UNIVERSITÀ DEGLI STUDI
DI MILANO

Effects of HRTF on video games performance

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Sound spatialization

Sound sources have 3 different DoF:

Azimuth

Elevation

Distance

Azimuth

Azimuth perception is based on mostly 2 things:

Interaural Time Difference

Interaural Level Difference

ILD alone gives good enough perception

Elevation

Elevation perception is a more complex phenome

Based on notches in the spectrum caused by different angles of incidence on the subject pinna

Harder to simulate: HRTF

Distance

Distance perception is based on subject knowledge and loudness

Was not an object of this experiment

The experiment

Subject asked to shoot asteroid in a 3D enviroment

Asteroid emitted sound to aid their localization

Asteroid position

Only one present at a time

Fixed distance

Randomized azimuth and elevation

Player movement

No locomotion

Free camera movement

Mouse aiming

Customizable sensibility

Audio clues

3 types of spatialization (latin square):

Mono, stereo and HRTF based spatializations

3 types of sound (random shuffle):

White noise, steps sound and gunshots sound

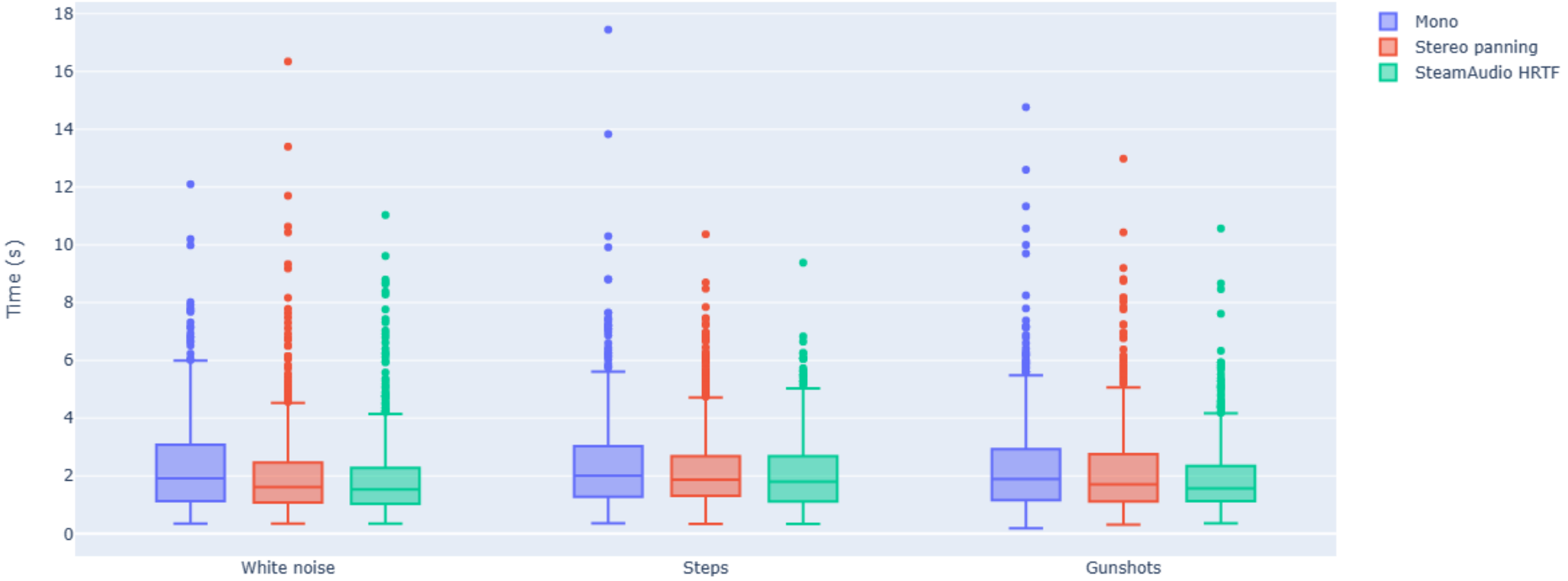
Data recorded

21 subjects, 30 asteroids per sound type for each spatialization method

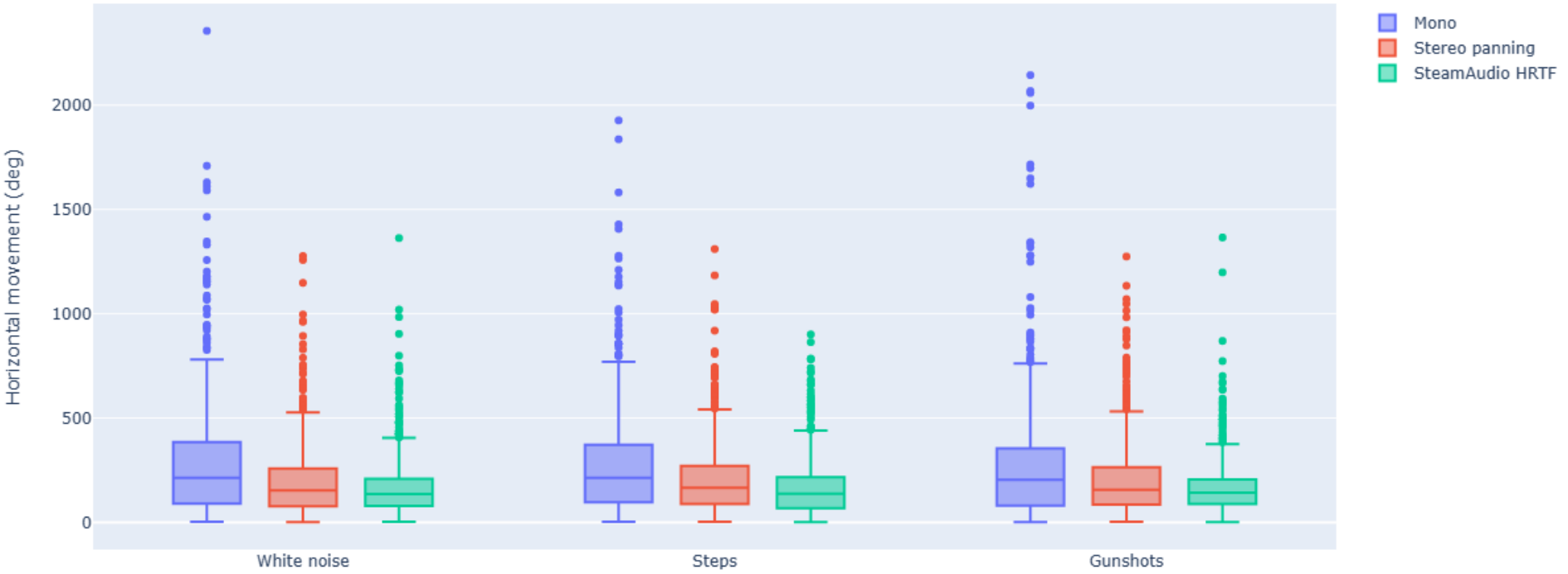
270 asteroids per subject

Different metrics: time and angular distance (both horizontal and vertical)

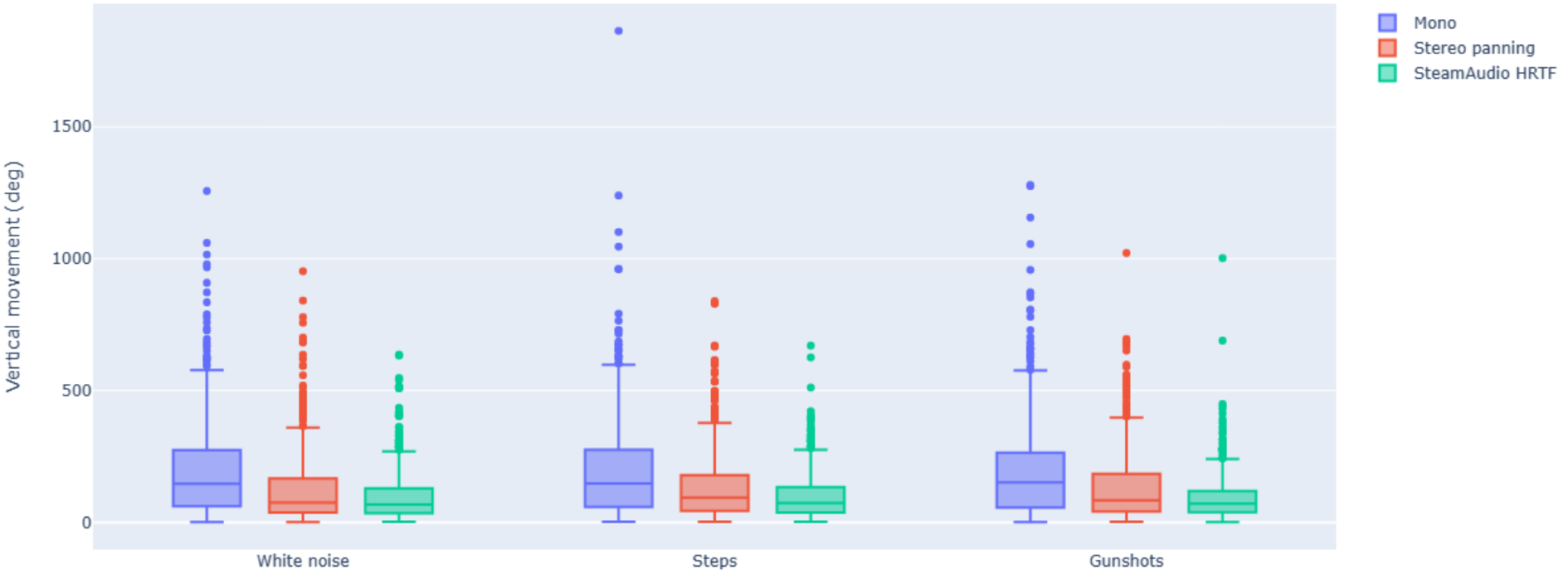
Box plot - time



Box plot - horizontal movement



Box plot - vertical movement



Kolmogorov Smirnov test

Check for statistically significant difference

Differences between spatialization techniques

Time being less consistent

No evidence on different sound types

Kolmogorov Smirnov test

TABLE I
WHITE NOISE TIMES - PVALUES

Sample type 1	Sample type 2	pvalue
Mono audio	Stereo panning	$4.19 \cdot 10^{-4}*$
Mono audio	Steam Audio HRTF	$1.75 \cdot 10^{-7}*$
Stereo panning	Steam Audio HRTF	$2.55 \cdot 10^{-1}$

TABLE II
STEPS SOUND TIMES - PVALUES

Sample type 1	Sample type 2	pvalue
Mono audio	Stereo panning	$1.64 \cdot 10^{-2}*$
Mono audio	Steam Audio HRTF	$6.57 \cdot 10^{-3}*$
Stereo panning	Steam Audio HRTF	$3.78 \cdot 10^{-2}*$

TABLE III
SHOTS SOUND TIMES - PVALUES

Sample type 1	Sample type 2	pvalue
Mono audio	Stereo panning	$4.42 \cdot 10^{-2}*$
Mono audio	Steam Audio HRTF	$4.53 \cdot 10^{-5}*$
Stereo panning	Steam Audio HRTF	$1.04 \cdot 10^{-3}*$

Kolmogorov Smirnov test

TABLE IV
MONO AUDIO TIMES - PVALUES

Sample type 1	Sample type 2	pvalue
White noise	Steps sound	$1.79 \cdot 10^{-1}$
White noise	Shots sound	$7.51 \cdot 10^{-1}$
Shots sound	Steps sound	$2.27 \cdot 10^{-1}$

TABLE V
STEREO AUDIO TIMES - PVALUES

Sample type 1	Sample type 2	pvalue
White noise	Steps sound	$9.79 \cdot 10^{-5}*$
White noise	Shots sound	$8.03 \cdot 10^{-2}$
Shots sound	Steps sound	$7.94 \cdot 10^{-3}*$

TABLE VI
STEAM AUDIO HRTF AUDIO TIMES - PVALUES

Sample type 1	Sample type 2	pvalue
White noise	Steps sound	$5.28 \cdot 10^{-4}*$
White noise	Shots sound	$1.58 \cdot 10^{-1}$
Shots sound	Steps sound	$5.42 \cdot 10^{-3}*$

Kolmogorov Smirnov test

TABLE VII
WHITE NOISE HORIZONTAL MOVEMENT - PVALUES

Sample type 1	Sample type 2	pvalue
Mono audio	Stereo panning	$9.54 \cdot 10^{-10}*$
Mono audio	Steam Audio HRTF	$2.43 \cdot 10^{-20}*$
Stereo panning	Steam Audio HRTF	$4.46 \cdot 10^{-3}*$

TABLE VIII
STEPS SOUND HORIZONTAL MOVEMENT - PVALUES

Sample type 1	Sample type 2	pvalue
Mono audio	Stereo panning	$2.38 \cdot 10^{-8}*$
Mono audio	Steam Audio HRTF	$2.31 \cdot 10^{-17}*$
Stereo panning	Steam Audio HRTF	$2.61 \cdot 10^{-4}*$

TABLE IX
SHOTS SOUND HORIZONTAL MOVEMENT - PVALUES

Sample type 1	Sample type 2	pvalue
Mono audio	Stereo panning	$4.56 \cdot 10^{-7}*$
Mono audio	Steam Audio HRTF	$1.24 \cdot 10^{-19}*$
Stereo panning	Steam Audio HRTF	$3.31 \cdot 10^{-4}*$

Kolmogorov Smirnov test

TABLE X
MONO AUDIO HORIZONTAL MOVEMENT - PVALUES

Sample type 1	Sample type 2	pvalue
White noise	Steps sound	$9.09 \cdot 10^{-1}$
White noise	Shots sound	$7.51 \cdot 10^{-1}$
Shots sound	Steps sound	$1.58 \cdot 10^{-1}$

TABLE XI
STEREO AUDIO HORIZONTAL MOVEMENT - PVALUES

Sample type 1	Sample type 2	pvalue
White noise	Steps sound	$2.02 \cdot 10^{-1}$
White noise	Shots sound	$5.63 \cdot 10^{-1}$
Shots sound	Steps sound	$4.31 \cdot 10^{-1}$

TABLE XII
STEAM AUDIO HRTF AUDIO HORIZONTAL MOVEMENT - PVALUES

Sample type 1	Sample type 2	pvalue
White noise	Steps sound	$6.57 \cdot 10^{-1}$
White noise	Shots sound	$3.53 \cdot 10^{-1}$
Shots sound	Steps sound	$2.85 \cdot 10^{-1}$

Kolmogorov Smirnov test

TABLE XIII
WHITE NOISE VERTICAL MOVEMENT - PVALUES

Sample type 1	Sample type 2	pvalue
Mono audio	Stereo panning	$2.13 \cdot 10^{-19}*$
Mono audio	Steam Audio HRTF	$6.62 \cdot 10^{-30}*$
Stereo panning	Steam Audio HRTF	$2.73 \cdot 10^{-2}*$

TABLE XIV
STEPS SOUND VERTICAL MOVEMENT - PVALUES

Sample type 1	Sample type 2	pvalue
Mono audio	Stereo panning	$9.63 \cdot 10^{-11}*$
Mono audio	Steam Audio HRTF	$1.30 \cdot 10^{-24}*$
Stereo panning	Steam Audio HRTF	$1.61 \cdot 10^{-4}*$

TABLE XV
SHOTS SOUND VERTICAL MOVEMENT - PVALUES

Sample type 1	Sample type 2	pvalue
Mono audio	Stereo panning	$1.06 \cdot 10^{-12}*$
Mono audio	Steam Audio HRTF	$3.19 \cdot 10^{-33}*$
Stereo panning	Steam Audio HRTF	$6.56 \cdot 10^{-8}*$

Kolmogorov Smirnov test

TABLE XVI
MONO AUDIO VERTICAL MOVEMENT - PVALUES

Sample type 1	Sample type 2	pvalue
White noise	Steps sound	$9.76 \cdot 10^{-1}$
White noise	Shots sound	$9.09 \cdot 10^{-1}$
Shots sound	Steps sound	$7.96 \cdot 10^{-1}$

TABLE XVII
STEREO AUDIO VERTICAL MOVEMENT - PVALUES

Sample type 1	Sample type 2	pvalue
White noise	Steps sound	$6.57 \cdot 10^{-3}*$
White noise	Shots sound	$1.06 \cdot 10^{-1}$
Shots sound	Steps sound	$5.17 \cdot 10^{-1}$

TABLE XVIII
STEAM AUDIO HRTF AUDIO VERTICAL MOVEMENT - PVALUES

Sample type 1	Sample type 2	pvalue
White noise	Steps sound	$2.02 \cdot 10^{-1}$
White noise	Shots sound	$3.18 \cdot 10^{-1}$
Shots sound	Steps sound	$4.31 \cdot 10^{-1}$

Conclusions

Spatialization methods matter

Sound type is inconclusive

Time is less sensible making angular distance more useful in some situation