



No. 1905b

FLOW

Stop playing and start floating

DEVELOPING THE NEW **MUSIC READER**

Graduation Project IDE 2012
Kine Handlykken
1279173

Content

0	Executive summary	4
1	Introduction	5
2	Written Music.....	6
2.1	What is musical notation?	6
2.2	Development of musical notation	6
2.3	Modern staff notation	6
2.4	Sheet music	8
2.4.1	Music format	8
2.4.2	Digital vs. paper	8
2.4.3	Types of sheet music	8
2.5	Other representations	10
2.5.1	Shape notes	10
2.5.2	Graphic representations	10
2.5	Conclusions	10
3	How we read music	12
3.1	Introduction	12
3.2	Sight-reading skills	12
3.3	Saccades and fixations	12
3.3	Perceptual span and eye-hand span	12
3.4.	Influence of cognitive load on eye-hand span	13
3.5	Influence of familiarity on perceptual span	14
3.6	Influence of music structure	14
3.7	Cross-modality: Hearing musical notation	15
3.8	Discussion and conclusion	15
4	The user	16
4.1	Defining the target group	16
4.2.	The symphony orchestra	16
4.3	The musician	18
4.3.1	Reading the music	18
4.3.2	Piece navigation	18
4.3.3	Making annotations	19
4.3.4	Managing the library	20
4.4	The conductor	20
4.4.1	Piece interpretation	20
4.4.2	Leading the rehearsals	20
4.4.3	Piece navigation	20
4.4.4	Making annotations	20

4.5 The librarian	21
4.5.1 Acquiring the sheet music	21
4.5.2 Preparing the sheet music	21
4.5.3 Distributing the sheet music	21
4.5.4 Assist musicians	21
4.5.5 Collecting and checking	21
the music	21
4.5.6 Managing the library	22
4.6 Music interaction phases	23
4.6.1 Practice	23
4.6.2 Rehearsal	25
4.6.3 Performance	33
4.7 The social environment	33
4.8 Attitudes towards digitization	34
4.9 Conclusions	34
5 The company.....	35
5.1 Leone Music Reader	36
5.2 Core competences	36
5.2 Current target group	37
5.3 Current reader	38
5.3.1 Functions	39
5.3.2 User test set up	43
5.3.3 Results	44
5.3.4 Advice from current users	45
5.3.5 Conclusions	46
5.3 Other commercial readers	47
5.3 Conclusions	49
6 Developments	50
6.1 Digital sheet music distribution	50
6.2 Digital navigation	51
6.3 Digital library	52
6.4 Free hand input	54
6.5 Augmentation	55
6.6 Dynamic function display	55
6.7 Optical Music Recognition (OMR)	56
6.8 Real time systems	58
6.9 Distributed environments	58

6.10 Screen developments	59
6.11 Designing for touch screens	59
6.12 Social media	60
6.13 Commercialization of the orchestra	60
7 Design direction.....	61
7.1 Vision	62
7.2 Future scenario	63
7.3 Area of focus	66
7.4.1 Navigation	66
7.4.2 Annotation	67
7.4.3 Interaction modes	67
7.4.4 Functions of the digital platform	68
7.4 Design criteria	69
8 Concept development.....	71
8.1 Navigation	71
8.1.2 Types of sheet music flow	72
8.1.3 Chosen combinations	72
8.1.4 Research set-up	74
8.1.5 Results	74
8.1.6 Conclusions	75
8.2 Annotation	76
8.3 Interaction modes	76
8.4 Digital platform	76
9 FLOW: final design	76
10 User testing	76
11 Conclusions	76
12 Recommendations	76
13. References.....	76
Appendix X: Instruments and categories.....	77
Appendix X: Librarian and sheet music	78
Appendix X: Library systems.....	79
Appendix X: Task occurancy estimation	80

I Introduction

What is a Digital Music Reader?

At its most basic, a Digital Music Stand is a system which displays digital sheet music files. It is a tool for musicians to manage and access their music collection without the need for bulky paper manuscripts. Features of the Digital Music Stand can include: repertoire management (through an underlying database or digital library), composition and editing tools, automatic score following, hands free page turning, networking for group playing, audio recording and playback, annotation facilities, and automatic accompaniment. Though the individual features may vary, the core idea remains the same: a digital music stand is a tool to help musicians view and interact with their music collection. It should provide all the affordances traditionally provided by physical printed scores and enhance the musician's experience in ways that only digital media can.

The main research question is:

- Can a networked digital sheet music system be effectively and satisfactory used by orchestras and ensembles in rehearsals and performances?

Since this new version of MusicReader is designed and implemented completely from scratch

again there are also some design and implementation issues:

- Which functions are required for

MusicReader?

- What type of communication layers and protocols are suitable for MusicReader?
- How can the central orchestra library be accessed remotely?
- Which user interface design should be used to operate MusicReader?
- What type of hardware should be used to run MusicReader?
- How can the functioning of systems be remotely monitored?

3

For the trial evaluation of the design implementation the following issues need to be included:

- Are the designed functions of MusicReader useful in practical situations?
- How do the designed functions perform in practice with respect to the usability, availability and performance?
- Which aspects of MusicReader should have priority in future research and development?
- Looking at music notation itself, how is it?
- Looking at specific needs in different settings
- Which functions should be in the reader?
- Which functions of the music reader should be the focus point of the project?
- What type of display for interface is suitable?
- Evaluation: Is the new interface suitable for orchestras and ensembles for rehearsals and performance?
- User things in terms of tasks, so stays the same also with digital music...

"To stop the flow of music would be like the stopping of time itself, incredible and inconceivable."

Aaron Copland

Not only re-design of the current reader but really take a step back and look at the whole concept of reading music. Not much came out of it for current reader, but for the future.

2 Written Music

2.1 What is musical notation?

The definition of musical notation, according to Webster's dictionary, is 'any system using written symbols to represent aurally perceived music'. As the main purpose of a music reader is to display these written symbols, different aspects of musical notation will be explored and explained.

2.2 Development of musical notation

Musical notation has existed in many forms in different parts of the world. The first developments of Western music notation started in the midst of the 9th century. These were neumes used for Gregorian chant (see figure 2a) and the notes were more insinuations, which could only be interpreted if one already knew the melody. The earliest staff systems to define the exact pitch date back to the 11th century. By the 16th century, the 5 lines staff was commonly used. Despite various attempts, not until the 14th century a fixed system for rhythm notation was introduced. The use of bar lines as rhythmic separators of groups of notes were not common until the 17th century, becoming the modern staff notation that is used today in Western music (Christensen 2002).

2.3 Modern staff notation

The history of the modern staff notation already tells a great deal about the complexity of the musical language: Not only the pitch has to be read, the exact rhythm of the notes is also derived from the musical notation. Furthermore, the notation system contains information about the key of the piece, together with indications of playing tempo and musical interpretation. Finally, navigational instructions are given regarding repetitions of certain parts and jumps in the music. All this information is explained in figure 2b.

"Any system using written symbols to represent aurally perceived music."

Figure 2a: Neuns used in monestries



PITCH

The placement of the notes on the five lines staff system defines the pitch. Ledger lines are used for pitches above or under the staff system.



RHYTHM

Duration of a note depends on shape and size. Rests in the music also have different durations depending on shape. Beams and ties cluster notes (of the same duration) for better readability.



NAVIGATION

Letters at new musical phrases and numbers at a new row of bars helps piece navigation. Repetition marks, brackets and codas indicate jumps in the music.

D.C. = Da Capo

⌂ Coda

D.S. = Dal Segno

⌂ Segno

Beams & Ties

Rests

Allegro

A

4

D.C. al Coda

Repetition Marks

Dynamics
mp sfz
fz fff

BAR
 Area separated by barlines. Bars vertically connected should be played simultaneously.

CLEF



Defines the pitch range of the staff on which it is placed. Clefs are often associated with specific instruments.

KEY

⌂ Natural ♭ Flat # Sharp

Defines the prevailing key for the music that follows. Each key has a certain number of flats or sharps. Sharps raise and flats lower the pitch with a semitone. Naturals cancel the accidentals.

TIME SIGNATURE

Note value of the basic pulse of the music. Tempo can be noted in beats per minute or with an indication (Allegro).

♩ = 120

Figure 2b: Symbol overview in modern staff notation

2.4 Sheet music

2.4.1 Music format

The format for displaying modern staff notation is historically connected to the format of documents for text reading: Modern staff notation is displayed on sheets with paper formats A4, B4 or A3, with several staff lines placed under each other. Each staff line consists of 4-8 bars, depending on the number of notes and information. The notation is in black on a white, light-yellow or off-white background for maximum contrast and readability. The size of the sheet and the notations are big enough to be readable for all types of musicians with reading distances from 0,3 up to 1,2 meters (Leone 2005). Typically, the sheets are displayed in portrait mode, although landscape mode is also used. The decision about landscape or portrait mode is made by the music publisher, along with other lay-out considerations. Research by Bell et al (2005) with vertical staff sizes of 9 mm and 5 mm, showed that musicians were able to read the smallest staff size (75% of normal size sheet music) without significantly higher error rates. However, the participating musicians expressed a preference for the larger staff sizes. Reading distance was not mentioned, but the research was conducted with three piano players, two bass players and a trumpet player.

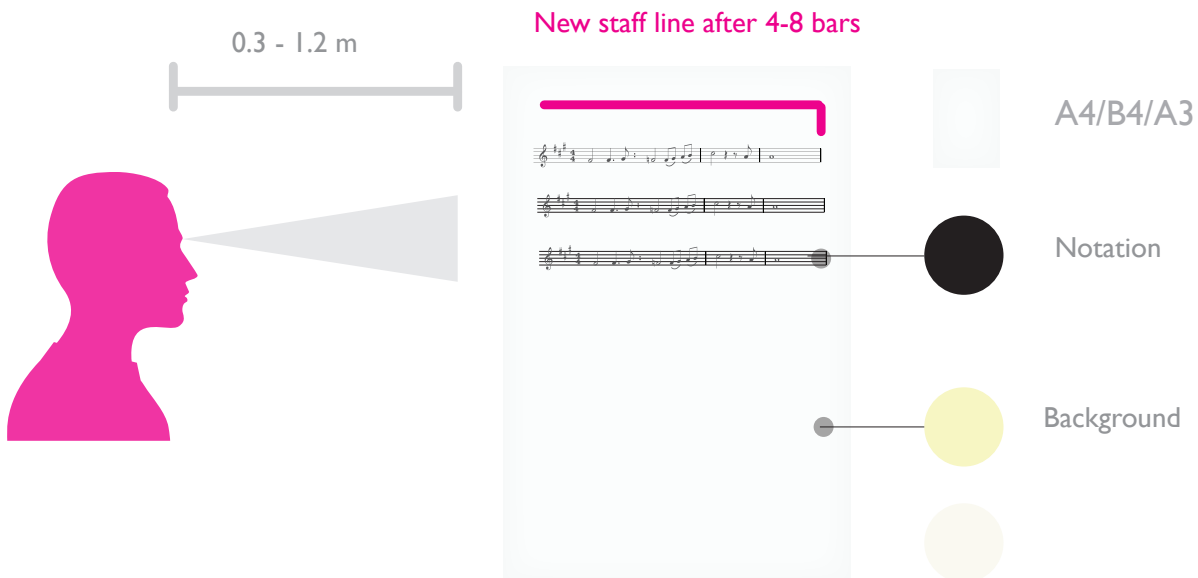
2.4.2 Digital vs. paper

The described format for sheet music is typical for printed sheet music. However, it is interesting to note that the growing number of digitally displayed sheet music constrain the same default proportions regarding notation size/sheet size, with the possibility to enlarge. Also, the used colors are still black notations on a white background.

2.4.3 Types of sheet music

There are different types of sheet music for different settings and usage areas. Sheet music showing the whole composition of a piece is called a **score**. Singers use **vocal scores** with an additional line of text corresponding with the notes. **Piano scores** and organ scores contain two or more connected staff lines played simultaneously. In an orchestra or ensemble, the sheet music is split into **parts** for the different instrument groups. The score is the overview of all parts played simultaneously, used by the conductor of the orchestra or the leader of the ensemble. The score and parts for a piece of music are divided into movements. In jazz, a **lead sheet** is often used, which is a melody line with the used chords written above. For guitar players, **tablature** is used, often in combination with staff lines. The types of sheet music are shown in figure 2c.

• “It is interesting
• to note that the
• growing number
• of digitally
• displayed sheet
• music constrain
• the same
• default propor-
• tions regarding
• notation size/
• sheet size as
• printed sheet
• music.”



Parts

Orchestra score

Vocal Score

Piano Score

Lead Sheet

Tablature

Figure 2c:
Overview types of sheet music
and specifications.

2.5 Other representations

The types of sheet music with modern staff notation described in section 2.4.1-3 will be the main focus of the music reader. It is however remarkable that the most common way of musical notation today has not been changed since the 14th century. It is therefore interesting to look at other representation of written music for inspiration.

2.5.1 Shape notes

With the current notation system, the pitch of the notes can only be distinguished from each other with only one variable: Placement on the staff lines. With shape notes, also the shape of the note has information about the pitch, see figure 2d. Shape notes were introduced in 1801 as a device in American singing schools but are not very common today. In the United States, a controlled study with fourth and fifth graders on the usefulness of shape notes was carried out in the 1950s by George H. Kyme. Results showed that students taught with shape notes learned to sight read significantly better than those taught without them (Kyme 1960). There is not much more research to be found about shape notes, but the concept of adding extra variables to pitch heights that are hard to distinguish is interesting, as an optional feature of the music reader.

2.5.2 Graphic representations

In the book *Notation 21* (2009), composers around the globe explore experimental notation systems liberated from the traditional staff. Two representations are shown in figure 2e. The third picture from the top is found in an online competition for new musical language, artist unknown. The representations use color as a way of showing pitch heights and more abstract figures to give a sense of overview of the structure of the piece. The third picture shows connections between note lines by moving the different notation wheels.

2.6 Conclusions

The basics of musical notation have been explained and the most common types of sheet music were discussed. In the transition from paper sheets to digital sheet music, the structure and form of the musical notation remains unchanged. Having shown the complexity of the written musical language, digital media offer new possibilities for better readability. Other representations of written music shown, using color, shape and abstract overview can be used as a source of inspiration for these possibilities.

“The concept of adding extra variables to pitch heights that are hard to distinguish, is interesting as an optional feature of the music reader.”



Figure 2d: Shape notes in C major

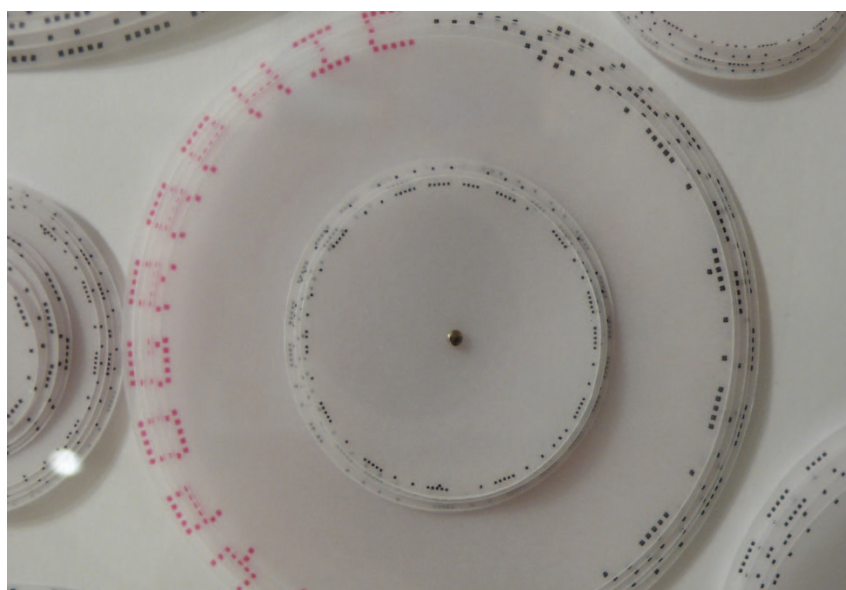
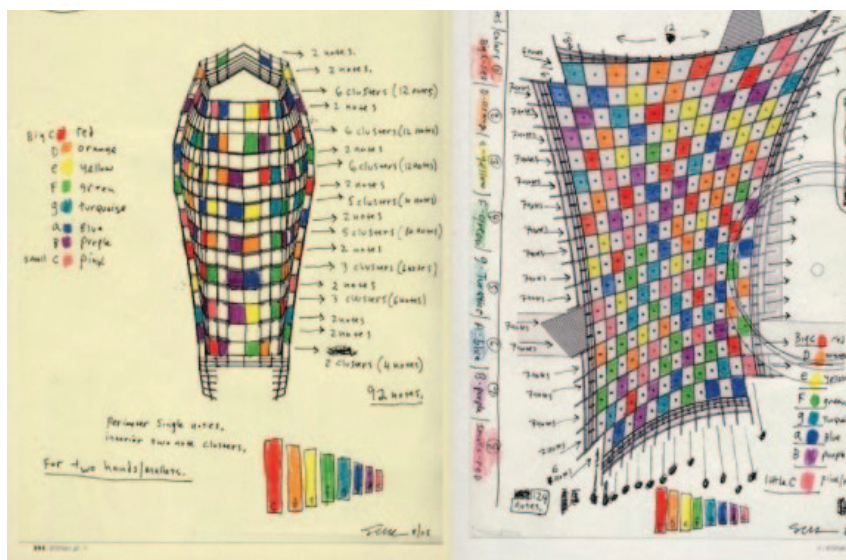
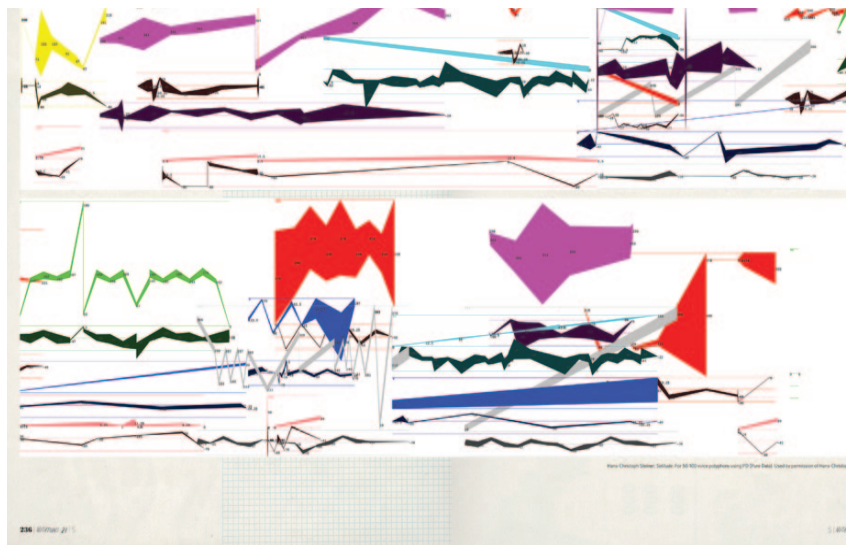


Figure 2e: Graphic representations of written music.

“It is remarkable that the most common way of musical notation today has not been changed since the 14th century.”

3 How we read music

3.1 Introduction

In order to make a new music reader interface with optimal readability, the way written music is read has been investigated through literature studies.

3.2 Sight-reading skills

Research done by Hayward and Gromko (2009) among wind players in university concert bands, concludes that the skill of sight-reading depends on three different types of processing: Technical proficiency (kinesthetic/aural); aural discrimination of tonal and rhythmic patterns (aural/spatial); and spatial-temporal reasoning (visual/spatial). These predictors all occur in coordination whilst sight-reading. The researchers suggest using this knowledge in an educational setting, by splitting up the complex task of sight-reading in the different predictors to practice the different skills separately. A digital music reader would provide new possibilities for doing so.

3.3 Saccades and fixations

When reading music, the eyes alternate between periods when the eyes are stable, fixations, and rapid shifts between the fixations, called saccades. Retrieving visual information happens during the fixations, see figure 3a. Fixations are either progressive or regressive movements and move back, forth, up and down the sheet music depending on the type of and number of melodic lines (Sloboda,

1984). For instance, sight-readers having to follow one melodic line have more horizontal saccades whereas pianists with two or more melodic lines to follow simultaneously move their fixations between upper and lower staff line, see 3a The average duration of every fixation is around 200 to 400 milliseconds, the duration of a saccadic movements varies between 15-50 ms. Duration depends on familiarity with the piece, the skill level of the musician and the structure of the music. Skilled sight-readers have more and shorter fixations than poorer sight-readers (Penttinen, Huovinen 2011).

3.3 Perceptual span and eye-hand span

The effective visual field for each fixation is called the 'perceptual span'. The size of this span is approximately 3-4 beats (the fixated beat plus 2-3 beats to the right) The eye-hand span is the distance between the played notes and where the eyes are fixated and gives an indication of how far the musician is reading ahead of what he or she is playing. The eye-hand span expressed in time seems to be about 1 second. Land and Furneaux (Penttinen Huovinen 2011) state that this 1 second is the time period that processed information is held in a working memory. Research on the eye-hand span expressed in beats or notes differ per study: Sloboda (1984) concludes with a maximal eye-hand span of seven notes ahead. Other studies

“When reading music, the eyes alternate between periods when the eyes are stable, fixations, and rapid shifts between the fixations, called saccades.”

suggest an average of two beats from the point of fixation (Truitt et al 1997, Gilman Underwood 2003). When the eye-hand span increases, the eyes often wander back to previously fixated notes as the working memory capacity has its limitations (Penttinen, Huovinen 2011).

The different findings in the research mentioned above can be explained by the different variables that influence the span: Skilled readers have larger eye-hand spans than less skilled readers. The cognitive load also influences the eye-hand span (see next section). The size of the *perceptual span* is undependable of the skill of the reader and the cognitive load. It can however be broadened significantly by familiarity of the piece. This will be discussed in section 3.5.

3.4. Influence of cognitive load on eye-hand span

In 2009, Wurtz, Mueri and Wiesendanger researched the influence of the structure of a piece on the eye-hand span of violinists while playing a difficult piece (many notes) by Telemann and a relatively easy piece by Corelli, see figure 3b. The results show that when a piece increases in difficulty, the mean fixation time increases and there is a tendency for more regressive fixations. Furthermore, the eye-hand span for the two pieces stays the same in time (about 1 s ahead, correlated to playing tempo). However, the anticipation expressed in notes is significantly lower for the difficult



Figure 3a: Fixations recorded with an eye-tracking device for music by Telemann. (Wurtz, Mueri, Wiesendanger 2009)



Figure 3b: A difficult piece by Telemann (A) and a relatively easy piece by Corelli (B).

piece, see figure 3c. It seems that not only the experience of the musician influences the eye-hand span, but also the structure and complexity of the played piece. The number of anticipated notes also depends on the playing tempo. As the eye-hand span stays the same in time, jumps and/or breaks in the interface of the music reader should be anticipated in time, not in notes, as the latter will vary.

3.5 Influence of familiarity on perceptual span

As mentioned earlier, the size of the *perceptual span* is undependable of the skill of the reader and the cognitive load. However, in an experiment by Burman and Booth, skilled and experienced users increased their effective visual field by 20 rehearsals of the same passages in a music piece. This does not mean that their sight-reading abilities had rapidly improved, but they relied more on memory and used the musical notation more as a reference instead of actually reading every note. This is an interesting fact for developing the interface of the music reader, as the needs regarding overview may alter when a piece becomes familiar to the musician. No research is found on the influence of piece familiarity on the eye-hand span.

3.6 Influence of music structure

The structure of the musical notation itself influence how musicians sight-read music:

- Pianists do not read the musical score

in single notes, but see them as a whole: a chord (Penttinen, Huovinen 2011).

- Skilled sight-readers tend to fixate on ‘chunks’ or musically clustered note patterns instead of a single note. (Penttinen, Huovinen 2011).
- Shorter notes (in performance length, not visual appearance) are less likely to be fixated than longer notes. (Kinsler, Carpenter 1994).
- Different studies show that professional musicians use the formal structure of a piece to help them memorize the music. The formal structure is also used to organize the performance, stopping at the boundary of musical phrases rather than in a middle of a section. (Draj-Zerbib, Baccino and Bigand, 2009).

“When a piece becomes familiar, the perceptual span broadens and the musicians uses the musical notation more as a reference.”

“Possibilities for new ways of piece navigation should be explored and user tested, finding the balance between readability and overview.”

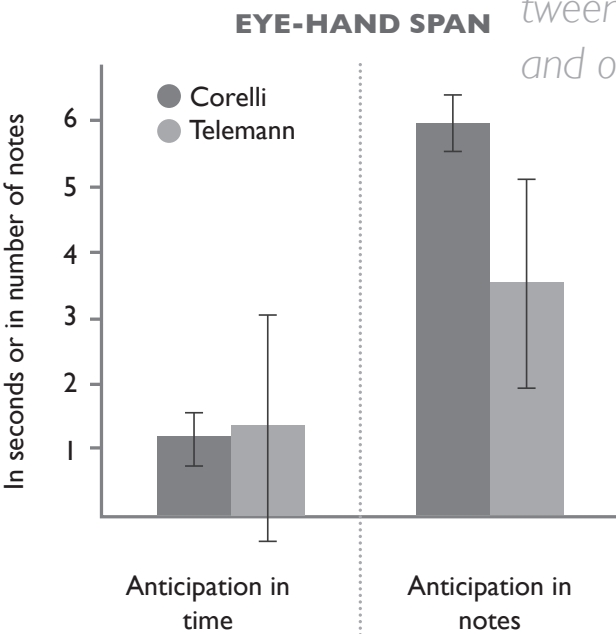


Figure 3c: Anticipation in time and number of notes for two pieces with high and low cognitive load.

Musicians also use the musical structure for orientation purposes when reading. They develop spatial memory for the lay-out and it is therefore important that the lay-out and structure of the music they are reading is not dramatically altered during or between readings, if the readability is to be optimal. See Appendix X for source.

It is also interesting to note that even when following the guide lines for modern staff notation, there are differences in lay-out for published sheet music. Every publisher company has their own 'house style'. Also in digital music notation software like Sibelius or Finale, one can choose between different lay-outs for the appearance of the sheet music. For further research, there should be tested which of these 'house styles' is better in matters of readability.

3.7 Cross-modality: Hearing musical notation

In the research of Draai-Zerbib, Baccino and Bigand (2011) it is proved that expert-readers are able to 'hear the music' in their heads before playing. Furthermore, according to Draai-Zerbib and Baccino (2005), expert musicians, compared to non-experts, were less dependent on the musical notation as their experience and musical memory made them able to reinsert phrasing into music from which it had been removed. Their research also suggested that the experts' relative written-code independence increased when they were provided with an auditory rendition of the piece first.

3.9 Discussion and conclusion

The perceptual span and eye-hand span of the musician has been investigated. The influence of the difficulty of and familiarity with the piece on the span has been discussed, giving design implications for display differences for first-time reads and familiar pieces. Research shows that even the most skilled sight-reader only moves the eyes a couple

of beats before the note that is actually played. With that argument, only one or two staff lines could be displayed at a time when playing. However, most of the research about eye-hand span and perceptual span is done in controlled studies with only a few bars of music being played. No research is found on eye movements during a whole piece in a natural playing situation. In such a situation, the need for orientation would become more important. We do, however, know that musicians use musical phrases for orientation within a piece. It is also shown that written music show bar numbers for each new staff line and have letters typically placed at the beginning of a new musical phrase as navigation tools for the musicians. As musicians actively use the structure of the piece to orientate, and develop spatial memory for it, it would lower their orientation ability if the structure and lay-out is altered during or between readings.

But exactly how much if the music has to be shown at once to be able to make meaningful connections for the musical structure? As more overview than a few beats is not needed for performing the actual playing task, the following question emerges: How much overview does the sight-reader want? And what is this overview for?

Furthermore, more details about which part of the musical structure is used for orientation should be investigated: Are the breaks in staff lines also used for orientation? Or are the jumps from one staff line to another perceived as annoying? If the latter is the case, going digital could provide solutions with one continuous staff line.

4 The user

4.1 Defining the target group

Typical users of the music reader would be all who make extensive use of written music during rehearsal, practice and/or performance. This includes:

- Solo musicians
- Instrumentalists in an ensemble:
 - Big band
 - Brass band
 - Chamber group
 - (Symphony) orchestra
- Singers in a choir
- Conductors
- Music teachers with music students

Researching the specific user needs for all these situations, however, would be too broad and time consuming. Therefore, the target group of this project will be musicians in a symphony orchestra. As orchestra musicians practice both alone as well as rehearsing together, insights are gained about different ways of interacting with the written music. This would help making the music reader suitable for solo instrumentalists as well. Also needs from different instrument groups can be established. Furthermore, during orchestra rehearsals, the musicians communicate about the piece and get instructions, which bears similarities to an educational setting with a music teacher and student.

There is a distinction between amateurs, semi-professional and professional musicians. The target group will be musicians

from all these skill levels, but with good sight-reading skills.

4.2. The symphony orchestra

The typical symphony orchestra has about 100 players, divided into four sections: strings, woodwinds, the brass and the percussion, see figure 4b. A full list of all instruments used, together with occasionally used instruments like the keyboard and organ, can be found in Appendix x. As can be seen on the pictures, the string section shares music stands for the sheet music in pairs of two. The seating is roughly as seen in figure 4b, but can vary depending on piece instrumentation and circumstances. The orchestra is led by a conductor, standing at the middle front.

Each instrument group has a group leader, or principal, who performs the orchestral solos and makes decisions regarding group bowing, fingering, breathing etc. (see section 4.7.2 for terminology explanation). The group leader also serves as a contact point between conductor and group when piece interpretation is discussed. The group leader of the 1st violin section is called the concertmaster. He or she acts as the head of the orchestra and is responsible for orchestra tuning before rehearsals (with oboe tuning tone). The concertmaster also acts as the right hand of the conductor, leading the rest of the musicians based on the instructions and cues from the conductor.

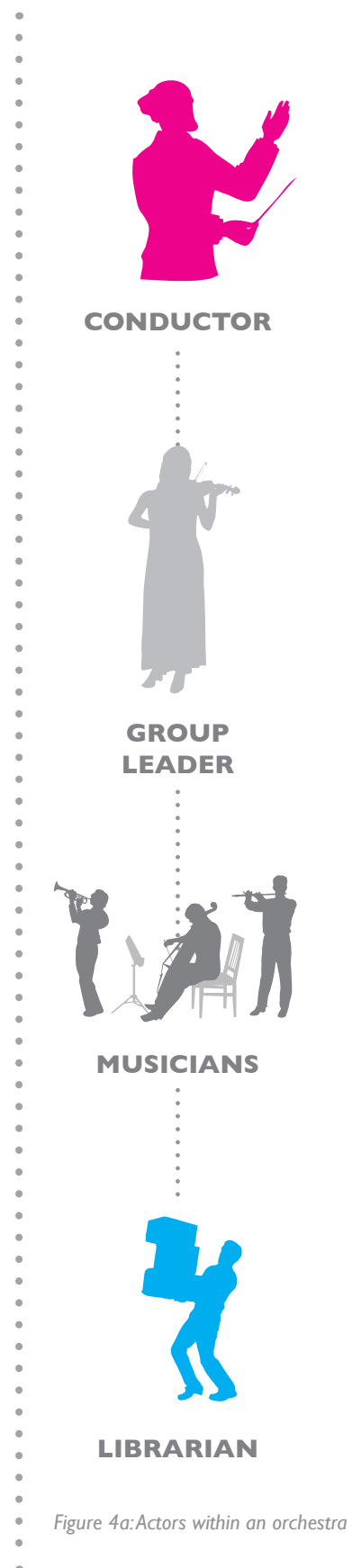


Figure 4a: Actors within an orchestra

Other notable parties involved with the orchestra include the music committee; the orchestra administration (and PR) together with composers cooperating with the orchestra.



4.3 The musician

Based on the research of Anna Offermans (2005) and Marco Leone (2007) together with own questionnaires (see Appendix X), interviews and observations made during a visit to the Noord Nederlands Orkest and Krashna Musica, the tasks and challenges of musicians were identified. Many of the interactions between the orchestra musician and the written music are context dependent and will be discussed in section 4.4. The more general tasks are as follows:

4.3.1 Reading the music

The primary task of the musician is to read the music and hereby be able to play. In order to do so, the readability of the music is important: The contrast between notation and background has to be sufficient; there has to be enough light for reading and the size of the notation has to be big enough to read. Sometimes musicians photocopy and enlarge difficult passages for better readability. Some musicians need to have a longer distance between the eyes and the music because of the size of their instrument, like the double bass players, or because the musicians share notations in pairs of two, like the string section in the orchestra. An overview of distances for different instrument groups can be found in appendix X. Percussionists prefer larger sheet music sizes than A4 (see appendix X), like B4, because of the large distance to the sheet music caused by their instruments. The asked percussionists did not think

reading from a screen with the size of the current iPad would be possible for them.

When confronted with the fact that only a few bars are necessary for reading music properly (see chapter 3), all musicians said that they wanted more overview than that. Reasoned mentioned were: Knowing when the difficult passages were coming; having a feeling of knowing where they 'were' in the piece (how long before the ending). This overview was primarily for looking ahead (to be played notes) and not looking back, except when certain passages were repeated. Visual suggestions for an interface with only one line of music were given the same arguments. Furthermore, the musician would miss the bar line break as an orientation point. This corresponds with the findings in section 3.6: The music structure helps musicians orientate. If they are missing parts of this structure due to a restricted viewing area, this may influence their ability to orientate. There might however, still be a gap between what the musicians say they need and what they actually need regarding overview.

4.3.2 Piece navigation

Besides reading the music, musicians must navigate through the piece. Many pieces are not linear from beginning until end, but have navigational jumps marked with repetition marks, Dal Segno and Coda, as described previously. These jumps often acquire some extra attention at first to be

“Even in digital form, there has to be some form of transformation from already displayed music notation to new notation. This still might be with some (physical) input from the user.”

figured out and played correctly. Also, the musicians have small jumps from the end of one staff line (upper right) to the beginning of the next one (lowered left). This is however not perceived as a problem by good sight readers.

Furthermore, to navigate from one page to another, pages have to be turned. The lay-out of the sheet music is often arranged in a way that page turns can be applied during a break, but often this is not possible. Some musicians solve the problem by memorizing part of the piece for earlier or later page turns. Sometimes a few extra bars are written by hand or photocopied and glued/taped to the music. In orchestras were the string section sits in pairs, the string player furthest away from the audience stops playing to turn the page. Pianists often have a page-turner sitting next to them. Some instrument types sometimes have a spare hand while playing, which is used to turn the page. When playing outside with wind, musicians often use clothespins, which makes page turning more difficult (see figure 4c.)

The number of page turns is also dependent on the number of staff lines being played simultaneously: Pianists or other double-staff-lined instruments therefore have more frequent page turns. Also in one-staff-lined instruments like the string section, there are sometimes 'Divisi'-sections with two staff lines which

take more space to notate, resulting in a higher page turn frequency.

Even if the musical notation becomes digital, there still has to be some form of transformation from already displayed music notation to new notations. This might still be with some physical input from the user, as the musician still wants to feel in control somehow. Therefore, an overview of hands and feet in use for different instruments can be found in appendix X.

• “Many of the
• interactions
• between the
• orchestra musician
• and the written
• music are context
• dependent.”
•
•
•
•
•
•
•
•
•
•
•



Figure 4c: String player with clothespins and extra lighting.

4.3.3 Making annotations

Most musicians write annotations in their music and always have a pencil (and a gum) with them. These annotations help the musicians with playing and performing the piece. The types of annotations that are being made are context dependent: Musicians annotate differently practicing alone compared to rehearsal with others (Winget 2006; 2008): Some annotations help exploring and figuring out a piece. Others are helping during a performance. Some annotations are personal, others are meant for the whole string group. Therefore, annotation making will be discussed for two different contexts in section 4.7.

4.3.4 Managing the library

Musicians are responsible for bringing their sheet music to rehearsals; taking the music with them after rehearsals and storing the music between rehearsals. They have often big music collections at home on the book shelf. This collection is mostly a mix of free photocopied sheet music and pieces which the musician has bought. Many musicians participate in different types of ensembles at the same time. They often index (photocopied) sheet music in (ring) folders, each belonging to the different ensembles or playing context and bring the different folders to the different rehearsals. In a professional orchestra, the musicians are usually given the original sheet music. As to avoid missing or damaged originals, some use photocopied versions for home

practice and leave the original music at the orchestra rehearsals.

Musicians work in projects. There is a distinction between sheet music they actively use during a period of time with their ensemble or for their solo projects, and the rest of the music in their library. The musicians often carry the pieces they are currently playing with them for instant access, while the rest of the music is stored in the library.

Even with digital music, musicians will have to retrieve the right piece of music for different ensemble use and would like to have some kind of indexing based on context, titles, time periods etc. The described project based way of organizing the sheet music should also be reflected in the layout of the music reader..

4.4 The conductor

4.4.1 Piece interpretation

The conductor makes sure that the music piece is interpreted properly by acting as the guide to the musicians. The conductor uses body language centered on the arm movements to communicate preferred volume, tempo and general piece interpretation, which the musicians follow. He or she also communicates through oral instructions given to the musicians. The conductor usually has a baton to enhance the arm movements, but there are conductors who conduct without it.

“The conductor uses body language centered on the arm movements to communicate preferred volume, tempo and general piece interpretation, which the musicians follow.”

4.4.2 Leading the rehearsals

Besides interpretation matters, the conductor also leads the orchestra rehearsals and decides upon which piece to play, when and where to stop and where to start again. Together with the librarian and other members of the orchestra administration, rehearsals are scheduled and the orchestra repertoire is planned.

4.4.3 Piece navigation

The sheet music of the conductor is the full score showing all the instruments playing the piece. With around 15 or more staff lines being shown, the conductor score is larger than the sheet music of the musicians. Still, the conductor has to page turn more than average.

4.4.4 Making annotations

The conductor studies the music score before the first rehearsal and often (partly) memorizes it. Performances by other orchestras or great conductors may be consulted, but as they are not easy to find, this seldom happens. Conductors would however like to see the annotations of other conductors (see appendix X: Interview with Vincent de Kort for source). Most of the personal annotations are made before the rehearsal; conductors do not annotate much during the rehearsal itself (Winget 2008). The annotations of the conductor is very personal with a high level of conceptualization. As the annotations only have to make sense to the conductor and not to any other reader, there is no need

for a 'common language'. Every conductor has their own personal style and 'colour codes'. The annotations of the conductor are the 'road map' during a performance. Without their annotations they would feel lost.

4.5 The librarian

Depending on the size of the orchestra, one or more librarians work full time with managing the sheet music of the orchestra.

4.5.1 Acquiring the sheet music

The sheet music for a certain orchestra piece is either bought or rented from publishers or libraries and rental companies. It is the responsibility of the librarian to make arrangements for renting or buying. The different publishers and copyright issues for paper sheet music will not be elaborated on in this report. Extra information about renting and copyright can be found in appendix X. However, distribution channels for digital sheet music will be discussed in section 6.1.

4.5.2 Preparing the sheet music

After getting the sheet music containing the score and parts for the different instruments, the librarian gives the music to the different group leaders and to the conductor. They then give the music back with annotations about preferred breath marks, bowings etc. concerning the whole group or structural changes in the piece. The librarian then writes the annotations into all identical parts *by hand*. Often pencil

*“The librarian writes the annotations into all identical parts **by hand**. Often pencil annotations from previous usage by other orchestras have to be erased first.”*

annotations from previous usage by other orchestras have to be erased first if the new annotations are different. Also, some pages are photocopied if page turning is difficult. According to the library section of the Noord Nederlands Orkest, among others, preparing the sheet music is an extremely time consuming task.

4.5.3 Distributing the sheet music

After preparing the parts, the librarian puts them in folders, often together with a rehearsal plan, and sends the music to the orchestra members by mail.

4.5.4 Assist musicians

Another task of the librarian is to assist in sheet music matters; when the musicians have questions about the sheet music or want insights in other instrument parts. This is mostly right before or during the time period that a piece is rehearsed and performed.

4.5.5 Collecting and checking the music

After the last performance of a piece, the librarian makes sure to get the original parts back from the musicians. The librarian checks if the parts are undamaged and erases pencil annotations (although this is often not done). Furthermore, in projects involving new music, with composers who attend the rehearsals, whole bars of music are often erased or cut and the structure of the piece can be changed, resulting in a

labyrinth of pencil annotations and arrows which only the musicians can interpret. These changes are often not implemented back in the digital/original files of the composer after being collected. New orchestras performing the piece have to start 'from scratch' again.

If the sheet music is rented, the librarian returns the music by mail. If the orchestra owns the music, it is stored in the orchestra library, see next section.

4.5.6 Managing the library

A big part of the tasks of the librarian is to manage the orchestra library, see figure 4d-e. This includes looking for new sheet music, repairing old music and indexing the collection. Lend-outs to musicians are registered and returned music gets re-indexed. Most orchestras use a digital system, OPAS (Orchestra Planning and Administration System) for the administration of the orchestra, with a digital library database. The transition from physical files to digital sheet music files could therefore be integrated as part of the program. OPAS is explained in appendix X.

“Most orchestras use a digital system, OPAS, for the administration of the orchestra.”



Figure 4d-e: The library section of the Noord Nederlands Orkest.

“After the last performance of a piece, the librarian makes sure to get the original parts back from the musicians. In projects involving new music, whole bars of music are often erased or cut, resulting in a labyrinth of pencil annotations and arrows which only the musicians can interpret.”

4.6 Music interaction phases

As part of the research of Winget (2006; 2008), she interviewed and observed classically trained musicians playing in amateur, semi-professional and professional chamber groups and orchestras. According to her research, there are three phases of interaction between musicians and their written music: early rehearsal, mid-rehearsal and pre-performance. In the early rehearsal period, musicians individually explore and learn the piece. In the mid-rehearsal period the musician come together and learn the piece as a group and in the pre-performance the music is being played through as a whole, like during a performance, with some last fine tunings. As the priorities regarding functions of the music reader might differ for these periods, the needs, the challenges and the context of the musicians for

three different interaction phases will be explained. For this project it is chosen for a distinction between 'practice', 'rehearsal' and 'performance'. In these interaction phases, interaction between conductor, group leaders and the rest of the musicians is also included.

4.6.1 Practice

Typically musicians explore their piece alone first. The musicians receive the music around 2 weeks before the first rehearsals. This is done in music practice rooms or at home. Many musicians use a mirror during practice to monitor their motoric use of the instrument, see figure 4f. Most musicians prefer to stand, if possible, during the practice period, even if they sit during ensemble rehearsals. A complete list of positions for different instruments can be found in appendix X.

“As the priorities regarding functions of the music reader might differ for these periods, the needs, the challenges and the context of the musicians for three different interaction phases will be explained.”



Figure 4f: Practice environment

EXPLORING THE PIECE

During the early encounters with a new piece, the musician often listens to other recordings of the same piece. This is usually not done in any organized form: The musician acquires the recording by own initiative. The musician might also look for background information about the piece on the internet or in the public library or orchestra library. Often the piece has textual expressions about the tempo or interpretation of the piece in Italian or German. After years of experience, the musician knows the commonly used expressions, but sometimes expressions have to be looked up.

LEARNING THE PIECE

When learning the piece, musicians play through the piece and identify difficult passages, which then are repeated many times in increased tempo. Tuner and metronome are helpful tools.

Pitch heights are also sought out. Many musicians, even the professional ones, cannot always identify the highest or lowest pitch heights placed far away from the regular staff lines (see figure 2b). The pitch heights have to be identified, for example by counting staff line steps. Some musicians who possessed good sight-reading skills, admitted to sometimes having trouble distinguishing the note G from the note B on the regular staff line (users of the G-staff) when reading fast through new sheet music.

ANNOTATION MAKING

During this phase, most notations in the music for orchestra musicians concern finger positions of the hand on the instrument (fingering) and some breathing marks (Winget 2006). The pitch heights that are hard to recognize are sometimes notated in letters or the note itself is notated on the staff line in a lower register (for high pitches). For solo musicians, the annotations are more about the interpretation of the piece and/or of a more personal character, being more conceptual (see 4.6.2 for further explanation). Yet the tendency for all musicians is that much more is notated during ensemble play. (Winget 2006, 2008).

PIECE NAVIGATION

During this phase, efficient page navigation is not that important. The musician usually does not play long passages in the piece, but breaks it down into small passages that are repeated many times. One difficult bar can be repeated for 15 minutes to 'get it right'. The practice phase is, however, an important input for building up spacial memory regarding the lay-out of the sheet music pages. The musician gets a sense of structure of the piece.

LEARNING BY HEART

From practice to rehearsal to performance is not a linear phase. Musicians also practice the same piece after a rehearsal. As part of the 'later' practice routine,

“Many musicians, even the professional ones, cannot always identify the pitch heights placed far below or above the regular staff lines.”

musicians memorize the music. This is not usual for symphony orchestra musicians, but most solo musicians play by heart. When learning a piece by heart, some of the earlier described techniques are used: The music is split up in musically logical passages which then are memorized before moving on to the next passage.

4.6.2 Rehearsal

Orchestras rehearse in big rehearsal rooms or, in case of professional orchestras, in the concert hall where they perform regularly. Typical rehearsal durations for orchestras are 4 hours with a break. Besides the general tasks and problems described in section 4.3, there are other tasks and problems related to the rehearsal phase. These tasks and problems generally involve the musicians, but also includes interaction with the conductor and librarian.

COMMUNICATION

There is a difference in the communication structure of small ensembles and symphony orchestras. In small ensembles like chamber groups, there is a flatter hierarchy and problems are discussed and solved between the group members as they emerge. In a symphony orchestra, the group leader (see section 4.2), communication goes from the conductor to the whole orchestra. Questions and/or remarks from the musicians are channeled through the group leaders. It is not usual that a 'regular' musician asks a question

directly to the conductor during the rehearsals (Winget 2006). When the group leader turns around and faces the other musicians, they automatically pay attention: Information is going to be given.

Information from the group leader is passed down orally until all members of the group have received it. When a group leader annotates something in the music, it is also expected that the musicians sitting behind (for the string section) copy the annotations and the musicians on the third row copy the second row's annotation etc. As one might expect, especially in large groups, given annotations and information are altered or missing in the end. Many communication processes occur at the same time. For example: While the conductor asks to hear only the woodwind section at a specific passage in the music, the group leader of the 2nd violin section uses the break to communicate with the group about changes in the music. This all has to happen quietly and discreetly.

FOLLOWING THE MUSIC

The eyes are a scarce resource for musicians. While following the sheet music, they also have to keep an eye on the visual cues of the conductor and the group leader. While the latter two are registered from the corner of the eyes at all time, the musicians sometimes have to actively look up from the sheet music and find the place to play from again. It is therefore important

“Information from the group leader is passed down orally until all members of the group have received it. Especially in large groups, given annotations and information are altered or missing in the end.”

that the sheet music itself does not move.

Even the most experienced sheet music reader ‘gets lost’ sometimes. This happens more frequently with ‘modern’ music where the melodies and musical phrases are less obvious and clear and the musician cannot calculate where the rest of the orchestra is playing. Also music with a lot of breaks that need to be counted or numerous repetitions of the same two bars is more challenging to follow. Tricks used by the musicians to keep the overview involves counting silently, confirming the bar number through silent cues with a fellow musicians using the same part or writ-

ing musical cues from other instrument groups into the music. As following the music poses extra challenges for musicians with a lot of breaks between the playing, an overview of playing ‘concentration’ can be found in appendix X. Percussionists, who switch a lot from one instrument to another, during a piece sometimes need several minutes to prepare their next instrument and has to not only follow the music, but be able to look ahead long before the musical passage is played (see appendix X).

“Even the most experienced sheet music reader ‘gets lost’ sometimes..”

Figure 4j: An orchestra rehearsing in the orchestra pit, placed below, in front of the stage. The musicians cannot see the people on the stage, but have to rely on the conductor for cues.



ALTERING THE MUSIC

Sometimes the musicians change the sheet music so radically that we cannot speak of annotations anymore, but alterations of the music. This is especially the case with new music with the composer present during rehearsals, where whole bars or sections are erased or changed, as described in section 4.5.5.

VIEWING OTHER INSTRUMENT PARTS

Musicians sometimes want to know the parts of other instruments. This is sometimes for quick views to sort out ambiguities or when playing the part of other (missing) instruments. Musicians now ask the other instrumentalists after the rehearsal or consult the library section for score and/or parts.

SPACE AND VIEWING ISSUES

When working with big productions, for example with a choir, all musicians have to see the conductor's cues, often from big distances. When doing opera productions or musicals, the orchestra is seated in the orchestra pit where space is scarce and it gets very crowded, see figure 4j. Also when moving the concert from the concert hall to locations that are not especially built for an orchestra performance, like a church, there is often not sufficient space for the musicians to move and play freely. Sometimes the viewing angle to the conductor or group leader is blocked.

ANNOTATION MAKING

When musicians bring the music with them to the first rehearsal, the annotations in their music are a mix of shared annotations from the group leaders/conductor written down by the librarian, and their personal annotations, for example fingering positions. The string section shares music stands in pairs of two and therefore chooses one set of sheet music, belonging to one of the two musicians. Sometimes the musicians have different personal annotations about fingering, which can be confusing for difficult passages. If the musician uses his or her own sheet music during rehearsal, this is not a problem. Most annotations are made during the rehearsal phase and the research of Winget (2006, 2008) provides valuable insights about the way musicians annotate their music. Together with observations of rehearsals, performances and 22 interviews, she collected and analyzed 25,000 annotations from 250 parts of music. The different annotations were clustered into types and can be seen in figure 4g.

Annotation mode

Winget established three annotation modes: Symbolic, numeric and textual. Symbolic annotations are non-textual images and symbols. Numeric annotations are numbers written for fingering, navigation or timing instructions. Textual annotations consist of letters or words.

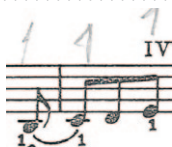
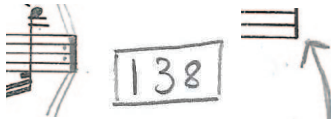
“Most annotations are made during the rehearsal phase. The research of Winget (2006, 2008) provides valuable insights about the way musicians annotate their music.”

“Sometimes the musicians have different personal annotations about fingering, which can be confusing when sharing sheet music in pairs.”

ANNOTATIONS

EXAMPLES

TECHNICAL

●	Articulation	Articulation marks Connecting notes Breath marks	
●	Attentive	Glasses, Stars Exclamation points "Solo" "Play" "Cello"	
●	Bowing	Up- and down-bow "Less bow!" "UH!"	
●	Fingering	1,2,3,4,5	
●	Navigation	Bar numbers Extensions Arrows "Turn"	
●	Pitch	Arrows Accidentals Renaming pitch	

TECHNICAL CONCEPTUAL

●	Dynamics	< - cresc > - dim	
●	Timing	Ritardando Accelerando	
●	Context	Representational Context: Notes from other parts Re-representing rests Informational context: Attitudes about the piece	

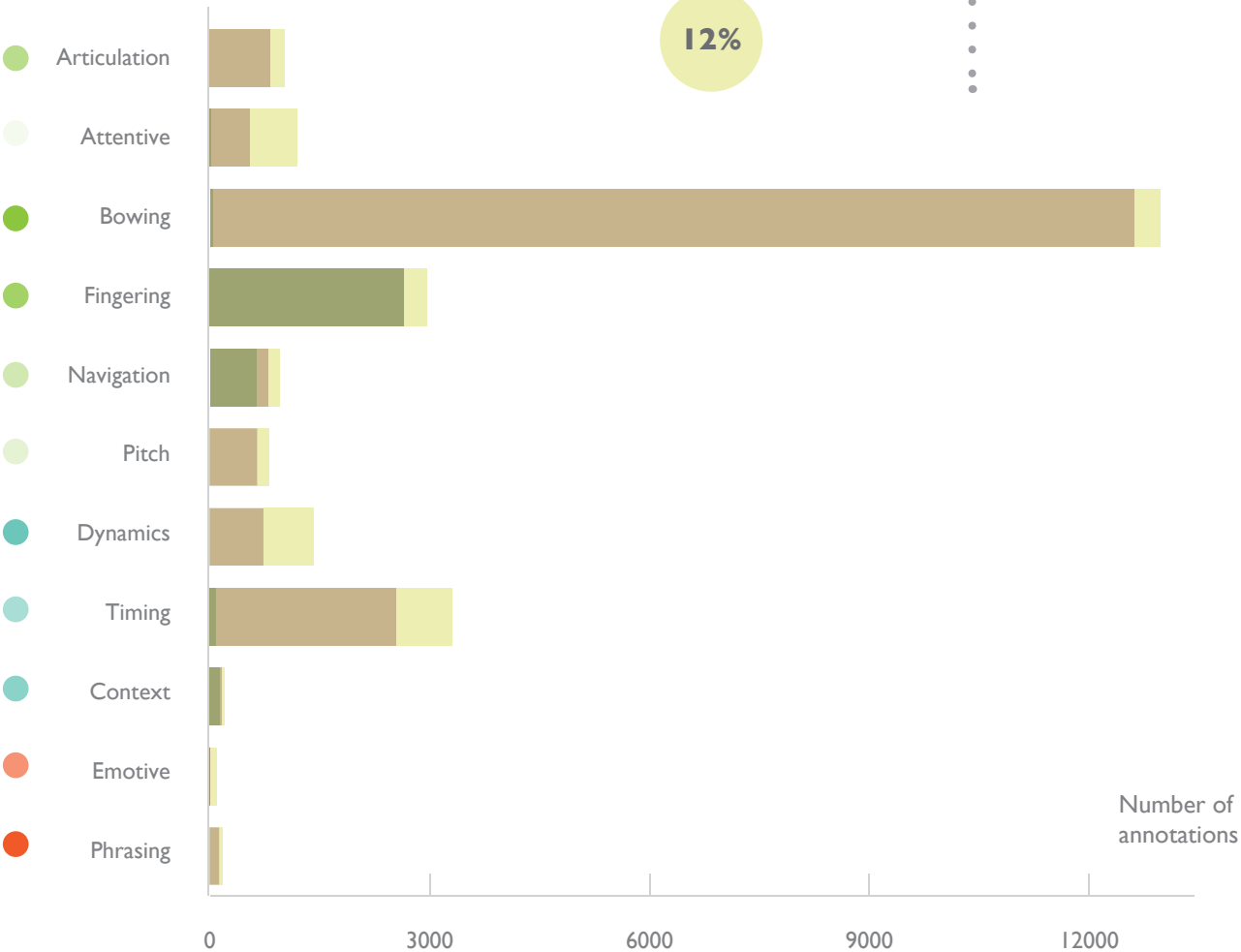
CONCEPTUAL

●	Emotive	Textual interpretations	
●	Phrasing	() []	

Figure 4g: Annotations clustered by type. The different types are arranged by level of abstraction.

Winget found that, in total, 72% of the annotations were symbolic. Only 16% of the annotations found were numeric and as little as 12% were textual, see figure 4h. These percentages did not differ much across skill level and ensemble type.

Figure 4h: Annotations clustered by annotation mode: Symbolic; Numeric; Textual



“Winget established three annotation modes: Symbolic, numeric and textual.”

Annotation purpose

Winget also clustered the annotations into three annotation purposes: Technical, technical-conceptual and conceptual. Technical annotations are those 'specifically concerned with the physicality of performing the piece', like which finger to use (fingering), piece navigation, how to place the bow (bowing, for string players), where to look (attentive), which notes to play (pitch) and how to articulate them, also with regards to breathing for wind instruments. In total, 78% of all annotations had a technical purpose. Technical-conceptual annotations, however, are more abstract and the meaning is not as specific, although they convey a musician action that should be taken. Technical-conceptual annotations include dynamics, timing and contextual information, both representational and informational. In total, 18% of the annotations were technical-conceptual. The last annotation purpose is conceptual. Conceptual annotations are the least physical and involve information about phrasing and emotions, the latter often expressed in text. Conceptual annotations are the least common, with only 4% of the total number of annotations investigated.

The percentages for annotation purposes were different for the type of ensemble: For technical annotations, the total percentage stays the same, but orchestras have more annotations regarding bowing (76%) than chamber orchestras (48%).

Also the other annotation types have different percentages. Orchestras also make more technical-conceptual annotations (20%) and less conceptual annotations (2%) than chamber groups, see figure 4i. According to the research this is due to the ambiguity of conceptual annotations: For a larger group, consistency becomes even more important in order to play the piece the same way multiple times.

TECHNICAL TOTAL

78%

TECHNICAL CONCEPTUAL TOTAL

18%

CHAMBER GROUPS 13%
ORCHESTRAS 20%

CONCEPTUAL TOTAL

4%

CHAMBER GROUPS 10%
ORCHESTRAS 2%

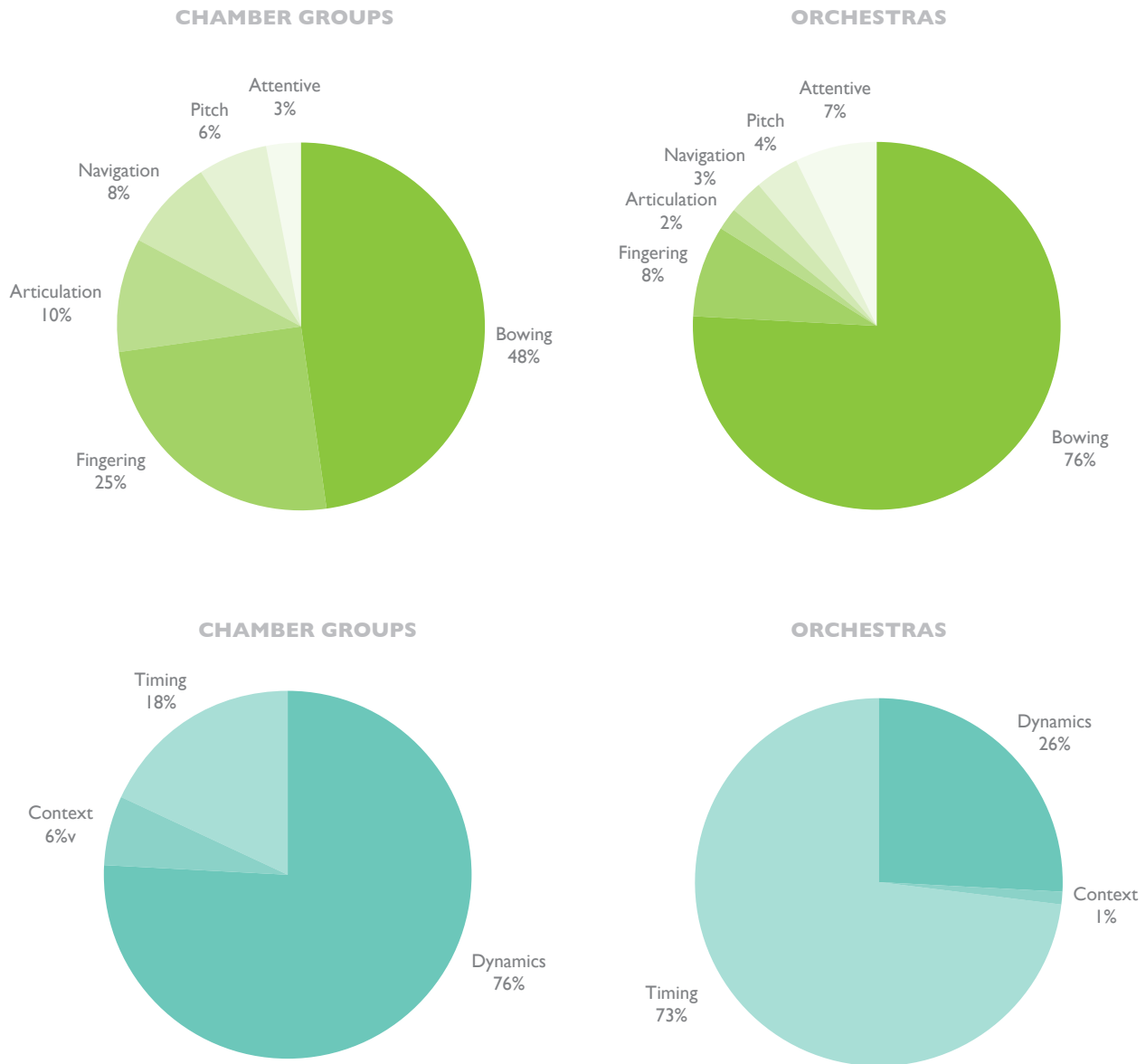


Figure 4i: The differences in the type of annotations made in chamber groups and orchestras are shown for technical and technical-conceptual annotations. On the left it is shown that chamber groups make more conceptual annotations meant for personal interpretation.

Other findings

- Orchestra musicians annotate less than chamber musicians, with an average of 0.22 annotations per bar (vs. 1.55 annotations for chamber musicians). For orchestras, much of the annotations are decided by the group leader and copied to the other musicians before the rehearsal starts.
- Professional musicians annotate much more than amateur musicians. Technically difficult pieces have more annotations than easy ones.
- The string section annotates the most of all the instrument groups of the symphony orchestra, see figure 4k.
- Annotations are often small and need to be placed precisely on note level
- Orchestra musicians made annotations steadily throughout the course of the piece, while chamber musicians could heavily annotate a particular phrase and then sometimes have forty or fifty bars without any annotations.
- In an orchestra, the string section annotates the most of all instrument groups, with an average of 0.58 annotations per bar, see figure 4k.
- Many musicians implied that, during performance, they used their personal annotations as land marks for orientation rather than specific instructions.
- Many musicians would like to use the annotations of famous musicians. They have no (copyright) issues with other people using their annotations.

“In an orchestra, the string section annotates the most of all instrument groups, with an average of 0.58 annotations per bar.”

“Many musicians implied that, during performance, they used their personal annotations as land marks for orientation.”

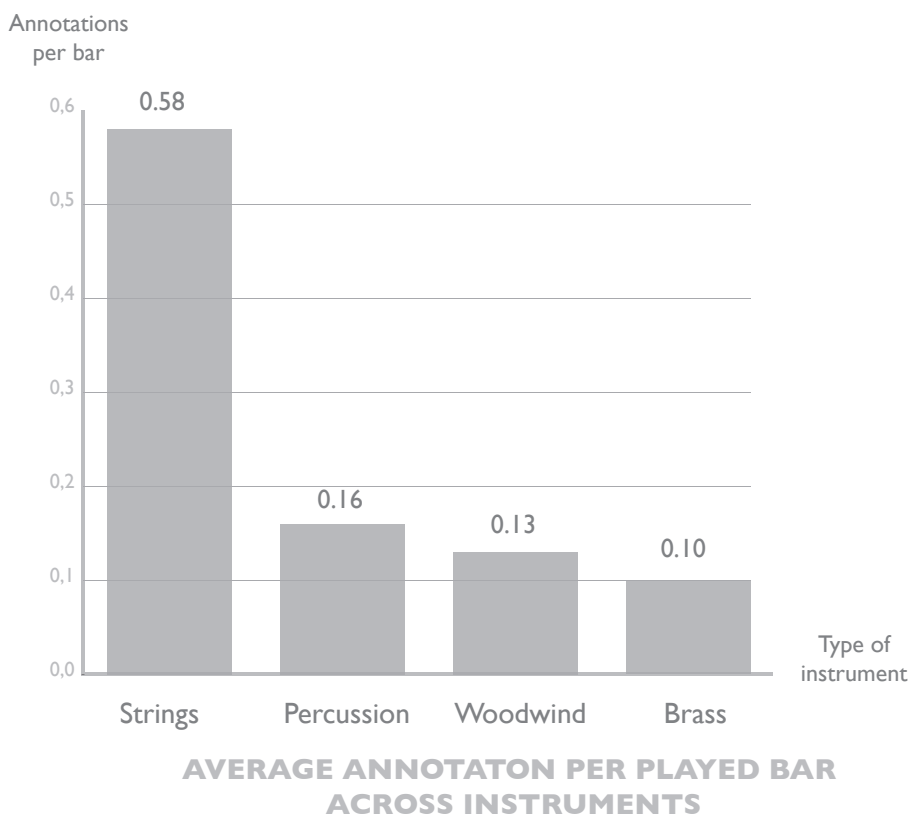


Figure 4k: The average number of annotations per played bar in the orchestra during rehearsals is much higher for the string section than any other instrument group.

4.6.3 Performance

The performance setting is similar to that of a rehearsal setting regarding tasks and challenges. The big difference is the presence of an audience and the fact that the piece is played from beginning to the end without any stops. The latter is, as Winget pointed out, also true for the last preparations in the rehearsal phase. During a performance, the following issues emerge:

NAVIGATION

Page turns have to happen silently, not attracting (visual) attention.

FOLLOWING THE MUSIC

The performance is the goal of the rehearsals, the one time that one really has to 'get it right'. Musicians therefore sometimes start doubting their counting (of breaks or repetitions) during a performance, even if the counting of the piece went smoothly during rehearsals.

MENTAL PREPARATION

Before and during a performance, the adrenaline level rises and the concentration level is high. Small, nervous contractions can ruin the fine tuned and delicate movements used to play the instrument. Most musicians have learned to control their 'concert nerves' after numerous performances, but feelings before a concert will always be different from those before a rehearsal. Many musicians have their own rituals before a performance, like finding

a quiet moment, washing their hands or practice some of the passages from the piece to be performed.

4.7 The social environment

The symphony orchestra is in fact a small community where everyone has its own part to play. The musicians often have closer relationship with each other than what is typical of work collegiality. The physical distance to every musician is small and intimate; partners who share stands see themselves as 'partners'. The orchestra, conductor, librarian, composer and other staff members all work together towards a clear, common goal: To perform a musical piece as good as possible. Matthews and Kitsantas (2012) studied the sociological patterns of large musical ensembles. They looked at the role of the conductor's goal orientation and use of shared performance cues and how this influenced collegiate instrumentalists' motivational beliefs and performance. They found that when conductors focused on mastery as the goal rather than performance, the ensemble had higher levels of collective and self-efficacy beliefs. They attributed the success or failure of the ensemble most frequently to the conductor's use of rehearsal strategies (i.e., baton technique, verbal directions regarding the music). In mastery goal orientation, emphasis is placed on the learning process. In contrast, performance goal orientation emphasizes normative performance. The instrumentalists who expe-

“When conductors focus on mastery as the goal rather than performance, the ensemble has higher levels of collective and self-efficacy beliefs.”

rienced the mastery condition reported a more positive sense of unity and communication, higher ability to perform skillfully and to their capabilities, and greater understanding of the conductor's expectations. In addition, the conductor's use of expressive shared performance cues instead basic performance cues, had a significant impact on instrumentalists' collective efficacy, self-efficacy, performance, and attributions. Aspects of this social phenomenon might somehow be integrated into the music reader.

4.8 Attitudes towards digitization

Based on answers from the questionnaires filled in by members of different symphony orchestras and ensembles, around 80% of the asked musicians were quite or very positive about the possibilities that digital sheet music could offer. Most of these were younger musicians, indicating a generation gap regarding attitude. Some concerns were uttered about battery life and reliability. Testing of music readers in the past (Offermans 2005; Leone 2007) have also documented positive reactions. Furthermore, the growth of commercial readers (see chapter 6.9) indicates an increasing interest for going digital with sheet music. However, the use of digital readers in an ensemble or orchestra, compared to individual use, requires a lot more organization and investment. The attitudes of the organization around the orchestra are of

great importance in such matters: In interviews with the library section and committee of the NNO, an orchestra known for its innovative profile, the librarians were very positive and open towards the use of digital readers. Correspondence about a new music reader with the public relations section of the Concertgebouw Orchestra and earlier with one of the librarians (Leone 2005), revealed a very conservative attitude about sheet music innovation.

4.9 Conclusions

In this chapter, the tasks and challenges of the musician and other actors involved with the sheet music of the symphony orchestra are described. It is difficult to give an exact overview of the importance of each task. However, following and playing the music, navigating through a piece of music and making annotations are all tasks that stand out as important areas to cover for a digital music reader. In the work of Leone (2007), an estimation is made about the duration and occurrence of these typical tasks (see appendix X). However, the work of Winget shows that making annotations is an even more important part of a rehearsal and individual practice: The string section of an orchestra has an average of 0.58 annotations per bar! Of course, often more annotations are written down in one 'writing turn', but it is an important indicator of the importance of smooth interaction with the reader regarding annotation making. Furthermore, this chapter

“The use of digital readers in an ensemble or orchestra, compared to individual use, requires a lot more organization and investment. The attitudes of the organization around the orchestra are of great importance.”

For the librarians it is shown that erasing, writing and copying group annotations is a very time consuming job. Also the copying of annotations during rehearsals is described as time consuming, sometimes with missing or altered annotations as a re-

Important navigational issues described are finding the right place to play from with the ensemble as a whole and turning pages. It is therefore interesting that musicians use their own annotations as landmarks. The annotations should therefore, also in digital form, be easily distinguishable from the sheet music. Another interesting finding is the fact that even the most experienced musicians 'gets lost' sometimes. It shows a need for some (optional) navigational cues. When discussing navigation, the difficulties of page turning must not be forgotten. Going digital should at least solve the page turning problem for the musician, but digital music could also change the traditional way of reading a piece of music page by page. Literature research and user research has both shown the importance of keeping the same musical structure for the sake of navigation and orientation, but there is still an interesting 'grey area' to explore between what musicians say they are comfortable with and what they actually are comfortable with regarding the need for overview. Is seeing a whole page really necessary for comfortable music reading? This necessity can be experimented with when developing a page-turn free way of digital navigation. During this experimental

“The digital annotation making should allow for effective editing by the librarian and the group leaders. It is also clear that a distinction between individual and group notation is needed.”

tion, it must be taken into consideration that the need for overview might differ depending on familiarity with and difficulty of piece, as described in section 3. Also the number of connected staff lines played simultaneously is of importance.

This chapter has described three music interaction phases and it shows that the needs regarding navigation and annotation change. Although there were no data found in the research about instrument based changes in annotations, simple customization can be made based on instrument input: More overview and help with counting for instruments with lower playing frequencies (see appendix X) and the absence of irrelevant annotation marks (like bowing for non-string players). With the knowledge about which functions of the music reader are the most important in a certain interaction mode and choice of instrument, more flexibility in the function display is possible: Not all functions have to be available at all times, and if they are not available, they do not need to be visible. They should however be easily reached if needed.

During the individual practice phase, it is described how the musician ‘explores’ the piece by cutting it up in smaller musical phrases, identifying pitch heights and tempo and listening to audio recordings of the piece. There seems to be little or no communication between the musicians,

between the conductor and the musicians or between the musicians and the library section during this phase; the communication starts at the first rehearsal. The possibilities of a digital system could allow for a communication overlap between individual practice, rehearsal and performance: A digital platform for audio recordings, questions about the piece and rehearsal dates etc. As mentioned earlier in this chapter, musicians are interesting in the annotations of other (famous) musicians, which could also be distributed through this platform.

Sharing annotations and starting points through the reader can replace some of the reasons for communication during rehearsal. The reader might also accentuate visual communication cues from the conductor in situations where the visual field is blocked (see end section 4.6.2). The reader could also allow for other forms of communication by integrating a simple chat function or by making the musicians aware of communication attempts from another musician. The reader should also take advantage of the already existing hierarchy within the orchestra communication channels and moments. One should however take into consideration the social community the orchestra represents (see 4.7). Rich face-to-face communication plays a part in forming common motivational beliefs,

“Not all functions of the reader have to be available at all times, and if they are not available, they do not need to be visible.”

“The possibilities of a digital system could allow for a communication overlap between individual practice, rehearsal and performance: A digital platform for audio recordings, questions about the piece and rehearsal dates etc. “

5 The company

5.1 Leone Music Reader

5.2 Core competences

5.2 Current target group

5.3 Current reader

5.3.1 Functions

5.3.2 User test set up

5.3.3 Results

5.3.5 Conclusions

- looks ok main menu
- most terrible annotation, has to go out again. Why is everything grey? Kleurenfeestje. Cutting and editing function of pdfs nice, clear what to do. The functions of the reader is nice, if you also regards to what is needed during the interaction phases. so that has been taken care of. Is just how it is done. Only no communication functions. Symbol use clear? yes, because there was also text next to it. Annotation very important, also taking into consideration wingest research. Only static menu, does not use possibilities of ipad. ...

5.3 Other commercial readers

- Vemus music project.
- Scroll navigation. does not work. Look up. during reading.
- not compatible.. software... Very little creativity regarding new ways of page turning. Ok, it has to be static, but there is more to

it than that.

5.3 Conclusions

All try to simulate paper.. Only for ipad. Not optimized for annotation. Need a package for the whole orchestra, target group is now individuals. How to make this shift....Encourage group use, not only individual use.

6 Developments

6.1 Digital sheet music distribution

formats... pdf.. midi... no digital library specialized in orchestra score. Doesn't have to go through a publisher anymore!!

6.2 Navigation

- new ways of page turning
- turning in the air (link Katja)
- Elements from adobe reader
- Creating overview
- Foot pedal Not used to it. Some instruments use their feet while playing. It is important to provide cues about that the action has taken place. After performing user action. (email and skype Tim Bell). Furthermore, kosakaya timing different for unexperienced users.

6.3 Digital library

- Written research Ofermans about how

to search

- Multi-modality
- Ways of indexing and searching.

6.4 Free hand input

The pen which everybody uses nowadays. Is handy for conductor. Conceptual annotations. Recognizes input.

6.5 Augmentation

Use of subtle animation, not being rushed by moving balletjes.... or

Colours of music Pitch height only one variable is something people have troubles with. Illuminated violin.. Moeten zich niet gejaagd voelen door animation (balletje or moving window where they play.)

6.6 Optical Music Recognition

6.7 Real time systems

6.8 Distributed environments

6.9 Screen developments

Assigned to make it for a touch screen by company. Also ipad size. People use more screens. Growth of ipad.. The size they know preferred. Also smaller or bigger.. Size is not a problem, software works on it.

6.10 Designing for touch screens

Different way of pinching... Design guide lines..

6.11 Social media

6.12 Commercialization of the orchestra

6.13 Conclusions

With all these information... gathered. Combine the ones that are interesting. We have looked at the way we read music to get a look back, we have looked at the current interaction and from there find the problems and the interactions that are the most important. We have also looked out what is 'out there' and established . Now we go to the next step.

7 Design direction

7.3 Area of focus

What now visual can be shown Focus on what is possible without rich format.. Biggest impact annotation and navigation.

7.4.1 Flexibility

7.4.2 Navigation

7.4.3 Annotation

- Dictionary for musical expressions.

7.4 Design criteria

- functions of digital platform

8 Concept development

Kleurencollage

8.1 Flexibility

Freedom within limitations. Colour palettes. Kleuren code.. moet aansluiten op hun wereldje.

8.1 Navigation

Flow navigation

How to time. Buffer of half page. Recording of different pieces next to each other to see the time difference. (show appendix?)

8.1.2 Types of sheet music flow

8.1.3 Chosen combinations

8.1.4 Research set-up

8.1.5 Results

8.1.6 Conclusions

Terugkoppelen aan familiariteit. Span zou dan groter worden. Maar hebben niet geklaagd om overzicht. Dus goed! Verder zou het anders zijn met dubbele stafs. Minder buffer.

Other NAVIGATION

- Waarom flipje zo en zo.

8.2 Annotation

Develop only for string players, have the most. Then covers

the rest. Iterative. Ask people...

No fingering with the blowers players... Chosen the string section. Research also has to be done to each instrument group to see differences in annotation style. Winget no information. Adding a consistent form language of the style. Gil sans.

8.3 Interaction modes

8.4 Digital platform

9 FLOW: final design

Flowchart.

10 Evaluation Product Process

Liked a lot to work from a scenario instead of starting with limitations. Now you start with possibilities, not limitations.

A lot of things not possible yet because of the rich format.. ipad screen size issues..

has to be better.

12 Recommendations

7 Design direction

7.1 Introduction

So far in this report, the concept of sheet music has been investigated. The way sheet music is read and explored has been explained. Furthermore, the needs of the musician, the conductor and the librarian in the symphony orchestra has been described, together with the current interaction with sheet music. The current state of the Leone Music Reader has been shown, together with the current market for music readers. Finally, technological and social developments relevant for the reader have been described. For all these steps, design implementations for a new music reader have been stated. Now it is time to combine all these implementations and create a new design.

In this section, a design vision will first be stated, which will function as a guideline through the design process to ensure a consistent concept. Using the ViP-method (Vision in product design, see appendix X), a future scenario will be described, creating a new design context using elements from all previous design implementations and elaborating on the possibilities from the described developments in section 6. The scenario also used input from an informal creative session with 3 musicians and one member of the librarian staff of the NNO.

The different elements of the scenario were clustered into categories and an area

of focus was established, based on level of feasibility and impact on user interaction. For the focus areas, a set of design criteria was defined.

7.1 Vision

With all the extra functions that can be added to the reader, it is important not to forget the core essence of why a musician would use a music reader: to enable the musician to play and make music. Actually, every user action described in section 6 is directly or indirectly related to making music. If the extra functions get in the way of this, you might end up with overly complex readers as described in section 5.3.

The design goal for the concept is to make the musician forget all his sorrows and enter a state of flow. The flow metaphor should not only be limited to playing, but serve as a guideline for all music related interaction: Finding the piece to play, looking up rehearsal dates, listening to recordings of the same piece, asking colleagues for tips about fingering positions etc. ‘Flow’ should not only be a music reader, but the name for a whole system that helps the musician doing what he loves the most, which is making music. The design vision is expressed in figure 7a.

“In this section, a design vision will be stated, functioning as a guide line through the design process to ensure a consistent concept.”

“Using the ViP-method, a future scenario will be described.”

“Helping the musician stay in the flow of doing what they love the most: making music”



Figure 7a: Design Vision.

7.2 Flow: scenario

Katja, one of the librarians at the Noord Nederlands Orkest logs in with her personal account on the FLOW online platform. She downloads the digital files of *The Mice Ate My Slippers*, a new opera by the British composer Thomas Adès. The opera is just finished and the parts are uploaded to the FLOW online platform by Thomas Adès himself. With a special Navigation annotation tool only accessible to assigned users, she marks all parts with orientation marks for quick navigational jumps during rehearsals, see figure 7b.

For older pieces, the online music publisher company connected to the FLOW platform usually already does this. The online music publisher company is specialized in digital files for symphony orchestras.



Figure 7b: Annotation marks

“The flow metaphor should not only be limited to playing, but serve as a guideline for all music related interaction.”



The circles and grey markings refer to previous sections in the report where the problem is described or the design implementation is mentioned.

Katja sends the parts to the group leaders for each instrument section through the group NNO on the FLOW online platform, allowing them to make group annotations before distributing the parts to all musicians in the orchestra. The part of the NNO opera choir is also sent to the leader of the choir for special annotations and is then distributed to the members of the choir. Katja also prepares and sends the parts of the six opera soloists. They have access to the online orchestra platform during the project. The composer Thomas Adès also is assigned a user account on the platform. He will be present during the re-

hearsals and performance

Maarten, the group leader for the viola section at the NNO wants to prepare for the upcoming rehearsal repertoire: A newly written opera by the British composer Thomas Adès. He logs into the online orchestra platform through his tablet at home. On his personal profile, he has filled in some information about himself: hobbies, his favourite pieces, great concert experiences etc. Besides his job as a viola player at the NNO, Maarten also plays in a string quartet and a small chamber orchestra: These three ensembles have different groups on the platform, see figure 7c,

“Katja sends the parts to the group leaders for each instrument section through the group NNO on the FLOW online platform.”

4.3.4

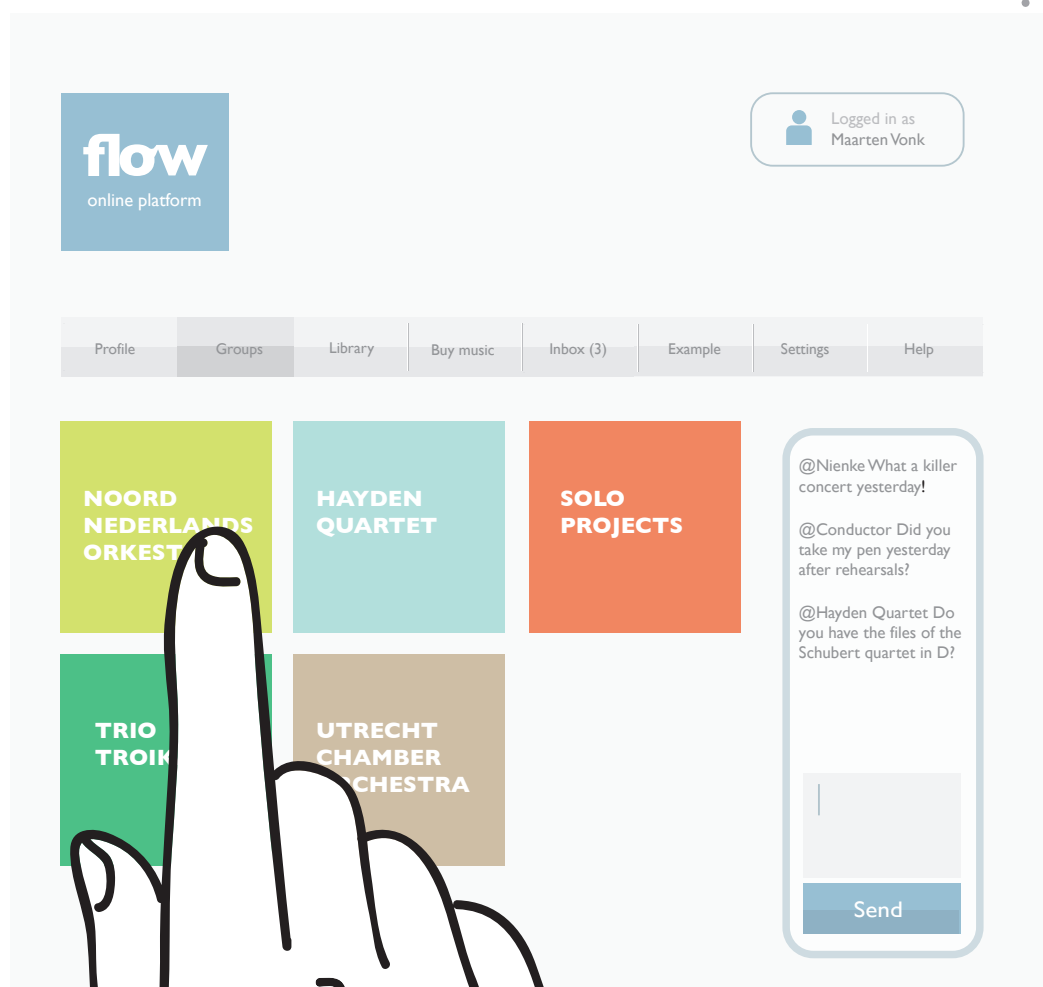


Figure 7c: Impression of the FLOW online platform.

Maarten clicks on the group called NNO. In the news feed Maarten can see status updates of his colleagues in the orchestra; remarks about the new repertoire, comments on last week's performance (and the visit to the pub afterwards) etc. He has also received a digital package from Katja, the librarian, in his inbox, containing the viola part of Thomas Adès' opera. He moves the package to the folder "My projects" under the group NNO.

All files in the folder "My projects" (for each ensemble group) are synced with the "My projects" folder on Maarten's FLOW reader through a wireless connection. The folder "My projects" shows the files the musician is currently working on. The touch tablet is Maarten's own property and responsibility, but the tablet is purchased in a deal where the orchestra organization pays 20% of the total tablet price.

Maarten opens the FLOW reader application on his tablet and chooses between three interaction modes: Practice; Rehearsal; Performance. He chooses "Practice". The interface opens. He opens the folder "My projects" and under the label NNO he opens the piece by Thomas Adès. All movements are presented in one file, but with a 'drag-out' sidebar all pages are shown in preview. With the navigational cues put in by Katja, the movements and pages are easy to tell apart, even when being small, see figure 7d.

6.11

6.9

4.6

6.2

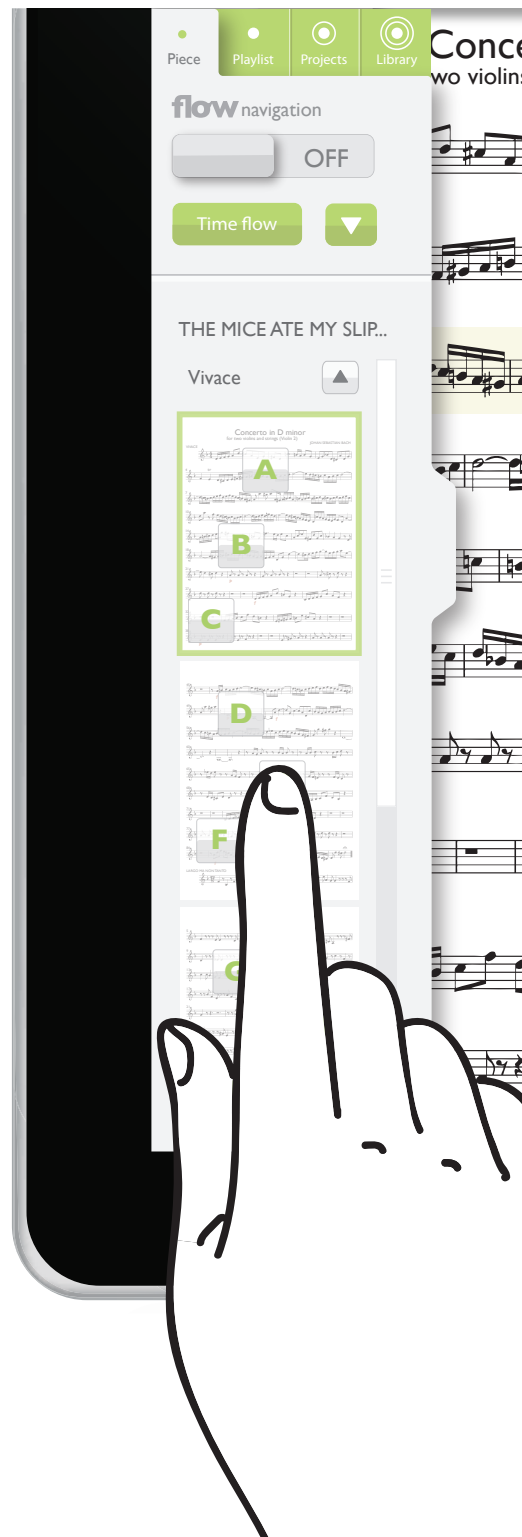


Figure 7d Drag-out side bar with all pages shown in preview.

The FLOW software knows which functions are important when practicing alone: the metronome, tuner and annotation functions regarding fingering positions are easily reachable. Furthermore, there is a special 'Learning by heart' function that divides the piece into logical musical structures with step-by-step memorization help. Maarten starts orienting through the piece to get an overview of length and difficulty with the sidebar preview function. He then starts at the piece from the beginning, playing slowly a couple of bars. The piece starts with a very high-pitched note, which Maarten does not immediately recognize. Maarten touch-holds the note, and the pitch is briefly heard and the note name is displayed for a couple of seconds in a colour corresponding to the pitch height.

When Maarten double-touches somewhere on a sheet music page, the annotation hot box appears, located closely above the place where he double-touched his finger. Maarten is now in 'edit mode'. From here, the most common annotation symbols are available in simple drag-and-drop based on the interaction mode selected by the user and automatically detected instrument type and type of piece (solo or ensemble piece). The software eventually also learns Maarten's preferences and personal editing styles and adjusts to these. As this is an orchestral piece, Maarten will typically not write very personal and conceptual interpretations and standard-

ized symbols and text are most commonly used. He does however prefer to write his fingering positions with free-hand input. The software recognizes his writings and transforms the annotation into numbers in a standardized graphic style, see figure 7e. Maarten leaves edit mode.

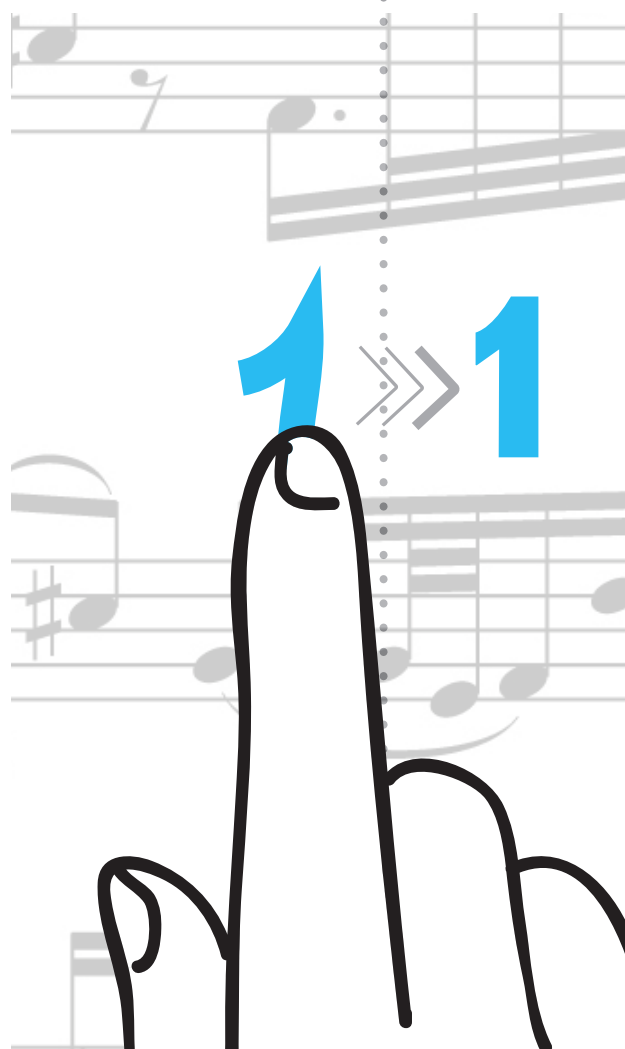


Figure 7e: The software in the FLOW reader recognizes the writing and transforms it into numbers in a standardized graphic style.

In this phase, there is no need for hands-free transitions from one page to another and Maarten can navigate through the pages by touching the screen anywhere on the left or right side of the screen. The FLOW reader will provide subtle yet clear feedback about the page turn. Maarten sometimes uses a foot pedal for page turning. This pedal is thin enough to be attached to the backside of his tablet.

After going through the piece, carefully repeating difficult passages in a low tempo, Maarten encounters a passage where he would like some interpretational feedback before the first rehearsal. He touch-holds at the beginning of the passage and drags his finger over the passage, marking it with a subtle colour. The notes of the selected passage will be played. When this field is marked, Maarten can also choose from different, available interpretations of the same passage by other orchestra recordings. However, as this is a new orchestral work, Maarten does not find any recordings – yet.

Maarten mostly meets up with the rest of the group leaders of the string section to quickly go through the bowing to assure coherence. However, two group leaders are not available and they have planned a short videoconference through the FLOW platform, where members of a certain can invite each other for a video conference. The video can be displayed at the top of

the FLOW reader interface, but Maarten uses his computer for a bigger video display of all three leaders while annotating the music simultaneously on his tablet. The four of them can see (the bows) and hear each other without noticeable delay, see figure 7f.



Figure 7f: Visualization of video conferencing through the FLOW online platform

In editing mode, Maarten makes sure he has ‘group annotations’ selected. He annotates bowings for the whole group. He changes some earlier annotated individual annotations into group annotations. At the end of his practice phase, Maarten checks his online rehearsal agenda on the online platform for the group “NNO” to see if he got the location and time for the next rehearsal right. Through the online platform, Maarten sends a message to Katja with his group annotations as an attachment.

Ria, another viola player at NNO is also practicing for the orchestra rehearsals. She has also received the viola part of the new opera by Thomas Adès from Katja in her inbox on the FLOW online platform. Along with the viola part, Ria has gotten Maarten's group annotations in a separate layer file. She puts the viola part with the group annotations layer file in her playlist for this month's repertoire at the NNO.

While using the FLOW reader application to practice at home, Ria encounters a passage where she is uncertain about which fingering position to choose. She wonders what the group leader for the viola section, Maarten, has written down, as he is likely to rehearse the piece before the others. Maarten has already anticipated on this and has uploaded his personal annotation layer file to the forum of NNO's viola players on the FLOW platform. Ria adds Maarten's personal annotations as an extra layer to her viola part and copies some of his fingering positions to her own personal layer. She hides Maarten's layer afterwards, but keeps it in her viola part to look at it later if necessary, see figure 7g.

For older pieces, Ria sometimes looks at other annotations by orchestras like the Berliner Philharmoniker or famous viola players like Tabea Zimmermann. Handwritten annotations are often scanned in and made available by the publisher together with the purchased music on the online platform.

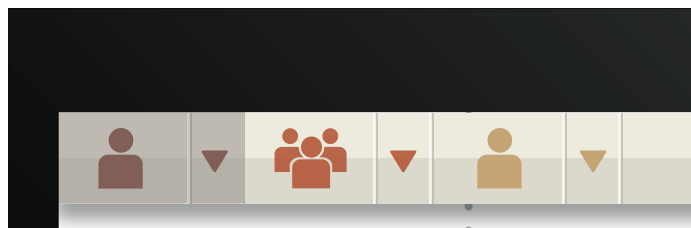


Figure 7g: The three different annotation layers in Ria's viola part: The left, active layer is her personal annotation layer, the middle layer contains the group annotations and the third layer is added with Maarten's personal annotations.

7.3 Area of focus What now visual can be shown

Focus on what is possible without rich format.. Biggest impact annotation and navigation and nothing is done with communication yet. Online platform is too big a project. Show impact-feasability graph. The digital platform is for the whole orchestra, so it is something that will distinguish it, but it is too big. A graduation project on its own.

7.4.1 Flexibility

7.4.2 Navigation

7.4.3 Annotation

- Dictionary for musical expressions.

7.4.4 Communication



8.3 Research set-up

WHAT

8.3.1 Introduction

After having explored the different ways of implementing automatic display of music notation frames, five different versions were chosen based on the earlier described design criteria. These five versions were part of a user test to determine the best way to implement automatic display in the music reader. An additional sixth version using the traditional way of changing notation frames was used as a control version.

8.3.2 The six test versions

General principle

The general design principle of the five designs is the metaphor of the rolled out paper or papyrus, see figure 1.

The new frames are gradually ‘rolled out’. The timing of the animations is based on previous input from the user: The time it takes the user to finish playing each music notation frame is recorded based on sound input and the moment where the user manually switches from one frame to another. With this recorded, the animation timing as shown in appendix A can be made for the designs. Version 4 uses another timing and is displayed at last.



Figure 8b: The rolled out paper metaphor.

Version 1:

New frame above the old frame

This version is inspired by the physical qualities of a piece of paper to provide use cues about the transition. Through drop shadows, the roll-out animation is designed to give the impression of a new frame appearing above the old one.

Version 2:

New frame under the old frame

This version is similar to version 2. Through drop shadows, the roll-out animation is designed to give the impression of a new frame appearing below the old one.

Version 3:

New frame with opacity change

This version uses changes in opacity to provide use cues for the roll-out animation of the new frame. The opacity of the

“The general design principle of the five test designs is the metaphor of the rolled out paper or papyrus.”

displayed music notation in the new frame changes gradually from light grey to black.

Version 4:

New frame with opacity change – double animation tempo

This version is similar to version 3, but with a roll-out animation that speeds up to double tempo after having reached the lower half of the old frame. This results in $\frac{1}{4}$ of the frame being free of animation with no roll-out transitions from one page to another.

Version 5: Horizontal line

This version displays the roll-out animation of the new frame with an additional horizontal line as a use cue.

Version 6: Control version

In this control version, the frame display changes immediately from one whole frame to another whole frame. The frame transition occurs when the user has finished reading one frame. This is close to the 'traditional' way of reading sheet music.

The six different versions are shown in figure 8c and figure 8d.

Version 6 is the control version where frame transitions occur when the user has finished reading one frame. This is close to the 'traditional' way of reading sheet music."

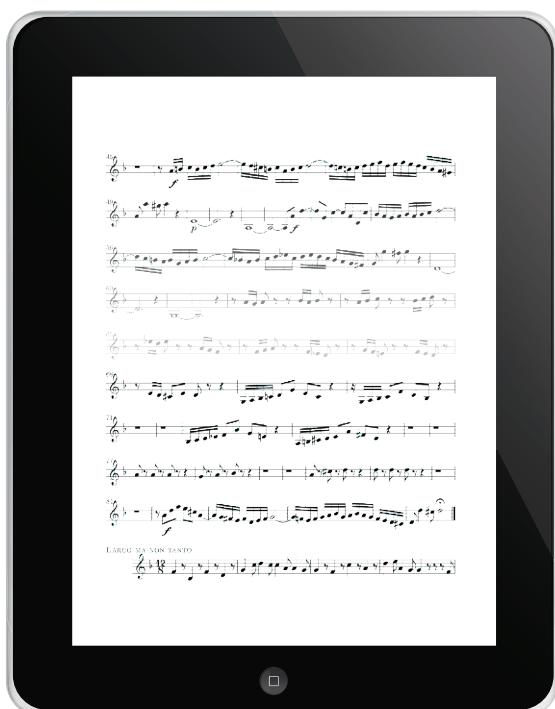
VERSION 1

VERSION 2



Figure 8c: Version 1: New frame above the old frame (left) and Version 2: New frame under the old frame (right).

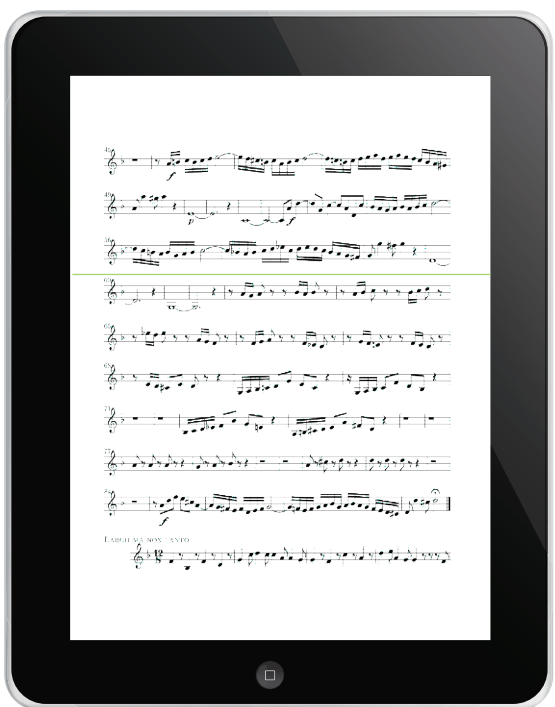
VERSION 3



VERSION 4



VERSION 5



VERSION 6 (no animation)

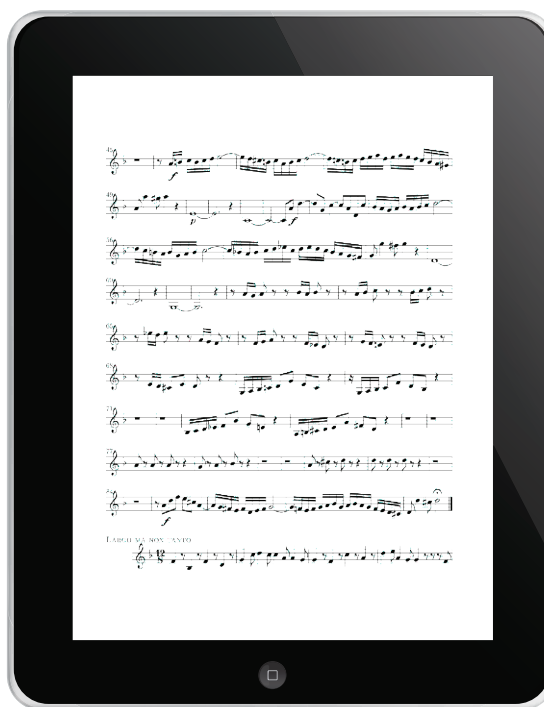


Figure 8d: Version 3: New frame with opacity change; Version 4: New frame with opacity change - double animation tempo; Version 5: Horizontal line; Version 6: Control version without animation.

WHY

8.3.3 Research goal

The goal of the research is to answer the following research questions:

1. Which of the six versions is most preferred by the participants? And why?
2. What is the influence on the participants of not being able to see a complete page without some kind of transition?

HOW

8.3.4 General procedure

Twelve participants will be asked to play the tutti violin I part of the Double concerto for two violins by J.S. Bach. The participants will play the first movement and the beginning of the second movement, a total of three pages. This work by Bach belongs to the standard repertoire of every classically trained semi-professional or professional violinist. The participant is therefore likely to have played the piece before and will have acquired the skills to play the piece without stops.

1. Before the test, each participant will be told an introduction text stating that the test is about reading music from an ipad (see appendix B)
2. Each participant is then asked to play the described part four times with four different versions. The test conductor will activate the different versions.

3. Each version will be played with a metronome cue to exclude side effects from tempo changes (1st movement = 90, 2nd movement = 50). The test conductor operates the metronome.
4. After each version, the participant is asked to rate the version on a scale from 1 to 10 (see appendix C)
5. After having tested all four versions, the participants will be asked a few questions about the versions (see appendix C).

8.3.5 The four versions

Due to time limitations, each participant will only be shown four versions instead of all six. The versions will be shown in random order, except from version 6 which will always be shown first. The selection of versions is as follows:

- Version 6
- Version 3
- Version 4
- Version 1,2 or 5

Every participant will be shown version 6, the control version, to ensure consistency. Also version 3 and 4 will be shown to all participants in order to answer research question 3. Version 1,2 or 4 will each be shown to four participants, 1/3 of the total number of participants. See appendix B for a scheme with the different versions for each participant.

“Twelve participants will be asked to play a piece by Bach four times, every time with a different version. After each version, the participant is asked to rate the version on a scale from 1 to 10.”

8.3.6 Context

The tests will be conducted in a room with only the test conductor and the participant present. The versions will be displayed on an iPad, placed on a music stand. With the exception of version 6, all versions are movies that only need to be started by the test conductor. For version 6, the test conductor will manually switch from the old music notation frame to the next.

The tests will be recorded with a video camera on a stand. The test conductor will write down the scores and comments by the participants.

8.3.7 Participants

The participants will all be classically trained, semi-professional or professional violinists with good sight-reading skills.

RESULTS

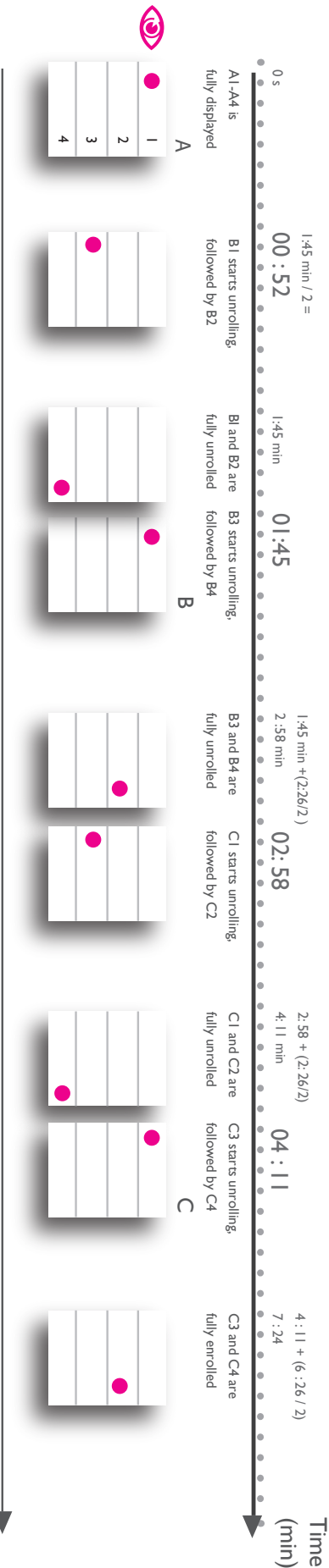
CONCLUSIONS

Were more familiar in the end so larger span and easier. Even then judged it positively. Of course, only for one staff line piece (see section ... 3) The influence of double for piano or a full score. The overview and space of buffer smaller.

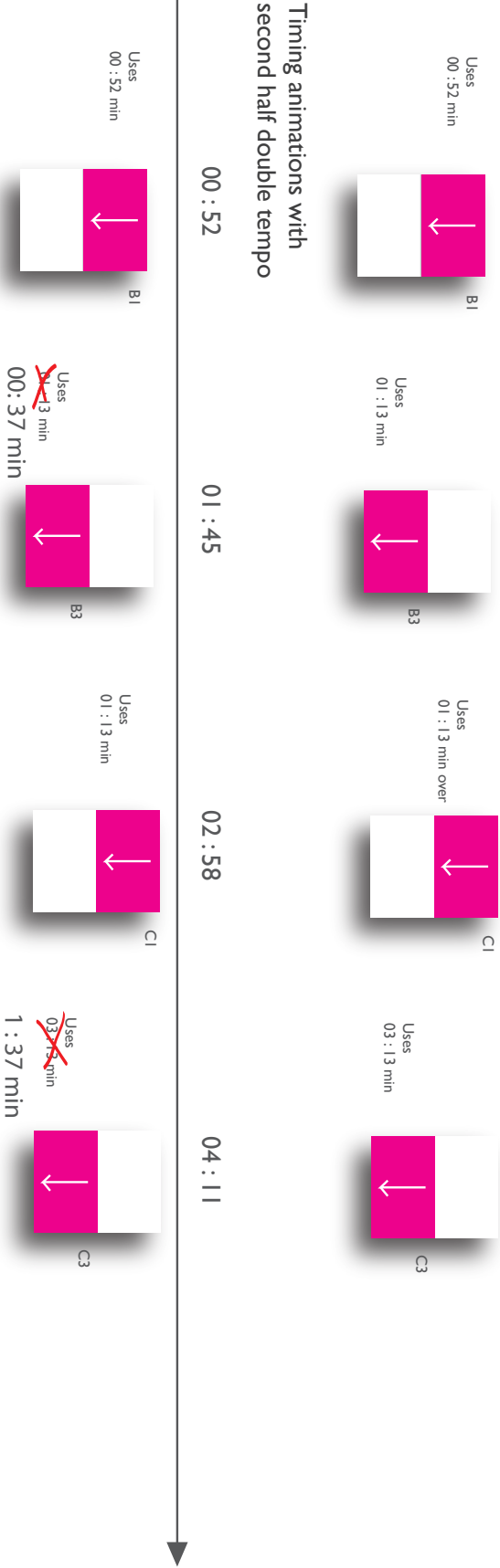
DISCUSSION

RECORDED DATA:

Playing time page 1: 1:45 min
Playing time page 2: 01:54 (first movement + break) + 00:32 (begin second movement) = 2:26 min
Playing time page 3: 06:26 min



Timing animations:



Appendix B: User test introduction and set-up

PARTICIPANTS INTRODUCTION TEXT

First of all, thank you for participating! This test is about playing sheet music from the ipad. I am going to ask you to play the first movement and the beginning of the second movement of Bach's double concerto.

You will play the same part four times, each with some changes in the way you read the music on the ipad screen. After each time, I will ask you to give the experience a score from 1 to 10, where 1 is the least pleasant and 10 is the most pleasant experience. Don't worry about page turns, you will see the next page on time.

You will play with a metronome to make sure you play everything in the same tempo. I will give you a four measure beat introduction before you start, is that ok? And remember, it is really not about how you play this piece, so it doesn't have to be perfect. And if you have any questions, please don't hesitate to ask.

VERSION DISTRIBUTION

Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6
Version 6	Version 6	Version 6	Version 6	Version 6	Version 6
Version 3	Version 2	Version 4	Version 3	Version 3	Version 1
Version 5	Version 4	Version 1	Version 4	Version 2	Version 4
Version 4	Version 3	Version 3	Version 5	Version 4	Version 3

Participant 7	Participant 8	Participant 9	Participant 10	Participant 11	Participant 12
Version 6	Version 6	Version 6	Version 6	Version 6	Version 6
Version 5	Version 3	Version 4	Version 3	Version 1	Version 3
Version 3	Version 2	Version 3	Version 5	Version 4	Version 2
Version 4	Version 4	Version 1	Version 4	Version 3	Version 4

Appendix C: User test score set-up and questions

QUESTIONS FOR THE PARTICIPANTS AFTER HAVING PLAYED ALL FOUR VERSIONS

General:

To be asked for each version:

- 1) What did you think about this version?
- 2) What did you like or not like about this version?

Only after version proceeding version 6:

- 1) Did you understand what was happening?

Referring to version 3 and 4:

If given the same score:

- 1) Did you notice any difference between these two versions?

If one score is higher than the other:

- 2) Why did you like this version better than the other one?
- 3) How do you feel about the fact that you can already see the next page when you are at the bottom of the old page?

RATING SCALE SET-UP

Version.....									
1	2	3	4	5	6	7	8	9	10
Comments:									

3. References

- Bell, T., Church, A., McPherson, J., Bainbridge, D (2005) Page turning and image size in a digital music stand. *Proc. International Computer Music Conference*.
- Burman, D., Booth, JR., (2009), Music rehearsal increases the perceptual span for notation. *Music Perception*, 26, 4, 303–320
- Christensen, T (2002). *The Cambridge History of Western Music Theory*. Cambridge University Press, pp. 628.
- Drai-Zerbib, V., Baccino, T., Bigand, E. (2009), Sight-reading expertise: Cross-modality integration investigated using eye tracking, *Psychology of Music*, 1–20
- Gilman, E., Underwood, G.. (2003). The perceptual span during music reading. In: Hyönä, J., Radach, R., Deubel, H. *The Mind's Eye: Cognitive and Applied Aspects of Eye Movement Research*. North-Holland: Elsevier. 177-192.
- Hayward, C.M. and Gromko, J.E. (2009) Relationships Among Music Sight-Reading and Technical Proficiency, Spatial Visualization, and Aural Discrimination. *Journal of Research in Music Education*, 57 (1), 26-36
- Kinsler, V., Carpenter, R.H.S.. (1995). Saccadic Eye Movements while Reading Music. *Vision Res.* 35, 1447-1458.
- Kyme, GH (1960) An experiment in teaching children to read with shape notes. *Journal of Research in Music Education* VIII (1). 3-8.
- Leone, M (2007). Report Music Reader. *Universiteit Twente*.
- Matthews, W.K., Kitsantas, A., (2012). The role of the conductor's goal orientation and use of shared performance cues on collegiate instrumentalists' motivational beliefs and performance in large musical ensembles. *Psychology of Music*. 40 (4), p1-17.
- Offermans, A (2005) *Electronic Music Book*. Delft University of Technology.
- Penttinen, M., Huovinen, E. (2011). The Early Development of Sight-Reading Skills in Adulthood: A Study of Eye Movements. *Journal of Research in Music Education*. 59 (2), 196– 220.
- Sauer, T. (2008). *Notations 2 I*. New York: Mark Batty.
- Sloboda, J.A. (1984). Experimental studies on music reading: A review. *Music Perception*, 2, 222–236.
- Truitt, F. E., Clifton, C., Pollatsek, A., & Rayner, K. (1997). The perceptual span and the eye-hand span in sight-reading music. *Visual Cognition*, 4, 143-161.
- Watanabe, J., Mochizuki, A., Horry, Y. (2009) Booksheet: Bendable Device for Browsing Content Using the Metaphor of

Leafing Through the Pages. *Proceedings of the 10th international conference on Ubiquitous computing*, p 360-369.

Winget, M. (2006) *Annotation of Musical Scores: Interaction and Use Behaviours of Performing Musicians*. PhD Thesis, University of North Carolina, Chapel Hill

Winget, M. (2008) Annotations on Musical Scores by Performing Musicians: Collaborative Models, Interactive Methods, and Music Digital Library Tool Development. *Journal of the American society for information science and technology*, 59 (12): 1878-1897.

Wurtz, P., Mueri, R., Wiesendanger M. (2009) Sight-reading of violinists: eye movements anticipate the musical flow. *Exp Brain Res*. 194, 445–450

Bellini, P., Nesi, P., Spinu, MB (2002). Cooperative Visual Manipulation of Music Notation. *ACM Transactions on Computer-Human Interaction (TOCHI)*. 9 (3), 194-237.

Blinov, A., (2007). An interaction study of a digital music stand. *University of Canterbury*.

Borchers, I., Hadjakos, A., Muhlhauser, M (2006). MICON a music stand for interactive conducting. *NIME '06 Proceedings of the 2006 conference on New interfaces for musical expression*, 254-259.

Forsberg, A., Dieterich, M., Zeleznik, R (1998). The Music Notepad. *Proceedings of UIST98*. San Francisco: ACM Press.

Foster, DP (2008). Illuminating music: A research and product design study applying synesthesia and ambient peripheral display theory. *Auburn University, Alabama*

Graefe, C., Wahila D., Maguire, J., Dasna, O (1996). Designing the muse: A digital music stand for the symphony orchestra. *Design Briefings, CHI 96*. 13 (1B), 436-441

Hankinson, A., L. Pugin, and I. Fuginaga (2009). Interfaces for document representation in digital music libraries. *Proceedings of the Conference of the International Society for Music Information Retrieval (ISMIR)*.

Kashioka, S. (2010). Method for displaying music score by using computer. U.S. Patent 7649134-B2, filed dec. 2004 and issued jan. 2010.

Konstantas, D. (2002). The Distributed Musical Rehearsal Environment. *Multimedia, IEEE*, 6 (3), 54-64

Kosakaya, J. (2003). Introduction of a performer-friendly Electronic Music Stand. *Joho Shori Gakkai Kenkyu Hokoku*, 111, 119-123.

Marshall, CC, (2005). Turning the page on navigation. *Procs. ACM/IEEE Joint Conference on Digital Libraries*, ACM, 225-234.

McPherson, JR (1999) Page Turning - Score Automation for Musicians. *University of Canterbury*.

Menoche, C. (2004). Digital Media Review. *Notes*, 516-519

Pagwiwoko, J. (2008) Improvements To A Digital Music Stand. *University of Canterbury*.

Pearson, J (2010). Supporting effective user navigation in digital documents. *Proceedings of the 28th of the international conference extended abstracts on Human factors in computing systems*.

Signer, B (2010) What is Wrong with Digital Documents? A Conceptual Model for Structural Cross-Media Content Composition and Reuse. *Proceedings of the 29th International Conference on Conceptual Modeling (ER 2010)*, Canada.

Tambouratzis, G.; Perifanos, K.; Voulgari, I.; Askenfelt, A.; Granqvist, S.; Hansen, K. F.; Orlarey, Y.; Fober, D. & Letz, S. (2008), VEMUS: An Integrated Platform to Support Music Tuition Tasks., in 'ICALT', *IEEE*, pp. 972-976.

Welchering, H (2008). Versatile electronic sheet music device with improved navigation system and method. U.S. Patent 2008/0060507 A1, filed Sep. 7, 2007 and issued Mar. 13 2008

Appendix X: Instruments and categories

An overview of orchestra instruments and the five variables:

- Distance to sheet music
- Playing concentration
- Position
- Both hand used whilst playing
- Feet used whilst playing?

The data input for the variable 'Playing concentration' was filled in by the Norwegian conductor Torodd Wigum. The other variables were found by observations during orchestra rehearsals at NNO and Krashan Musica.

EXPLANATION OF VARIABLES

Distance to sheet music

1 = Closest

3 = Furthest away (up to 1.30 m)

Playing concentration

1 = The most

3 = The least

* = These instruments are being played seated in a symphony orchestra, but the players usually stand during (home) practice and solo performances.

** = Whereas jazz musicians always stand whilst playing, many double bass players prefer to sit on a high stool during long rehearsals.

*** = Classical guitar players always sit whilst playing, guitarist from other musical genres often stand.

Instrument	Distance to sheet music	Playing concentration	Position	Both hands used whilst playing?	Feet used whilst playing?
KEYBOARD					
Piano	1	-	Seated	Sometimes	Yes
Organ	1	-	Seated	Sometimes	Yes
Celesta	1	3	Seated	Sometimes	Sometimes
OTHER					
Conductor	2	-	Standing	Yes	No
Vocalist	1	-	Standing	No	No
Guitar	1	-	Seated***	Yes	Yes (if electric)
Recorder	1	-	Seated*	Yes	No
Accordeon	2	-	Seated	Sometimes	No

Instrument	Distance to sheet music	Playing concentration	Position	Both hands used whilst playing?	Feet used whilst playing?
STRINGS					
Violin	2	4	Seated	Yes	No
Viola	2	4	Seated	Yes	No
Cello	2	4	Seated	Yes	No
Double Bass	3	3	Seated**	Yes	No
Harp	1	2	Seated	Yes	Yes
WOODWINDS					
Piccolo	1	2	Seated*	Yes	No
Flute	1	3	Seated*	Yes	No
Oboe	1	3	Seated*	Yes	No
English Horn	1	1	Seated*	Yes	No
Clarinet	1	3	Seated*	Yes	No
Bass Clarinet	1	1	Seated*	Yes	No
Bassoon	2	3	Seated*	Yes	No
Contrabassoon	2	1	Seated*	Yes	No
Saxophone	1	1	Seated*	Yes	No
BRASS					
Horn	1	3	Seated*	Sometimes	No
Trumpet	1	3	Seated*	Sometimes	No
Cornet	1	1	Seated*	Sometimes	No
Trombone	3	2	Seated*	Yes	No
Tuba	2	2	Seated	Sometimes	No
Euphonium	2	1	Seated*	Sometimes	No
PERCUSSION					
Timpani	3	3	Standing	Sometimes	No
Snare Drum	2	2	Standing	Sometimes	No
Bass Drum	2	2	Standing	Sometimes	No
Cymbals	2	2	Standing	Yes	No
Triangle	1	2	Standing	Yes	No
Xylophone	2	2	Standing	Sometimes	No
Gong	3	1	Standing	Sometimes	No
Tambourine	2	1	Standing	Yes	No
Bells	1	1	Standing	Sometimes	No
Chimes			Standing		

Appendix X: Librarian and sheet music

RENTING

Orchestras mostly buy (or rent) their sheet music from publishers or rent it from libraries (or commercial rental companies). Music which still is copyrighted can usually not be rented from libraries, but from the publisher. There are also commercial companies like for example Albertsen in the Netherlands which have contracts with nearly all major publishers for renting their sheet music to orchestras and musicians. These companies have access to nearly all music available for rent and a large number of orchestras and ensembles use them. Albertsen has the largest part of the Dutch orchestra music rental market. Orchestras make rental contract with libraries for specific scores parts. For a limited period they can then use the scores and parts for rehearsals and performances.

COPYRIGHT

You may not normally copy or perform a sheet music edition, which you can buy, because an editor also has a copyright on the edition, and an arranger may have too. The copyright on the edition only expires 70 years after the decease of all right holders. For this reason most orchestras play from original score. The law for this is not the same in all countries, in some countries you are allowed to copy the whole piece for you own use and sometimes just part of it. In the Netherlands you are only allowed to copy a part of it. If you need extra copies of the whole score or whole parts you have to buy them separately or you must have permission from the copyright owner to copy them.

There are several foundations, like Musi©opy [W1], that try to determine rules and fixed prices for making copies of sheet music, to help the owners of the copyright to get their share. A lot of countries have

their own copyright organization. Those organizations represent composers, text writers and music publishers. Composers, text writers and music publishers can register their work at those organizations. The copyright organizations make sure that the right holders receive their payments for the copyright. In the Netherlands, Buma/Stemra is the organisation that represents the right holders.

Source: This information is copied from the reports of Anna Offermans (2005) and Marco Leone (2005).

Appendix X: Library systems

LIBRARY SYSTEM

Most orchestras and ensembles have their own library of sheet music. Some of these libraries only consist of a small numbers of pieces, others consist of 5000 or more pieces of music. Orchestra Planning and Administration System

(OPAS) is used by most of the large orchestras around the world. It is a complete solution for the administration of orchestras including the music library. There are multiple versions of OPAS which differ in functionality; the lite version for example

doesn't have the library functionality, but the other two versions do. The functionality can however also be customized to the need of the specific orchestra. This also means that the metadata structure of the library can be changed. The library of OPAS has a build-in database with repertoire and composers with all important information about it. In the library it is also possible to include digital version of the music as attachment.

When sheet music is stored in the (electronic) catalog of the library the following information is mostly used:

- Title
- Subtitle(s)
- Composer and/or arranger
- Sort: Original or arrangement
- State of the music
- Instrumentation of the music
- Version number of the music
- Length in time
- Year of publication
- Owned or rented
- Location in the library

The title, composer and version number can identify

a unique piece in the library. Version numbers are only used when there are multiple pieces with the same title and composer or when there are different versions of a piece available (i.e. arrangements).

Source: This information is copied from the report of Marco Leone (2007).

Appendix X: Task occurancy estimation

Task		Occurrence per piece	Execution time	
			Traditional	Requirement
Changing pieces		0-1	2-3	2
Searching pieces		1	2-3	1
Making annotations	personal	2-3	1	1
	group	2-3	2-3	1-2
Navigation	location searching	2-3	1-2	1
	page turning	3	1	0
Location indication		3	1	0-1
Library tasks	distribution of repertoire	0	4	2-3
	view other parts	0-3	3-4	1-2
		Occurrence 0 – once per piece 1 – once per piece and rehearsal session 2 – incidental during rehearsal sessions 3 – always during each rehearsal session Execution time 0 – real-time, no noticeable delay 1 – small delay (< 10 sec) 2 – medium delay (< 30 sec) 3 – larger delay (> 30 sec) 4 – very large delay (> 5 min)		

Appendix X: Email Tim Bell

Hi Kine,

It's good to hear of your work. I'm not working in this area any more, and you've probably found most of my work on the topic. David Bainbridge and Waikato university still works in music retrieval, but not in music readers so much as far as I know.

> Animations used > to simulate the old medium, an actual paper page turn therefore seem a bit> silly.

For sure - a lot of work (and many commercial music systems) simulate a traditional page turn, which actually obscures the very thing you want to see (the last bar), and the next thing you'll look at comes up last (first bar of the next page). So it's cute, but silly. Except there's one important point we discovered: people have spacial memory for layout, so while you don't want to limit yourself to animating as for traditional books, it does seem important to have the same bar of music appear at the same place on the screen every time it is used, otherwise it can confuse the reader. This then becomes very close to the old idea of paper pages, but doesn't tie you to the turning mechanism. Also, people need some sort of cue that the page has turned, even if just a flash or slight change of colour. Replacing a page instantaneously often made users think that it hadn't turned yet, especially if the pages look similar.

The pen-based work was a one-off experiment in the early days of music editing systems. I expect the parameters are all different now with touch input and with Sibelius being so standard that many people can use it without thinking.

I'll follow your work with interest... I now play nearly all my music off an iPad, and I still think there's room for improvement.

Regards,
Tim Bell

Appendix X: Email percussionist

Email correspondance about annotations and wishes for a digital music reader with Lars Sitter, head at percussion at Trondheim Symphony Orchestra (TSO). Correspondance in Norwegian.

Hei igjen Kine

Svar på spørsmål.

1. Som slagverker i orkester har vi en del lange pauser, ja. Måten vi orienterer oss på er enten telling, stikknoter, notater eller kjennskap/gjennkjennelse av musikken. Ofte en kombinasjon av dette. Det er viktig for oss å hele tiden være i forkant mentalt, ofte flere minutter i musikken, så vi rekker å forberede oss, reise oss opp, ta opp riktige køller og gå til rett instrument. Vi orienterer oss derfor langt frem på notene i forhold til hvor vi er. Vi bruker derfor store noter med fler sider frem samtidig. Unngår hefter med blaing, og bruker heller løsark som vi kan flytte sidelengs etterhvert. Formatet på arkene som fungerer best er B4 (en slags mellomstørrelse mellom A4, som blir for lite pga ofte stor avstand til notestativ bak masse trommer og marimba osv, og A3 som blir for stort og krøller seg over notepulten. Med B4 kan vi ha 3 sider frem samtidig per stativ. (ofte bruker hver slagverker 2 stativ hvis det er for travelt til å bla) Ser for øvrig ikke helt for meg ipad størrelse som noen løsning for oss. Må være mye større, feks 24"

2. Ideer som jeg kunne tenkt meg integrert i en digital skjermvisning er:

Mulighet for å skrive inn notater (selvsagt) men også markeringstusjfunksjon i forskjellige farger. osv

Mulighet å se også partitur og andre enkeltstemmer (må ofte sjekke hva andre instrument spiller)

Klipp og lim, flytt, kopier osv.

Hoppende ball hadde vært ok, men ikke nødvendig (muligens på lange operaer, der er det lett å komme ut av tellinga)

Mulighet for lett å kunne distrubiere notene (i feks pdf) ut til vikarer per e-post (som ofte kommer tilreisende)

Seriekoble lesebrett, med samme visning på flere stasjoner (når vi beveger oss fra et stort instrument til et annet må vi ofte ta med notene, eller ha 2-3 sett.)

Tuner (for pauker) i samme vindu feks flatt nederst

Mulighet for meg som gruppeleder og notere inn notater som sprer seg til alle brettene på gruppa.

Oversettelsesfunksjon (italiensk, fransk, tysk, spansk, engelsk)

Kommer ikke på mer nå, men bare kom med oppfølgingsspørsmål hvis noe er uklart, eller du vil ha mer.

Lykke til med prosjektet.

mvh

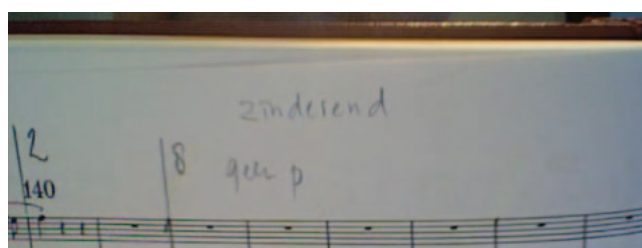
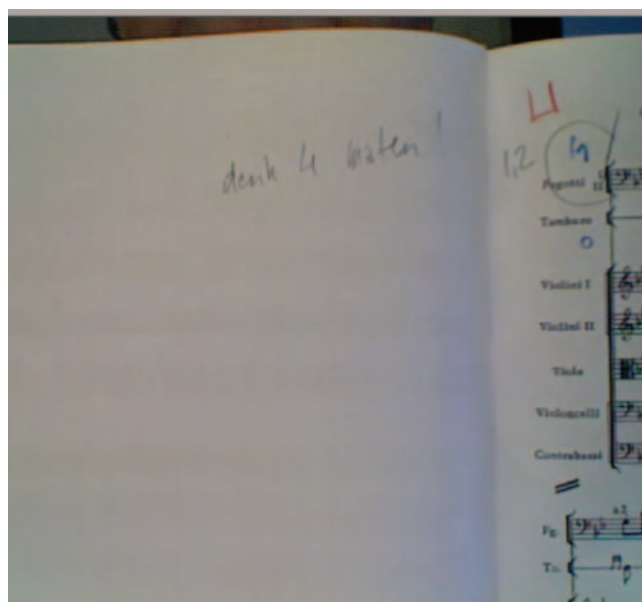
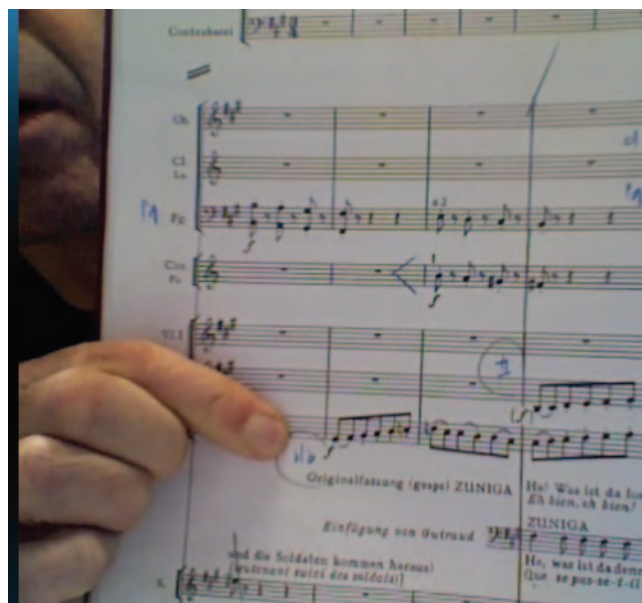
Lars Sitter

TSO

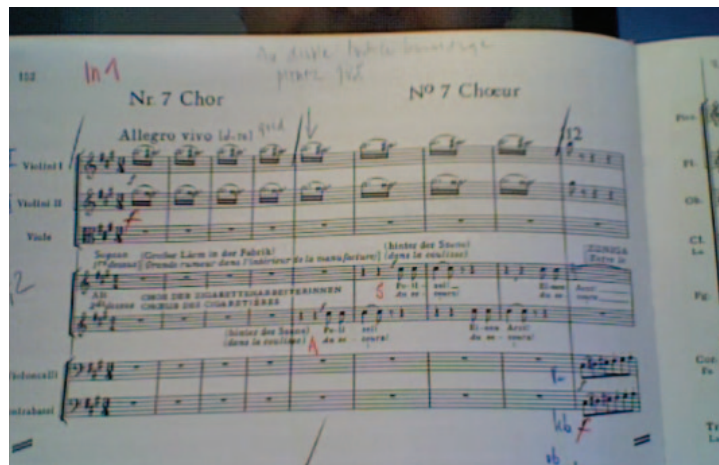
Appendix X: Interview Vincent de Kort

Conductor Vincent de Kort was interviewed through Skype about his way of annotating in sheet music and interaction with the orchestra. Here are the main findings from the interview.

- Conductors always buy their own personal score due to the importance of the annotations. Opening a score without your own annotations feels like starting all over again. One makes the score 'your own' with the annotations.
- The first thing de Kort does when opening a new score is splitting the score into musical phrases instead of bars. This is according to de Kort the reason why he never gets lost during a piece. His annotations allows him to easily find a new musical phrase instead of looking at only bars. He compares it with dividing the piece into sentences instead of only words.
- Although you learn some guidelines during education, there are big individual differences when it comes to how conductors annotate in their music.
- Examples from the score of 'Carmen' show a high level of conceptual annotations that sometimes do not make sense for anyone else than the annotator. De Kort has made his own colour codes for his annotations: Red annotations are 'louder' and blue annotations are 'softer'.
- de Kort makes his sheet music himself by printing out pages and bind them in at a publishing company in the Netherlands. This way he gets the 'feel' right: Hard case covers like a book.
- de Kort does not have the need to have any form of communication with the orchestra musicians before the first rehearsal. That is also the 'magic' of the first rehearsal. He meets the orchestra, the director of the orchestra is there and greets him. Then they play the



whole piece through. First then they start talking together. The music is the most important. That is the main way of communicating. In de Kort's experience, the musicians want to play. Cutting them off during the first playing-through is not good for the group discipline, you can see that the musicians become annoyed: they do not want to stop.



- According to de Kort, the scores with annotations of famous conductors are lying in dusty cellars. Even though it is possible, hardly any conductors exchange or look at each other's scores due to practical matters. He finds the possibility to easily exchange scores on the internet very interesting and would love to get the opportunity.



- de Kort does not perceive musicians that annotate during rehearsal as a problem. If he tells a message to the whole orchestra, he waits afterwards to give people time to annotate, then he tells them from where to play. This indicates that annotations are made based on feedback from the conductor, not randomly.
- The conductor is the mirror of the orchestra. They tend to adapt his mood while playing. If he is standing in front of them being nervous, the orchestra will play nervously.

Appendix X:ViP method

Vision in Product Design (ViP) is a widely applied design method that focuses on possibilities rather than on problem solving. The essence of ViP is to create the raison d'être of a future product by creating a context before designing the product.

A main part of the created context consists of a combination of statements on human tendencies (things that people tend to do when given the opportunity), an identification where these tendencies conflict, and an idea how to solve this conflict through a specific intervention of a product. The product would elicit certain behaviour that solves the conflict between the tendencies. For this reason there is a focus on the experience users have when confronted with products. The deliverable of ViP can be anything that results from a creative process, not just on traditional product categories but also on problems of management, architecture, services, etc. The process of ViP starts by selecting a set of factors (ideas, observations, principles, states, developments, beliefs, trends, obsessions) that form a context from which an appropriate product can be designed.

Source

http://en.wikipedia.org/wiki/Vision_in_Product_Design

