



Chapitre de livre

1998

Published version

Open Access

This is the published version of the publication, made available in accordance with the publisher's policy.

Distributed Musical Rehearsal: Evaluation Report

Konstantas, Dimitri; Orlarey, Yann; Carbonel, Olivier; Gibbs, Simon

How to cite

KONSTANTAS, Dimitri et al. Distributed Musical Rehearsal: Evaluation Report. In: Electronic commerce objects. Tsichritzis, D. (Ed.). Geneva : University of Geneva, Centre Universitaire d'Informatique, 1998. p. 269–299.

This publication URL: <https://archive-ouverte.unige.ch/unige:72833>

Distributed Musical Rehearsal : Evaluation Report¹

Yann Orlarey
Olivier Carbonel
Dimitri Konstantas
Simon Gibbs

Abstract

One of the most important part of the Distributed Musical Rehearsal project was the evaluation of the overall system performance. This task required the development of precise methodology, based on both subjective and objective performance measurements. The results of the evaluation are presented in the report in their raw form and from these we draw our conclusion concerning the quality, usability and possible improvement of the Distributed Rehearsal System.

1 Introduction

One goal of the DVP project [1] was to evaluate State of the Art communication and telepresence equipment for innovative distributed applications. Music rehearsal [2][3] was retained as a particularly challenging activity for such technologies in terms of human communication and collaboration, as well as a potentially usefull mean of artistic collaboration between european countries.

Towards this goal the GRAME contemporary music orchestra, directed by Daniel Kawka, performed two full scale distributed musical rehearsal trials in November 1996 and May 1997. The contemporary music pieces retained for the trials were Pierre Boulez's "*Derive*" and Robert (HP) Platz's "*Piece Noire*". Both pieces are very demanding in terms of orcherstra-conductor synchronization and sound quality.

The trials were organized in a two site setup [4]. The first site, where the musicians were located, was at the the University of Geneva in Switzerland. The second site, where the conductor was located was at GMD, the German National Research Center for Information Technology, outside Bonn in Germany. The two sites were connected with a 24 Mbps ATM line using the FORE StreamRunner AVA/ATV Motion JPEG codec set.

The most important element in a musical rehearsal is the tight and continous audio-visual communication between the musicians and the conductor. The conductor coordinates the musicians using body language and he is able to distinguish the music played by each and every musician. In a distributed musical rehearsal environment these elements translate to strict requirements for high quality video, three dimensional sound recreation and very low communication delay [5]. In order to satisfy the video requirements, large video wall screens were used at both

1. This work was supported by the Commision of the Europena Union under the ACTS project DVP (AC 089) and by the Swiss Federal Government with the OFES grand No. 95.0493.

sites, for the full size reproduction of the video image. For the audio requirements a dummy head was used at the musicians' site for the capture of the sound, while the conductor wore a head set for listening to the orchestra. The dummy head, which was different in each trial, was connected to a matrix and was placed approximately where the conductor's head would be if he was physically present in the rehearsal.

In order to evaluate the performance of the distributed musical rehearsal environment a series of objective and subjective evaluation tests were conducted. The objective performance measurements were conducted for both the conductor's and musicians' points of view. From the conductor's point of view we measured the affects of the Distributed rehearsal environment to his ability to perceive the music played by the musicians.

This was done during a special session where specific scores containing errors were given to the musicians and the conductor. The errors ranged from very difficult to detect, to very easy ones and the conductor was asked to detect the errors in the musicians scores. The same test with different but equivalent scores, was reproduced in a local situation. This way an objective measurement of the quality of the distributed rehearsal environment was established.

From the musicians point of view we measured the effects of the Distributed Rehearsal environment to their ability to identify the designation signals of the conductor. This was done by a set of designation tests carried out with the help of students from the University of Geneva. By counting the mistakes in the interpretation of the designation we were able to measure the performance of the system.

The subjective measurement of the quality of the distributed rehearsal environment was established by the means of a questionnaire and interviews given by the musicians and the conductor to a specialized psychologist. The answers and comments were classified and a measure of the acceptability of the system by its users was established.

In this report we present in detail the subjective and objective evaluation data and results and describe at the same the methodology used and the different issues taken into account for the evaluation. Our evaluation results indicate that with the present technological state of the art the Distributed Musical Rehearsal environment cannot fully replace the direct contact of a traditional rehearsal. Nevertheless the tool proved to be useful in progressing the rehearsal work and allowing the musicians and conductor to collaborate and work productively.

2 The Organization of a Musical Rehearsal

As for any live performance, rehearsals are essential in music. The rehearsal work aims at leading the musicians to their best performance for the concert, both individually and collectively. When the music is complex and requires several musicians to be performed, the coordination of the ensemble is provided by a conductor. The role of the conductor is also to give his artistic interpretation of the piece. He should be able to transmit this interpretation to the musicians (the greatest conductors are recognizable by their style and orchestral sound).

The total amount of work to prepare a concert for a piece of contemporary music depends of its complexity and length. On average, three weeks full-time per musicians are required for a

20mn piece. The first work for the conductor is the careful study and analysis of the score in order to define his interpretation and the way he will conduce the musicians. In the meantime the musicians are required to work their parts.

It is only after this large amount of personal work of all the participants, that rehearsals can take place. Rehearsals are roughly organized into three major phases :

- a protocol phase to settle the notation problems and the musical difficulties, and to explain how the piece will be conducted;
- rhythm phase to work out all the rhythmical problems;
- a sound phase for the phrasing, the dynamic, the sound color and balance.

During rehearsals, deep and complex interactions between the conductor and the musicians occur (Figure 1). These interactions are visual, gestural, verbal and auditory, as well as psychological and affective. In terms of human communications, rehearsals can be even more demanding than the actual concert.

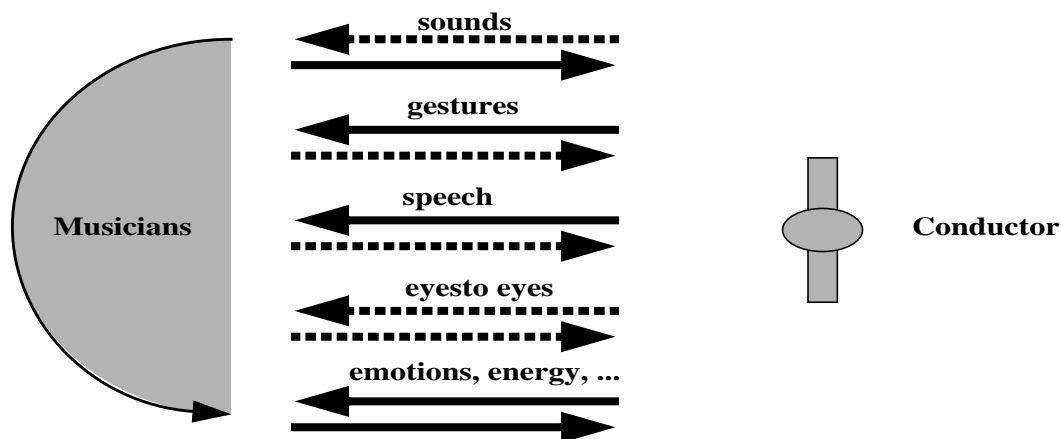


Figure 1 Interactions between the conductor and the musicians during rehearsals

3 Evaluation methodology

The goal of a *Distributed Rehearsal* (DR) system is to allow music rehearsals to take place when the participants are distributed over several physical places. Figure 2 shows the EOC music ensemble conducted by Daniel Kawka during a 2-sites distributed rehearsal. The musicians were located at CUI in Geneva, while the conductor was at GMD in Sankt-Augustin. This requires specific equipment like video walls, cameras, sound capture and reproduction systems as well as transmission equipment.

All these elements interfere with the complex human communications involved during a rehearsal (Figure 3). The purpose of this report is to state if such distributed rehearsal systems allow effective, realistic and useful rehearsal work for professional musicians.

The answer could not be simply yes or no. The evaluation should try :



Figure 2 Distributed Rehearsal between CUI (Geneva) and GMD (Sankt-Augustin)

- to characterize the differences between a rehearsal in local situation (LS) and a rehearsal in a distributed situation (DS) making use of the DR system.
- to evaluate in what these differences are positive or negative for the musical work.
- to understand how some negative points could be overcome by a different behavior of the participants.
- to estimate the acceptance of the DR system by the musicians
- to suggest technical improvements for the DR system.

While many books are available on orchestras and conductors and research works are available on “Tele-Teaching”, to the best of our knowledge, musical rehearsals have never been studied from a psychocognitive point of view. Therefore we had to define a specific methodology.

Our starting hypothesis of work were :

- Increased threshold of perception between a local and a distributed rehearsal (DS) on :
 - Timbre
 - Pitches
 - Rhythm

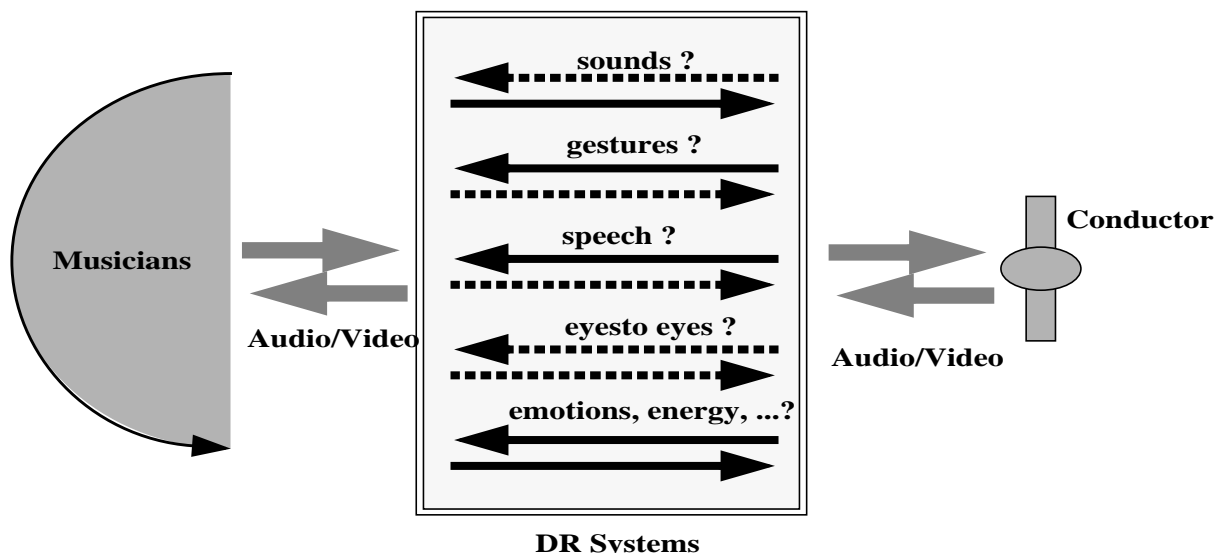


Figure 3 2-site Distributed Rehearsal

- Dynamic
- Modifications of the individual behaviors within the music ensemble :
 - increased inter-individual listening
 - increased role of the score
 - increased individual decision

From these hypothesis, we defined an experimental protocol to analyze and compare rehearsals in local and distributed situations. The experimental protocol is based on :

- Observation of the rehearsals of a “real” piece (a piece to be later played in concert) in both local and distributed situations.
- Individual interviews of the musicians and the conductor after the rehearsals.
- Rehearsals of *test pieces* , with specific errors in the score of the conductor (the conductor was asked to detect the errors) in order to have some measurements of perceptual thresholds.
- A detailed evaluation questionnaire sent to the conductor and the musicians at the end of the evaluation period.

In accordance with the conductor, we chose two different pieces for the tests :

- *Dérive* (Pierre Boulez) for Flute, Clarinet, Violin, Cello, Piano and Vibraphone.
- *Pièce Noire* (Robert H.P. Platz) for 2 Flutes, Oboe, Clarinet, Trumpet, Horn, Trombone, Violin, Alto, Cello, Double Bass and Piano.

We also asked composer and conductor J. Dorival to write two short test pieces, *Varia Bleue* and *Varia Rouge*, for the error detection tests.

In order to compare rehearsal situation, four full day trials were organized, a local and a distributed one for *Dérive*, and a local and a distributed one for *Pièce Noire*. During the distributed rehearsals the musicians were located at CUI in Geneva and the conductor at GMD in Sankt-Augustin.

All the rehearsal were performed by the EOC (Ensemble Orchestral Contemporain) conducted by Daniel Kawka, a music ensemble specialized in contemporary music.

4 interviews of the musicians and the conductor

After the first distributed rehearsal, the conductor and the musicians were interviewed to collect their impressions. This was a 20 mn semi-directed interview of each participant. We have transcribed and analyzed these interviews according to three different points of view :

- according to the situation : positive and negative points in local and distributed rehearsals
- according to the subject : personal attitude in local and distributed rehearsals
- according to the audio and video quality and the DR system in general

We give here the results of this analysis.

4.1 Analysis according to the situation

4.1.1 Negative and positive points of the distributed rehearsal for the musicians

<i>Negative</i>	<i>Positive</i>
Frustrated not to feel the conductor	Stronger links between the musicians without the conductor
The breathing of the conductor is missing	The conductor trust us
Impossible to look straight in the eyes	To take the work seriously
Tiring for the eyes	work for the best results
Headache	It was OK for the rehearsal
Difficult to start	Admiration for the technological aspects
To much setting and tuning	Well, we can get used to the system
The test scores	An adaptation took place
Don't like the system from a human point of view	I was expecting more delays, I am pleasantly surprised
Too far from the screen	
Explanations and dialogs are difficult	
Less detailed work	
Less satisfactory work	
6 hours of distributed work = 3 hours of local work.	
We have less confidence in the conductor	
Screen too far	
image definition	
Sound-Images time-lag	

4.1.2 Negative and positive points of the distributed rehearsal for the conductor

<i>Negative</i>	<i>Positive</i>
Bad analysis of the sound sources	small video delay, small inconvenient
Adaptation in relation to the acoustic image	Less inconvenient than expected.
Lack of timbre	We found the right tempo
The acoustic image should be improved	Interesting things have been said
The distance distorts my perception	Sympathetic verbal exchanges are inevitable

<i>Negative</i>	<i>Positive</i>
Refusal of visual adaptation due to a bad image quality	We made progress in the interpretation of the piece
Darkness of the images	
Refusal of visual communications	
I didn't feel I was able to transmit my energy	
The working space not very comfortable	
Working space open	
For the concert we will have to rework the dynamics	

4.1.3 Negative and positive points of the distributed rehearsal for the conductor

<i>Positive</i>	<i>Negative</i>
To feel a progression in the work	to have noise around me
Never an headache	Lack of human qualities of the conductor
	Incompetence of the other musicians
	Not being satisfied of its own work

4.1.4 Positive and negative points in a local rehearsal for the conductor

<i>Positive</i>	<i>Negative</i>
Feel the interpretation in accordance to my ideal image	heaviness in the interpretation
	Not being in phase with the tempo giusto
	discontented with the wrong acoustic image

4.2 Analysis according to the subject

4.2.1 Personal attitude of the musicians

<i>Distributed Rehearsal</i>	<i>Local Rehearsal</i>
The breathing of the conductor is missing	Progress with respect to the other musicians
Impossible to look straight in the eyes	Expecting an improvement during the rehearsal
Embarrassment	to have noise around me

<i>Distributed Rehearsal</i>	<i>Local Rehearsal</i>
work for the best results	No feeling of crushing
To take the work seriously	Clear relationship with Daniel
Daniel more a professor than a conductor	A constructive and progressive work
Tiring	Every one has his own values
A lot of work	A progress both at musical and gestual level
A month like this I am drained of energy	The conductor leads us, we can see if he is happy or not.
Difficult to start	Not being satisfied of its own work
To much setting and tuning	
The test scores not good	
I have been told to play louder	
No particular efforts	
To play, it was OK.	
Explanations and dialogs are difficult	
Constructive work	
An adaptation took place	
A good experience after all	
Feel more comfortable with the piece,	
Discover a new freedom	
Less work on the details	
Exaggeration of the dynamics	
Pay more attention to the conductor gestures	

4.2.2 Personal attitude of the conductor

<i>Distributed Rehearsal</i>	<i>Local Rehearsal</i>
A different kind of concentration	Not being in phase with the tempo giusto
Refusal of visual adaptation to the bad image quality	To feel the interpretation in accordance to my ideal image
adaptation to the loudspeakers	heaviness in the interpretation
Lack of concentration due to the open space	discontented with the wrong acoustic image
I didn't tried to work on details	eyes expression

<i>Distributed Rehearsal</i>	<i>Local Rehearsal</i>
The test score with limited time was a fire-proof	Visual acuteness with regard to the musician
	Acuteness beyond information

4.2.3 Attitude of the musicians towards the group

<i>Distributed Rehearsal</i>
Stronger links between the musicians without the conductor
frustrated not to feel the conductor
The conductor trust us
At the end we felt good together
This gives us a sense of responsibility
Less precise gestures of the conductor
Same level of quality with the rehearsal, but it takes more time
The required dynamics will be corrected later
On lui (au chef) fait un petit moins confiance

4.2.4 Attitude of the conductor towards the group

<i>Distributed Rehearsal</i>
We progressed for the interpretation of the piece
Interesting things have been said
The distance distorts my perception
I refused to create a visual communication
Sympathetic verbal exchanges
No visual acuteness
Pas perçu cette absorption d'énergie que je donne
We found the right tempo
The interpretation improved throughout the rehearsal

4.3 Quality Analysis

4.3.1 For the musicians

<i>Audio Quality</i>	<i>Video Quality</i>	<i>DVP in general</i>
Better sound image with the headphone	My eyes are sore	Distance to the conductor : 800km
Exaggeration due to the acoustic of the room	The image could have been larger	A good experience after all
Room less reverberant than usual	The distance to the screen could be improved	Not the same work as usual
	Definition of the image too low	Admiration for the technological aspects
	Sound-Images time-lag	Rejection from the human point of view
	Screen too far	Less satisfactory work
	We get used to the image	6 hours spent for a 3 hours work
		Boring exercise

4.3.2 For the conductor

<i>Audio Quality</i>	<i>Video Quality</i>	<i>DVP in general</i>
Exaggeration due to the acoustic of the room	One must get used to the video image	An unusual tiredness
Bad analysis of the sound sources	The delay was not such a problem	A different kind of concentration
A restricted dynamic scale	Darkness of the video image	One rehearsal in two
Lack of timbre		Improvement for the rehearsal : 60%
Improve the acoustic image		Working space not very comfortable
Lack of resonance		Open working space
The loudspeakers introduced a distortion in the sound space		Distance of the musicians : 5 meters
Lack of presence of the violin		
Confusion between the clarinet and the cello		

<i>Audio Quality</i>	<i>Video Quality</i>	<i>DVP in general</i>
Lack of resonance and confusion with the cello		
An absorbing wall and a reflective wall		
Bad localization of the sound		
Adaptation to the acoustic image		

Several combinations were tried for the sound capture and restitution. For the sound capture on the musicians side we tried :

- a pair of microphone
- a pair of microphone with an M+S matrix
- a dummy head

The best results were achieved with the dummy head.

For the sound restitution, on the conductor side, we tried :

- Loudspeakers
- headphone set

With loudspeakers the localization of the sounds was not very precise due to differences between the walls at GMD : the left wall was reflexive and the right wall absorbent. The judgment of the conductor regarding the perception of the instruments was the following

<i>Positive points</i>	<i>Negative points</i>
good perception of the flute	lack of depths of the piano
good perception of the clarinet	lack of resonance and brightness of the vibra
	lack of presence of the violin
	wrong localization of the cello (too large)

As expected, better results were obtained combining the dummy head and the headphones, but still with a lack of details and presence of the sound, specially for the instruments far from the dummy head

<i>Positive points</i>	<i>Negative points</i>
good perception of the flute	lack of depths of the piano
good perception of the clarinet	lack of resonance and brightness of the vibra
better localization	

5 Error detection tests

To measure the impact of the distributed rehearsal situation on several categories of perception, we asked composer and conductor J. Dorival to write two test pieces : *Varia Bleu* and *Varia Rouge*, for Piano, Flute, Vibraphone, Clarinet, Violin and Cello, and to introduced several errors in the score of the conductor.

The conductor and the musicians were asked to rehearse the pieces as usual, but the conductor was also asked to detect the errors and to annotate his score. The verbal exchanges were limited to precise questions of the conductor. The rehearsal time was limited to 30 minutes for each piece.

The image shows a page of handwritten musical notation for a piece titled 'VARIA'. At the top, it is labeled 'Conducteur DANIEL Béa'. There are several handwritten annotations in blue ink, including circled notes and phrases like 'ramp forte-pianissimo' and 'crescendo fortissimo'. The score is written for multiple instruments: Flute (Fl), Vibraphone (vibra), Piano (p), Violin (vl), and Cello (vc). The notation includes various musical symbols such as notes, rests, and dynamic markings.

Figure 4 Figure 4 : *Varia Bleu*, annotated by the conductor

The test has been performed both in local and distributed situation. By comparing the errors detected in each situation, differences in the threshold of perception for the defined categories can be evaluated.

5.1 The Test Scores

23 errors were introduced in each test score, according to the 6 instruments and 4 perceptual categories : timbre, pitch, dynamic, rhythm.

5.1.1 Errors introduced in *Varia Bleu* score

<i>Instrument</i>	<i>Measure</i>	<i>Beat</i>	<i>Category</i>	<i>Modification Type</i>
vibra	3	2	rhythm	accents
clarinet	5	2	rhythm	trille-liaison
clarinet	6	2	timbre	notes ajoutées

<i>Instrument</i>	<i>Measure</i>	<i>Beat</i>	<i>Category</i>	<i>Modification Type</i>
flute	6	2	timbre	notes supprimées
piano	7	1	nuance	ff->decrescendo
vibra	7	1	harmony	bémol->bécare
violin	8	3	rhythm	condensé de notes
flute	9	3	harmony	bécare->dièse
vibra	9	3	nuance	pp->f
piano	10	1	rhythm	ajout note
vibra	10	1	rhythm	suppression notes
clarinet	11	2	nuance	pp supprimé (mf)
violoncello	11	2	harmony	bémol->bécare
flute	13	2	nuance	pp->crescendo
flute	15	1	timbre	transposition
violin	15	1	timbre	remplacement note
clarinet	15	2	rhythm	décalage
violoncello	15	2	harmony	dièse->bécare
piano	17	3	harmony	ajout altération dièse
piano	18	1	nuance	ajout crescendo vers mf
clarinet	18	3	rhythm	suppression altération
flute	19	1	timbre	suppression note
vibra	19	1	timbre	ajout note idem flute

5.1.2 Errors introduced in *Varia Rouge* score

<i>Instrument</i>	<i>Measure</i>	<i>Beat</i>	<i>Category</i>	<i>Modification Type</i>
vibra	5	1	rhythm	ajout double croche
clarinet	5	2	timbre	suppress 1 double
flute	5	2	timbre	ajout double croche
piano	6	1	harmony	3 dièses supplément.
vibra	6	1	nuance	ff au lieu de fp
piano	9	1	nuance	ff -> p
clarinet	9	3	timbre	ajout 4 doubles

<i>Instrument</i>	<i>Measure</i>	<i>Beat</i>	<i>Category</i>	<i>Modification Type</i>
vibra	9	3	timbre	suppression noire
violoncello	9	3	harmony	chgt altération
violin	10	1	rhythm	suppression 1/4 de soupire
piano	11	1	nuance	p+cresc au lieu de forte
clarinet	11	2	timbre	mi ->sib
piano	11	2	rhythm	ajout double +chgt alté
violin	11	2	timbre	lab->fa
clarinet	13	1	timbre	ajout blanche
violin	13	1	timbre	suppression blanche
violoncello	14	1	rhythm	croche pointée->croche
clarinet	14	2	nuance	pp->mf
vibra	14	2	harmony	la bécarre->la bémol
piano	17	2	harmony	chgt altération
violoncello	17	2	timbre	descente 1 octave
vibra	17	3	rhythm	ajout croche
clarinet	18	1	nuance	cresc. au lieu diminu.

5.2 Error detection results

The performances in error detection, (the ratio between the detected errors and the existing errors), are summarized in the following tables :

performances in local situation

Category	Instrument						Total
	clarinet	flute	piano	vibra	violin	cello	
harmony		100%	67%	50%		33%	56%
nuance	100%	0%	25%	50%			50%
rhythm	33%		100%	50%	0%	0%	42%
timbre	60%	0%		50%	67%	0%	40%
Total	64%	17%	56%	50%	40%	20%	46%

performances in distributed situatio

Category	Instrument						Total
	clarinet	flute	piano	vibra	violin	cello	
harmony		100%	0%	50%		0%	22%
nuance	67%	0%	25%	50%			40%
rhythm	0%		0%	25%	0%	0%	8%
timbre	40%	25%		50%	67%	0%	40%
Total	36%	33%	11%	40%	40%	0%	28%

As we can see, on the whole, there is a 40% degradation of the performances of the conductor. The performance falls from 46% in local rehearsal to 28% in distributed rehearsal.

The graph in Figure 5 compares the performances for the perceptual categories and instruments between local and distributed situation.

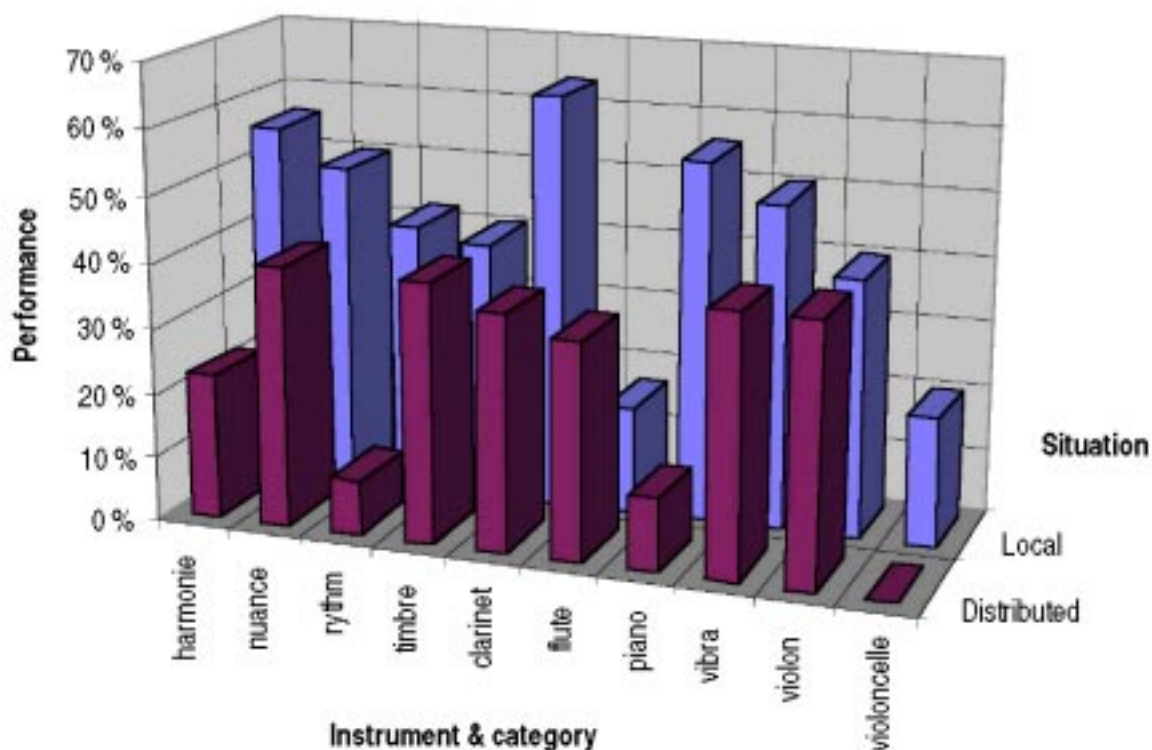


Figure 5 Performances of the perceptual categories and instruments

For all the perceptual categories, the performances are equivalent or better in local situation. The most dramatic degradation of performances is on rhythm errors, from 42% to 8%. This is probably related to the transmission delay introduced by the DR system.

On the timbre category, the results are equivalent, the DR system doesn't seem to have a real influence in this case.

Good results were also obtained on the dynamic (nuance) category with only a small degradation of the performances in distributed situation, despite a restricted dynamic scale introduced by the sound system and the feeling of the participants that the whole dynamic of the piece will have to be adjusted later during a local rehearsal.

The performance in detecting errors on the piano and the cello were very bad in distributed situation. No pitch and rhythm errors were detected on the Piano and no errors at all on the Cello.

Surprisingly the errors on the flute were better detected in distributed situation, but this is the only case.

6 Gestural designation Experiment



Figure 6 CUI students during the Gestural Designation Experiment

Eyes to eyes communication and gestural designation were reported by the participants to be nearly impossible with the DR system. The main two reasons invoked are the lack of image definition and the 2D image. With a 2D image, even if cameras and screens are correctly aligned, you always see the viewpoint of the camera, as if you were in front of the conductor. Therefore, if you are on a side of the screen and the conductor points his finger in your direction, you never really feel designated. We decided to make an experiment (Figure 6) to see how successful could be gestural designations using the DR system, with groups of 3, 6 and 9 persons.

6.1 Experimentation protocol

We asked two groups of 9 students, in Geneva, to participate to the experiment, as well as the person in charge of the gestural designation, in Sankt-Augustin. The setup of the DR system was the same than for a rehearsal.

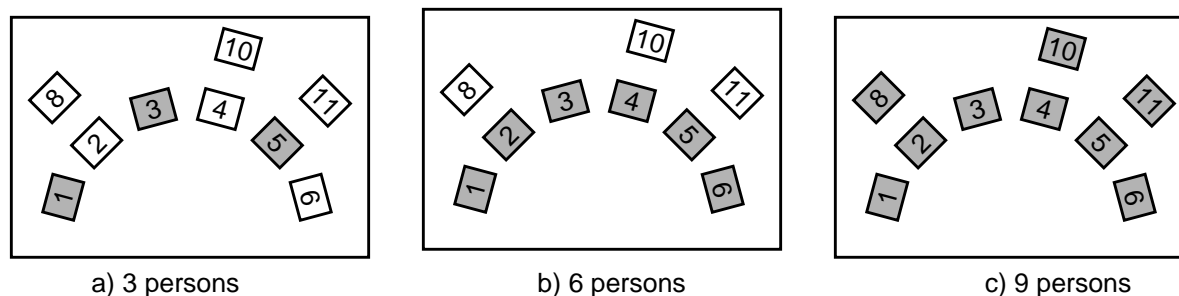


Figure 7 Seats layout during the experiment.

We started with the first group of 9 students (group A), itself subdivided in 3 subgroups of 3 students (subgroups A1, A2, A3). We first asked subgroup A1 to take seats 1, 3, 5 (see Figure 7a). Each student received a sheet to report, for each designation, if he *was* or *not* the target of

the designation. A tape of 9 randomly chosen designation order on seats 1, 3, 5 was then played in the headphones of the designator in Sankt-Augustin.

After this first series, we asked group A1 to remain on the same seats and group A2 to take seats 2,4,6 (figure 4.b) for a new series of 20 designation orders on seats 1,2,3,4,5,6. We ended with group A by asking subgroup A3 to take the remaining seats for a series 30 designation orders on all the seats.

We performed the same series of tests on group B, with the same tapes.

6.2 Results

Each designation can generate two kinds of errors :

- *Missing Errors* (ME) : the target of the designation don't report he was the target,
- *Abuse Errors* (AE) : a non-target report he was the target.

For a n -persons configuration we can have up to n errors per designation : 1 Missing Errors and $n-1$ Abuse Errors.

6.2.1 3-persons configuration

Here are the results in 3-persons configuration, for groups A1 and B1.

Group A1

Seat	ND	ME	AE	TE	
1	3	1	0	1	11%
3	2	1	1	2	22%
5	4	0	0	0	0%
	9	2	1	3	33%
		22%	11%	33%	

Group A1

Seat	ND	ME	AE	TE	
1	3	2	3	5	56%
3	2	0	1	1	11%
5	4	0	0	0	0%
	9	2	4	6	67%
		22%	44%	67%	

The first column ND is the number of designation per seat. The Column ME indicates the number of *Missing Errors* per seat. The third column AE indicates the number of *Abuse Errors*. The column TE gives the total number of errors per seat (ME+AE). The last column is the ration between TE and the total number of designation (here 9) : the number of errors per designations. It gives us a performance indication for each seat (low figures are better). The row TD gives the total of column ND, ME, AE and TE. The last row is the ratio between TD and the total number of designation. It indicates the performance for the whole group, according to the type of error.

The configuration was very simple, only three persons, one on the left, one almost on the center, and one on the right. Despite this apparently simple configuration, we notice a lot of errors. A1 performs twice better than B1, but in both case, errors are only on seats 1 and 3. The fact that seat 3 is not exactly on the center, but slightly on the left, is enough to create an ambiguity between seats 1 and 3.

Therefore, for untrained people, as it was the case for the students, the only things that seems easy is to distinguish between left and right designation.

6.2.2 6-persons configuration

We present now the results in 6-persons configuration for A1+A2 and B1+B2. In both cases A1 and B1 remain on the same seats (1,3,5) in order to see if a training effect was noticeable..

Group A1 + A2						Group B1 + B2						
Seat	ND	ME	AE	TE		Seat	ND	ME	AE	TE		
1	4	1	0	1	5%	1	4	0	0	0	0%	
2	4	2	2	4	20%	2	4	0	0	0	0%	
3	3	0	0	0	0%	3	3	0	2	2	10%	
4	3	1	2	3	15%	4	3	0	3	3	15%	
5	3	0	0	0	0%	5	3	2	3	5	25%	
6	3	1	0	1	5%	6	3	0	1	1	5%	
					20	5	4	9	45%			
					25%	20%	45%					
							10%	45%	55%			

The two groups show similar performances on this second test. The evolution of the errors ratios of A1 and B1 are interesting. Although the ambiguity has increased on the left side due to the arrival of seat 2, seats 1 and 3 have better results, in both groups, than previously. In this case, it seems that there is a training effect.

The situation is more difficult now for seat 5. It was the only one on the right side in the previous test. He have now two neighbors, seats 4 and 6. The performance of seat 5 of A1 is perfect with these new conditions, but the one of seat 5 of B1 rise to 25%.

6.2.3 9-persons configuration

For the 9-persons configuration, A1+A2 and B1+B2 remain on the same seats (1, 2, 3, 4, 5, 6), and the new comers, A3 and B3, take the rear seats 8, 10, 11..

Group A1 + A2 + A3						Group B1 + B2 +B3					
Seat	ND	ME	AE	TE		Seat	ND	ME	AE	TE	
1	1	0	0	0	0%	1	1	0	2	2	7%
2	4	0	0	0	0%	2	4	4	3	7	23%
3	2	0	0	0	0%	3	2	2	2	4	13%
4	2	0	1	1	3%	4	2	0	1	1	3%
5	3	0	0	0	0%	5	3	0	0	0	0%

Group A1 + A2 + A3						Group B1 + B2 +B3					
Seat	ND	ME	AE	TE		Seat	ND	ME	AE	TE	
6	4	2	0	2	7%	5	4	1	4	5	17%
8	4	4	1	5	17%	5	4	4	0	4	13%
10	3	3	0	3	10%	5	3	3	0	3	10%
11	7	7	3	10	33%	6	7	7	0	7	23%
	30	16	5	21	70%		30	21	12	33	110%
		53%	17%	70%				70%	40%	110%	

In both groups we have an increased number errors compared to the 6-persons situation

6.2.4 Comparative performances

As expected, errors rise with the number of participants, but also decrease with the training. The two graphs in Figure 8 show the evolution of the errors ratios for the two groups.

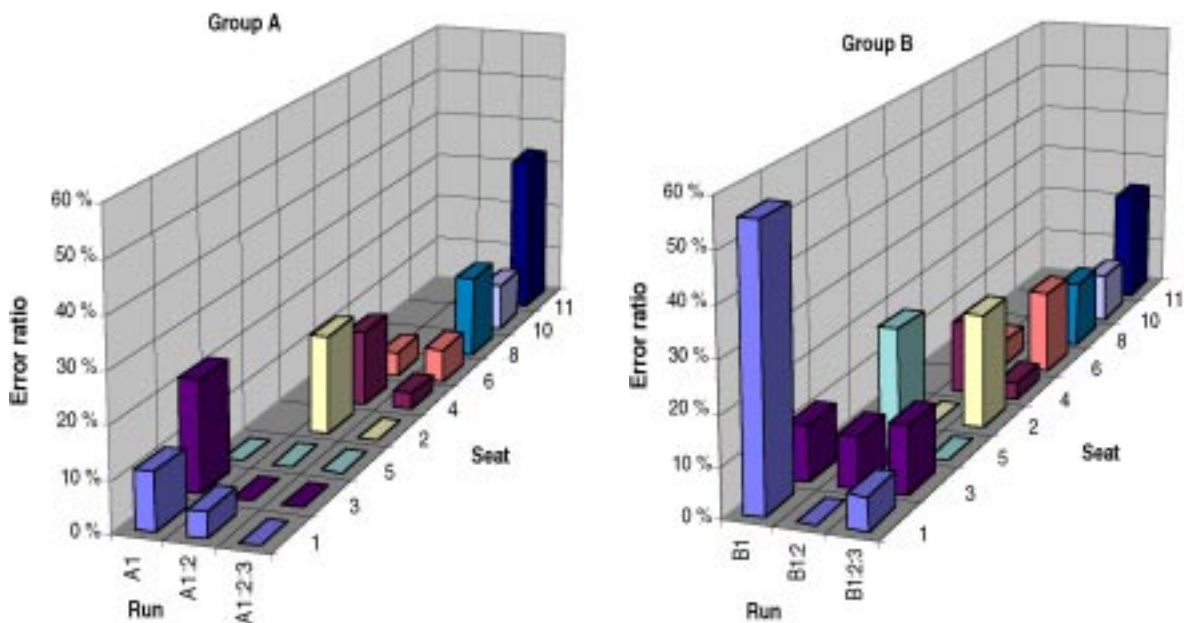


Figure 8 Evolution of erros of the designation groups.

As a whole, group A performs better than group B, but it is interesting to average the results of the two groups, and to compare the performances of the trained and untrained subgroups as in the graph in Figure 9.

Clearly, the first subgroups, A1 and B1, improved their performance on the three runs. They obtained their best results in the last situation, which was the most difficult. The second subgroups, A2 and B2 also improved their performance in the last situation. The last subgroups, A3 and B3, were newcomers and untrained in the most complex situation. As expected, they obtained the worst results.

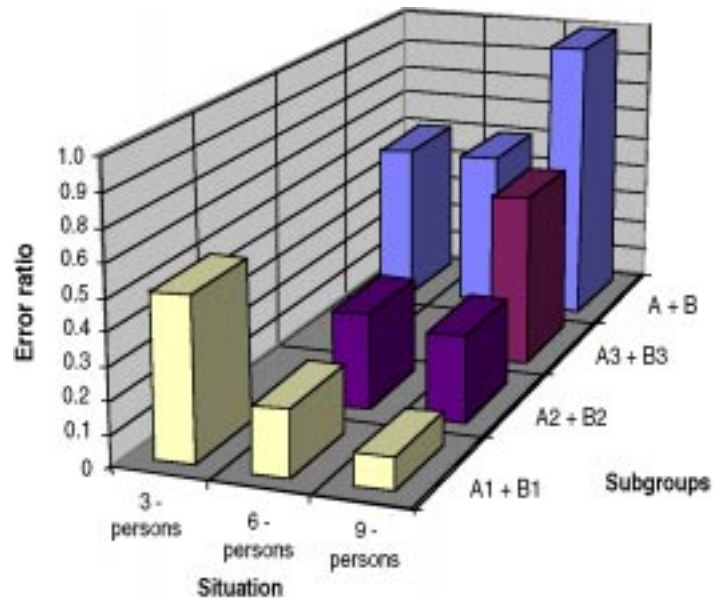


Figure 9 Trained and untrained subgroups in designation tests

To summarize, gestural designation through a 2D-image creates an artificial situation where you never "feel" designated. Without training you can distinguish left and right designation, but not really more. Being trained, it is possible to distinguish gestural designation in a 9-persons group with fairly good results or even excellent results like subgroup A1 (0% errors in the 9-persons situation).

This is an encouraging result, nevertheless the test conditions were not equivalent to a rehearsal situation in terms of speed of the designation and stress of the participants. Therefore it is not clear, without further experiments, how this result could be transposed to a real distributed rehearsal situation.

7 Questionnaire

A 47 questions questionnaire has been sent to all the participants (the conductor and the 15 musicians involved in the trials) after the last experiments, in July 96. A total of 14 questionnaires have been received.

A first group of 5 questions was proposed to evaluate the technical quality of the Distributed Rehearsal system. Then 3 groups of 4, 11 and 9 questions were asked to compare the local and distributed rehearsal according to the working conditions, the interaction between the participants and the musical work. Finally, a group of 18 questions was proposed to evaluate the future of the DR system and its acceptance by the musicians.

7.1 Technical evaluation

In order to evaluate the quality of several parameters of the DR system, the participants were asked to answer the following questions :

a1) Synchronization between image and Sound

Very Bad	Bad	Acceptable	Good	Excellent
	69%	31%		

a2) Quality of the music sound

Very Bad	Bad	Acceptable	Good	Excellent
	30%	40%	20%	10%

a3) Quality of the speech sound

Very Bad	Bad	Acceptable	Good	Excellent
	8%	46%	38%	8%

a4) Quality of the image

Very Bad	Bad	Acceptable	Good	Excellent
8%	23%	62%	8%	

a5) Influence of the transmission delay

Very Bad	Bad	Acceptable	Good	Excellent
17%	58%	25%		

a6) Technical feat of the DR system

Bad	Good	Don't know
25%	58%	17%

Answers to question a1) and a5) reflect the influence of the transmission delay, which is a major problem to solve.

The image quality must also be improved. The use of a 2D image is a problem to establish a good visual communication between the conductor and the musicians. Several participants suggested a 3D image to improve the DR system.

The results of question a2) are surprising because the musicians had the direct sound. It reflects the acoustic of the room which was a classroom, not a concert hall. The answer of the conductor on the quality of the music sound was "bad".

Despite these shortcomings, a majority of the participants appreciate the technical feat of the DR system.

7.2 Working conditions

The participants were asked to compare their working conditions in local and distributed rehearsal.

b1) Tiredness after the distributed rehearsal

Bad	Less Good	Equivalent	Better	Excellent
38%	46%	8%	8%	

b2) Noise conditions during the distributed rehearsal

Bad	Less Good	Equivalent	Better	Excellent
17%	33%	55%		

b3) Concentration during the distributed rehearsal

Bad	Less Good	Equivalent	Better	Excellent
31%	46%	23%		

b4) Pleasure to play during the distributed rehearsal

Bad	Less Good	Equivalent	Better	Excellent
38%	54%	8%		

The distributed rehearsals were a tiring experience for all the participants, requiring a lot of concentration. For a part this is due to the DR system, but also to the experimental conditions.

7.3 Interactions between the participants

Music rehearsals involve complex interactions between the musicians and the conductor. We asked the participants to evaluate the quality of human interactions during a Distributed Rehearsal compared to a Local Rehearsal :

c1) Perception of the conductor « energy »

Bad	Less Good	Equivalent	Better	Excellent
38%	62%			

c2) « distance » between the conductor and the musicians

Bad	Less Good	Equivalent	Better	Excellent
38%	38%	23%		

c3) Perception of the breathing of the conductor:

Bad	Less Good	Equivalent	Better	Excellent
33%	58%	8%		

c4) Quality of the verbal interactions between the musicians

Bad	Less Good	Equivalent	Better	Excellent
	18%	73%	9%	

c5) Quality of the musical interactions between the musicians

Bad	Less Good	Equivalent	Better	Excellent
	17%	75%	8%	

c6) Quality of the « eyes to eyes » communication between the conductor and the musicians

Bad	Less Good	Equivalent	Better	Excellent
92%	8%			

c7) Quality of the gestural communication between the conductor and the musicians:

Bad	Less Good	Equivalent	Better	Excellent
83%	17%			

c8) Quality of the verbal communication between the conductor and the musicians:

Bad	Less Good	Equivalent	Better	Excellent
	62%	38%		

c9) Quality of the « emotional » communication between the conductor and the musicians

Bad	Less Good	Equivalent	Better	Excellent
31%	69%			

c10) Quality of the overall communication between the musicians

Bad	Less Good	Equivalent	Better	Excellent
	23%	62%	15%	

c11) Quality of the « presence » of the conductor

Bad	Less Good	Equivalent	Better	Excellent
42%	58%			

All the answers, apart c4) and c5), reflect the lack of presence of the conductor. Answers c6) and c7) show that a 2D image (and a lack of definition) is a major problem to “eyes to eyes” and gestural communication between the conductor and the musicians.

Answers c4) and c5) are interesting. They show that the lack of presence of the conductor reinforce the interactions between the musicians. This is a confirmation of what appears in the interviews.

7.4 Musical Work

In this group of questions we asked the participants to compare the quality of the musical work in a Distributed Rehearsal with respect to a Local Rehearsal :

d1) Fulfillment of your responsibility

Bad	Less Good	Equivalent	Better	Excellent
8%	25%	67%		

d2) Feeling of freedom in the interactions with the conductor

Bad	Less Good	Equivalent	Better	Excellent
17%	42%	33%	8%	

d3) Assessment of your own work

Bad	Less Good	Equivalent	Better	Excellent
8%	67%	25%		

d4) Assessment of the group work

Bad	Less Good	Equivalent	Better	Excellent
8%	75%	17%		

d5) Easiness to be « in the swing » of the rehearsal

Bad	Less Good	Equivalent	Better	Excellent
33%	50%	17%		

d6) Ability to find the « tempo giusto »

Bad	Less Good	Equivalent	Better	Excellent
8%	67%	25%		

d7) Ability to find the right « nuances »

Bad	Less Good	Equivalent	Better	Excellent
40%	50%	10%		

d8) Ability to find the right sound color

Bad	Less Good	Equivalent	Better	Excellent
30%	40%	30%		

d9) Efficiency of the distributed rehearsal

Bad	Less Good	Equivalent	Better	Excellent
30%	70%			

The results here are a bit surprising compared to those of the interviews. The interviews shows that the “lack” of the conductor induces more responsibility for the musicians, but this is not reflected in answer d1). The assessment on the personal work of each musicians is better than the one to the whole group.

7.5 Usefulness of the DR system

We asked the participants to judge the usefulness of the DR system for different kinds of applications.

e1) Save time

No	Yes	Don't know
73%	27%	

e2) Could encourage international collaborations ?

No	Yes	Don't know
27%	45%	27%

e3) Could be used in musical teaching ?

No	Yes	Don't know
55%	45%	

e4) Could be used for classical music ?

No	Yes	Don't know
27%	36%	36%

e5) Could be used for contemporary music ?

No	Yes	Don't know
50%	30%	20%

e6) Do you wish such DR system to spread ?

No	Yes	Don't know
50%	17%	33%

A large majority of the participants agreed to say that the DR system don't save time. A distributed rehearsal is not as efficient as a local rehearsal.

A relative majority think that DR systems could encourage international collaboration. But they are very divided on the use of DR system for teaching music.

They think that the DR system is more adapted to classical music than to contemporary music. The more stable rhythmic structures of classical music are probably easier to conduct with the transmission delay.

7.6 Influence of the DR system

We asked the participants to judge the influence of the DR system on their profession and their own technique.

f1) Do you think one can get used, with enough practice, to the shortcomings of the DR system

No	Yes	Don't know
40%	30%	30%

f2) How do you judge the influence of the DR system on the technique of the musician

Bad	Good	Don't know
44%		56%

f3) How do you judge the influence of the DR system on the technique of the conductor

Bad	Good	Don't know
50%		50%

f4) How do you judge the influence of the DR system on the musician profession

Bad	Good	Don't know
55%	18%	27%

f5) How do you judge the influence of the DR system on the conductor profession

Bad	Good	Don't know
45%	18%	36%

Opinions differ on the influence of the DR system. We have an average of 50% of “Bad” answers, but also a high percentage of “don't know” due to the lack of experience and practice with DR systems.

7.7 Other questions

Finally we asked the participants some open questions. We list here the answers.

g1) The maximal tempo the DR system can be used :

- Sixteenth notes, with a tempo of 152 per quarter note
- Sixteenth notes, with a tempo of 160 per quarter note
- Don't know exactly, but Distributed Rehearsal are difficult when the tempo is fast
- Pieces with a tempo of 130 per quarter note
- Tempo 72
- No limits if the delay problem is solved

During the first distributed rehearsal, the transmission delay was annoying but acceptable for the chosen piece, “*Dérive*” of P. Boulez. The piece of the second distributed rehearsal, “*Pièce Noire*” of H. P. Platz, was very demanding from the rhythmic point of view, with fast tempi. It turns out that it was impossible for the conductor to conduct the fastest part of the piece, when the tempo was greater than 150 per quarter note. At this speed, sixteenth notes have approximately the duration of the delay perceived by the conductor, between his gesture and the sound feedback.

g2) Well-known piece adapted to the DR system :

- Pieces for small ensemble (i.e. quatuor)
- Slow tempo pieces, not requiring too much precision for attacks and rhythms
- Classic chamber music
- Mozart, Haydn for small ensemble
- Boléro (Ravel)
- Concertos Brandebourgeois (Bach)

g3) Well-known piece not adapted to the DR system :

- Piece pour cordes, percussions et celesta de B. Bartok
- Pieces for large ensemble
- Every music piece
- Fast rhythmic and precise pieces
- Dérives (P. Boulez)
- Pièce Noir (H.P. Platz)
- La mer (Debussy)
- Le marteau sans maître (Boulez)
- l’Histoire du Soldat (Stravinsky)

g4) Invention close to the DR system :

- Videophone
- The MIR station (the technology has to be improved)
- Television
- Phone,
- Answering machine
- Internet
- Minitel
- Virtual reality

g5) Improvements of the DR system:

- 3D image
- Improvements in the transmission delay.
- Better sound-image synchronization
- A better image quality in order to have a good “presence” of the conductor and to be able to see the conductor while looking at the score.
- More accuracy in every domain (image, sound, timbre, space, etc.)
- Better visual communication
- The DR system should adapt to the musicians and the music, not the reverse.
- The DR system can be improved and must be improved.
- n-sites distributed rehearsal instead of 2-sites.

g6) Suggested application for the DR system :

- Lessons,
- Master class
- Early rehearsals
- International concerts (in the future)
- Musical work groups

8 Conclusion

Music rehearsals involve complex and multiple factors : the genre of music, the complexity of the piece, the instrumentation, the choice of the musicians and the conductor, the size of the ensemble, the rehearsal phase, the acoustic qualities of the rehearsal room, etc. An exhaustive evaluation of the Distributed Rehearsal system on all these variables was out of reach within the framework of the DVP project and therefore we had to make several choices.

We chose contemporary music instead of classic music because of the potential application of the DR system in this field. For example, Contemporary Music Centers, like *Game*, are used to commission foreign composers to write a piece. A new piece is generally very demanding in terms of rehearsals and often requires close connections between the composer, the conductor and the musicians. Unfortunately, in the “real life”, the opportunities for a foreign composer to work with the ensemble are always too limited. In this case DR systems could provide a flexible mean, not replace local rehearsals, but to increase rehearsals opportunities.

We also thought that the technical complexity of some contemporary pieces was a good test for the DR system, in particular complex and unstable rhythmic structure which are difficult to conduct with a transmission delay. Although no test were made with classical pieces we think that the results we have obtained also apply to this genre.

The choice of the pieces was made in accordance with the conductor. We chose two pieces, quite different in order to have a range of musical situations and difficulties : *Dérive* of Pierre Boulez for 6 instruments, and *Piece Noire* of Robert H.P. Platz for 12 instruments.

To achieve a real statistical validity in the results, the experimentation we have made should have been repeated far more times than what was possible within this project. Therefore the results have the validity of a limited number of observations but of a reasonably real and general situation, made with experts in their field. The EOC is a professional music ensemble which has performed in many European countries and Daniel Kawka, a very talented conductor which has conducted various ensembles and orchestras, including the Groupe Vocal de France and the Orchestre National de Lyon, both for classical and contemporary repertoire.

These observations reveal several distortions introduced by the DR system in the interactions between the musicians and the conductor. A first distortion is the transmission delay. It is a strange and annoying experience for the conductor to have an additional delay of about 90ms between his gestures and the sound of the musicians. This delay proved to be acceptable during the distributed rehearsal of Pierre Boulez piece *Dérive*, but not for Robert H.P. Platz piece *Pièce Noire* which had fast and complex rhythmic parts. It was impossible for the conductor to conduct the fastest part of this piece, when the tempo was greater than 150 per quarter note.

A second distortion is introduced by the video image. The lack of definition of the image requires a lot of effort and concentration for the musicians to see the conductor while they are playing. During a local performance, the musicians can look at the score and still perceive the gesture of the conductor in their field of vision. This is far more difficult during a distributed rehearsal and the musicians have to switch between the screen and the score. The expression of the face of the conductor are also more difficult to see, and eyes to eyes communication is impossible. This last point is also induced by the 2-D image : you never have the feeling to be looked at or designated by a gesture. The experiments we have done on gesture designation shows that if you are trained, you cannot feel, but you can recognize when you are designated within a group of 9 persons.

On the whole for the musicians, the conductor seems to be far, less present. His “energy” is not transmitted as usual. They tend to compensate this “lack of conductor” by more tight relationships between them. This last point was an unexpected and positive result of the DR system.

A third distortion is caused by the quality of the sound. The best stereo recording of an orchestra is far from being equivalent to what the conductor can hear in front of the musicians. In particular, precise sound localization and distance estimation are far more difficult, the dynamic scale is restricted and the different sound sources are harder to separate. This, added with the problem of the delay and the quality of the audio transmission, increases the threshold of perception of the conductor and makes more difficult for him to detect the interpretation errors made by the musicians, especially rhythm errors and, to a lesser extent, harmony errors. On the error detection tests we have made, we found that the distributed situation induces a 40% degradation of the conductor performances in this domain.

These distortions have implications on the usability of the DR system. A first limit is the rhythmic complexity of the piece in relation with the transmission delay. Our estimation is that the total round trip delay should not exceed 85% of the duration of a sixteenth note. This means tempi less than 142 per quarter notes with a 90 ms delay.

Another limit is the number of musicians. In its current state, the DR system is not suited for large ensemble due to both acoustic and visual problems. To be comfortable, distributed rehearsals should not exceed 8-10 musicians. Beyond, visual communication and gestural designation start to be difficult, as well as the ability for the conductor to focus his listening on a particular instrument when the whole ensemble is playing. We also recommend to use the DR system for the first rehearsal phases since a very fine and detailed musical work is more difficult to achieve.

Within these limits, and even if the efficiency is not exactly the same as in a local situation, *an effective rehearsal work can be done*. This is a very encouraging result, specially if we consider the potential applications of DR systems for the various musical institutions and in particular master class for the conservatoire of music, and if we consider that the efficiency and usability of DR systems should improve in the near future with lower transmission delays, higher video resolution and possibly 3-D sound and image techniques.

The adoption of the Distributed rehearsal environment will allow musicians and conductors to collaborate over long distances for the first stages of the rehearsals, saving them time and money that would have otherwise be spend for traveling from one city to another. In addition the Distributed rehearsal environment will allow music conservatories and students to attend courses and practice under the guidance of famous musicians from other conservatories, established in other cities or even countries without the need for long and expensive traveling.

9 Acknowledgments

Daniel Kawka and the EOC musicians : Henry-Charles Caget, Valérie Caget-Dulac, Hervé Cligniez, Christine Comtet, Bruno Florit, Bernard Gaviot-Blanc, Stéphane Genay, Hugues Joriot, Antoinette Lecampion, Jean-Charles Masurier, Roland Meillier, Fabrice Philippe, Cecile Richard, François Sales, Marine Triolet. They accepted enthusiastically to participate to the trials and to be “tested”. They gave generously of their time for the many questions of the authors.

Jérôme Dorival who wrote the test pieces *Aria Bleue* and *Aria Rouge*.

The students of the CUI who participated to the designation test.

The technical/scientific collaborators : Costas Arapis, Laurent Dami, Thomi Pilioura, Jacques Flumet (CUI), Christian Breitender, Vali Lalioti, Lothar Zier (GMD), Xavier Boyer, Florence Catrin, Pierre-Alain Jaffrennou, Christophe Lebreton, Stephane Letz, Michel Stievenard (GRAME)

References

- [1] Distributed Video Production - DVP, ACTS project AC 089, <http://www.gmd.de/DVP/>

- [2] DVP Work Package 4.3 Distributed Rehearsal, <http://cuiwww.unige.ch/OSG/projects/dvp/>
- [3] *Distributed Musical Rehearsal*, Dimitri Konstantas, Yann Orlarey, Simon Gibbs and Olivier Carbonel Proceedings of ICMS'97, International Computer Music Conference 97, September 25-30 1997, Thessaloniki, Greece.
- [4] *A Telepresence Environment for the Organization of Distributed Musical Rehearsals*, Dimitri Konstantas, Proceedings of SAC '98 - The 1998 ACM Symposium on Applied Computing, February 27-March 1, 1998, Marriott Marquis, Atlanta, Georgia, U. S. A.
- [5] *Design and Implementation of an ATM based Distributed Musical Rehearsal Studio*, Dimitri Konstantas, Proceedings of ECMAST'98, 3rd European Conference on Multimedia Applications, Services and Techniques, Berlin-Germany, 26 - 28 May 1998.