IMMERSIVE MICROPHONE ARRAYS FOR DRUMS Documentation

ASSOCIATED PAPER "Subjective Evaluation of Immersive Microphone Arrays for Drums"

accessible as an Open Access paper on the AES E-Library

PXL MUSIC-RESEARCH

CONTENT

On the download page you will find three folders containing **FLAT** (unprocessed), **PROCESSED** (EQ, comp) and **RAW** (individual channels) for each of the four immersive microphone arrays that were used for the experiment described in the AES paper "Subjective Evaluation of Immersive Microphone Arrays for Drums", which can be found as an Open Access download on the AES E-Library.

OCT-3D	(non-coincident)	**Native B-Format**	(coincident)
IRT Cross	(near-coincident)	**A-Format**	(coincident)

These four immersive microphone arrays were recorded in the context of two songs that were each recorded in a different acoustic environment.

Manfrotto

FOLDERS

FLAT

Contains a 5.0.4 output of each of the four microphone arrays. No additional processing was applied. Loudness was measured at -20 LUFS integrated (across the entire song) on a 5.0.4 bus, except for the IRT Cross, which was measured at -20 LUFS on a quad bus instead.

OCT 3D **(5.0.4)**
9 microphones (L, R, C, Ls, Rs, Ltf, Rtf, Ltr, Rtr) routed straight to their corresponding channels in a 5.0.4 layout.

Native B-Format Ambisonics **(1OA > 5.0.4)**
"WXYZ" First Order Ambisonics decoding, using common MS-style principles, summing either a 'positive' or 'negative' (polarity reversed) lobe of a bidirectional X, Y or Z channel to the omnidirectional W 'pressure' channel.
E.g.: the "Left Top Front" speaker would receive the W omni capsule with the positive X (front), negative Y (left) and positive Z (top) channels, whereas the "Right Surround" speaker would receive W, X-, Y+ and Z-.

A-Format "Prosumer" Ambisonics
A Sennheiser AMBEO VR Mic. Decoded from A-Format to B-Format using their DearVR AMBI MICRO plugin. Then, the B-Format was distributed to the 5.0.4 speakers as described for the Native B-Format array above. The capsules capture significantly more high frequencies than the other systems. A high shelf of -3 to -6dB at 1kHz is therefore advised for clearer comparison. This EQ-curve is not applied in to downloadable files.

IRT Cross
4 microphones (L, R, Ls, Rs) routed straight to their corresponding channels of a quad configuration within the 5.0.4 output. The center and top channels are not assessed.

PROCESSED

To present listeners a 'finalized' result, the tracks were processed using only EQ, compression and a touch of artificial reverb. The approach was "what would a mixing engineer do to mix the drums into the song if they were faced with each of the four microphone arrays.

RAW

Contains all the individual channels of each microphone array, as well as individual closemics on the drums. This enables custom decoding. Close mics differ for each of the two songs.

ARTISTIC CONTENT

song selection, recording acoustics and approach

SONGS

The musical context of the drum recordings was based on two songs, written and performed by drummer and studio engineer Harm Peeters. He created these songs as part of his bachelor's thesis at PXL-Music. He studied the approach of four renowned recording engineers – Steve Albini, Nick DiDia, Darrel Thorp and Tchad Blake – by video calling and emailing them. He wrote four songs, that were each based directly on an existing song that each of them recorded.
Aside from creating these songs. Harm carefully selected the proper drum shells, recording acoustic and closemics to faithfully recreate the vision and style of each of the four recording engineers.

As our paper "Subjective Evaluation of Immersive Microphone Arrays" aimed to research whether the preferred – or 'most fitting' – immersive microphone array would change depending on the musical context (including instrumentation, genre, acoustics...), we felt that Harm's research was a good starting point. Each of these four recording engineers has a different style and approach to evoke emotion that fits the song.

For this experiment, two songs are chosen: "Drive With Me" (based on Nick DiDia) and "Crazy" (based on Darrel Thorp), as they were most different to each other.

SONG 1
dry drum booth

"Drive With Me" is a calm, yet uplifting pop song with sparse instrumentation. The drums used only kick, snare and hihat and were recorded in the dry drum booth of the Motormusic studio's in Mechelen, Belgium.

SONG 2
large studio hall

"Crazy" is a poppunk song. A full drum set, utilizing also toms and cymbals, was recorded in Motormusic's live hall, which had an RT60 of around 1 second at the time of recording.

TECHNICAL

microphone specifications

MICROPHONES

Schoeps Colette series
CMC 6 amplifiers

Schoeps MK2

Pickup pattern	omnidirectional
Sensitivity	17mV/Pa (-35.5dBV/Pa)

Schoeps MK4

Pickup pattern	cardioid
Sensitivity	15mV/Pa (-36.5dBV/Pa)

Schoeps MK8

Pickup pattern	bidirectional
Sensitivity	12mV/Pa (-38.5dBV/Pa)

matching output level of Schoeps MK 2 to Sennheiser MKH 8020.
20log10(17/31.6) ≈ -5.38 dB

matching output level of Schoeps MK 4 to Sennheiser MKH 8040.
20log10(15/20) ≈ -2.50 dB

Sennheiser MKH series
MKH 8000 amplifiers

Sennheiser MKH 8020

Pickup pattern	omnidirectional
Sensitivity	31.6mV/Pa (-30dBV/Pa)

Sennheiser MKH 8040

Pickup pattern	cardioid
Sensitivity	20mV/Pa (-34dBV/Pa)

Sennheiser MKH 8050

Pickup pattern	hypercardioid
Sensitivity	20mV/Pa (-34dBV/Pa)

Sennheiser AMBEO VR Mic
Tetraether A-Format Type 1

Sensitivity	31.6mV/Pa (-30dBV/Pa)

MICROPHONE ARRAYS

microphone selection and decoding

PXL MUSIC-RESEARCH

OCT-3D

(5.0.4)

microphones

MKH 8000 series

(MKH 8020, MKH 8040, MKH 8050)

L	Sennheiser	MKH 8050	hypercardioid
C	Schoeps	MK2 (CMC 6)	omnidirectional
C alt	Schoeps	MK4 (CMC 6)	cardioid
R	Sennheiser	MKH 8050	hyper cardioid
Ls	Sennheiser	MKH 8040	cardioid
Rs	Sennheiser	MKH 8040	cardioid
Ltf	Sennheiser	MKH 8050	hypercardioid
Rtf	Sennheiser	MKH 8050	hypercardioid
Ltr	Sennheiser	MKH 8050	hypercardioid
Rtr	Sennheiser	MKH 8050	hypercardioid

alternative setup

For the center mic, the same individual Schoeps MK2 omni microphone was used as for the W-channel of the Native B-Format setup. This ensured that the center point (the closest point to the sound source) was equal for each setup. For a conventional OCT-3D setup, a cardioid capsule is required for the center channel. Therefore, an additional Schoeps MK4 capsule was added, placed close to the MK2 capsule.

capsule level compensation

All preamps (Grace m802) are set to the same level. To compensate for the difference in capsule sensitivity, the MK2 (17mV/Pa) is digitally attenuated to match the sensitivity of an MKH 8020 (-31.6mV/Pa).
The additional MK4 capsule was then matched to the MK2 so that both have the same integrated LUFS measurement.

The digital level compensation is calculated using the following method:

$$20 \times \log_{10} (17/31.6) \approx -5.38 \text{ dB}$$

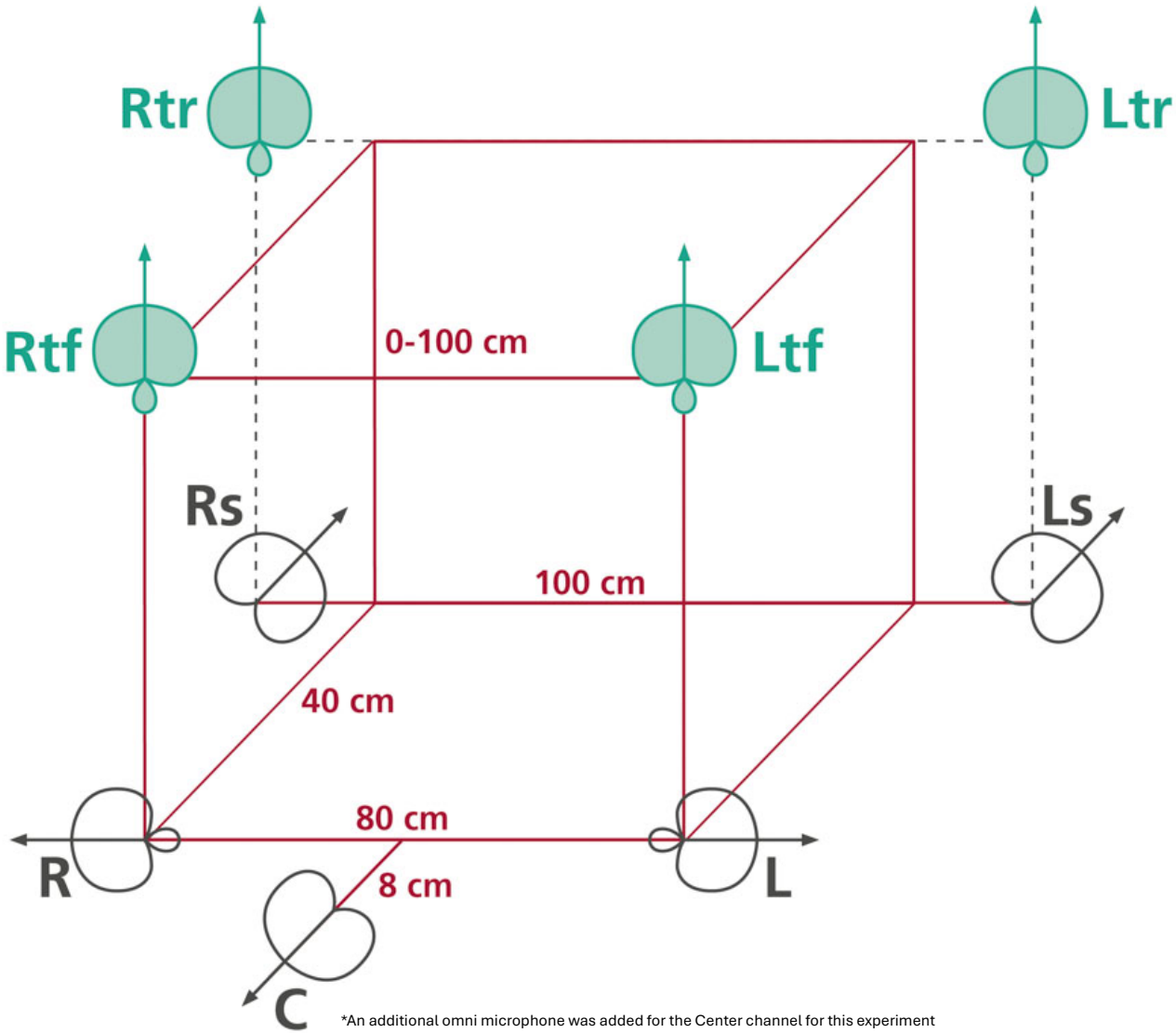
The Schoeps MK2 channel is attenuated by 5.4dB at clip level in the DAW.

decoding

Channel based routing

Each microphone is routed directly to its corresponding channel in a 5.0.4 output bus.

OCT-3D



*An additional omni microphone was added for the Center channel for this experiment

Image by SCHOEPS Mikrofone

Native B-Format

Ambisonics to 5.0.4 channel based

microphones

Schoeps MK series with CMC 6 amplifiers
(MK2, MK8)

W	Schoeps	MK2 (CMC 6)	omnidirectional
X	Schoeps	MK8 (CMC 6)	bidirectional
Y	Schoeps	MK8 (CMC 6)	bidirectional
Z	Schoeps	MK8 (CMC 6)	bidirectional

note: the W-channel of the Native B-Format is the same individual microphone as the center channel of the OCT-3D setup.

The bidirectional microphone are placed around the omnidirectional microphone, at equal distances. Each bidirectional microphone is pointed to a different axis (X, Y and Z). The “X” microphone is placed on the front/rear axis, with its positive lobe at the front, “Y” is placed on the left/right axis, its positive side facing left and the “Z” microphone is positioned in the up/down direction, its positive side facing upwards.

Note that the sensitivity of the Schoeps MK8 capsule (12mV/Pa) is exactly 3dB lower than that of the Schoeps MK2 (17mV/Pa).

$$20 \times \log_{10} (17/12) \approx 3.02\text{dB}$$

With the microphone preamps (Grace m802) set to the same level, no digital attenuation is necessary.

decoding

Ambisonics B-Format to 5.0.4

For each channel of the 5.0.4 channel based output, coordinates are translated to summations of the positive or negative (polarity reversed) lobes of X, Y and Z to W. The summing happened manually in the DAW through the use of sends, and later through a plugin, designed by our research team, executing the same summations.
As an example, for the Right Surround (Rs) channel, the W, as well as X-, Y+ and Z-, are sent to an aux called ‘Ls’, that is routed straight to the Ls channel of the 5.0.4 output bus.

W	omni (routed to each channel)
X+	front
X-	rear
Y+	left
Y-	right
Z+	up
Z-	down

Selected X, Y and Z lobes are summed to W for each channel of a 5.0.4:

L	W	X+	Y+	Z-
C	W	X+	/	Z-
R	W	X+	Y-	Z-
Ls	W	X-	Y+	Z-
Rs	W	X-	Y-	Z-
Ltf	W	X+	Y+	Z+
Rtf	W	X+	Y-	Z+
Ltr	W	X-	Y+	Z+
Rtr	W	X-	Y-	Z+

Native B-Format Ambisonics

A-Format Ambisonics (Prosumer)

Ambisonics to 5.0.4 channel based

microphone

Sennheiser AMBEO VR mic

decoding

Ambisonics A-Format to 5.0.4

FLAT

For the FLAT exports, the A to B-format decoding is executed through the dearVR AMBI MICRO plugin by Dear Reality. The A-Format that comes out of the AMBEO VR Mic is converted to B-Format AmbiX.
Decoding from B-Format (WXYZ) to 5.0.4 is done in a similar fashion to the native B-Format setup. For each channel of the 5.0.4, specific X, Y and Z lobes are summed with W to create a distinct signal per channel. In our own PXL Microphone Array Decoder plugin, the AmbiX (ACN) channel order is selected. For the output order the 5.0.4 order is selected. The plugin decodes in a similar fashion as decoding manually using sends in a DAW.

PROCESSED

For the PROCESSED exports, the approach was to decode the ‘prosumer’ microphone with plugins that are ‘consumer-available, therefore the Illusonic A/B-Format Decoder plugin from their Test Balloon suite was chosen. The decoding went straight from A-Format to 7.1.4 in the “7.1 + 4H”-setting. Levels of height and rears were pushed to better match the loudness of those channels from the other arrays.

A-Format Ambisonics “Prosumer”

IRT Cross

Quad to 5.0.4 channel based

microphones

L	Sennheiser	MKH 8040	cardioid
R	Sennheiser	MKH 8040	cardioid
Ls	Sennheiser	MKH 8040	cardioid
Rs	Sennheiser	MKH 8040	cardioid

note: this setup does not incorporate height-layer microphones.

decoding

Channel based routing

Each microphone of the quad array is routed directly to its corresponding channel in a 5.0.4 output bus. Therefore, the C channel of the 5.0.4 is inactive.

IRT Cross

MATCHING

creating an equal comparison in a subjective environment

Performing comparisons for subjective qualities brings some challenges. Microphones may sound different due to their capsules, or position. Decoding arrays from one format to another (e.g. ambisonic A-format to 5.0.4) can also impact the sound significantly, based on how it's performed. While these parameters are kept to a minimum as much as possible, some of these differences are just inherent to these different microphone techniques. The question then whether to match or not match variations in sound, is a difficult topic. When matching we alter the 'true' output of each array, which may result in a wrong judgement. Also, which microphone array do we use as the basis to match the others to, and does that give it an advantage? Therefore we opted to include unprocessed 'FLAT' exports, as well as 'PROCESSED' options.

EQ

The OCT-3D and IRT Cross both used the Sennheiser MKH 8000 series microphones. However, due to – at the time – an unfortunate lack of 8030 bidirectional microphones, the native B-format had to be built with Schoeps Colette series. Both series are at a high standard and differences between their capsules are not very noticeable. The difference, however, is of course worth mentioning.

Due to the impossibility to change (and thus match) the capsules of the AMBEO VR Mic, there is a very noticeable change in the timbral character of the capsules, most noticeably a boost in the high frequencies. This difference could distract from making observations about the technique itself compared to the others.
Therefore, it is **advised to put a high shelf of -3 to -6db at 1kHz** on the AMBEO VR Mic for proper comparison to the other three arrays.

LOUDNESS

of different microphone arrays

After conversion from their original format to a channel based format, the four microphone arrays are routed to a 5.0.4 output bus. The loudness of each microphone array is measured at -20 LUFS integrated (over the course of each whole song).

Comparing quad measurement to 5.0.4

To compensate for the inactive C channel of the IRT Cross array, its measurement is not taken on the 5.0.4 bus, but instead on a quad bus. IRT Cross measured on a quad bus will give the -20 LUFS result, whereas measuring it on a 5.0.4 bus results in -19.5 LUFS, for which loudness compensation would create a quieter perception compared to the other microphone arrays.

OCT-3D	-20 LUFS*	-3.8dB peak	on a 5.0.4 bus
Native B-Format	-20 LUFS*	-1.7dB peak	on a 5.0.4 bus
A-Format	-20 LUFS*	-3.0dB peak	on a 5.0.4 bus
IRT Cross	-20 LUFS**	-3.0dB peak	on a quad bus

Measurements taken with a FabFilter Pro-L2.

Note: The OCT-3D measurement was taken using the MK2 omni microphone for the center channel, however, as the MK2 omni and MK4 cardio center mics were matched at the same integrated LUFS measurement (-26.7 LUFS for each center channel microphone), the total OCT-3D LUFS measurement of -20 LUFS will not be affected when swapping the omni center mic for cardio alternative.

Picture taken at the
Motormusic studio's in Mechelen, Belgium