Perceptual evaluation of the recording and musical performance quality of DOSim and OrchSim orchestral simulations compared to professional recordings

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Purpose

This report presents perceptual tests to evaluate the degree to which orchestral simulations created with the earlier Digital Orchestra Simulator (DOSim) and the more recent upgraded version OrchSim used for the OrchPlayMusic Library (www.orchplaymusic.com) can be considered as “plausible” versions in comparison with live and commercial orchestral recordings for experimentation on perception and orchestration. Two separate experiments were conducted: the first one in June 2015 with simulations using the original Digital Orchestra Simulator (DOSim) and the second one in May 2017 using the upgraded OrchSim system. Listeners rated professionally recorded excerpts and excerpts realized with simulation systems on a number of scales related to musical and recording quality. Direct comparisons of recorded and simulated versions of the same piece were not used, and listeners were not informed that some of the excerpts were simulations in order not to bias their musical listening strategy. This latter approach has been used in other studies with the aim of determining whether recordings and simulations could be discriminated (Kopiez, Platz, Wolf, Mons & Kreutz, 2015), which was not the goal of the current study.

OrchPlayMusic simulations[1]

There is a wide range of sampled acoustical instruments of various qualities, which can be controlled through the MIDI transmission protocol. These have been on the market for more than two decades. The best ones allow a potentially convincing simulation of instrumental performance through a large array of sampled modes of playing and variations with programmed scripts. The musician using them must have a very clear idea of the result being aimed for and then explore which of its different modes and techniques might potentially serve that idea, modifying and reprogramming the virtual instruments as needed. This amounts to the precise carving of each individual line and balancing it within the orchestral context, a prowess that only a few experienced musicians have.

OrchPlayMusic, Inc. has developed a simulation system for orchestral scores combining the best techniques gained from sound sampling with the expertise of professional performers. The initial system developed prior to forming the company was DOSim and the current, more fully developed version, is OrchSim.

Each excerpt created with these systems is not only a rendering of the composer's prescriptions already in the score, but also relies on the interpretation traditions transmitted from generation to generation by performers. For example, given a Haydn symphony, it is obvious that the score alone does not describe and prescribe all details contributing to a convincing interpretation of the piece; information is lacking concerning the modes of attack, the different types of phrasing, the modulations of timbre and agogic accents, the goal-oriented fluctuations of rhythm, intonation,

[1] Much of the text describing the simulations is drawn from https://www.orchplaymusic.com/en/library_presentation.

vibrato and tempo, as well as the constantly varying balance between members of a section or instrumental families in order to prioritize specific musical layers. All of these elements are nevertheless essential, and the OrchSim system has been developed to implement them. The goal is to make the modalities of production recede into the background so that the listener can concentrate on the music itself.

All OrchPlayMusic renderings are produced in multi-track format, enabling the selection of each instrument individually, which can be heard from its specific location on stage and in the acoustics of the hall. The recordings are made in 24-bit audio format and then converted to the .opl proprietary format that can be played by the OrchPlay software. Any instrumental combination can be selected in real time and the balance and tempo can be modified at will.

The simulation system employs some of the best virtual instruments with the expertise of professional performers to propose a realistic rendition of symphonic works. The OrchPlayMusic team has developed this system over the last 7 years testing each step regularly with focus groups of listeners (music students at various levels, professional musicians as well as sound recording specialists).

The first step was to make sure that every virtual instrument (integrated or created from scratch) "behaves" like the acoustic instrument on which it is modelled. This involves much more than simply selecting a sample bank with some accompanying scripts. A comprehensive taxonomy of all modes of playing was constructed that incorporates their interactions. Many individual samples had to be "normalized" and "harmonized" in order to obtain better control of each of their parameters. This also implied the normalization of the different response curves of sample groups (sampled modes of playing) according to tessitura (pitch register), dynamics and articulation. Each instrument of every instrumental family and section thus has a specific sound palette where all playing modes are balanced, enabling very swift and convincing alternations from one to the other as well as complex combinations and variations over time. The relative loudness levels and dynamic ranges of each virtual instrument also had to match those of the acoustical models. This enabled the balance of each instrument within its family. Subsequently, all instrumental families were balanced against each other according to the orchestral model, taking into consideration the spatial disposition.

Relying on the structure and possibilities of the MIDI transmission protocol as well as the structure of the sample engine, a global mapping of all modes of playing and their variations for all instruments was prepared to enable their control in real time with minimal latency to ensure a realistic orchestral rendering. Many basic "instrumental behaviours" were then scripted into primary routines accessible via meta-tools in the simulation environment.

The simulation system assigns a specific command to the sample engine for every graphic symbol a musician encounters in a score. A comprehensive classification of all music symbols was developed to provide logical categories corresponding to the experience of the performer. These categories were integrated into the OrchPlayMusic music notation program and adapted to the program's formatting.

The simulation system was then enriched with a whole new series of (non-printable) symbols to allow—as orchestral musicians would do—the modulation of most parameters of the "primary" information transmitted by the score into a real instrumental performance. The possibilities range from the placement of agogic and metrical stresses, the duration and variation of timbre and dynamics over the course of held notes to the control of the speed of attack, of parasitic noise, the position and pressure of the bow for the strings, the control of the "cuivré" and sordino aperture for the brasses, and vibrato, as well as key noises of wind instruments and the choice of beaters and their strike position on percussion instruments, among many others.

Table 1. DOSim and OrchSim in perspective: New developments in OrchSim

DOSim [2010-2015 | Versions 1.0 > 1.7]		**OrchSim** [2015-2017 | Versions 1.8 > 2.4]
- Comprehensive taxonomy of all modes of playing of all orchestral instruments and link to a comprehensive list and classification of all graphical symbols encountered in a traditional music score. - Selection of electronic notation software and scripting. - Selection of sample engine and scripting. - Selection and analysis of recorded sound-sample banks; modification, normalization, harmonization and combination of several thousands of instrumental samples. - Link between virtual instruments and symbolic notation. - Scripting of all basic virtual orchestral instruments. - Balance of all modes of playing of each instrument to match acoustical models. - Balance of all instruments and instrumental families against each other to match acoustical models. - Establishment of criteria for emulating acoustic instruments' behavior with virtual instruments. - Comprehensive list of (non-printing) "interpretation symbols/commands" that enable musical interpretation from the digitized music score. - Establishment of protocol for "Note Entry" and "Interpretation". - Realization of a "Rendering protocol" to transfer audio channels from the sample engine to multi-channel recording software. - Production of about 100 renderings of representative works of the repertoire, from the classical to modern eras. Each excerpt was modeled on a selection of reference recordings and each individual part on the performance of a professional performer. - Informal and formal testing for critical appreciation by professional colleagues (composers, researchers, performers, sound engineers). - Continuous improvement of the quality of the renderings through refinement, expansion and redesign of the virtual instruments.		- Considerable **development** of the **String** and **Woodwinds** instrumental families. - Completion of the **Percussion** family. - Significant **improvement** of **Keyboard and Brass** families. - Considerable **improvement** of the **timbral quality** and **flexibility** of each instrumental family, including: • **Addition** of many new, **large, state-of-the-art sample banks** and **intensive new scripting** to match with all existing ones. • **Addition** of a very **large number of modes of playing** to enrich the expressive palette. • **Improvement** of the **individual control of all playing parameters**, including much more varied **attack modes**, **sustained sound shaping**, **legato** and **portato** phrasing, **vibrato** types as well as **evolutive timbral shaping**. - Improved **realistic "synchronization"** protocols, mimicking more exactly the interaction of musicians in a large ensemble, including **micro-temporal onset fluctuations** and **micro-temporal pitch deviations**. - Significant improvement of the **room simulation** possibilities, enabling more precise control of **positioning** on the stage and the concomitant **timbral variations**, all this resulting in a more realistic acoustical and improved "3D" feel. - Development of **OrchPlay**: OrchSim recordings are produced in true multi-track format in 24-bit audio and then converted to the .opl proprietary format that can be played by the OrchPlay software, enabling the selection of any combination of instruments heard from their specific location on stage and in the acoustics of the hall. - Improvement of the **global transfer protocol towards encoding into OrchPlay format**: Score digitization > score interpretation > data to software sample engine > audio signal generation and recording > encoding to OrchPlay format. - Reworking of most existing DOSim interpretations and recordings. Production of a new series of large orchestral pieces.

Methods

Participants

Listeners were music students (minimum of 2 years completed in undergraduate degree in music) and sound recording students at McGill University. In Experiment 1 (DOSim), there were 31 musicians (10 female) aged 20-44 years (M=27) and 9 sound recordists (3 female) aged 22-28 years (M=25). In Experiment 2 (OrchSim), there were 29 musicians (13 female) aged 18-29 years (M=24) and 11 sound recordists (6 female) aged 22-36 years (M=26). Although the original aim was to compare musicians and sound recordists, the small number of the latter group in both experiments made this unreliable, so all participants are treated as a single group. All participants provided informed consent and the study was certified for ethical compliance by the McGill University Research Ethics Board II. None of the participants in Experiment 1 also participated in Experiment 2.

Stimuli

The stimuli were excerpts from the Western orchestral repertoire from the High Classical period to the early 20th century (Table 2). All stimuli were prepared in two versions: 1) excerpted from nine commercial recordings or seven recordings with Pierre Bleuse conducting the Karlovy Vary Symphony Orchestra in the Czech Republic in the summer of 2014 (recorded by a team from the Haute école de musique de Genève and Félix Baril), and 2) simulations created with the DOSim (Exp. 1) or OrchSim (Exp. 2) orchestral simulation environment by Denys Bouliane and Félix Baril. In addition, there were two excerpts for practice trials (1 DOSim or OrchSim [P1], 1 commercial recording [P2]). The stimuli varied in duration from 12 sec to 3 min 24 sec (Table 1). All excerpts were in .aiff format sampled at 44.1 kHz with 16-bit amplitude resolution. The same recordings were presented with both sets of simulations. The recordings are drawn from a variety of orchestras, ranging from top-quality internationally renowned orchestras such as the London and Chicago Symphony Orchestras to the provincial Karlovy Vary Symphony Orchestra. The aim was to have a range of qualities, albeit all done by professional orchestras. The levels of the stimuli varied greatly depending on the dynamics in the score, but the playback levels were set globally to be equivalent to what would be heard in a concert hall.

Table 2. Orchestral excerpts used in the study, duration of the recordings and simulations, and origin of the recorded versions (P=practice, SO=Symphony Orchestra, PO=Philharmonic Orchestra)

#	Composer	Piece, movement (measures)	Duration		Max level	Recording (Conductor, Orchestra)
			Record.	Simul.		
P1	Debussy (orch. Bouliane)	Children's Corner, Arabesque (1-46)	—	0:43		Simulation only
P2	Haydn	Symphony 101, iv (1-18)	0:30	—		Norrington, SW German Radio SO
1	Beethoven	Symphony 1, i (1-19)	1:26	1:17		Bleuse, Karlovy Vary SO
2	Beethoven	Symphony 7, iii (1-24)	0:12	0:13		Haitink, London SO
3	Beethoven	Violin Concerto, i (1-19)	0:45	0:45		Zinman, Baltimore SO
4	Brahms	Symphony 3, iii (1-53)	1:57	1:55		Bleuse, Karlovy Vary SO
5	Brahms	Symphony 4, iv (1-33)	1:09	0:54		Masur, New York PO
6	Debussy	La Mer, i (122-141)	2:14	1:57		Bleuse, Karlovy Vary SO
7	Haydn	Symphony 104, iv (259-312)	0:54	0:47		Bleuse, Karlovy Vary SO
8	Mozart	Symphony 40, i (1-20)	1:07	0:48		Bleuse, Karlovy Vary SO
9	Mozart	Symphony 40, iii (1-126)	0:25	0:24		Marriner, Academy of St. Martin
10	Ravel	Pavane pour une Infante Défunte (1-72)	2:26	2:31		Previn, Royal PO
11	Schoenberg	Five Pieces for Orchestra, i (1-25)	0:40	0:32		Berbig, Berlin SO
12	Schubert	Symphony 8, i (1-30)	0:56	0:50		Bleuse, Karlovy Vary SO
13	J. Strauss	Danube (1-109)	2:48	2:33		Bleuse, Karlovy Vary SO
14	Stravinsky	Quatre Etudes, iv "Madrid" (1-112)	2:44	2:36		Boulez, Chicago SO
15	Tchaikovsky	Nutcracker Suite, Marche (1-88)	2:24	2:29		Previn, Royal PO
16	Vaughan Williams	A London Symphony (1-53)	2:42	3:24		Stewart, Royal Liverpool PO

Procedure

Listeners heard the 18 excerpts shown in Table 2 (2 practice and 16 experimental). The 16 excerpts were divided into two sets with 8 presented as simulations and 8 as recordings. Simulations were never compared to the recorded version of the same piece. The partitioning was performed at random for each odd-numbered participant: 8 of the 16 stimuli were assigned to the simulation group and the other 8 to the recording group. The following even-numbered participant received the complement of the previous odd-numbered participant, switching simulations and recordings. For the analyses of variance, pairs of participants were analyzed as a single subject to include Version (recording, simulation) as a repeated measure. The 16 excerpts were presented in random order for each participant. DOSim and OrchSim simulations were presented in separate experiments.

The experiment took place in the ITU-R BS.775-1 standard Critical Listening Lab at the Centre for Interdisciplinary Research in Music Media and Technology (CIRMMT) at McGill University. Stimuli were presented over B&W 802D loudspeakers amplified through a Crookwood C10 7.1 monitor controller. The loudspeakers were situated at ±60° azimuth at head height about 2 m from the participant.

Participants were told that the aim of the experiment was to study performance and recording quality. They were not told that some of the excerpts were digital simulations. On each trial, participants were automatically presented with an excerpt. They could replay the excerpt once during the trial if they wished. They were asked to rate the excerpt on eleven 7-point scales.

Musical parameters

1. Rhythmic precision – accuracy of the rhythmic profiles [not at all precise -> very precise]
2. Intonation precision – realization of pitch accuracy [not at all precise -> very precise]
3. Musicality of articulation and phrasing – continuity and connection between notes within phrases [not at all musical -> very musical]
4. Musicality of the use of dynamics and dynamic contrasts [not at all musical -> very musical]
5. Timbral quality of the instruments [very low quality -> very high quality]
6. Balance among instrumental families [poorly balanced -> very well balanced]
7. Balance within each instrumental family [poorly balanced -> very well balanced]
8. Quality of the spatial image – refers to the aspect of the sound recording concerning the spatial locations of the sound sources from left to right and front to back [very low quality -> very high quality]

General impression

9. Ability to evoke emotional responses during listening [not at all emotion-inducing -> very emotion-inducing]
10. Global quality of the recording [very low quality -> very high quality]
11. Expressivity of the performance [very low expressivity -> very high expressivity]

An optional free-response text box was also provided within which they could answer the question: "Was there anything else in particular that you did or did not appreciate about this recording?"

Results

Similar analyses of variance were performed on each of the 11 dependent variables (rating scales). Initial analyses compared recordings to simulations with Piece (16) and Version (recording, simulation) as repeated measures. These analyses were conducted separately for DOSim and OrchSim simulations. The primary effects of interest in these analyses are Version (testing ratings of recordings against simulations globally) and the Piece X Version interaction (testing for interactive effects of the pieces on the comparison between versions).

Subsequently, two comparisons between the DOSim and OrchSim experiments were conducted: one comparing ratings on the simulations and another comparing ratings on the recordings, with Piece (16) as repeated measure and Simulation as between-subjects factor. In this case, the primary effect of interest is Simulation.

The ANOVA tables for the four analyses and data plots for each dependent variable are presented in Appendices 1-11.

Globally, the grand means across pieces for the 11 rating scales were in the top 25% of the scale for the recordings, in the top half of the scale for the DOSim simulations and in the top 40% for the OrchSim simulations. This indicates qualititatively an acceptable level of recording and performance quality. For ratings of rhythmic precision, DOSim slightly outperformed the recordings, although the simulations and recordings were of equivalent quality with OrchSim. For the ratings of intonation precision, there was no global difference between either simulation method and the recordings. For the other nine rating scales, the recordings were rated significantly higher in quality than the simulations by from 0.9 to 2.0 points on the 7-point rating scale for DOSim and from 0.5 to 1.3 points for OrchSim. The overall improvement between DOSim and OrchSim was 0.44 points on the scale, with the greatest improvement in timbral quality, emotional response and expressivity.

Conclusion

Both simulation methods had lower ratings on 9 of the 11 scales than did the recordings on average. The recordings had mean ratings across the 16 pieces that ranged from 5.4 to 5.9 on the 7-point scale. The rendering system DOSim had mean ratings from 3.7 to 6.0. For the OrchSim system, the mean ratings ranged from 4.2 to 5.7, indicating above-average to good quality on all the scales for both simulation systems. There was an overall improvement in OrchSim ratings for these measures of 0.4 above the DOSim ratings; the greatest improvement was recorded for timbral quality, emotional response and expressivity, crucial to the work on the perception of orchestration that is one of the main contributions of this orchestral rendering system to the Orchestration and Perception project.

Reference

Kopiez, R., Wolf, A., Platz, F. & Mons, J. (2016). Replacing the orchestra?—The discernability of sample library and live orchestra sounds. *PLoS ONE*, *11*(7): e0158324.

Appendices: Analysis Results

1. Rhythm
2. Intonation
3. Articulation
4. Dynamics
5. Timbre
6. Between-family balance
7. Within-family balance
8. Spatial image
9. Emotional response
10. Recording quality
11. Expressivity

Each appendix contains tables with the results of four ANOVAs as well as plots of the data comparing simulations and recordings for each experiment, as well as comparing the data for the recordings across the two experiments and the two simulation systems (DOSim and OrchSim). Statistically significant effects are highlighted in yellow.

1. Rhythm

DOSim:

Source	dfs	F	ε	p	η_p^2
Piece	15, 255	4.20		<.001	.198
Version	1, 17	9.29		.007	.353
Piece X Version	15, 255	2.21		.007	.115

OrchSim:

Source	dfs	F	ε	p	η_p^2
Piece	7.96, 151.30	5.34	.531	<.001	.219
Version	1, 19	2.03		.17	.097
Piece X Version	15, 285	2.36		.003	.110

DOSim vs. OrchSim (simulations only)

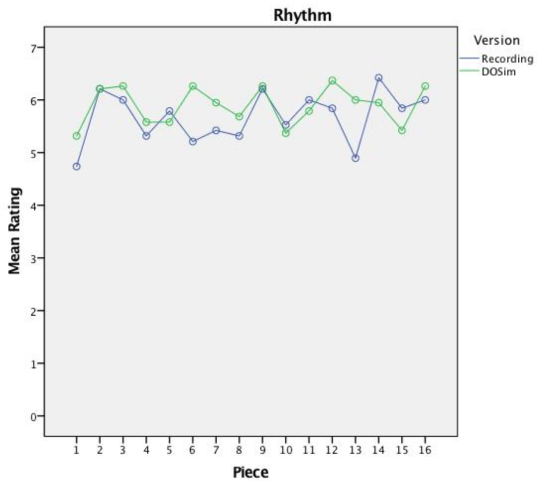
Source	dfs	F	ε	p	η_p^2
Piece	9.42, 348.40	4.33	.628	<.001	.105
Piece X Simul	9.42, 348.40	1.44	.628	.16	.038
Simul	1, 37	<1		.60	.007

DOSim vs. OrchSim (recordings only)

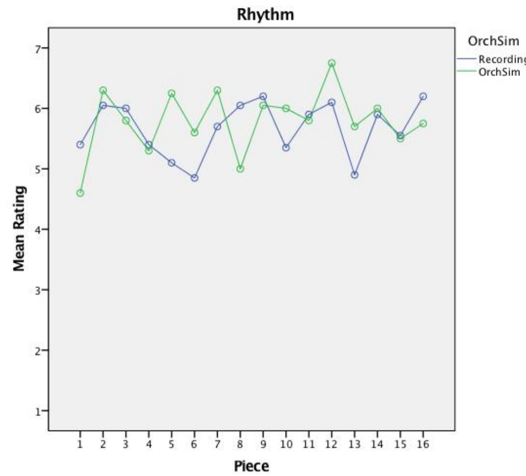
Source	dfs	F	ε	p	η_p^2
Piece	9.40, 347.74	4.33	.627	<.001	.105
Piece X Simul	9.40, 347.74	1.17	.627	.31	.031
Simul	1, 37	<1		.97	<.001

1. Rhythm (cont'd.)

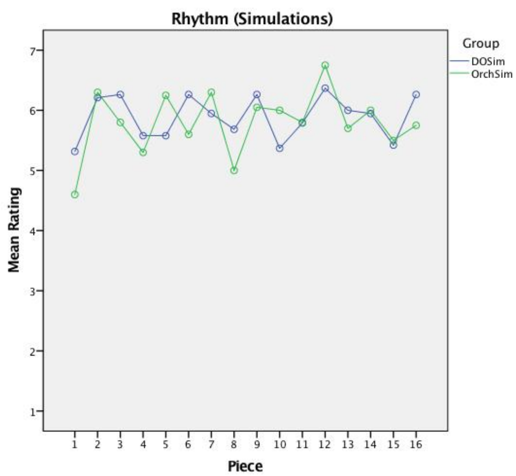
DOSim



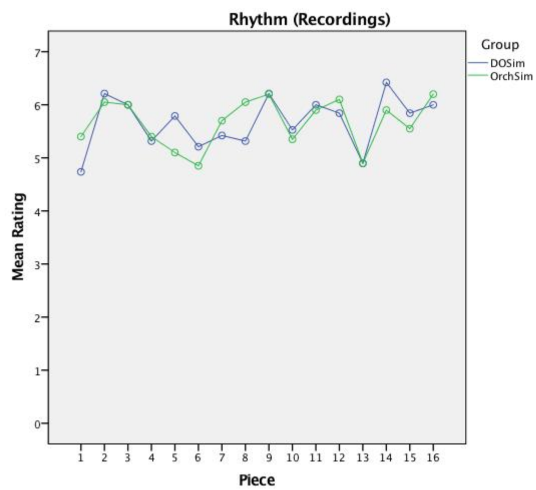
OrchSim



DOSim vs. OrchSim



DOSim vs. OrchSim



2. Intonation

DOSim:

Source	dfs	F	ε	p	η_p^2
Piece	6.81, 115.72	2.91	.454	.008	.146
Version	1, 17	4.10		.059	.194
Piece X Version	5.71, 97.01	2.57	.380	.025	.131

OrchSim:

Source	dfs	F	ε	p	η_p^2
Piece	7.63, 144.89	3.45	.508	.001	.154
Version	1, 19	<1		.75	.005
Piece X Version	15, 285	1.16		.30	.058

DOSim vs. OrchSim (simulations only)

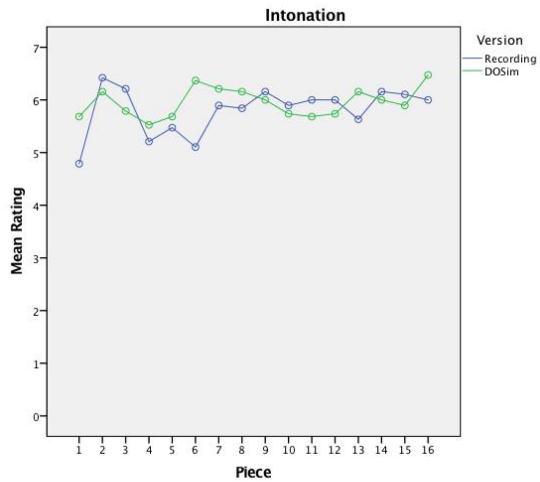
Source	dfs	F	ε	p	η_p^2
Piece	9.48, 350.89	2.17	.632	.021	.055
Piece X Simul	9.48, 350.89	<1	.632	.71	.019
Simul	1, 37	1.28		.26	.033

DOSim vs. OrchSim (recordings only)

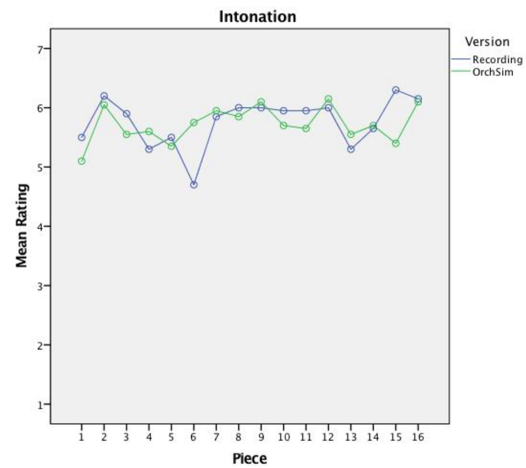
Source	dfs	F	ε	p	η_p^2
Piece	9.19, 340.01	5.84	.613	<.001	.136
Piece X Simul	9.19, 340.01	<1	.613	.66	.020
Simul	1, 37	<1		.80	.002

2. Intonation (cont'd.)

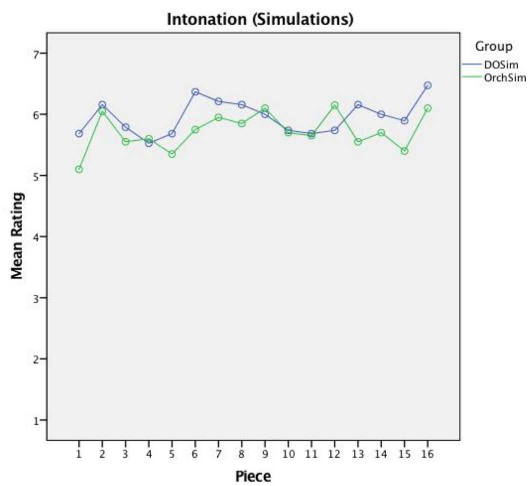
DOSim



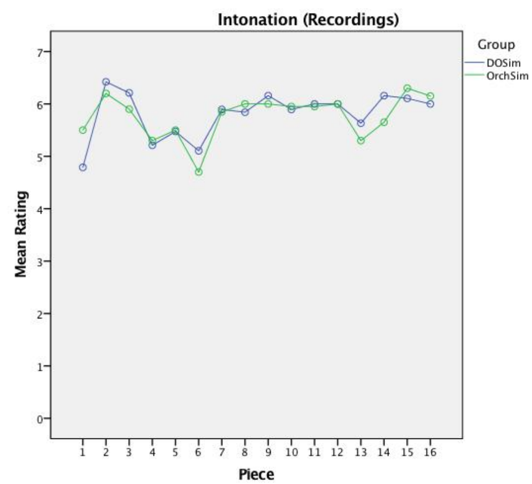
OrchSim



DOSim vs. OrchSim



DOSim vs. OrchSim



3. Articulation

DOSim:

Source	dfs	F	ε	p	η_p^2
Piece	15, 255	2.03		.014	.107
Version	1, 17	23.77		<.001	.583
Piece X Version	7.14, 121.40	2.06	.476	.052	.108

OrchSim:

Source	dfs	F	ε	p	η_p^2
Piece	6.86, 130.27	3.13	.457	.005	.142
Version	1, 19	40.34		<.001	.680
Piece X Version	15, 285	1.10		.354	.055

DOSim vs. OrchSim (simulations only)

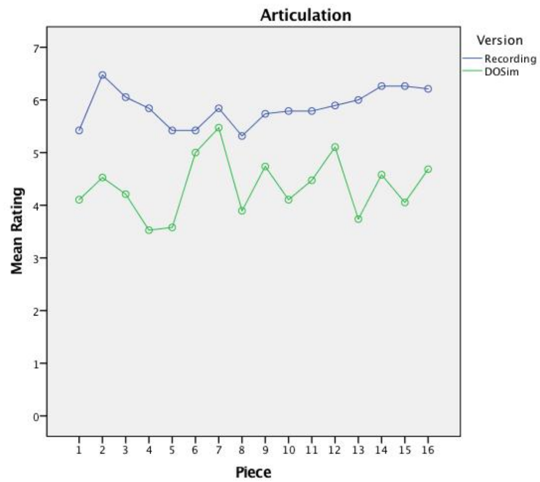
Source	dfs	F	ε	p	η_p^2
Piece	9.57, 354.18	3.45	.638	<.001	.085
Piece X Simul	9.57, 354.18	1.02	.638	.43	.027
Simul	1, 37	2.45		.13	.062

DOSim vs. OrchSim (recordings only)

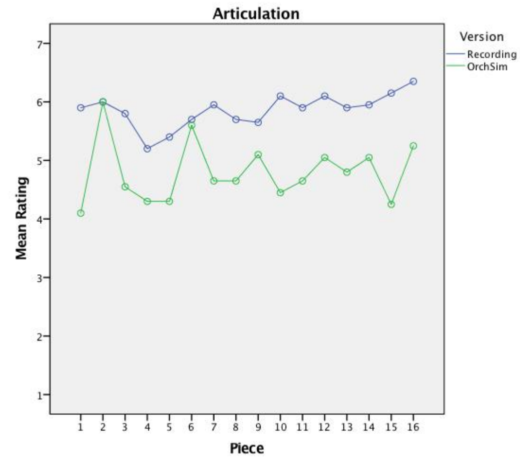
Source	dfs	F	ε	p	η_p^2
Piece	9.93, 367.48	2.44	.662	.008	.062
Piece X Simul	9.93, 367.48	<1	.662	.64	.021
Simul	1, 37	<1		.99	<.001

3. Articulation (cont'd.)

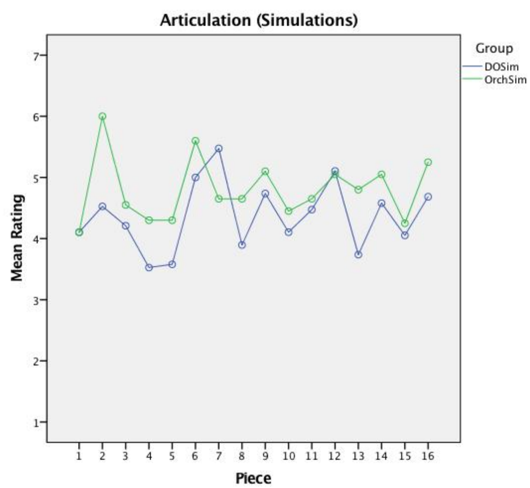
DOSim



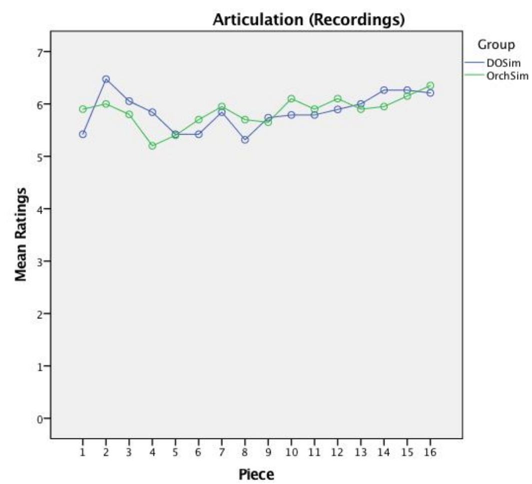
OrchSim



DOSim vs. OrchSim



DOSim vs. OrchSim



4. Dynamics

DOSim:

Source	dfs	F	ε	p	η_p^2
Piece	15, 255	2.68		.001	.136
Version	1, 17	25.65		<.001	.601
Piece X Version	15, 255	1.96		.019	.103

OrchSim:

Source	dfs	F	ε	p	η_p^2
Piece	7.19, 136.54	4.54	.479	<.001	.193
Version	1, 19	41.33		<.001	.685
Piece X Version	15,0285	1.16		.30	.058

DOSim vs. OrchSim (simulations only)

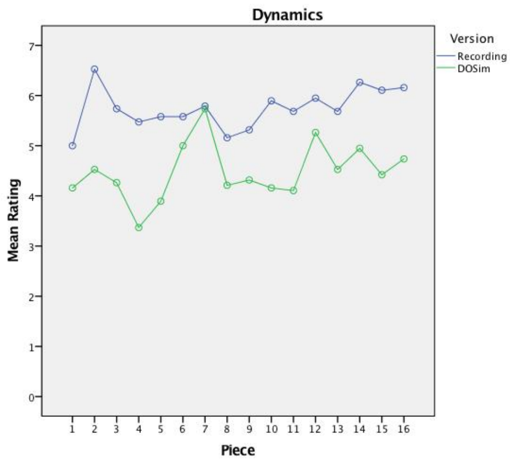
Source	dfs	F	ε	p	η_p^2
Piece	15, 555	3.63		<.001	.089
Piece X Simul	15, 555	1.06		.39	.028
Simul	1, 37	4.65		.038	.112

DOSim vs. OrchSim (recordings only)

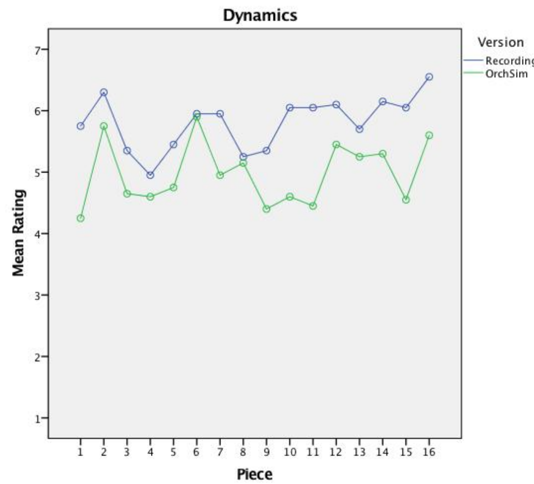
Source	dfs	F	ε	p	η_p^2
Piece	9.00, 333.07	4.58	.600	<.001	.110
Piece X Simul	9.00, 333.07	<1	.600	.65	.020
Simul	1, 37	<1		.68	.005

4. Dynamics (cont'd.)

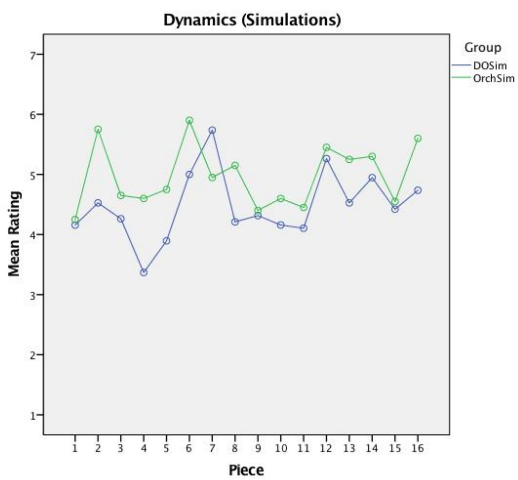
DOSim



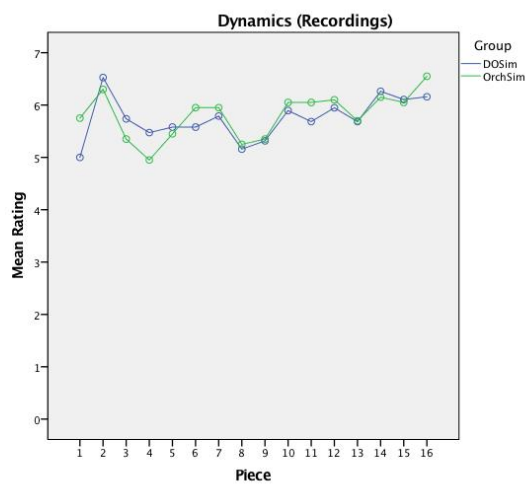
OrchSim



DOSim vs. OrchSim



DOSim vs. OrchSim



5. Timbre

DOSim:

Source	dfs	F	ε	p	η_p^2
Piece	7.72, 131.21	1.33	.515	.24	.072
Version	1, 17	51.77		<.001	.753
Piece X Version	15, 255	2.81		<.001	.142

OrchSim:

Source	dfs	F	ε	p	η_p^2
Piece	7.40, 140.59	2.94	.493	.006	.134
Version	1, 19	41.22		<.001	.685
Piece X Version	15, 285	2.30		.004	.108

DOSim vs. OrchSim (simulations only)

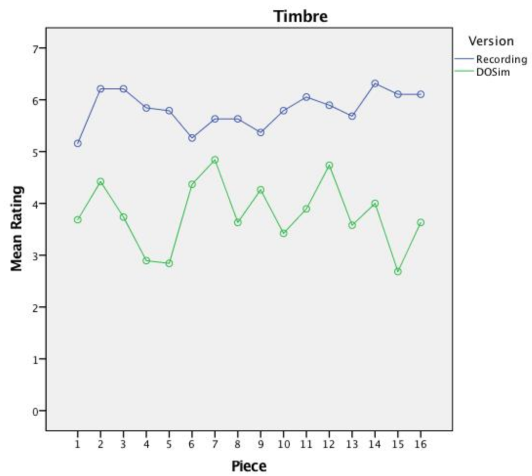
Source	dfs	F	ε	p	η_p^2
Piece	9.10, 336.76	4.42	.607	<.001	.107
Piece X Simul	9.10, 336.76	1.44	.607	.17	.038
Simul	1, 37	4.52		.040	.109

DOSim vs. OrchSim (recordings only)

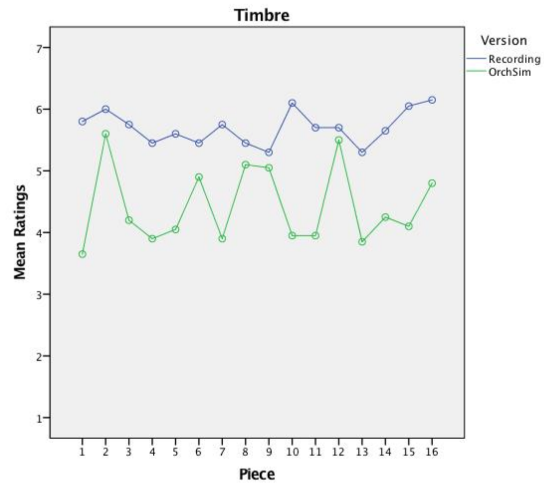
Source	dfs	F	ε	p	η_p^2
Piece	15, 555	2.50		.001	.063
Piece X Simul	15, 555	<1		.53	.024
Simul	1, 37	<1		.45	.015

5. Timbre (cont'd.)

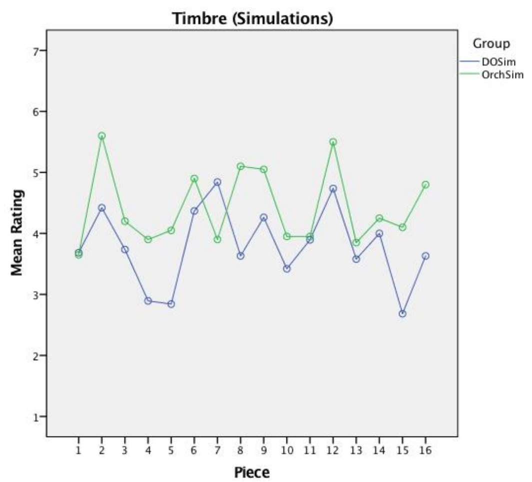
DOSim



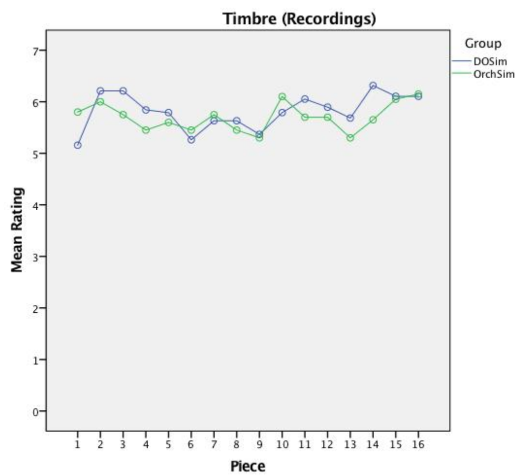
OrchSim



DOSim vs. OrchSim



DOSim vs. OrchSim



6. Between-family balance

DOSim:

Source	dfs	F	ε	p	η_p^2
Piece	15, 255	1.81		.034	.096
Version	1, 17	36.83		<.001	.684
Piece X Version	7.08, 120.27	1.22	.472	.296	.067

OrchSim:

Source	dfs	F	ε	p	η_p^2
Piece	15, 285	2.85		<.001	.130
Version	1, 19	21.56		<.001	.532
Piece X Version	15, 285	1.12		.336	.056

DOSim vs. OrchSim (simulations only)

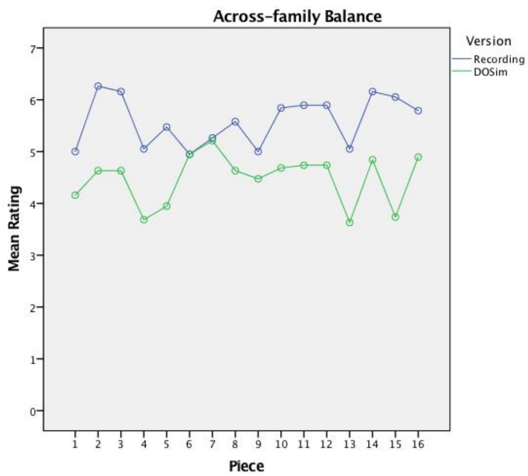
Source	dfs	F	ε	p	η_p^2
Piece	15, 555	2.52		.001	.064
Piece X Simul	15, 555	<1		.69	.021
Simul	1, 37	3.60		.066	.089

DOSim vs. OrchSim (recordings only)

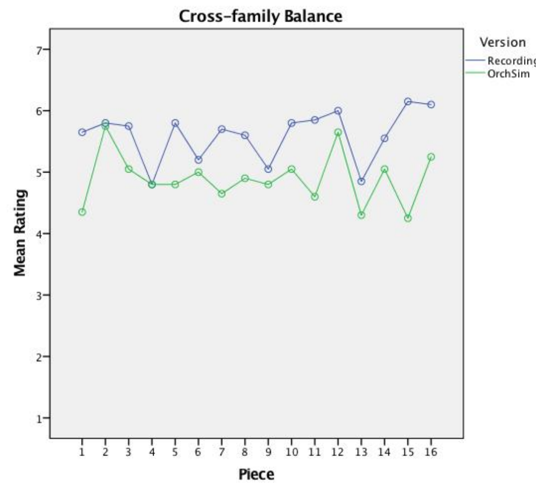
Source	dfs	F	ε	p	η_p^2
Piece	9.32, 344.89	4.60	.621	<.001	.111
Piece X Simul	9.32, 344.89	<1	.621	.63	.021
Simul	1, 37	<1		.94	<.001

6. Between-family balance (cont'd.)

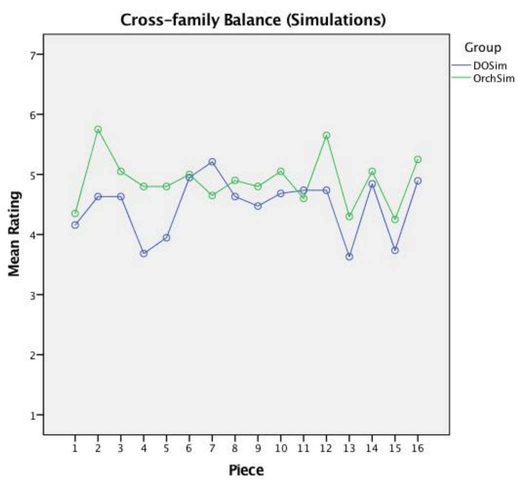
DOSim



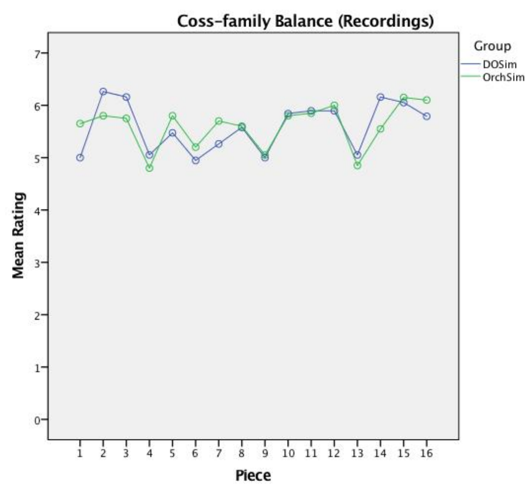
OrchSim



DOSim vs. OrchSim



DOSim vs. OrchSim



7. Within-family balance

DOSim:

Source	dfs	F	ε	p	η_p^2
Piece	7.67, 130.47	1.10	.512	.37	.061
Version	1, 17	20.92		<.001	.552
Piece X Version	15, 255	2.56		.001	.131

OrchSim:

Source	dfs	F	ε	p	η_p^2
Piece	7.94, 150.75	2.69	.529	.009	.124
Version	1, 19	18.39		<.001	.492
Piece X Version	15, 285	<1		.62	.043

DOSim vs. OrchSim (simulations only)

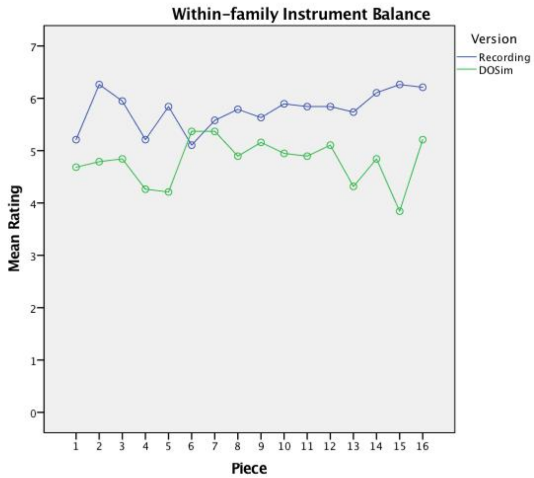
Source	dfs	F	ε	p	η_p^2
Piece	9.88, 365.75	2.17	.659	.019	.056
Piece X Simul	9.88, 365.75	<1	.659	.61	.022
Simul	1, 37	2.45		.13	.062

DOSim vs. OrchSim (recordings only)

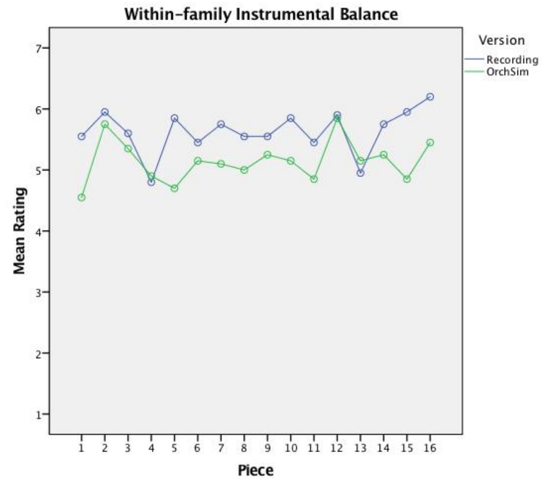
Source	dfs	F	ε	p	η_p^2
Piece	15, 555	3.84		<.001	.094
Piece X Simul	15, 555	<1		.67	.021
Simul	1, 37	<1		.34	.024

7. Within-family balance (cont'd.)

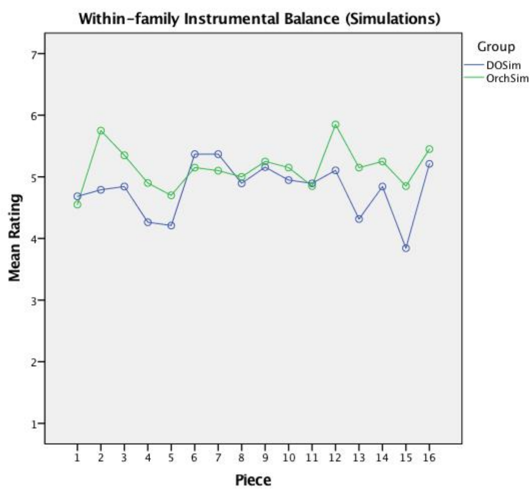
DOSim



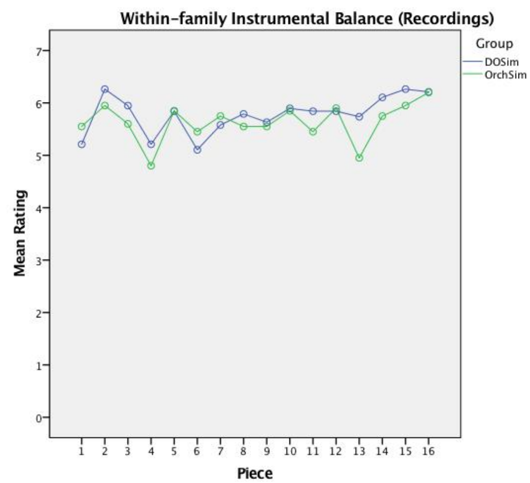
OrchSim



DOSim vs. OrchSim



DOSim vs. OrchSim



8. Spatial image

DOSim:

Source	dfs	F	ε	p	η_p^2
Piece	7.08, 120.27	1.36	.472	.23	.074
Version	1, 17	32.61		<.001	.657
Piece X Version	15, 255	2.24		.006	.116

OrchSim:

Source	dfs	F	ε	p	η_p^2
Piece	15, 285	2.35		.003	.110
Version	1, 19	15.19		.001	.444
Piece X Version	6.85, 130.25	1.90	.457	.076	.091

DOSim vs. OrchSim (simulations only)

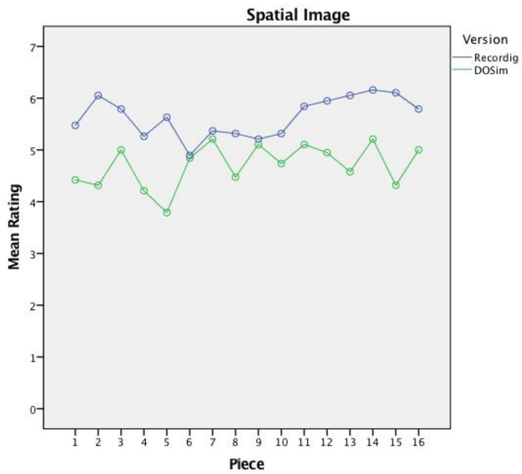
Source	dfs	F	ε	p	η_p^2
Piece	15, 555	2,19		.006	.056
Piece X Simul	15, 555	1.40		.14	.036
Simul	1, 37	1.77		.19	.046

DOSim vs. OrchSim (recordings only)

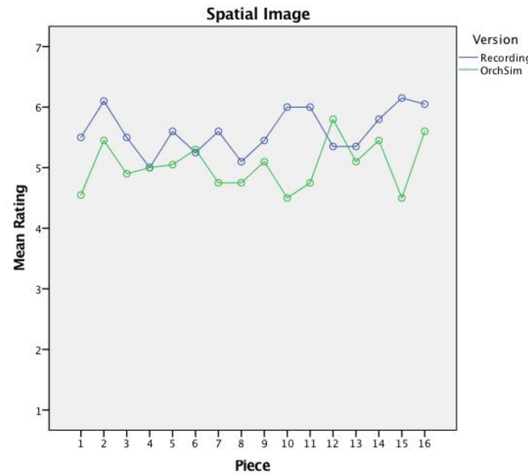
Source	dfs	F	ε	p	η_p^2
Piece	15, 555	3.76		<.001	.092
Piece X Simul	15, 555	1.15		.31	.030
Simul	1, 37	<1		.86	.001

8. Spatial image (cont'd.)

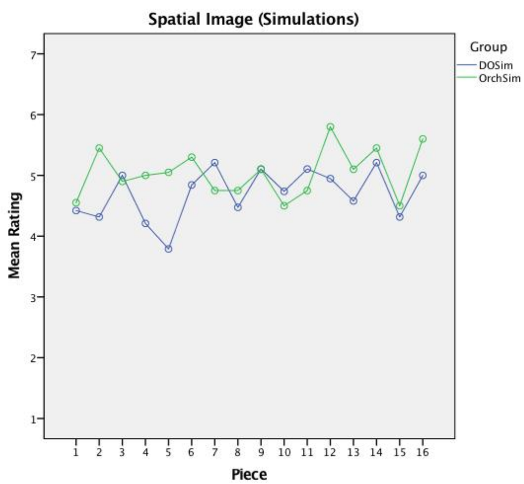
DOSim



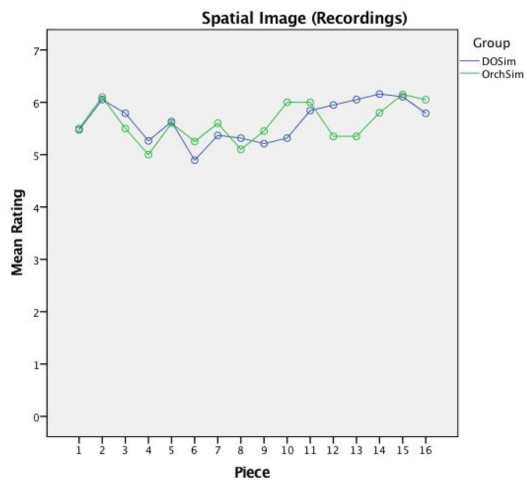
OrchSim



DOSim vs. OrchSim



DOSim vs. OrchSim



9. Emotional response

DOSim:

Source	dfs	F	ε	p	η_p^2
Piece	15, 255	2.41		.003	.124
Version	1, 17	38.03		<.001	.691
Piece X Version	15, 255	2.90		<.001	.146

OrchSim:

Source	dfs	F	ε	p	η_p^2
Piece	15, 285	5.26		<.001	.217
Version	1, 19	20.57		<.001	.520
Piece X Version	15, 285	<1		.67	.041

DOSim vs. OrchSim (simulations only)

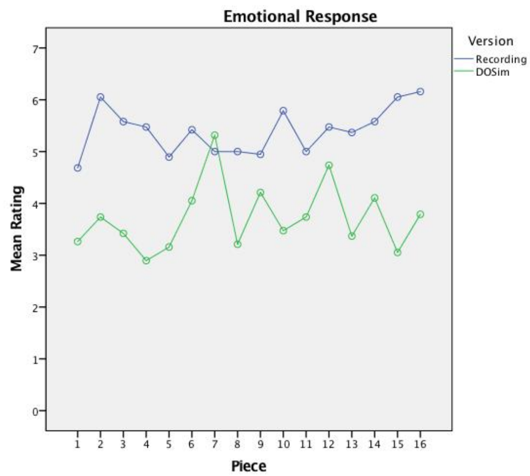
Source	dfs	F	ε	p	η_p^2
Piece	9.76, 360.97	2.72	.650	<.001	.068
Piece X Simul	9.76, 360.97	1.75	.650	.071	.045
Simul	1, 37	14.11		.001	.276

DOSim vs. OrchSim (recordings only)

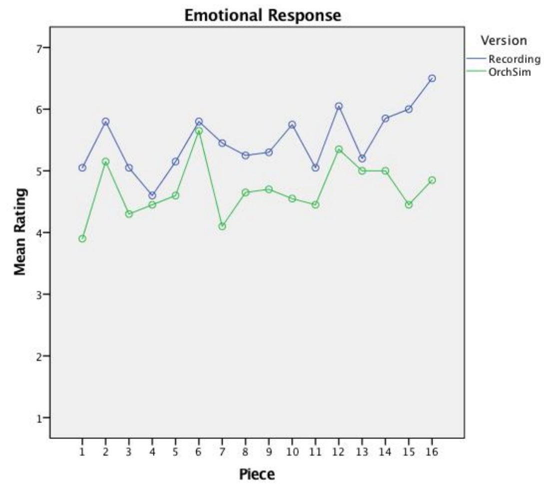
Source	dfs	F	ε	p	η_p^2
Piece	9.14, 338.05	4.90	.609	<.001	.117
Piece X Simul	9.14, 338.05	<1	.609	.44	.026
Simul	1, 37	<1		.68	.004

9. Emotional response (cont'd.)

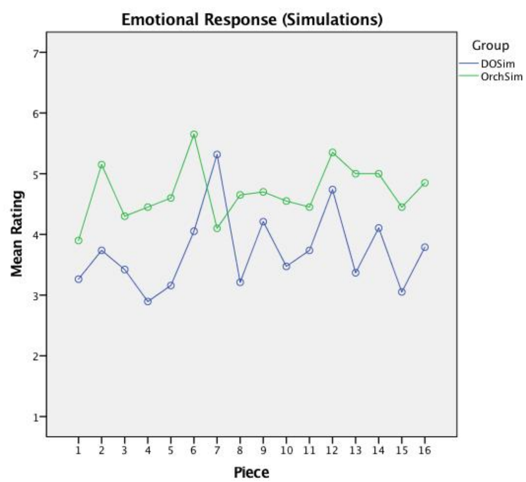
DOSim



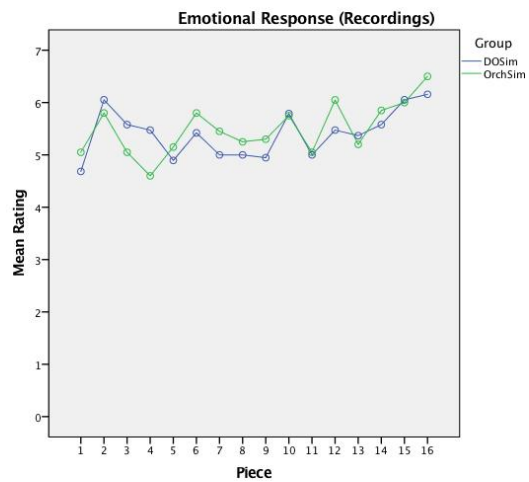
OrchSim



DOSim vs. OrchSim



DOSim vs. OrchSim



10. Recording quality

DOSim:

Source	dfs	F	ε	p	η_p^2
Piece	15, 255	2.85		<.001	.144
Version	1, 17	31.20		<.001	.647
Piece X Version	6.52, 110.90	2.42	.435	.027	.125

OrchSim:

Source	dfs	F	ε	p	η_p^2
Piece	15, 285	3.45		<.001	.154
Version	1, 19	30.36		<.001	.615
Piece X Version	15, 285	2.48		.002	.115

DOSim vs. OrchSim (simulations only)

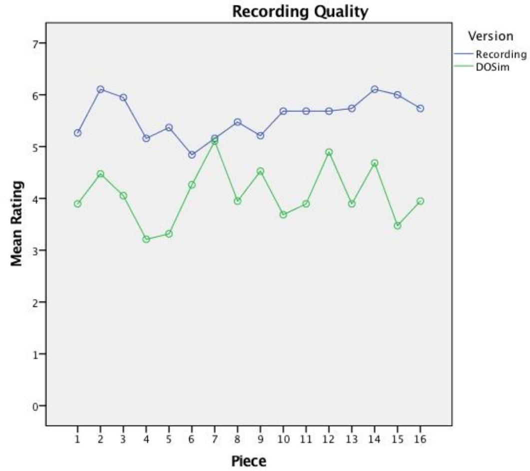
Source	dfs	F	ε	p	η_p^2
Piece	9.44, 349.17	4.00	.629	<.001	.097
Piece X Simul	9.44, 349.17	1.18	.629	.31	.031
Simul	1, 37	2.69		.11	.068

DOSim vs. OrchSim (recordings only)

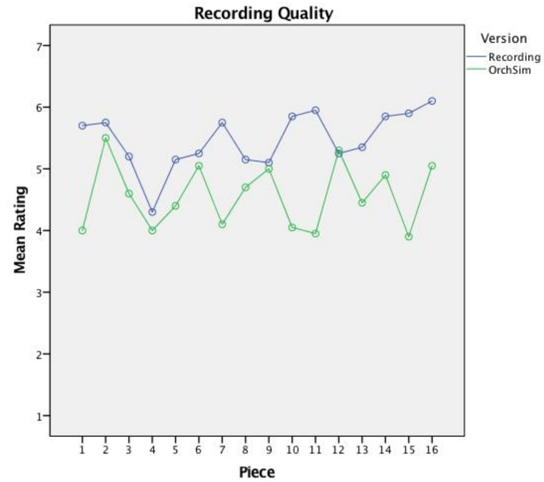
Source	dfs	F	ε	p	η_p^2
Piece	9.27, 343.19	4.80	.618	<.001	.115
Piece X Simul	9.27, 343.19	1.69	.618	.087	.044
Simul	1, 37	<1		.54	.010

10. Recording quality (cont'd.)

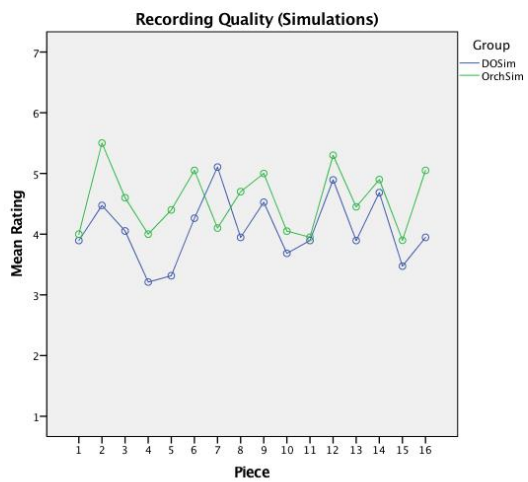
DOSim



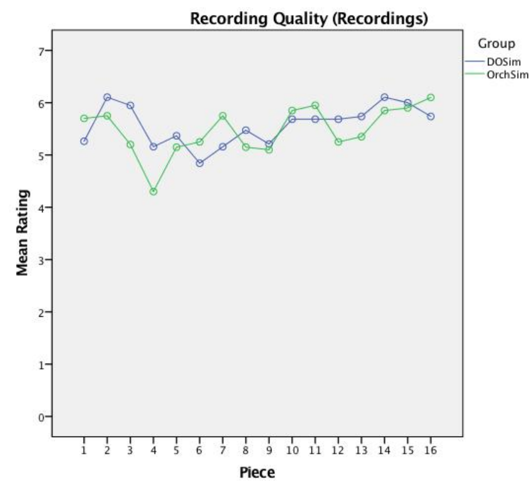
OrchSim



DOSim vs. OrchSim



DOSim vs. OrchSim



11. Expressivity

DOSim:

Source	dfs	F	ε	p	η_p^2
Piece	7.57, 128.76	3.20	.505	.003	.158
Version	1, 17	46.34		<.001	.732
Piece X Version	15, 255	2.42		.003	.125

OrchSim:

Source	dfs	F	ε	p	η_p^2
Piece	15, 285	4.27		<.001	.184
Version	1, 19	35.67		<.001	.652
Piece X Version	15, 285	<1		.66	.041

DOSim vs. OrchSim (simulations only)

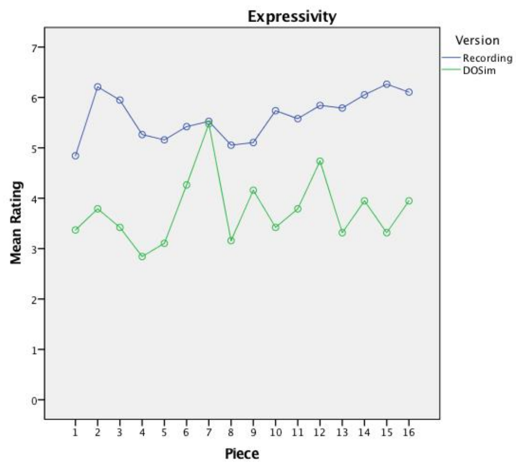
Source	dfs	F	ε	p	η_p^2
Piece	9.46, 350.16	3.06	.631	<.001	.076
Piece X Simul	9.46, 350.16	1.53	.631	.13	.040
Simul	1, 30	6.23		.018	.172

DOSim vs. OrchSim (recordings and simulations)

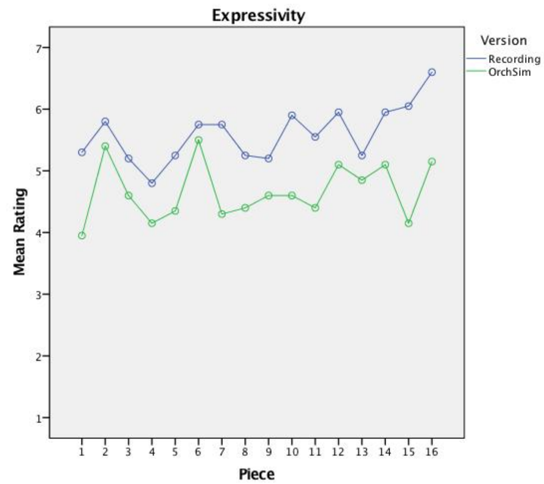
Source	dfs	F	ε	p	η_p^2
Piece	9.00, 333.17	4.86	.600	<.001	.116
Piece X Simul	9.00, 333.17	<1	.600	.47	.025
Simul	1, 37	<1		.91	<.001

11. Expressivity (cont'd.)

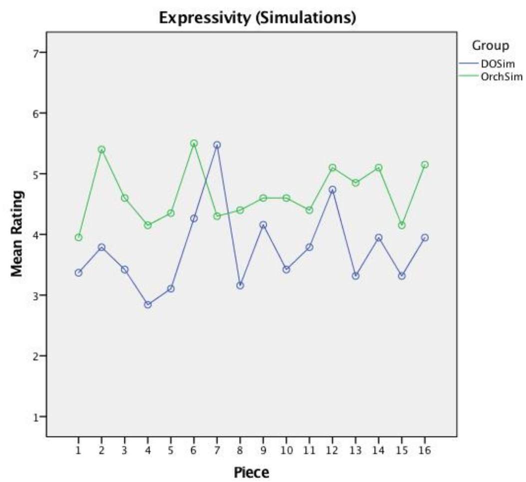
DOSim



OrchSim



DOSim vs. OrchSim



DOSim vs. OrchSim