A Perceptual Analysis of **Off-Center Sound Degradation in Surround-Sound Reproduction** Based on Geometrical Properties

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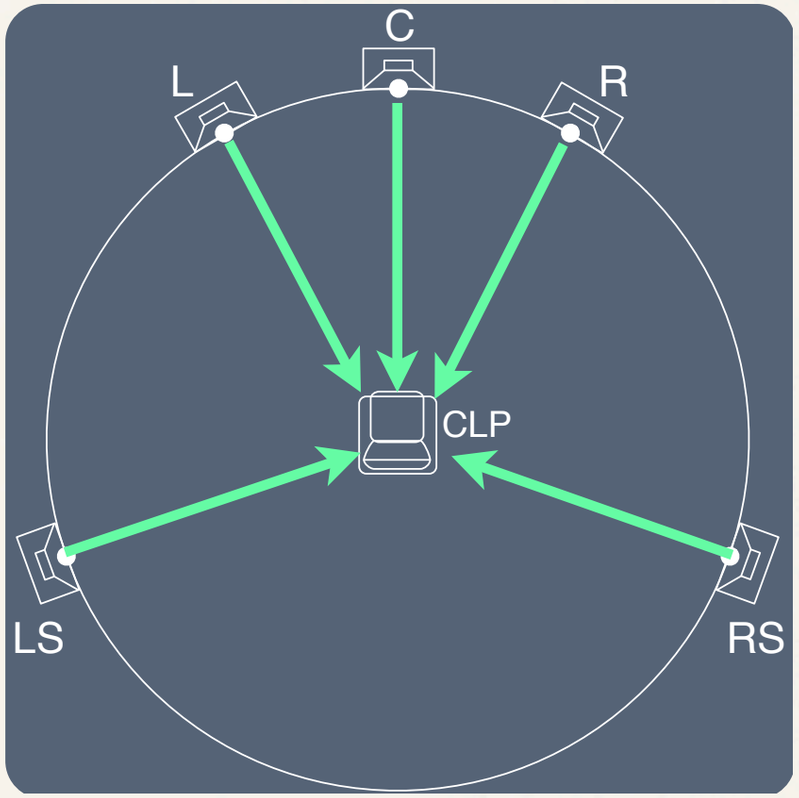
Centre for Interdisciplinary Research in Music Media and Technology

McGill

Listening Positions

Sweet Spot



The sweet spot is the focal <u>point</u> between loudspeakers where an <u>individual</u> is fully capable of hearing the audio mix the way it was <u>intended</u> to be heard

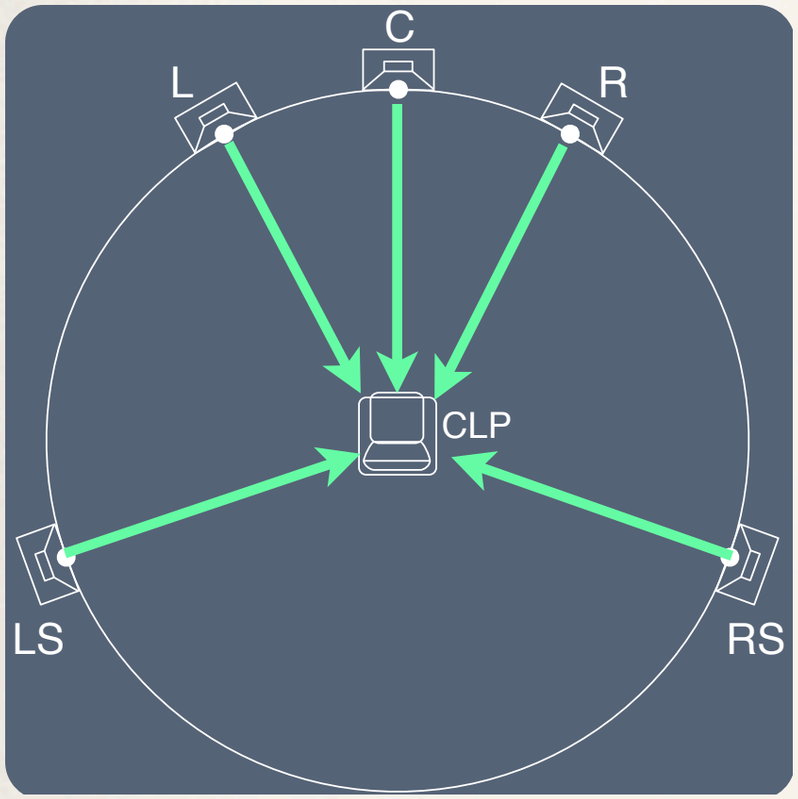
Improving off-center listening

Opera broadcasting

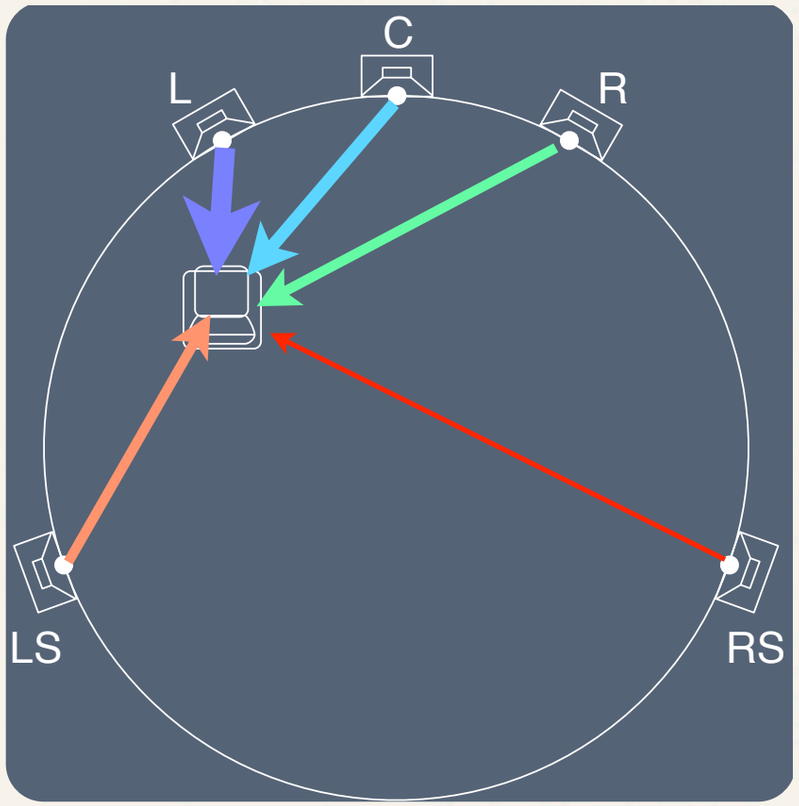
New media work

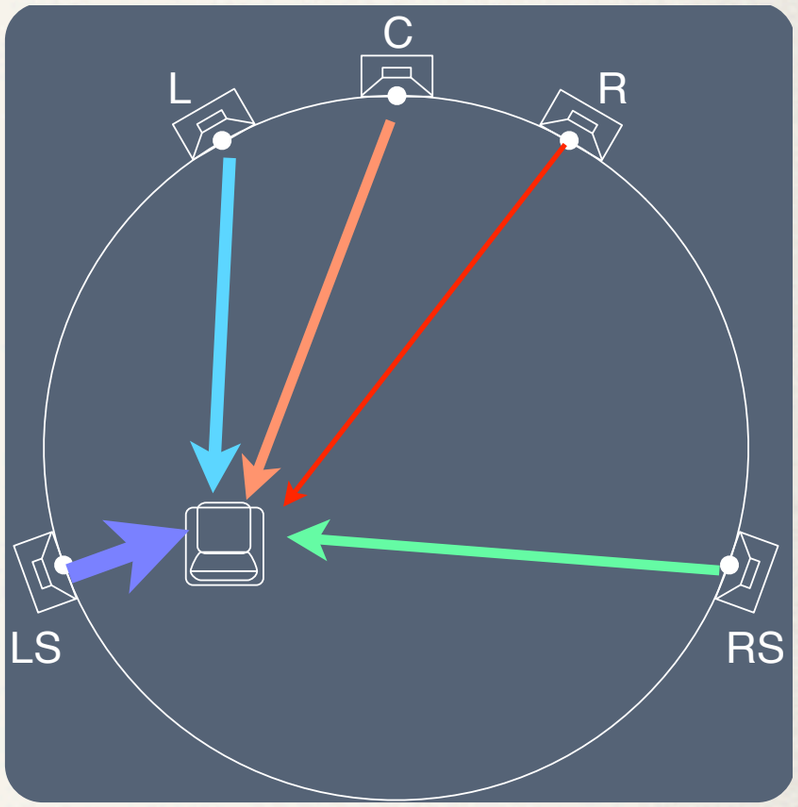
Listening Positions

Center (sweet spot)



Off-center

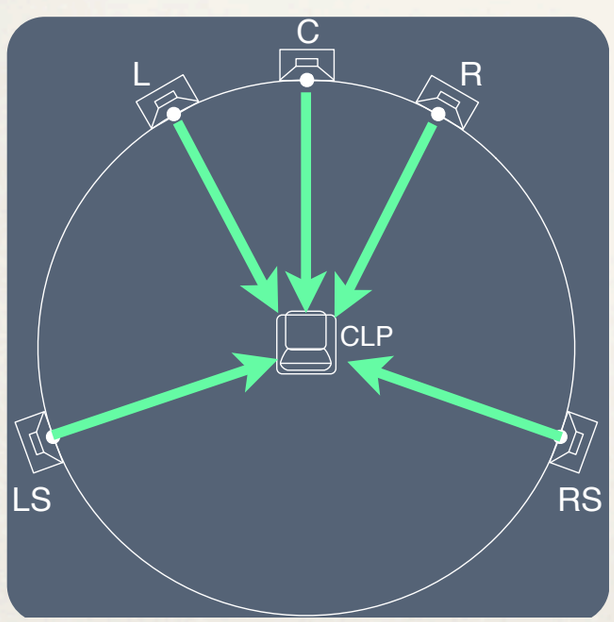


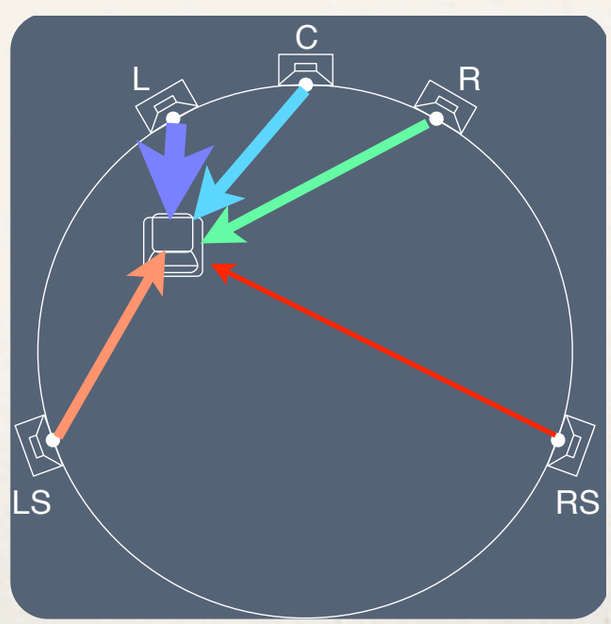


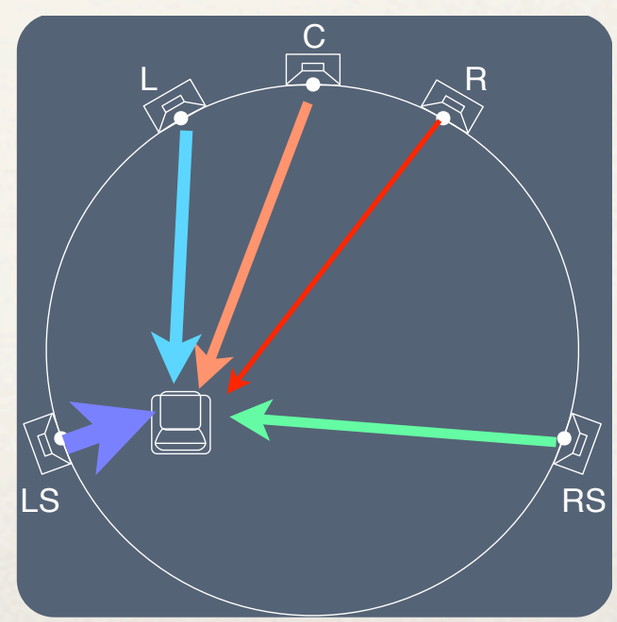
Three geometrical factors

- Time-of-arrival (ToA)
- Sound Pressure (SPL)
- Direction of Arriving Wavefront

Research Questions







Research Questions

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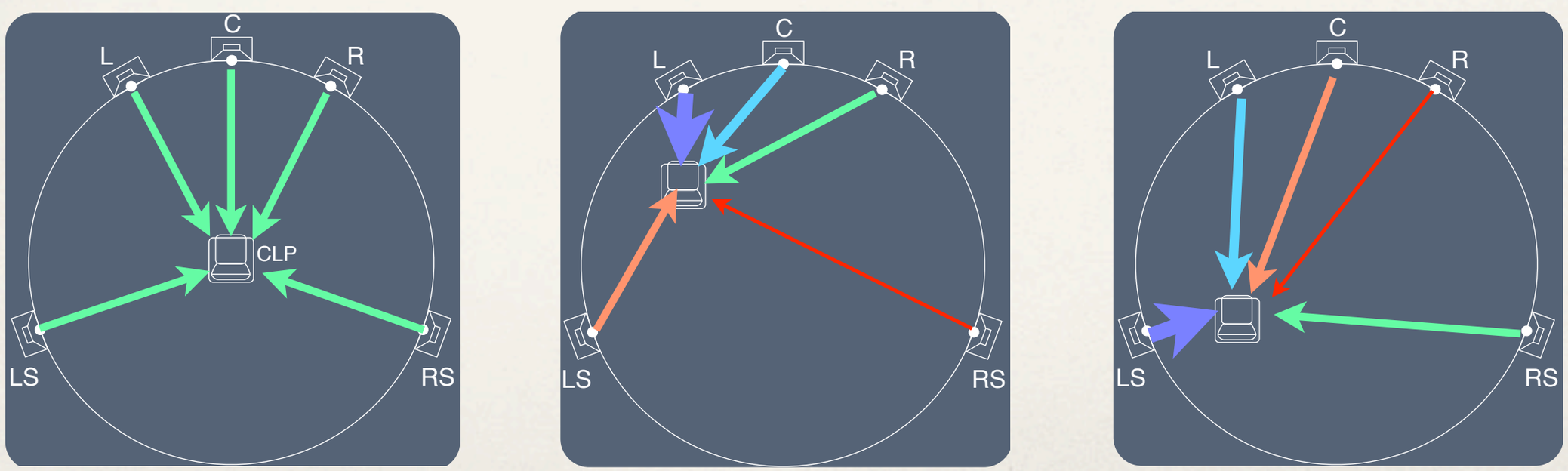
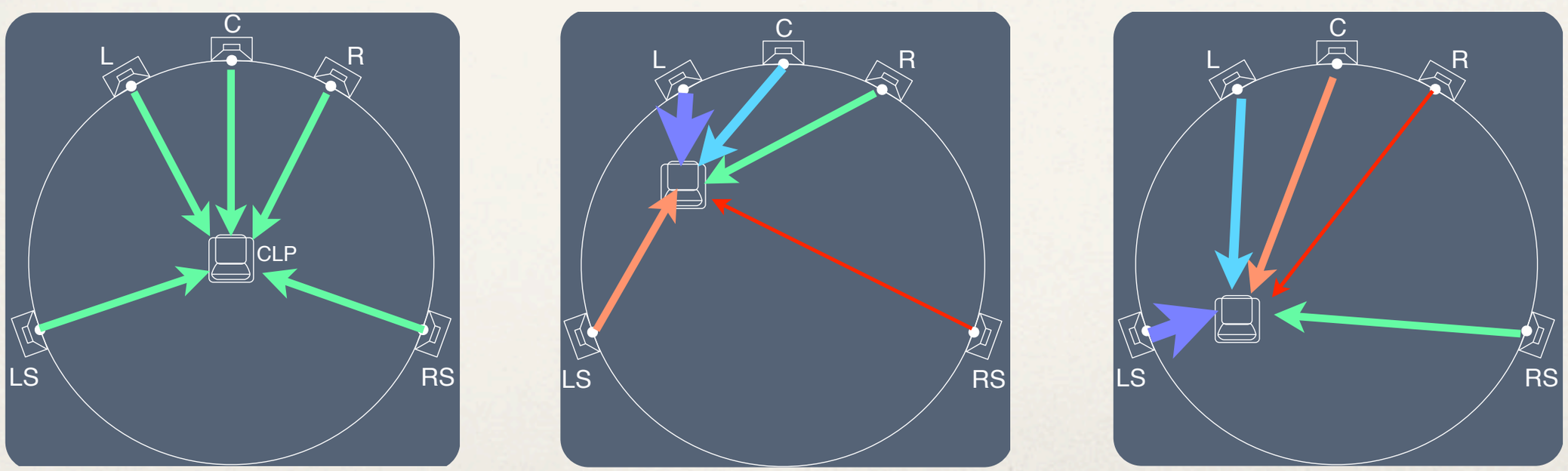


Research Questions

1. How can off-center sound degradation verbally be described?

2. How do the three geometrical factors contribute to the degradation?

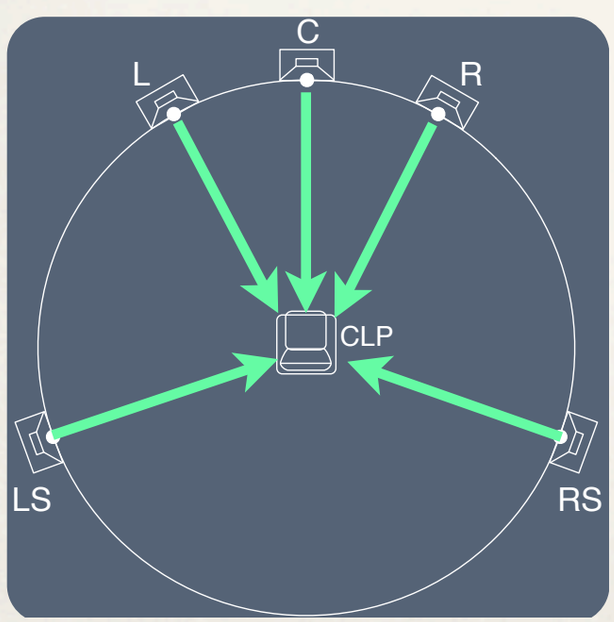


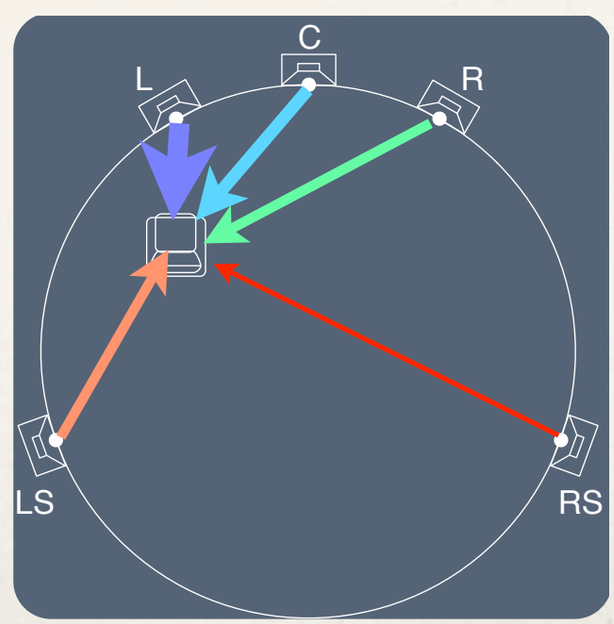
Research Questions

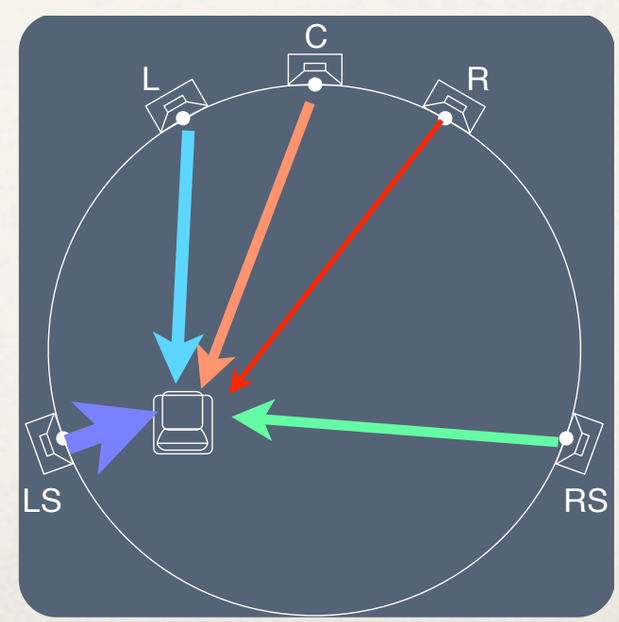
1. How can off-center sound degradation verbally be described?

2. How do the three geometrical factors contribute to the degradation?

3. Does the listening room acoustic affect off-center sound degradation?







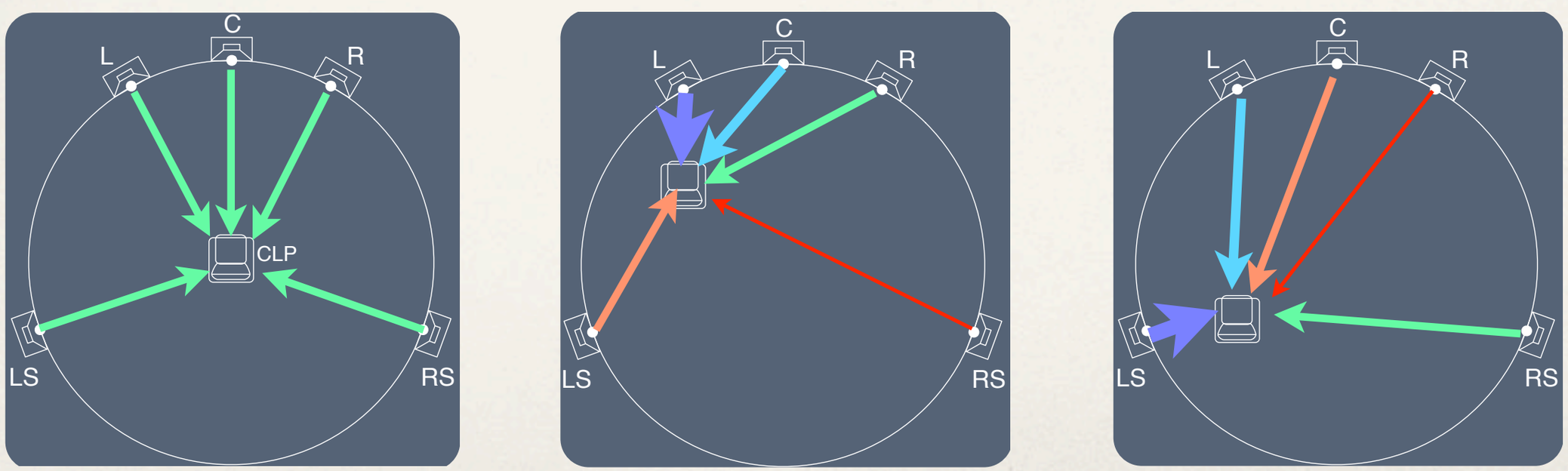
Research Questions

1. How can off-center sound degradation verbally be described?

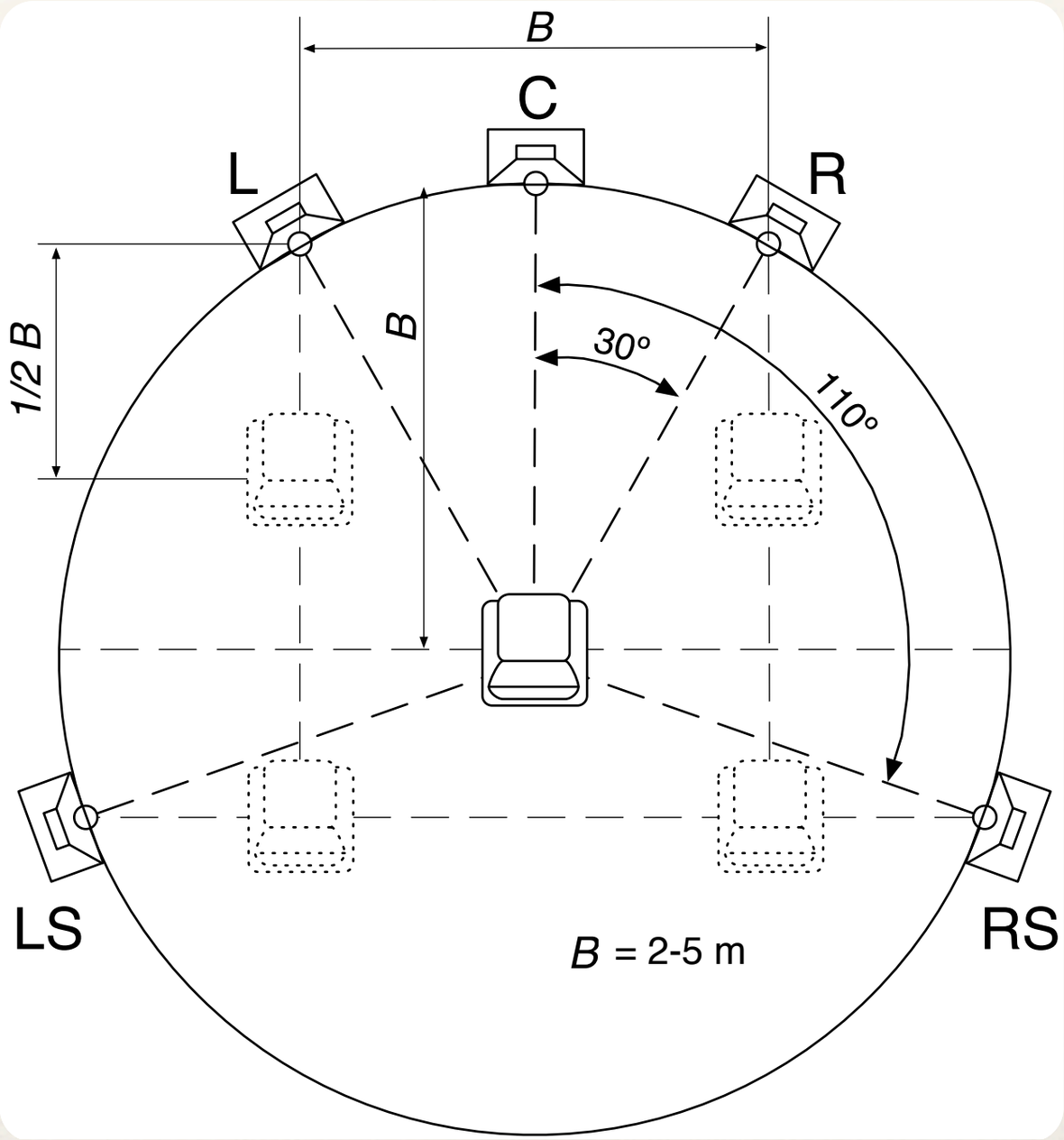
2. How do the three geometrical factors contribute to the degradation?

3. Does the listening room acoustic affect off-center sound degradation?

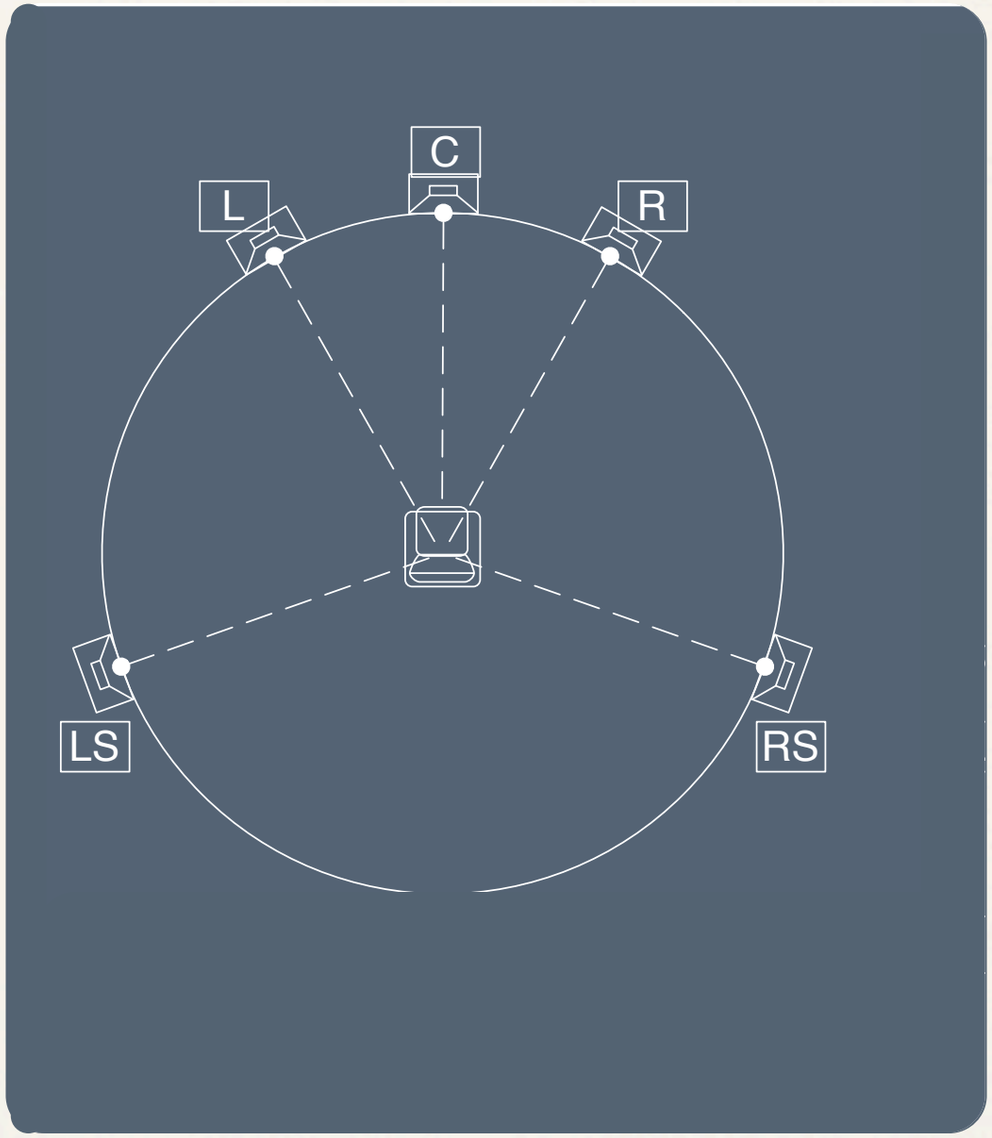
4. Is off-center sound degradation content-related ?



Listening positions ITU-R 1116



Experimental method for sweet-spot experiments



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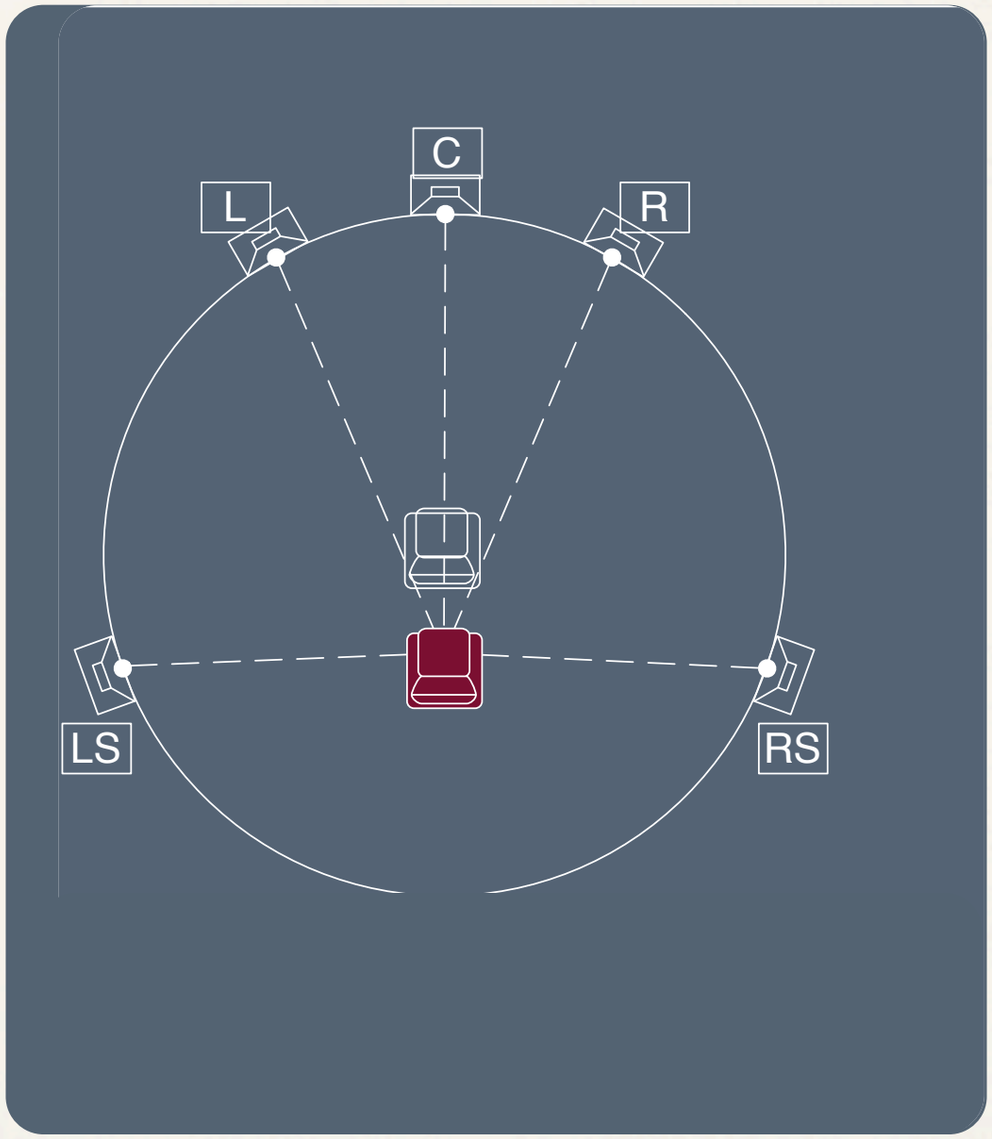

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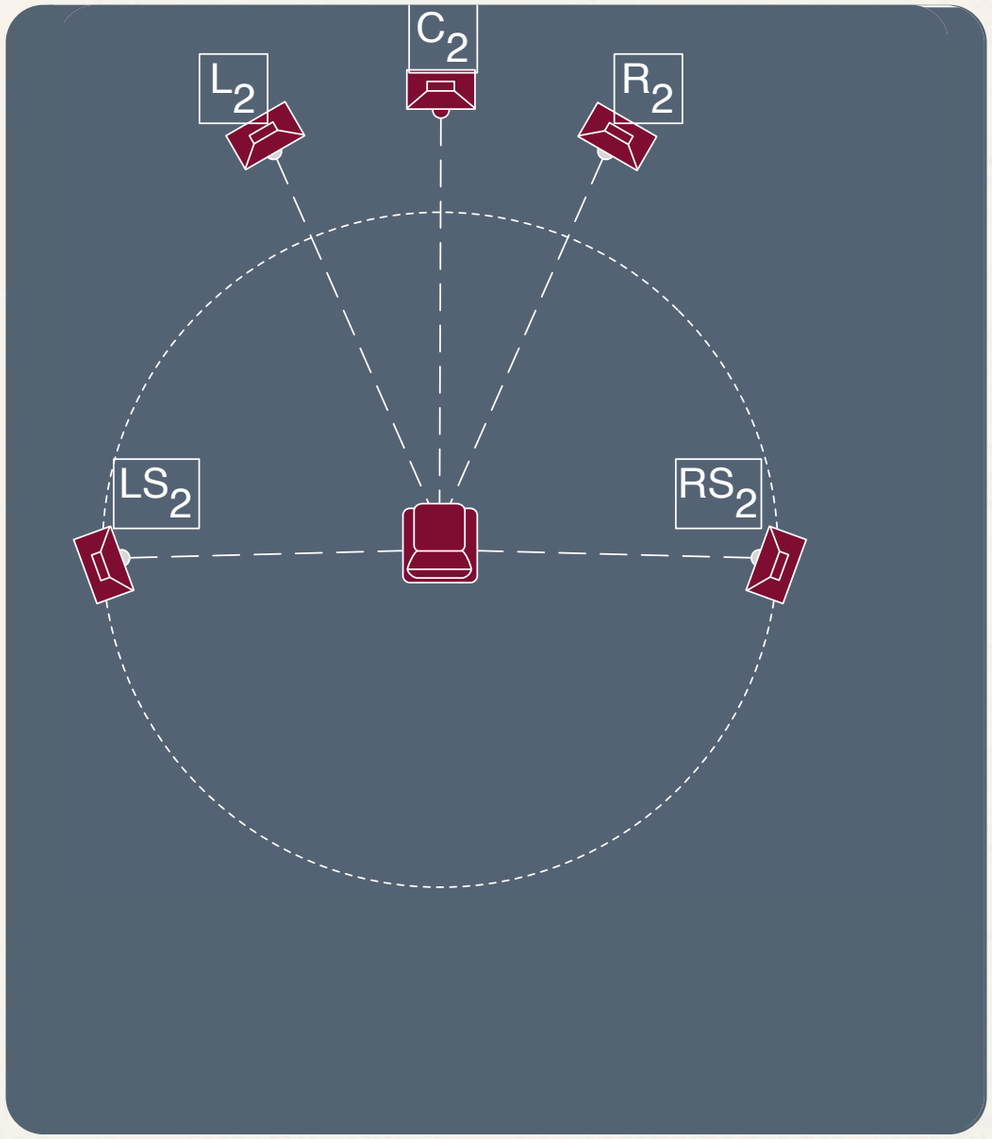

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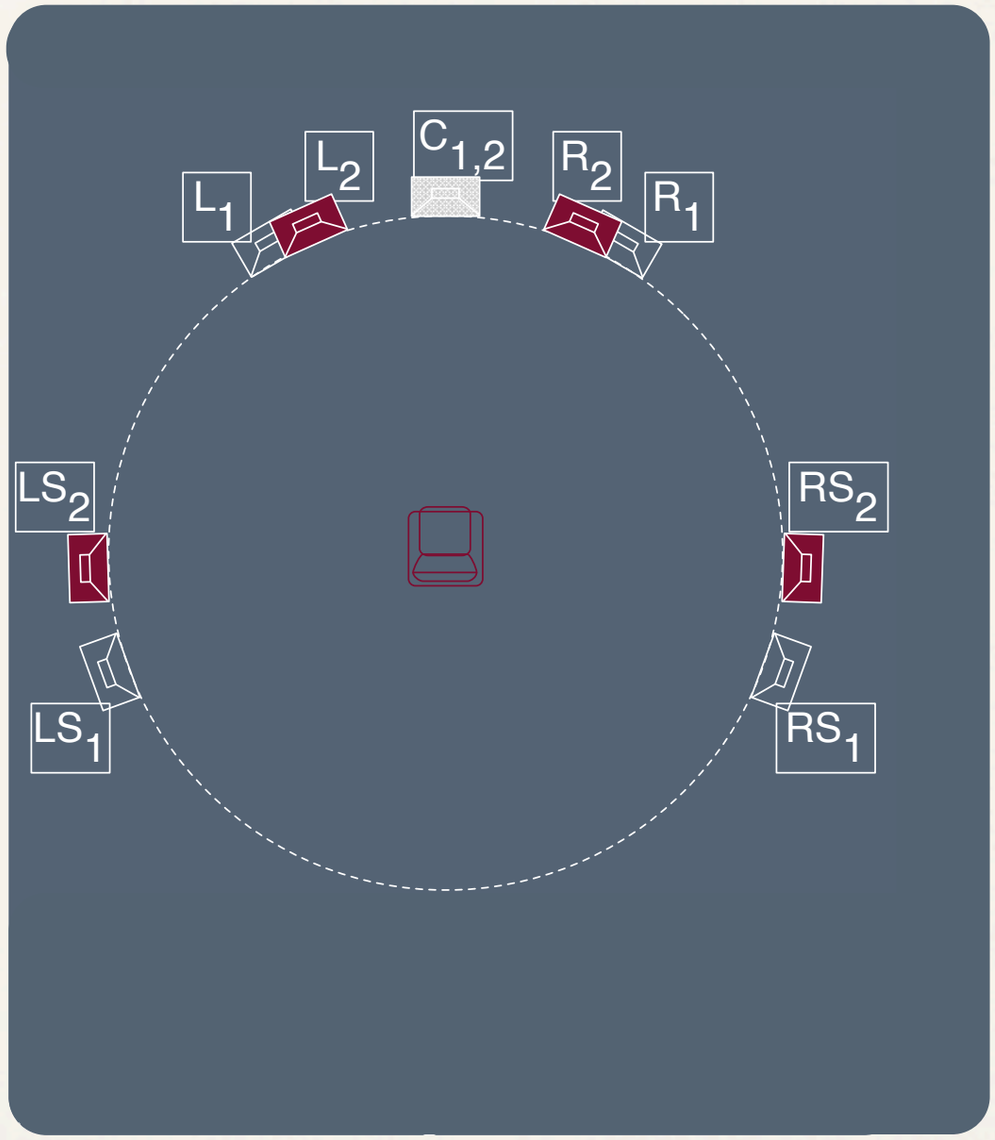
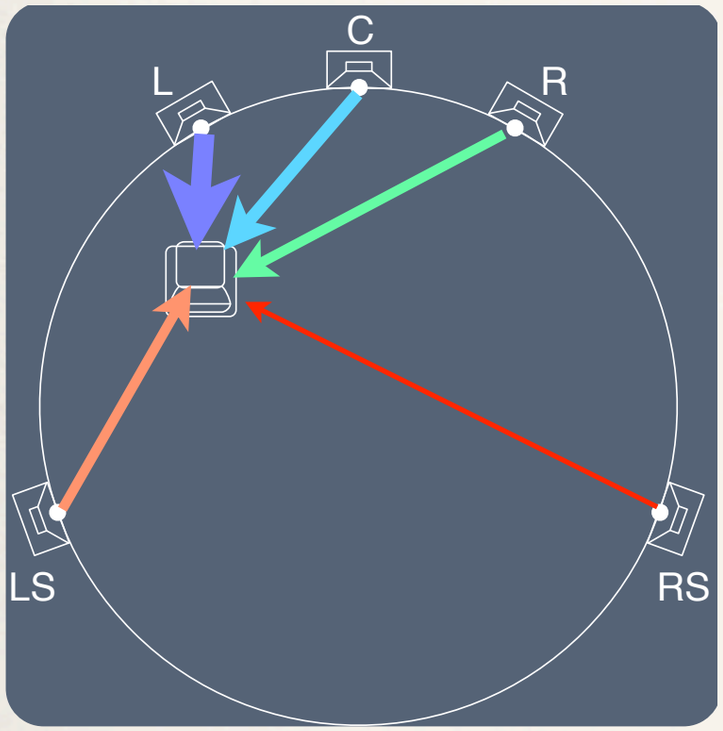
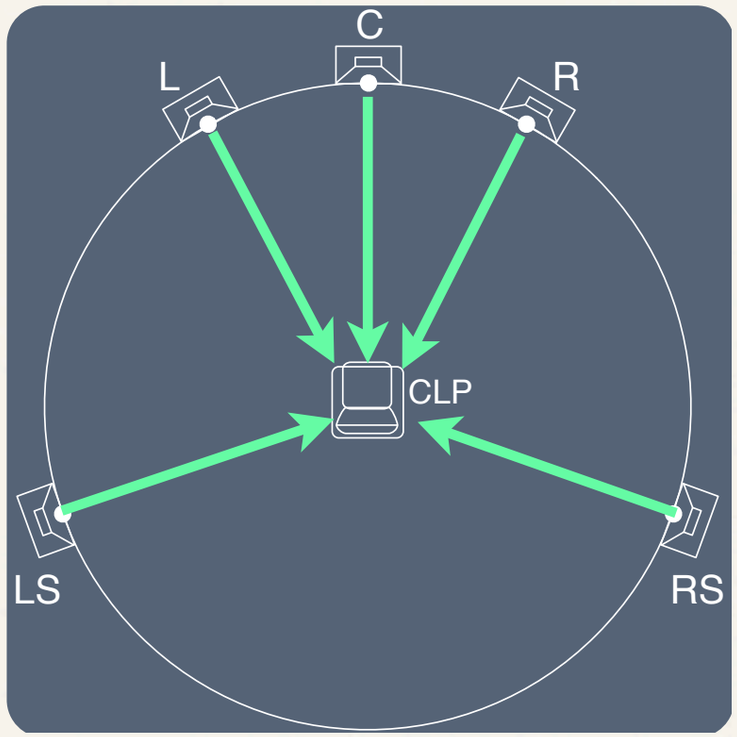


Tested listening positions and simulated geometrical effects





Effect in

- Time-of-arrival (ToA)
- Sound Pressure (SPL)
- Direction of Arriving Waves

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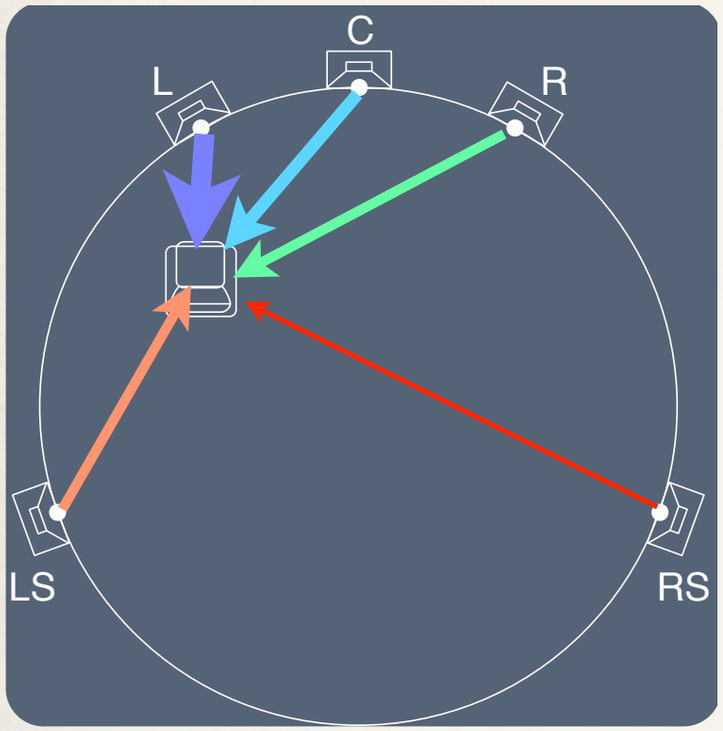

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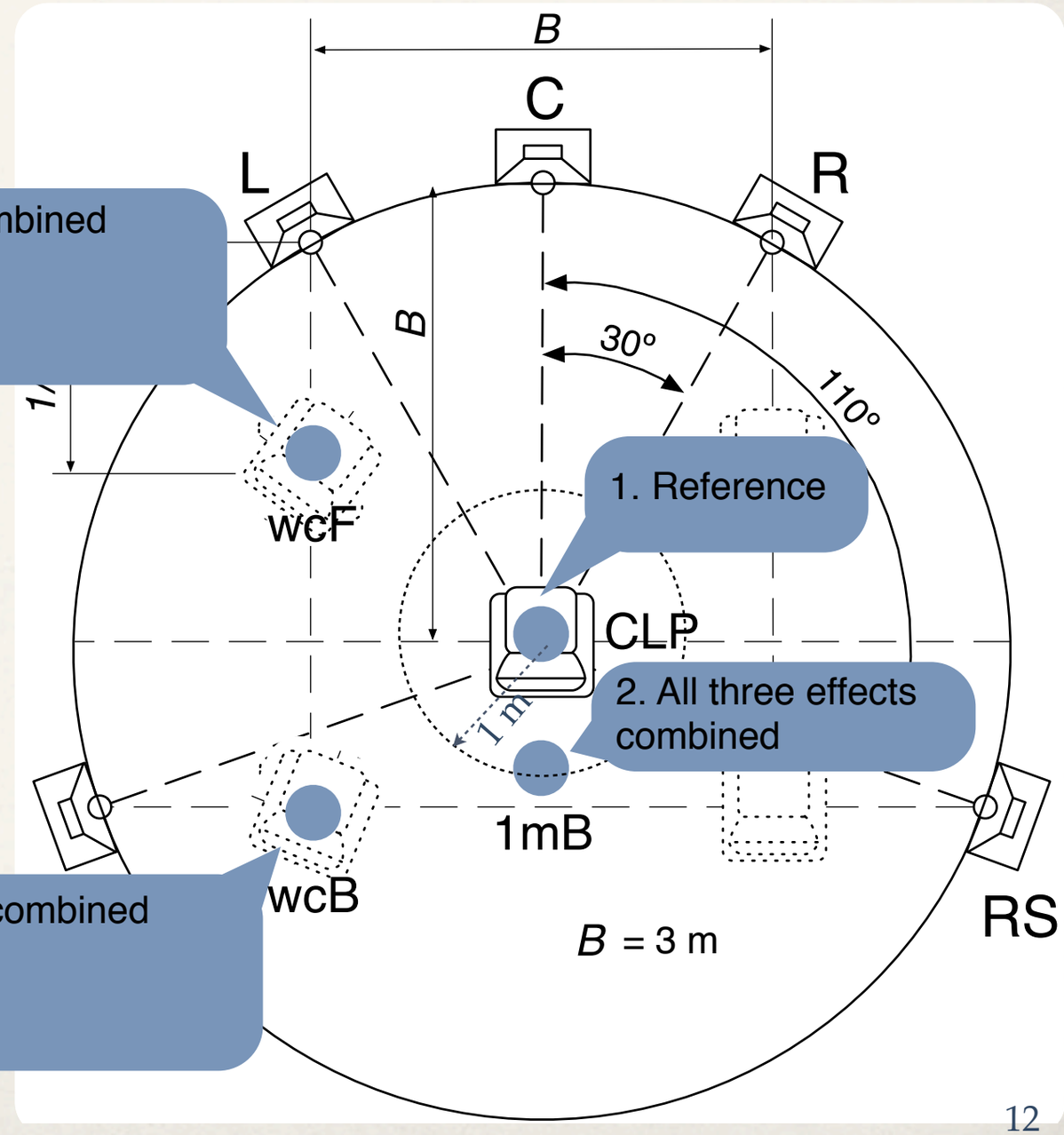


3. All three effects combined
4. just ToA
5. just SPL
6. just Direction

1. Reference

2. All three effects combined

7. All three effects combined
8. just ToA
9. just SPL
10. just Direction

Tested musical excerpts

1

<u>Solo piano</u>

- J.S. Bach: Goldberg Variations
- Fukada Tree recording technique
- Recorded in Pollack hall by Martha DeFrancisco

2

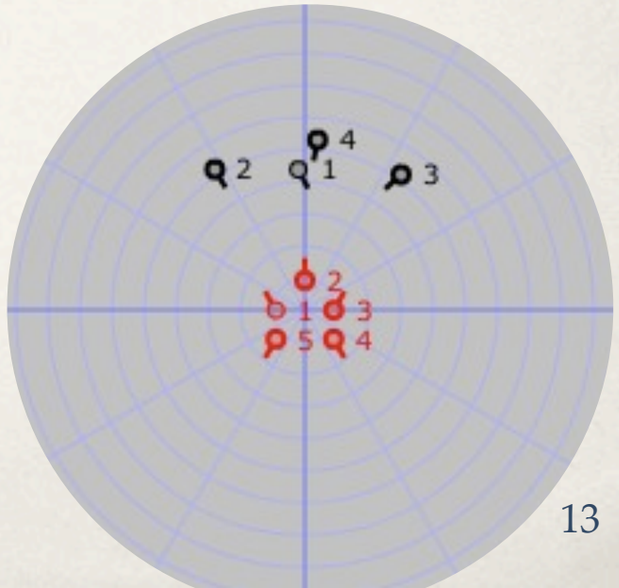
<u>Percussion</u>

- Roger Reynolds: Sanctuary
- Surround recording provided by composer

3

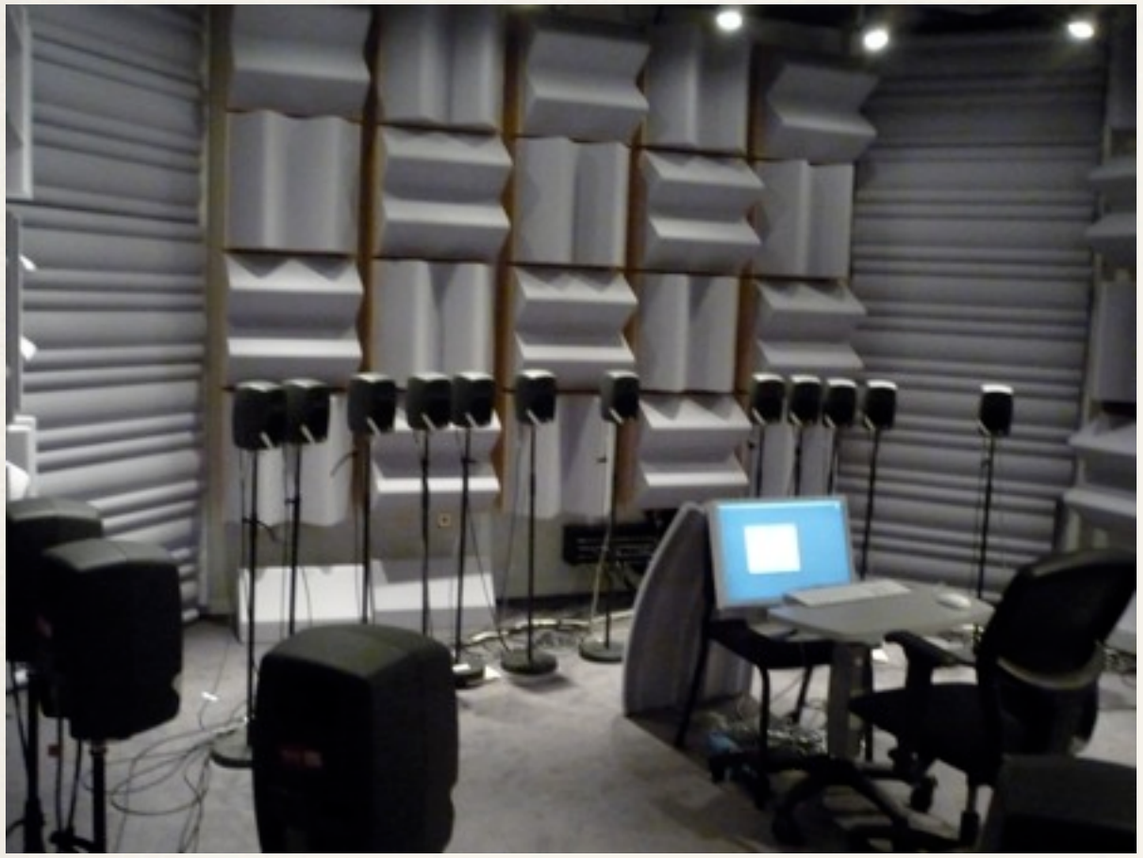
<u>Acoustic guitar ensemble plus female singer</u>

- Tango ensemble, each instrument in a single audio file
- Rendered with ViMiC software (Fukada Tree setting)
- *fine-tuned* by professional sound engineer



Tested listening room acoustics

CIRMMT Spatial Audio Lab

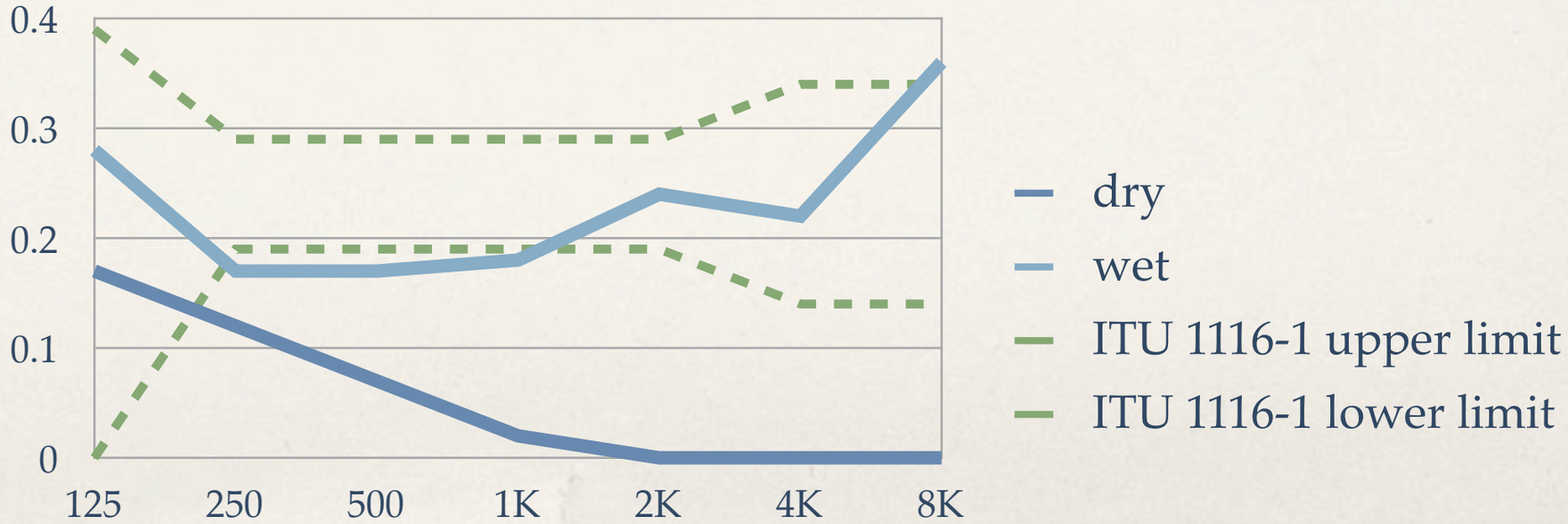


DRY Condition: Absorbers

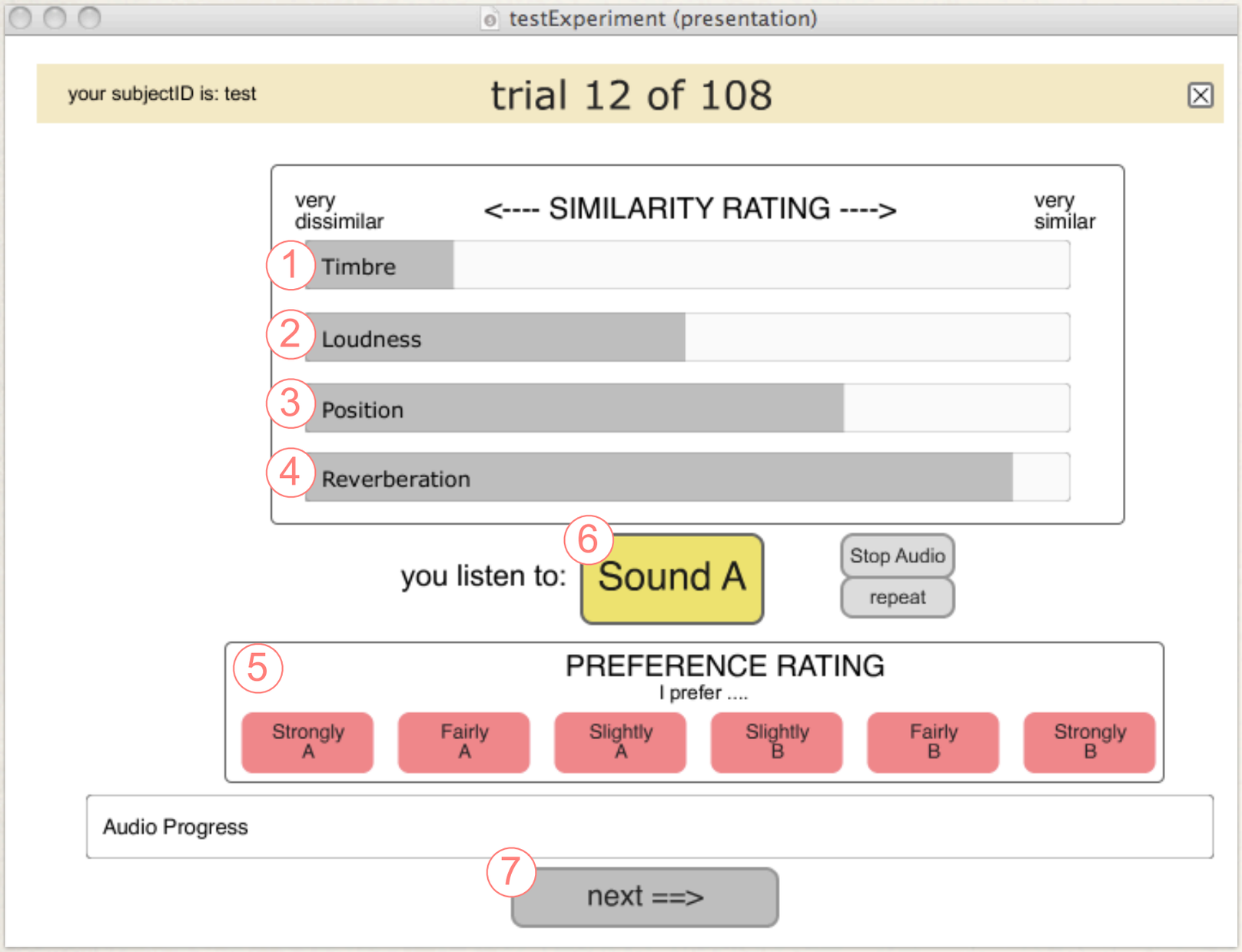
(RPG ProFoam Wedge 14")

WET Condition: Diffusors

(RPG Skyline 4"/8"/12")



Experimental Design

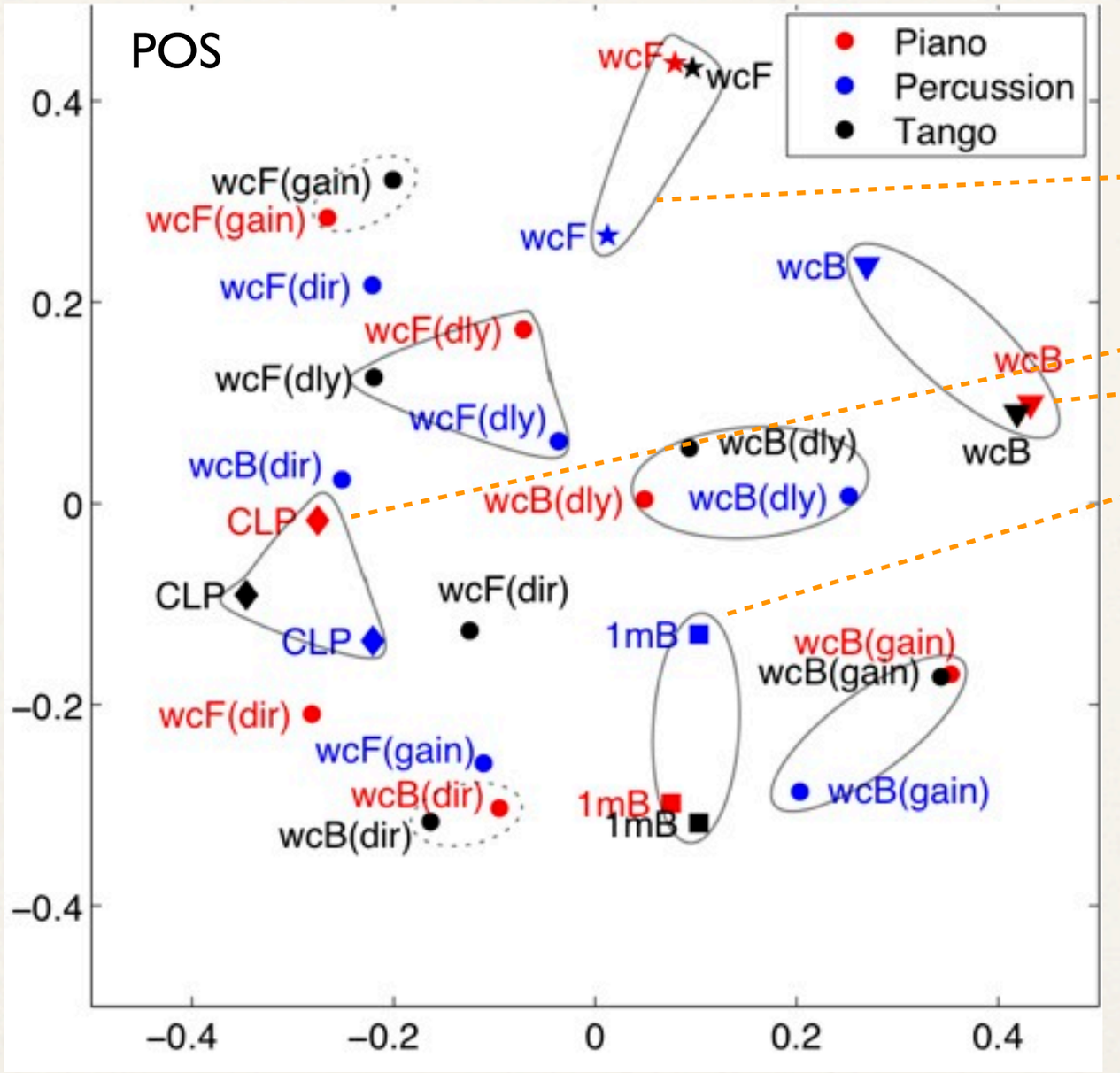


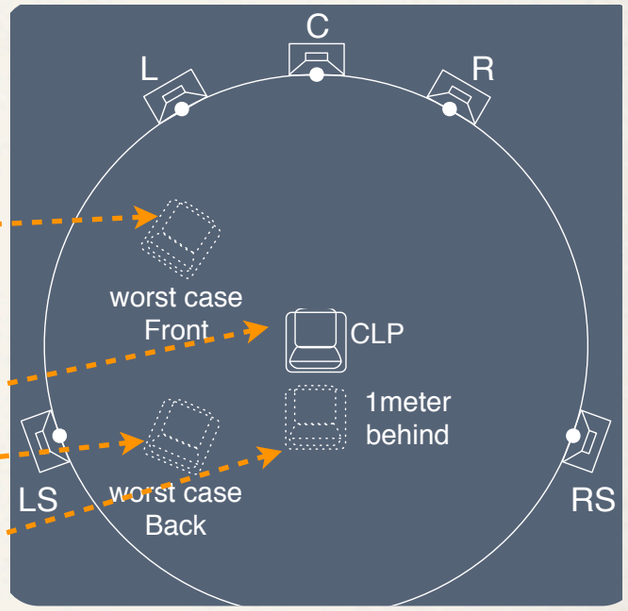
Independent Variables	Levels	
Listening Positions	10	POS
Musical Excerpts	3	EXC
Room Acoustics Condition	2	COND

Two groups, 15 subjects per group:
Group A (5 female), aged between 22 and 54 years (median 26)
Group B (7 females), aged between 20 and 42 years (median 28)

Analysis of Similarity Ratings

Generalized MDS *MultiDimensional Scaling*





Analysis of Similarity Ratings

Repeated-measure MANOVA

Independent Variables	Levels	
Listening Positions	10	POS
Musical Excerpts	3	EXC
Room Acoustics Condition	2	CON

Effect	df	F	p	η_P^2
EXC	8, 104	28.5	< **.001**	.69
POS	176, 4752	16.9	< **.001**	.39
CON	4, 24	0.9	.464	.13
EXC×CON	8, 104	1.0	.072	.07
EXC×POS	352, 9504	6.9	< **.001**	.20
CON×POS	176, 4752	1.1	.555	.03
CON×POS×EXC	352, 9504	.95	.771	.03

Analysis for Similarity Ratings

Repeated-measure MANOVA

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EXC	8, 104	28.5	< **.001**	.69
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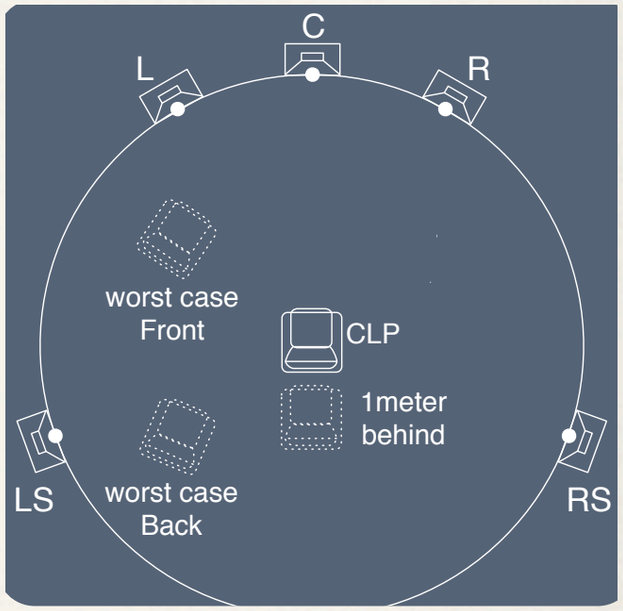
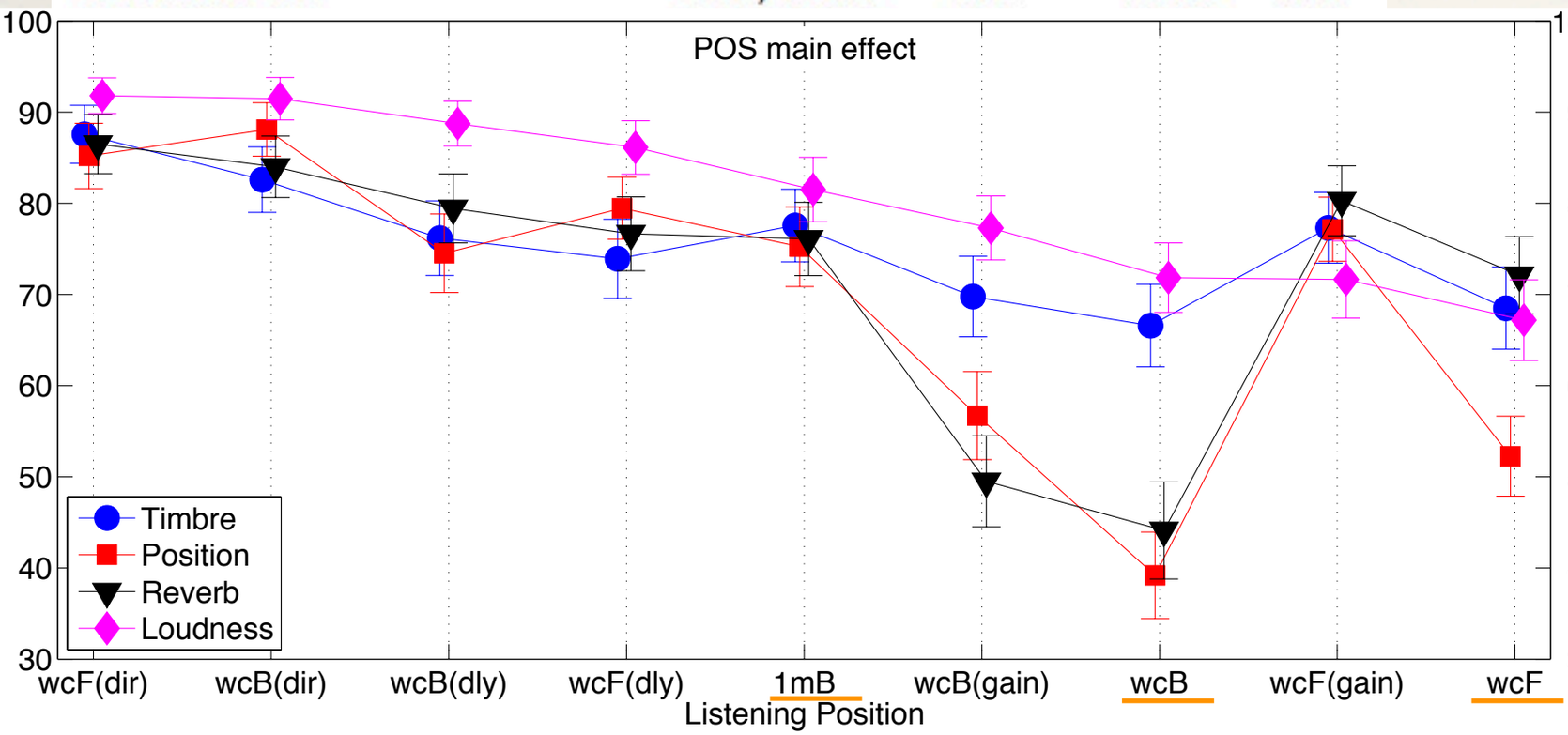
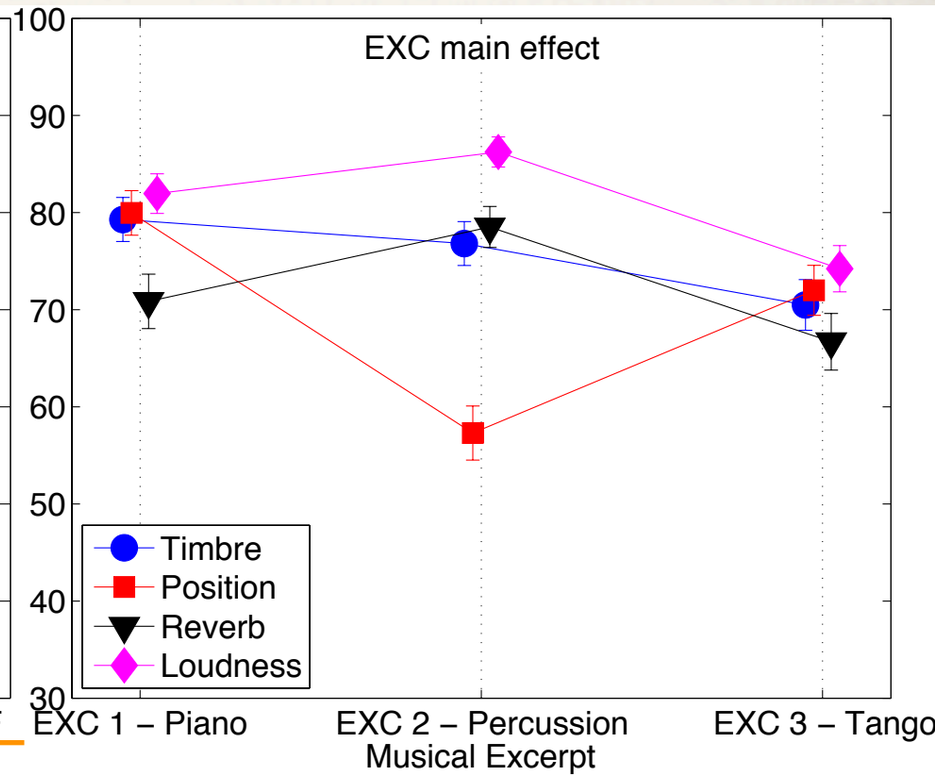
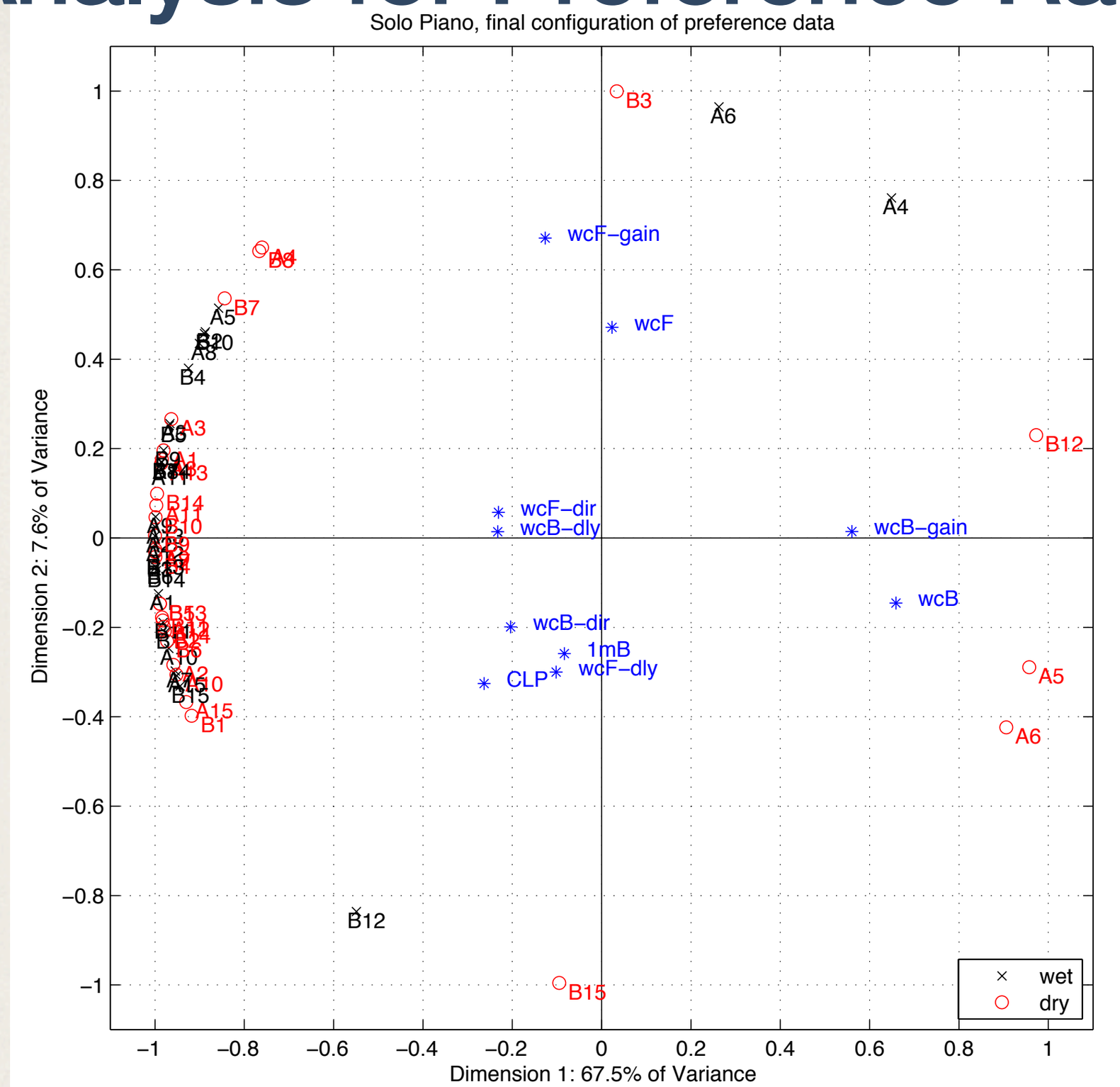






Analysis for Preference Ratings



MDPREF - MultiDimensional PREFerence scaling

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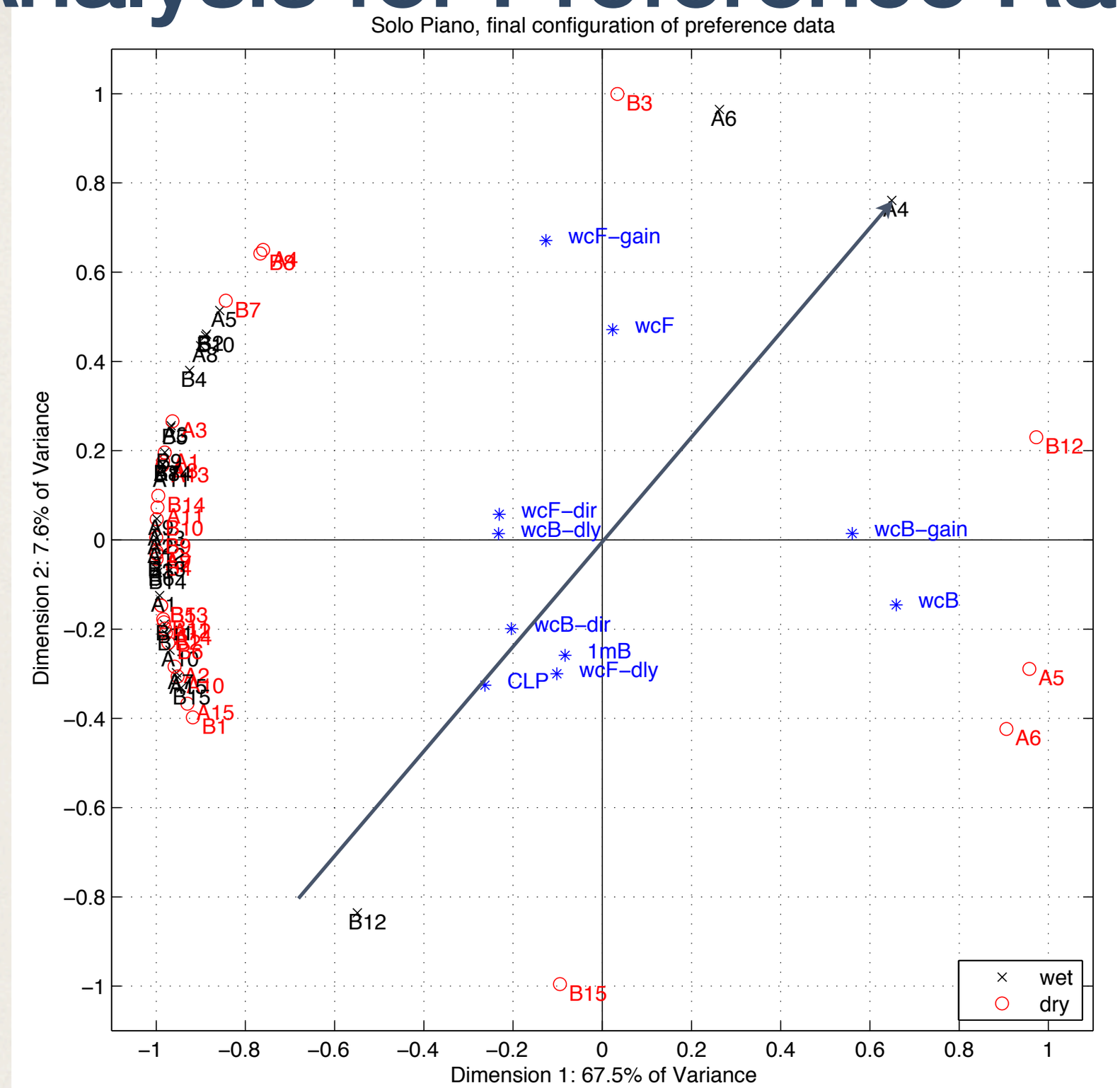

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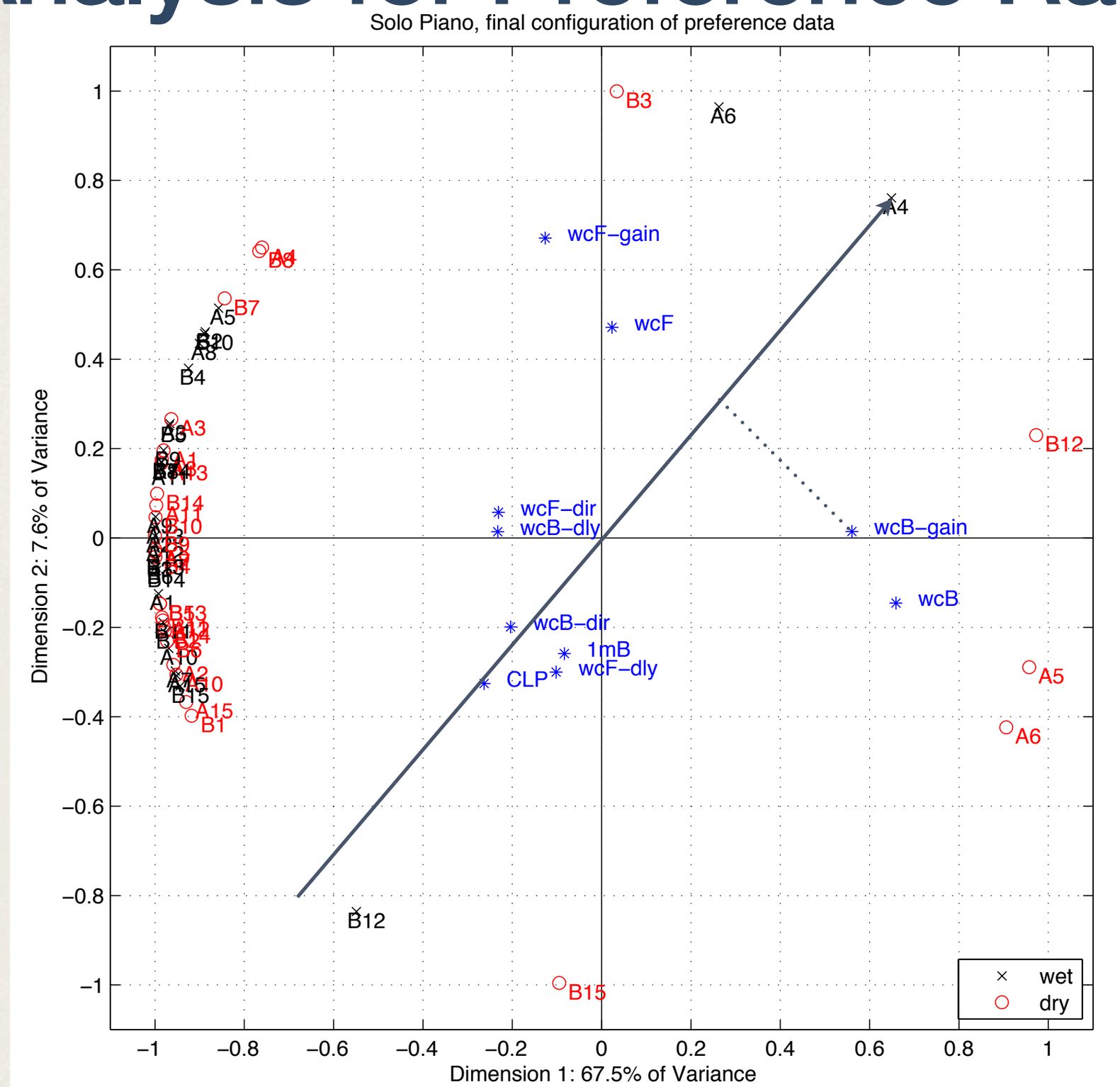

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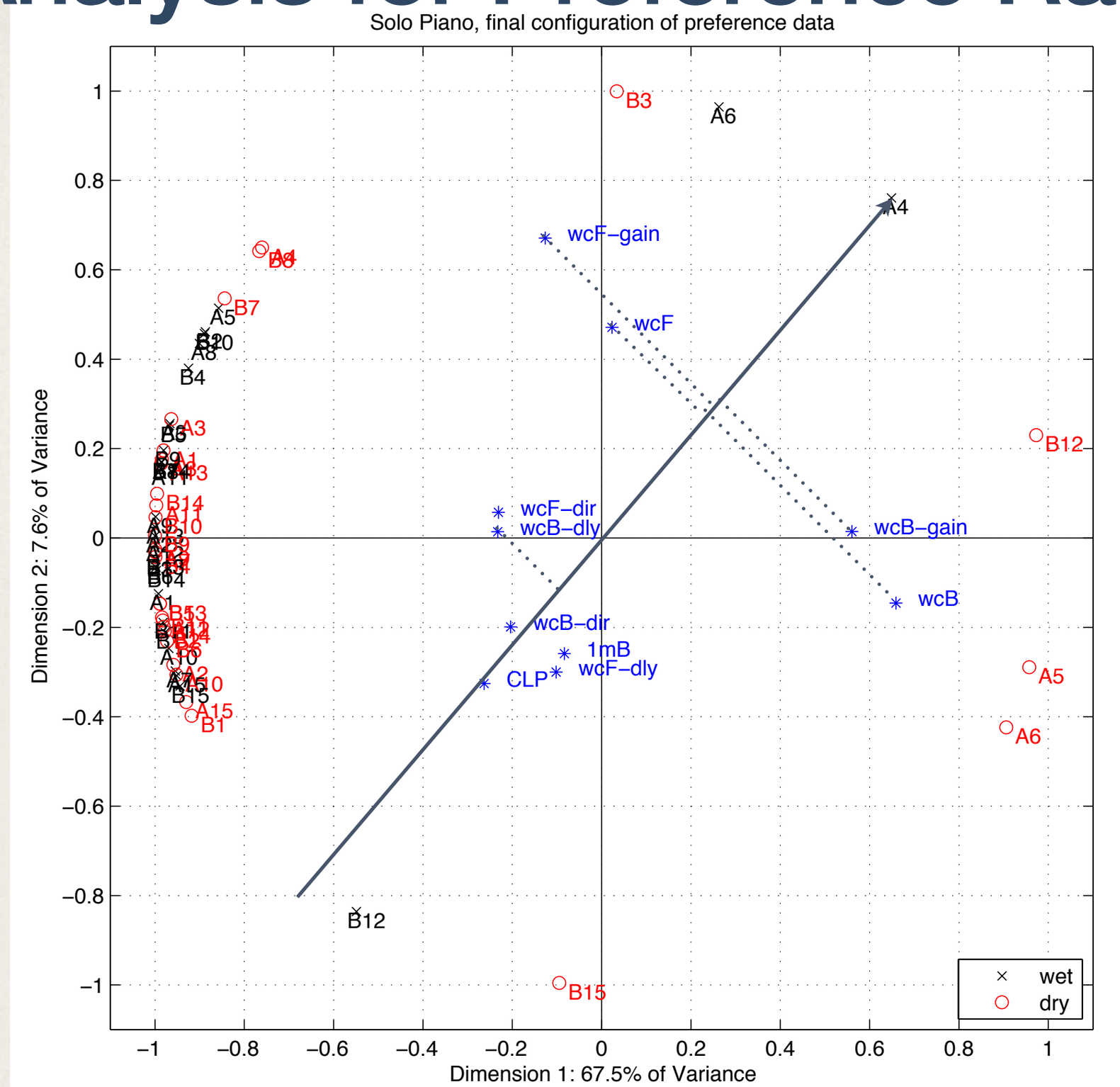

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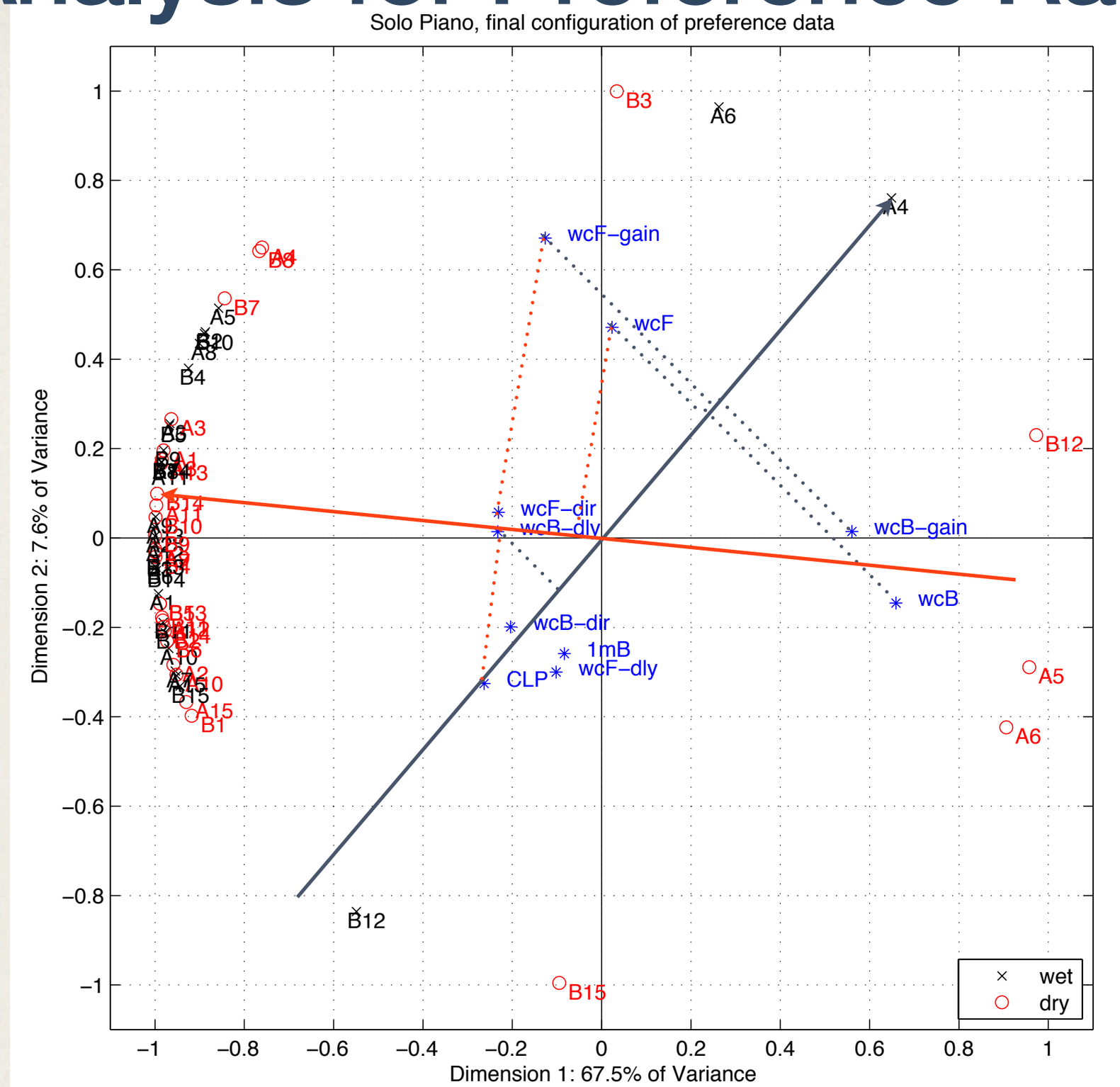

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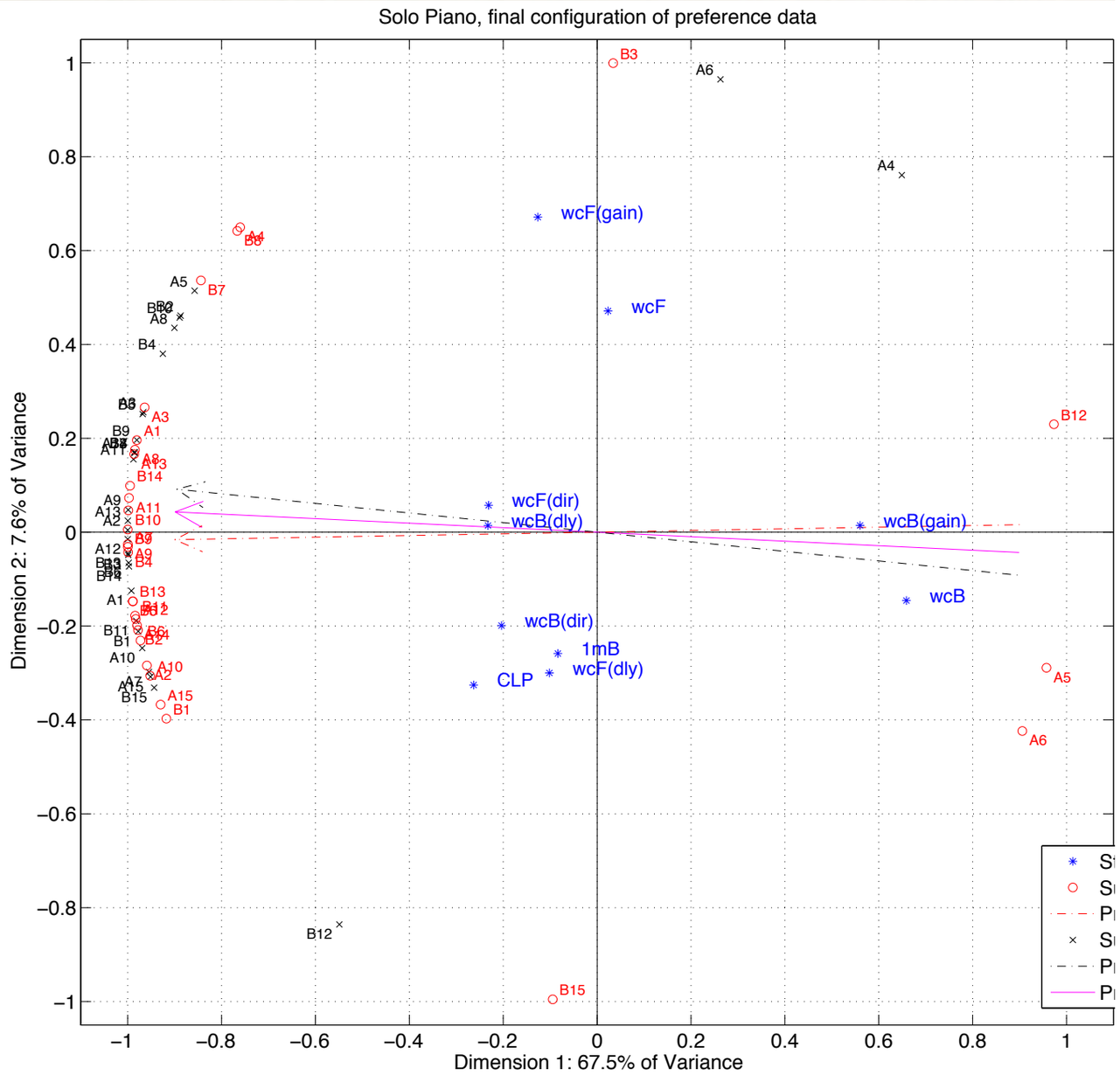
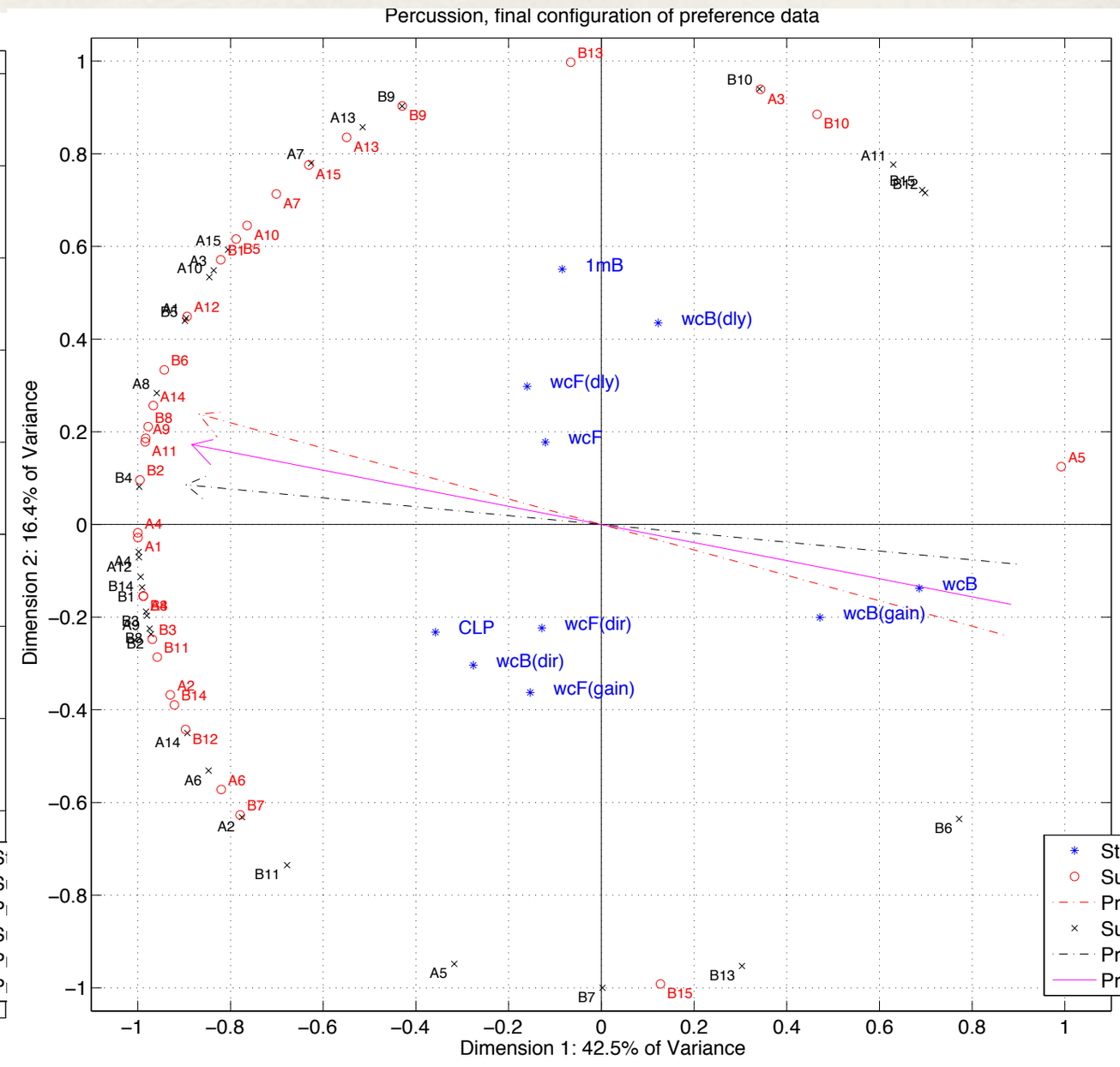
Solo Piano



Percussion



- ✳ Stimulus points (Listening Positions)
- ○ Subject points, Dry Room Condition
- — · — Preference vector of the average over subjects, Dry Room Condition
- × Subject points, Wet Room Condition
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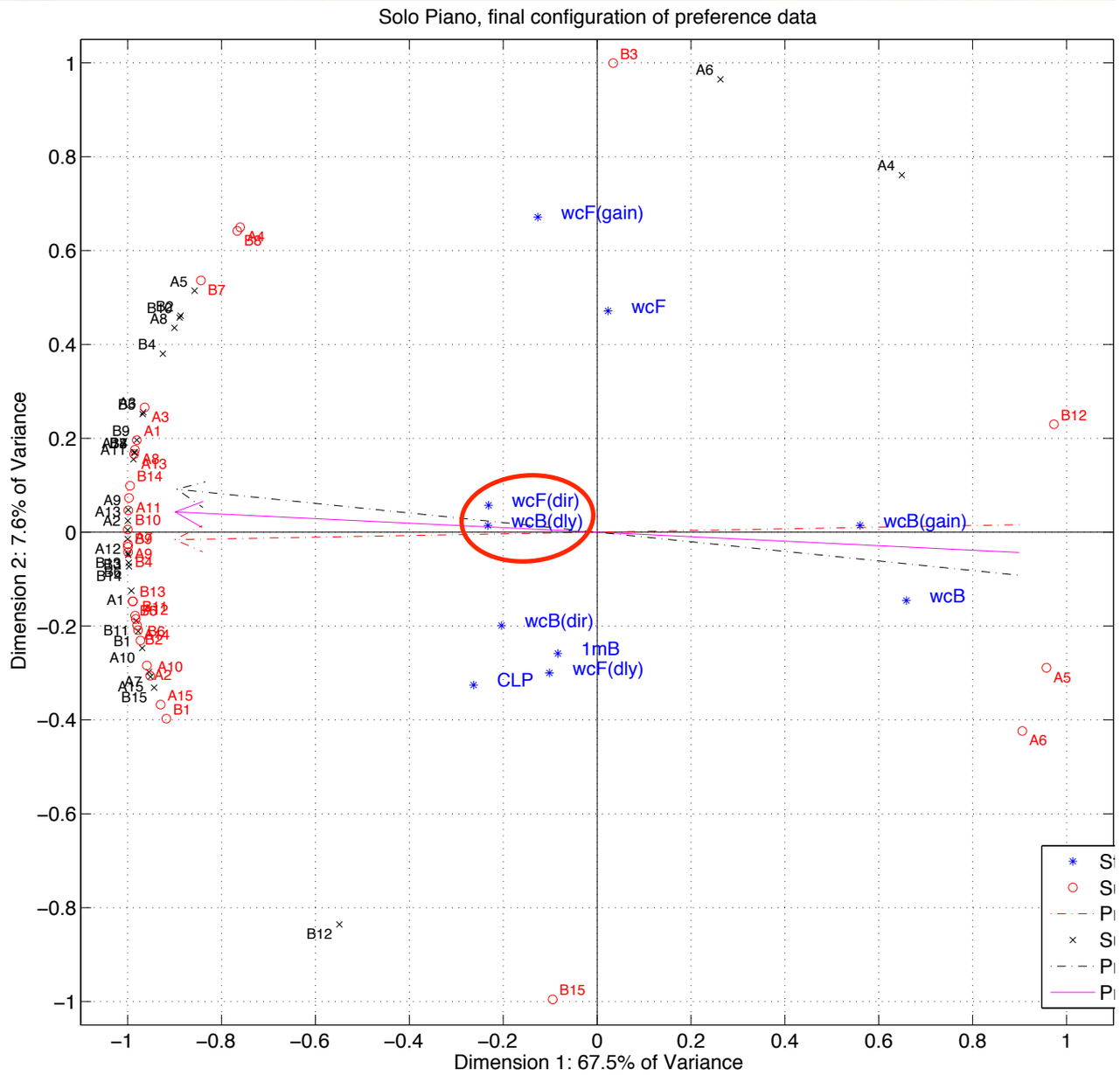

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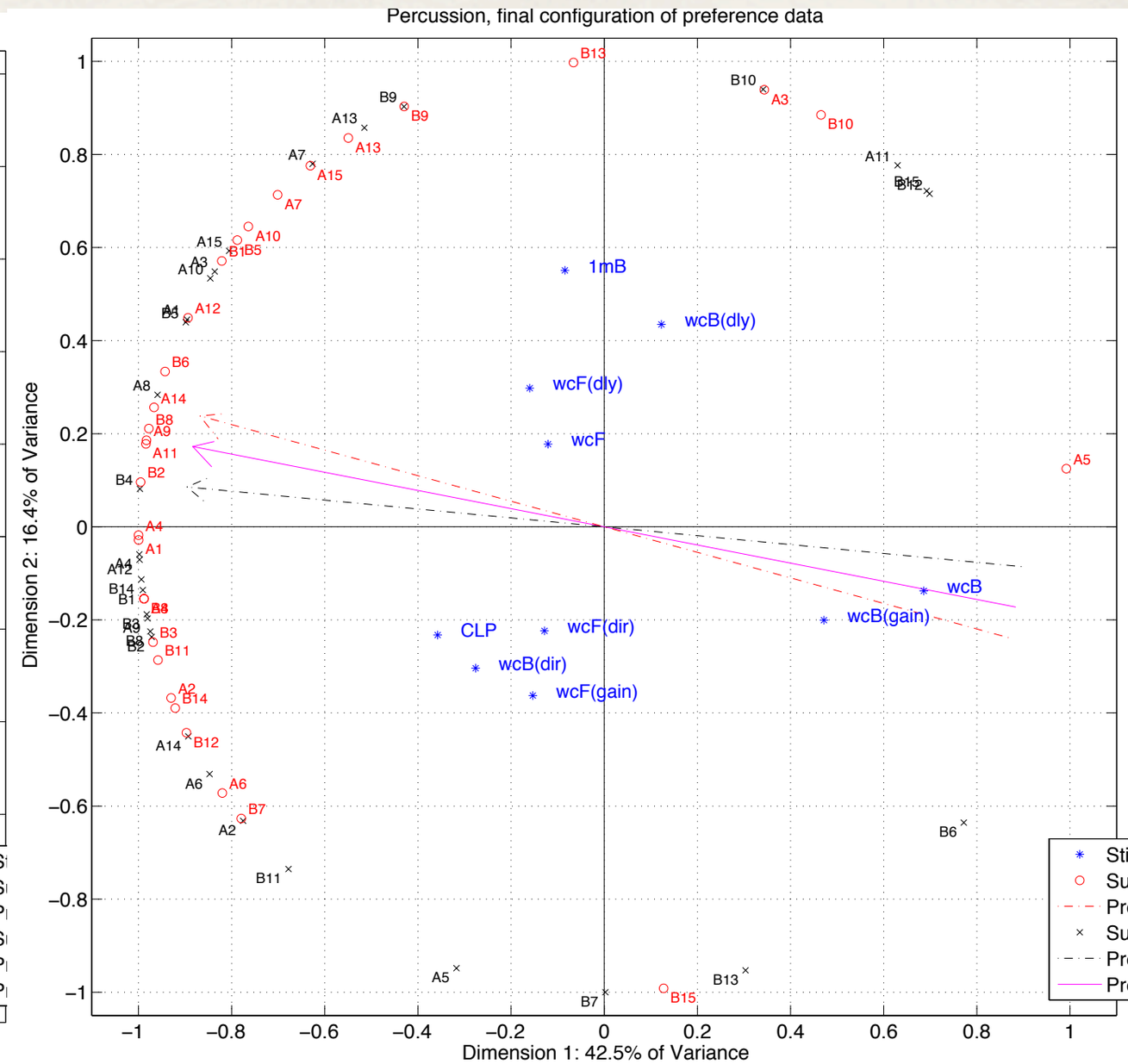

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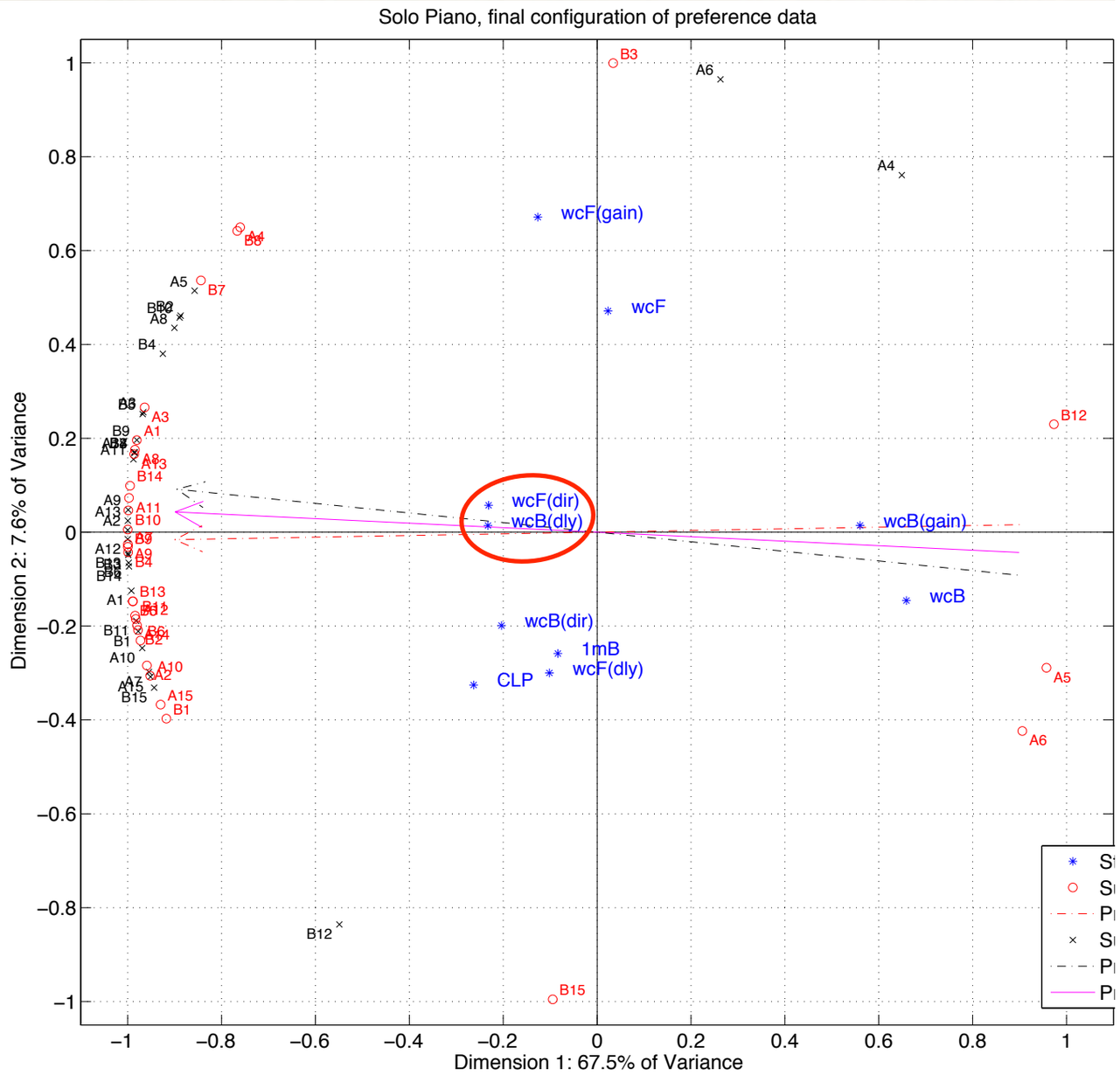

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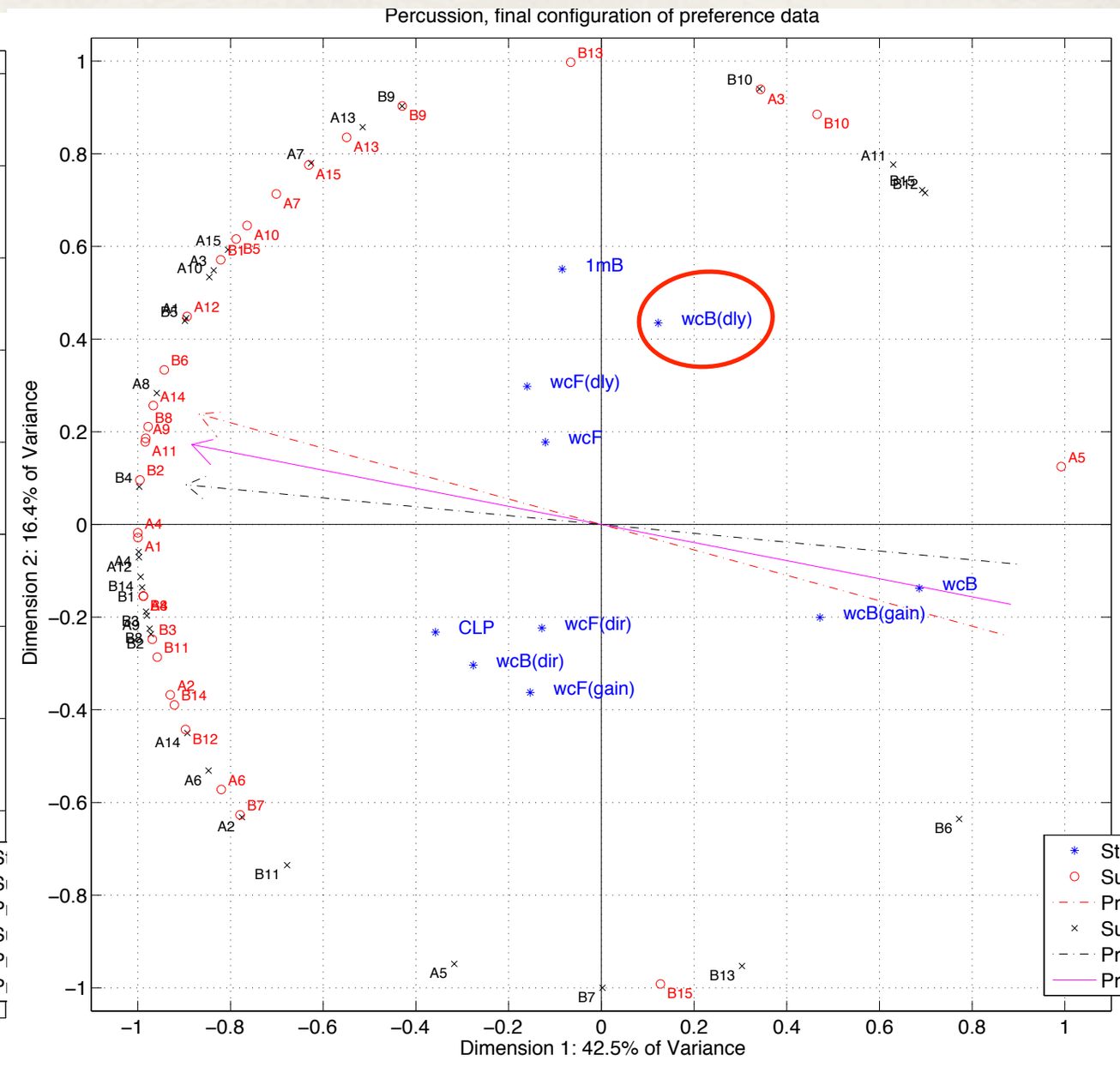

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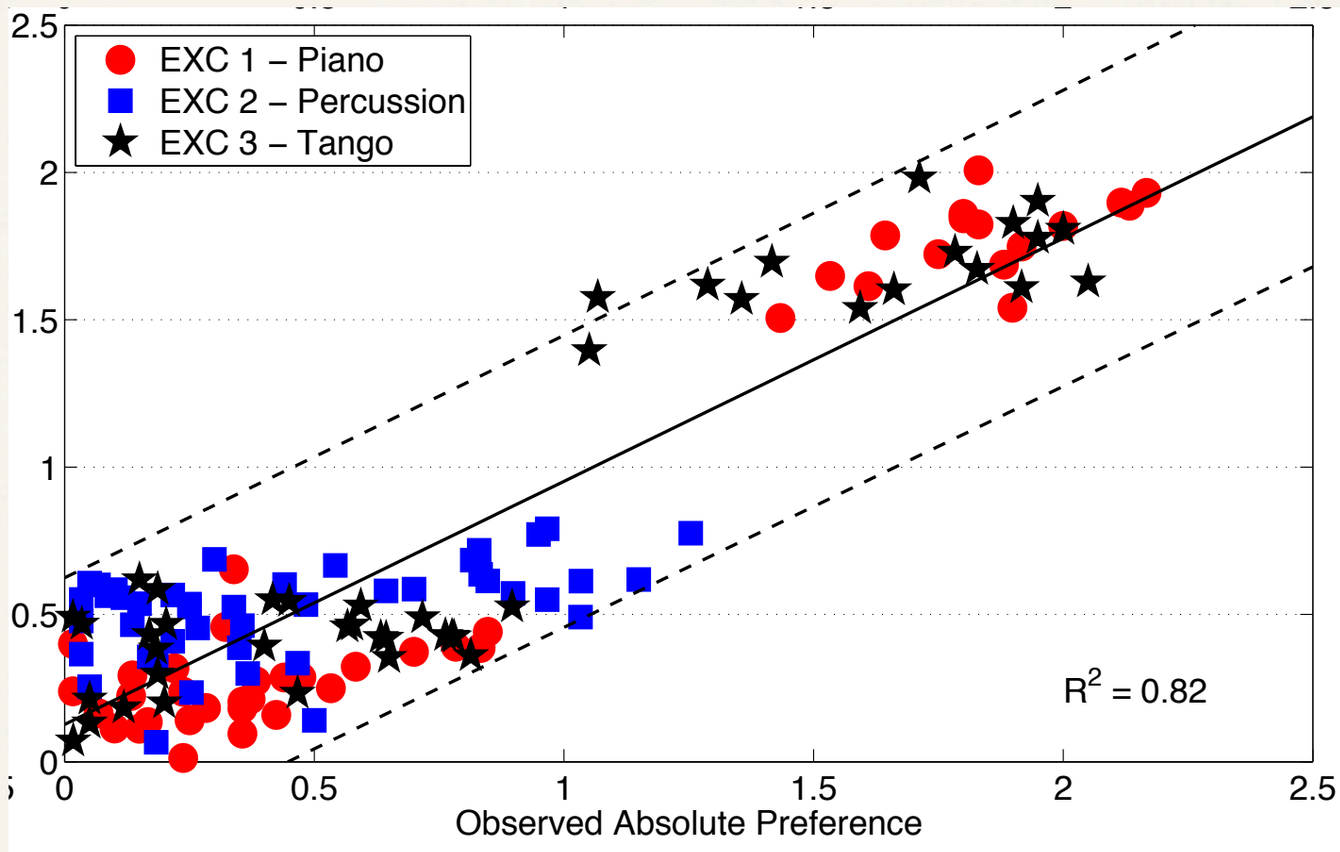
Predicting Preference from Similarity



Predictor successively entered	Partial R	Std. coeff. B	Accum. $R^2_{adj.}$	VIF
1. Reverb	-.891	-.972	.78	1.39
2. Loudness	.425	.231	.81	1.38
3. Position	-.331	-.092	**.82**	1.15

Conclusion

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   - *The simulated loudspeaker direction contribute least*

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2. Do listening room acoustics affect off-center sound degradation?

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   - *Effect not significant for Similarity rating*

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   - *Time-of-flight delays contribute for percussion excerpt*
   - *The simulated loudspeaker direction contribute least*
2. Do listening room acoustics affect off-center sound degradation?
   - *Effect not significant for Similarity rating*
   - *Room-adaptation effect ? (see S. Olive 2008)*

Conclusion

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   - *Yes, biggest effect size in MANOVA*

A Perceptual Analysis of

Off-Center Sound Degradation in Surround-Sound Reproduction

Based on Geometrical Properties

Thank you!

Questions ?

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