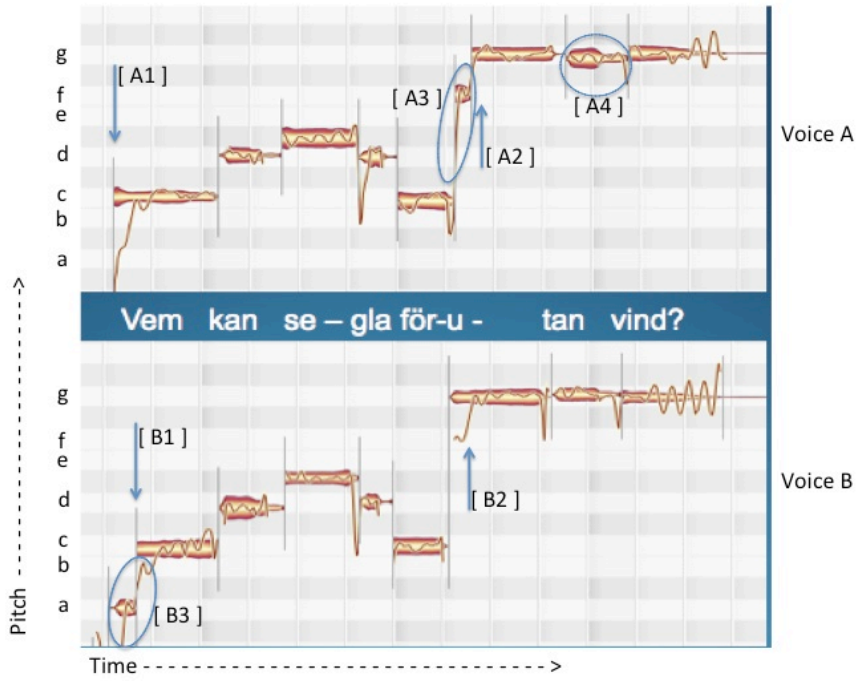


Figure 3: Two simultaneous singers (sopranos, A and B). Each voice represented by one curve A and B, showing pitch (y-axis) and time (x-axis). Deviances are circled.

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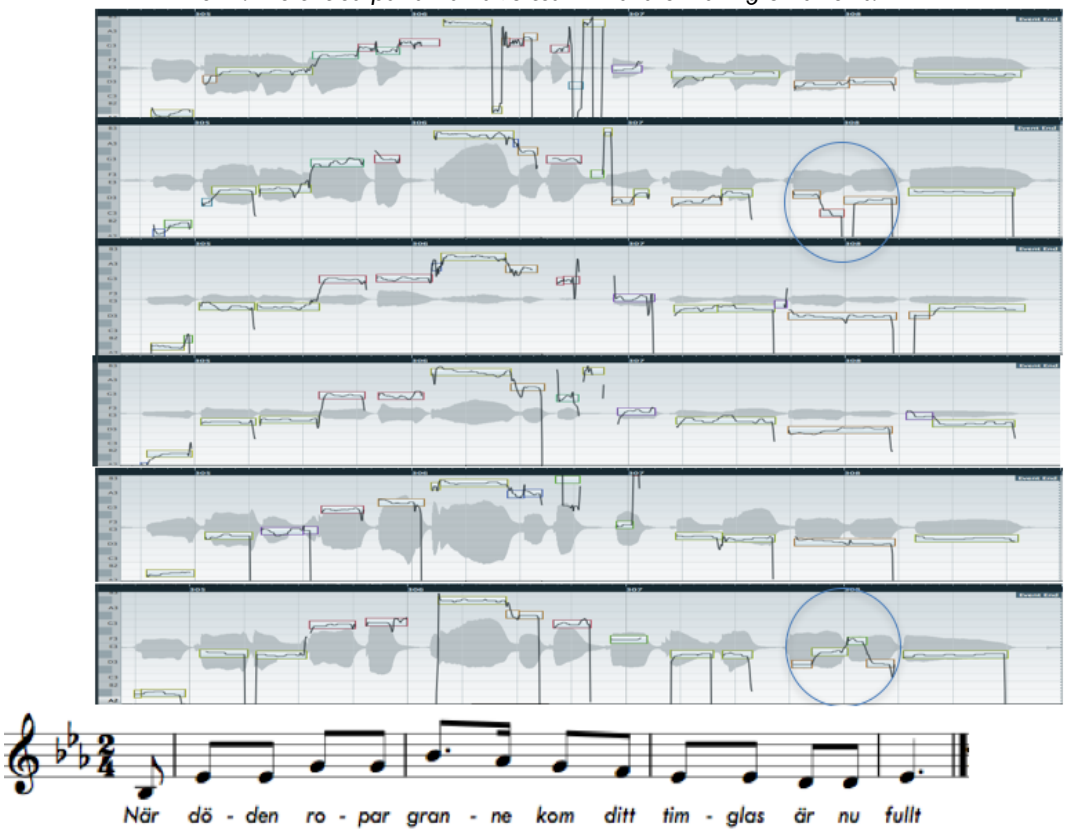
In summary, the results of the recordings showed that both the set-up and the equipment for analysis were useful for comparing and analysing more than one simultaneous voice. With this setting and equipment, it was however not possible to simultaneously study more than two voices since this soundcard only handle two channels.

3.2 Sub-study 2: Analysis of multi-track recordings

Sub-study 2 presents the levels of analysing the voices. The first step entailed getting an overview of all recorded individual voices. Later steps zoomed in on details, making it possible to focus on differences or similarities between voices. Tcompare more than two voices, the program Cubase was used for this and following studies. Figure 4 shows the voices of six student sopranos, singing simultaneously. This figure is merely an example on how to compare several voices in an overview. For detail focus a more enlarged picture is necessary. Each voice, recorded on a separate track, is represented in the graph. For Figure 4 the horizontal scale was set up manually as a reference to make it possible to track the exact performance of each singer. The sopranos sang the tune from Carl Michael Bellman's drinking-song #21 "Så lunka vi så småningom" – the part "…när döden ropar granne kom, ditt timglas är nu fullt" [..when death is calling: neighbour come, your hourglass is full] (Lower part of Figure 4), during one rehearsal session. The marked circles will be examined closer by more detailed enlargement. From Figure 4, it is possible to identify the exact note sung for each voice/graph. The length and pitch of each note is shown by the time axis and the pitch axis. To the left of every voice it is possible to identify a specific note with the help of the outlay of the keyboard. The "boxes" presenting the "tones" of the melody line, are the result of the program's automatic analyses, marking "boxes" around what it conceives as a note, which the listener would perceive as a

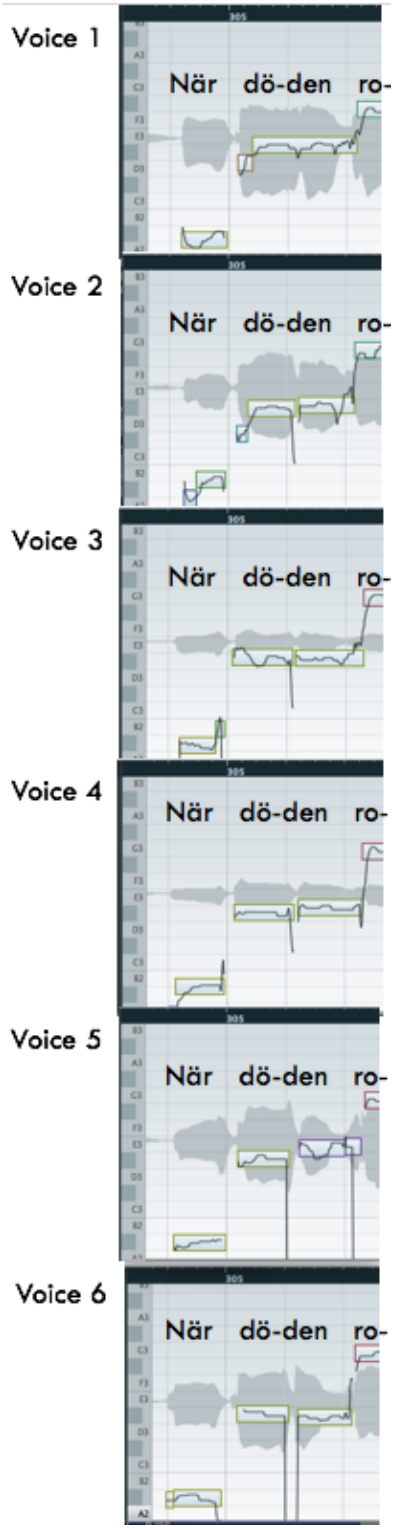
tone. The actual pitch is represented by a thin line. The shadow in the background of the pictures shows the amplitude of the recorded voice, which explains why the shadow is large on vowels and minimal in between the syllables. The vertical timelines are not coordinated to the singing, they just mark time but without any reference to the beat or pulse of the song. When comparing to the written music below the graph, it is possible to discern that singers 2 and 6 probably already knew the song when it was presented to them. A clear sign of this is that the sopranos in voices number 2 and 6 make small ornaments (circled).

Figure 4: "Bellman, song #21" Six sopranos singing in unison "När döden ropar granne kom, ditt timglas är nu fullt". The circled parts marks voices nr 2 and 6 making ornaments.



To show possibilities on identifying differences, the voices will be presented and examined in some more details in the following Figure 5 where all voices show different details in the start of the excerpt.

Figure 5: "Bellman, song #21" Close up of the start of the excerpt with all 6 voices.



Voice 1: slight glissando to the second syllable "dö"

Voice 2: slight glissando both to the first and second syllable

Voice 3: Together with voice 6 voice 3 reaches earliest on the second syllable sooner than others, but the vowel "dö" is quite unstable in voice 3.

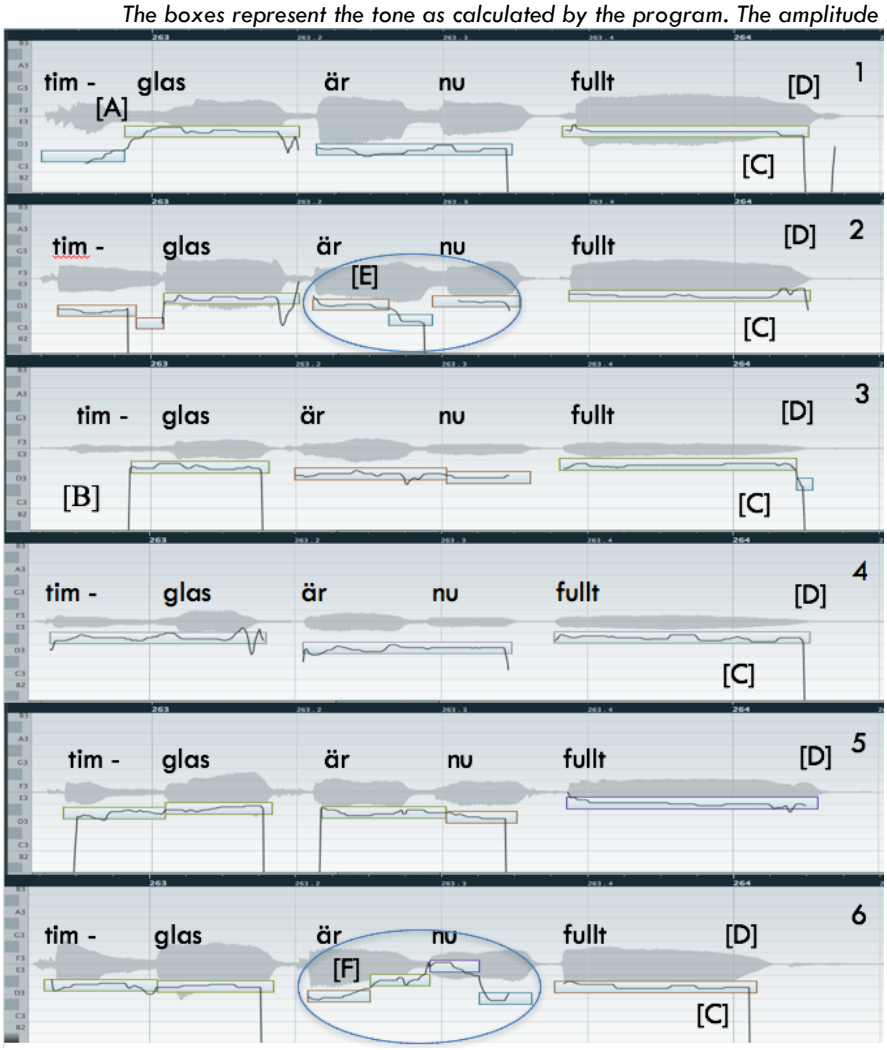
Voice 4: a slide up to the first syllable

Voice 5: the third syllable is not at the same pitch as the second syllable, as it should have been.

Voice 6: drop of pitch at the end of the first syllable.

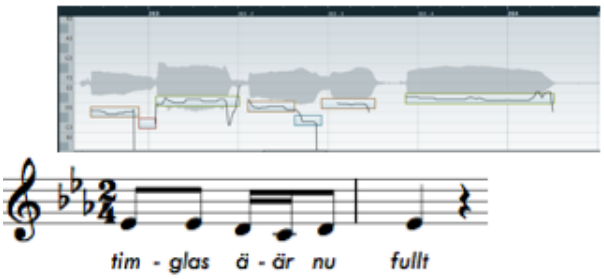
Another close up example of this specific part of the song is shown in Figure 6 where all the voices are compared to each other at the end of the phrase. These graphs also show many details in each individual voice.

Figure 6: "Bellman, song #21" The part "timglas är nu fullt" where differences between the six sopranos are shown. The boxes represent the tone as calculated by the program. The amplitude is shadowed in grey.



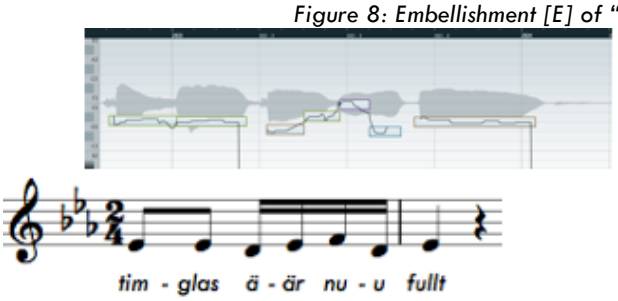
Voice 1 makes a glissando up by the first two notes [A], seen in the thin vocal line, even though the program analyses this as two separate tones. Voice 3 misses the first note [B]. All voices but number 5 make a slide down at the end of the phrase [C] and it is also notable that they all hold the last note differently at length [D]. Voices 2 and 6 make one embellishment each. Voice 2 at [E] and voice 6 at [F]. These embellishments can also be seen with music in Figure 7 [E] and Figure 8 F].

Figure 7: Embellishment [D] of "Bellman, song #21", voice 2.



Voice 6 even makes a little trill on the third and second last syllables "[tim-glas] ä-är nu-u [fullt]" (Figure 8).

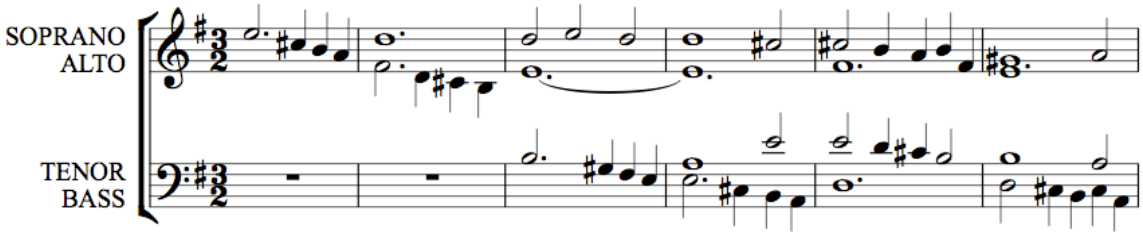
Figure 8: Embellishment [E] of "Bellman, song #21", voice 6.



3.3 Sub-study 3: Recordings of the tenor voice

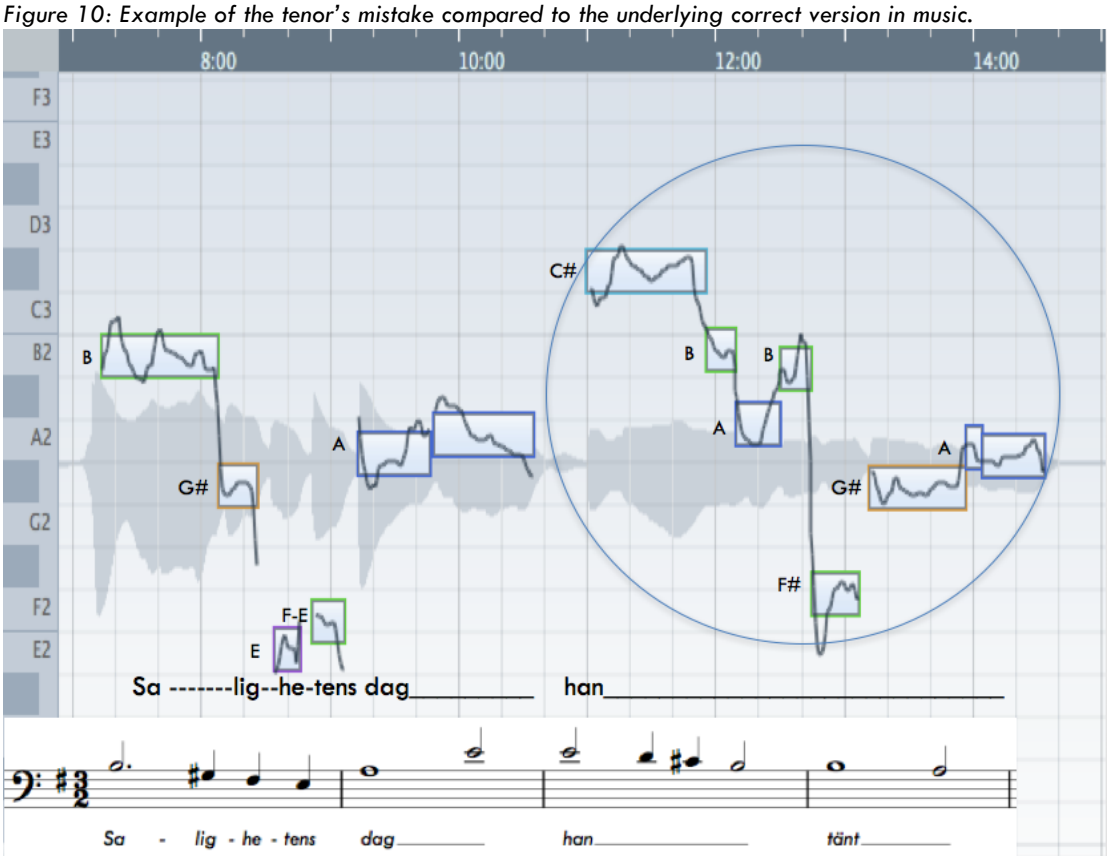
For Sub-study 3, recordings of the tenor voice, consisting of seven singers, were performed and analysed with Cubase. Figure 9 shows an excerpt from a well-known Swedish composition by Otto Olsson (1879–1964) "Advent", traditionally sung for the Advent celebration before Christmas. The lyrics for this excerpt is in Swedish; "Salighetens dag, han tänt"; [The day of bliss, he has light]. The eight bars in focus for the analysis (Figure 9) is a short imitation section of the soprano, alto, tenor and bass voices.

Figure 9: Excerpt from the printed music of Otto Olsson's "Advent" without lyrics. SATB The tenor part is in focus for Sub-study 3.



When analysing the recordings from this rehearsal it became clear that something unexpected happened in the tenor part. One of the tenors got the part wrong, but kept on making/repeating that same mistake at every re-take. More and more of his fellow singers in that vocal part, adopted his mistake. He ended up a third below the printed note and continued a peculiar vocal figure. Figure 10 shows the part of this singer with the mistake circled.

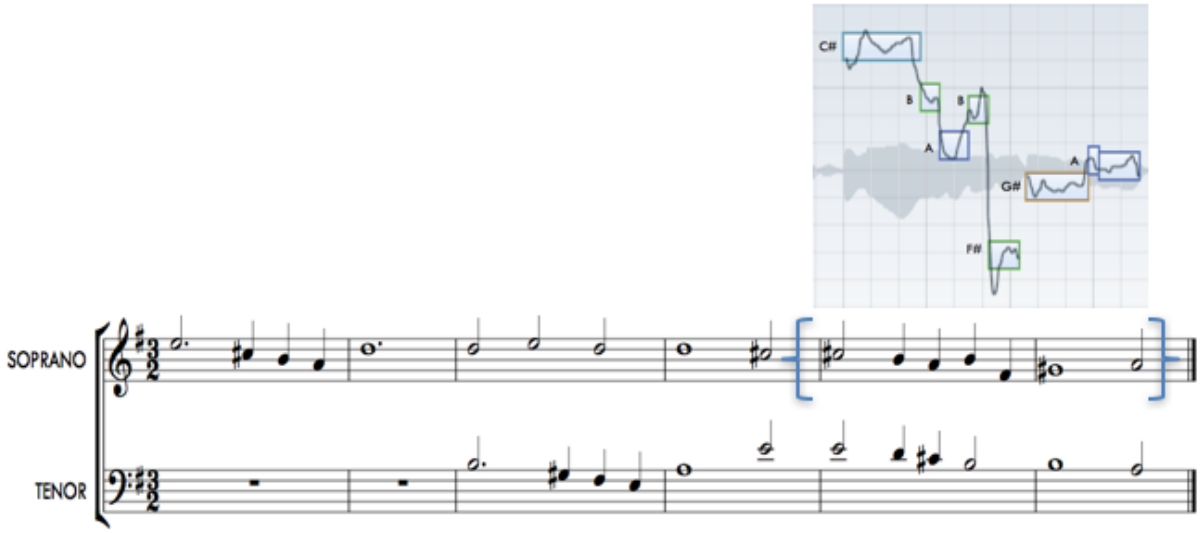
Figure 10: Example of the tenor's mistake compared to the underlying correct version in music.



As shown in Figure 11, the mistake can be recognized as derived from the soprano part. The music shows the choral setting with the soprano and tenor voices, together with the graph of the mentioned mistake.

The analysis of the recording of all tenors showed that this mistake was adopted by other singers in the group, thus pointing out that they "followed" this unintentional "leader".

Figure 11: Example of the sung mistake compared to the influencing soprano part.



In summary, the present results show that through the use of a tool for multi-track recordings and analysis, it is possible to track each individual's voice and to compare two or more singers singing simultaneously concerning aspects of timing: Sub-study 1, Sub-study 2, and accuracy Sub-study 1, Sub-study 2, Sub-study 3.

4 Discussion

With the overall aim of investigating informal leadership in choirs, the present study was intended to investigate and validate a method for recording of separate, however simultaneous voices in choirs. The use of a computer application intended for commercial use (Cubase) was shown to be a reliable instrument for the analysis of recordings of individual singers in a choral-voice. Similar results would be possible also with programs such as ProTools in combination with Melodyne and eventually others too.

Jensen et al. (2011) mentions three different modes of communication during performance: (i) verbal, when the musicians talk to each other, (ii) non-verbal, when the musicians give each other cues like nods or smiles and (iii) musical, when the musicians give each other cues via their instrumental sound production.

This investigation focuses on this 3rd mode, the musical cooperation between the singers and uses graphs to show this. The advantage of using graphs is the possibility of getting a more detailed focus on what the singers do than is possible by listening only. It is further possible to do a detailed analysis of a specific time-point and thus, compare the graphs of several voices.

With the aim of developing and trying out a method for investigating actions in a choir voice, the present article covers three studies of choir singing with recordings of two voice teachers; a group of sopranos and a group of tenors. The recordings in each study were made simultaneously with each voice recorded on a separate channel. In the first study a ProTools equipment for recordings along with the analysing program Melodyne, were used for exploring of two soprano voices. However, with this set-up, it was only possible to record two parallel tracks. Thus, for the following studies, Cubase with VaryAudio integrated were used for recordings of up 8 separate voices. For each voice, the recordings/graphs showed exact pitch. Moreover, the exact events were shown on a timeline. The timeline is used only for comparing simultaneous recordings.

Sub-study 1 showed that a computer and a recording program for analysis made it possible to identify differences between two experienced singers. Singers can rapidly abandon their own tone and switch to the tone of a leader thus corroborating the findings by Grell et al., 2009). The identification of differences between the two singers led to expanding the recordings to a choral voice with several singers. Following, Sub-study 2 showed what could be gained by detailed analysis, by examining and comparing the graphs depicting the choral voices. What emerged was the possibility to catch a lapse that possibly would have aurally misled even a skilled conductor: a couple of the sopranos made ornaments, never introduced by the conductor. These embellishments were possible to detect through the analysis of the recordings, and could of course have been detected aurally as well. However, with the help of the graphs it was possible to detect several later and fundamental mistakes made by the two

sopranos. Without these recordings/graphs, the embellishments could deceptively have been perceived as some signs of "expertise". A conductor could be misled to believe that these sopranos probably were the best or most experienced singers, assigning possible faults to someone else. In Sub-study 3, the analysis made it possible to spot an unintentional leader, as one tenor made an unexpected mistake and was followed by his fellow singers. Without the recording showing what caused the tenor part to lose control, a conductor probably would have noticed that they made the mistake, and thus corrected the whole voice part, but the conductor would not have been aware of how it happened or what or who caused the faulty result. The visualized vocal lines are exact and precise in a way an audio example could never be.

It is important to underline that the present article describes a research method. A more in-depth exploration of informal leadership using this method is presented in an ensuing article (Zadig, Folkestad & Lyberg-Åhlander, forthcoming). Based on the statements by the informants in Zadig & Folkestad (2015), more in-depth research of possible ways of informal leaders will be described. With the help of the presented method it is possible to show actions in the choral voice that would not be identifiable by ordinary rehearsal techniques. The audio recordings/graphs are more objective registrations, and it presents possibilities beyond what can be perceived aurally. As discussed above, a conductor might be misled by visual expressions from the singers, and further, conductors need to have information about how the singers "cooperate" vocally, a task that depends today on the skill and experience of the conductor. Also, for a conductor with longstanding routine to decide who is taking a leading role, can be somewhat difficult.

Further research regarding leaders in choirs is called for and in an ongoing project the method presented in this article is applied (Zadig et al., forthcoming). The leading of others, mentioned by the interview informants (Zadig & Folkestad, 2015) is audible for the peer singers in the choral voice and doesn't need to be sung. Based on experience, sometimes a singer just by taking a breath before a vocal entry can prompt others to start singing. In a study on performance interaction, Jensen, Frimodt-Møller & Grund, (2014) state that most of the musical communication within a professional ensemble is auditive.

One important conclusion has been drawn from the initial observations: at the level of professional performance, a performance of music based on notation (scores, parts, etc.) contains very little visible communication (p. 269): Thus to use a method of registration gives a possibility to visually understand the aurally perceived.

4.1 Methodological considerations

Although the computer and analysing program Cubase is user friendly, one disadvantage is that it is not meant to compare synchronized voices. Only one single voice at a time can be analysed, stored by a screen shot, while analysing the next and so on. This entails rather slow work, and leaves nothing to analyse during the ongoing rehearsals. When all the voices are analysed for a specific phrase or "incident" they can be lined up and compared. The first author has approached the Steinberg–Cubase team and informed them about this problem, unfortunately without any reaction.

Reading and interpreting the graphs requires specific knowledge. Moreover, it is essential also to *listen* to the parts compared, and not to judge solely from the base of the analysed graphs. For example, it is not always the singer singing ahead of others, who is the leader. This singer might just as well be a little too early in each attack of notes. Further, to ensure a correct conclusion of which singer who is acting as an informal leader, more than one recording is needed, and preferably with different music. Specific knowledge about the music being sung/recorded is also needed in order to set some of the decisions made by the program aside. The program decides about the vocal line according to the rules made for the program and these might not always be corresponding to what is perceived. Moreover, skilled conductors need to make decisions based on their experience and not solely based on the contribution from the software: the ear and common sense cannot be omitted. This method can be an objective help in creating a good basis for placement of singers in choirs.

4.2 Future research

To refine the presented method and to explore who acts as a vocal leader in the choral voice, several recordings need to be made, and preferably in different circumstances, such as a variety of chosen music, different seating arrangements and placements of the singers. In the presentation of this method it is possible to recognize cooperation between choral singers. Further research is needed to explore this more in detail. Many more choral situations can also be looked more closely upon using the presented method, both on amateur and more advanced levels. There are also choirs for people that are inexperienced in singing or who regard themselves as "non-singers" (Richards, & Durrant, 2003; Knight, 2010). To investigate these and perhaps find ways to help them improve their choral singing, through cooperation with others, might give fruitful results.

The effect of recognizing informal leadership trough the described method might be used to improve a choir, and could thus be interesting to further research. Also the singers' view on their choir singing and informal leadership would be a valuable contribution to the knowledge of choir leading.

5 Conclusion

The present investigation demonstrates that it is possible and purposeful to record and analyse several simultaneous singers in a choir. Furthermore, it showed that through multi track recordings it is possible to clarify who acts as a musical leader in a choral voice. From the graphs, an objective picture emerges of what the singers do, possibly helping the conductor to stay objective. Getting a more objective analysis a choral conductor knowing his or her choir can ignore personal bonds to the singers. What is sung is registered in an absolute same way.

The present results show that for the recording and individual comparative analysis of simultaneous voices, software such as ProTools-Melodyne or Cubase-VaryAudio, are useful. It is a convenient tool for identifying differences concerning timing and to some extent, quality (for example. intonation, glissandi). These findings can be valuable for assessment in group performances.

If choral conductors can better understand how voices and singers really work together, and accordingly place the singers vocally in their best positions, much progress could be achieved in the choir. Singers that act, blend and synchronize their voices in optimal cooperation may enhance the choral sound. With a better understanding of vocal cooperation within the choir, it might be possible to guide choirs and conductors to better musical results.

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