Queen Mary University of London

centre for digital music

Metaphors we listen with

Semantic (conceptual?) spaces of timbre

Charalampos Saitis

Timbre Topologies, ZHdK, 3.2.2023

Charalampos Saitis

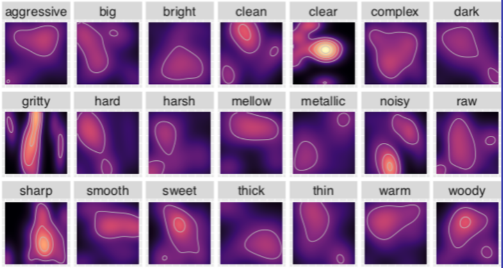
Communication Acoustics Lab

https://comma.eecs.qmul.ac.uk/

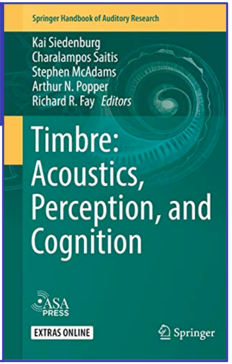
Data Science and AI for Music

Turing Fellow 2021-2023

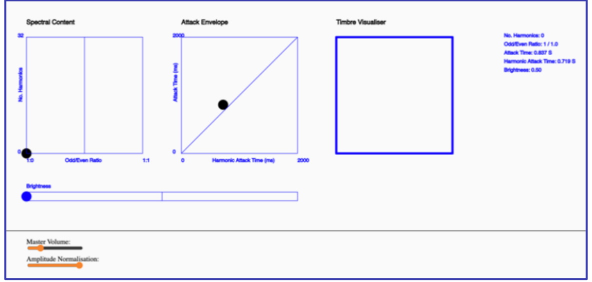
Audio/ timbre semantics



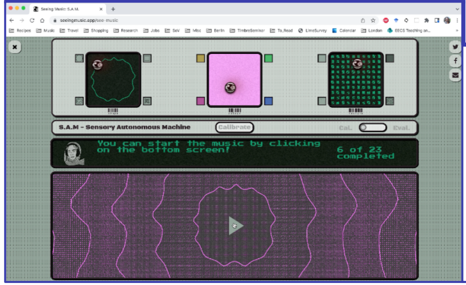
Have some timbre.fun



Timbre tools for digital makers

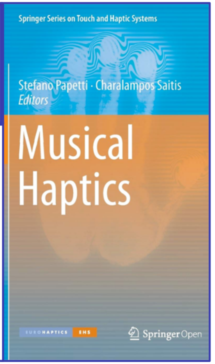


Crossmodal perception

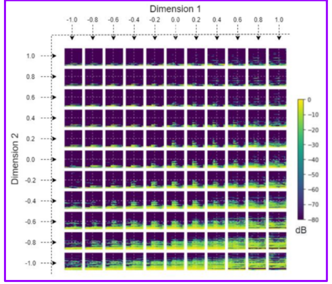


Play our game

seeingmusic.app



Neural audio



Music data science


VOUS AVEZ UN JOLI TIMBRE
J'AIME VOTRE ENVELOPPE
La Poste
Lettre 20 g
FRANCE
GELUCK
ITVF

How does it sound to you?

After consultations […] Yehudi [Menuhin] played on all three [Stradivari violins] and opted for the “Khevenhüller”. […] It was to be his principal instrument for over twenty years. He described it as “**ample** and **round**, varnished in a deep, glowing red, its grand proportions [...] matched by a sound at once **powerful**, **mellow** and **sweet**.”

We use a diverse vocabulary to communicate timbral qualities

Not crucial for *perceptualising* timbre—we can compare, recognize, memorize, imagine timbres without having to describe them

But central to *conceptualizing* timbre—they allow us to communicate acoustic variations in terms of other, more commonly shared experiences

Burton H (2016) Menuhin: A Life, Revised (Faber & Faber, London)

Timbre discourse

onomatopoeia

Matter

Material

Spoken/sung vocables

Crossmodal correspondence

Lexical onomatopoeia

Acoustics

Sensory

Pure metaphor

Action

Association

Mimesis

Activity

Evaluation

Affect

Porcello T (2004) Speaking of sound: Language and the professionalization of sound-recording engineers. Soc Studies Sci 34:733–758

Wallmark Z (2018) A corpus analysis of timbre semantics in orchestration treatises. Psychol Mus 1–21

Timbre discourse

onomatopoeia

Matter

Spoken/sung vocables

Crossmodal correspondence

Lexical onomatopoeia

Acoustics

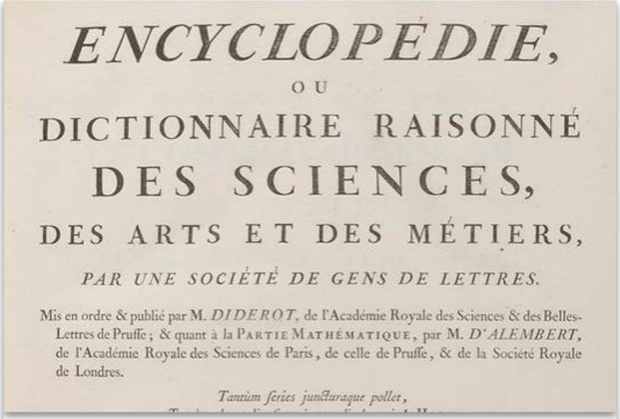
Pure metaphor

Action

Mimesis

Affect

“codified, especially among musicians and sound engineers,” (Porcello, 2004, p. 747)


ENCYCLOPÉDIE,
OU
DICTIONNAIRE RAISONNÉ
DES SCIENCES,
DES ARTS ET DES MÉTIERS,
PAR UNE SOCIÉTÉ DE GENS DE LETTRES.
Mis en ordre & publié par M. DIDEROT, de l'Académie Royale des Sciences & des Belles-Lettres de Pruſſe; & quant à la PARTIE MATHÉMATIQUE, par M. D'ALEMBERT, de l'Académie Royale des Sciences de Paris, de celle de Pruſſe, & de la Société Royale de Londres.
Tantùm ſeries juncturaque pollet,

“A sound’s *tymbre* describes its harshness or softness, its dullness or brightness.” (J-J Rousseau, 1772)

Porcel… and th… **engineers**. Soc Studies Sci 34:733–758

Wallmark Z (2018) A corpus analysis of timbre semantics in orchestration treatises. Psychol Mus 1–21

Metaphors we listen with

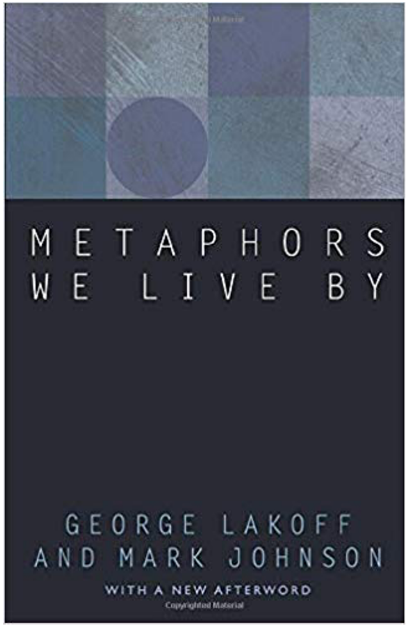
Metaphors as indexes of conceptual representations grounded in perception and action (Wallmark, 2014)

3 conceptual metaphors (Lakoff & Johnson, 2003)

Instruments are Voices (nasal, howling, open, …)

Sound is Material (bell-like, metallic, hollow, velvety, …)

Noise is Friction (harsh, rough, shrill, …)



Wallmark Z (2014) Appraising timbre: embodiment and affect at the threshold of music and noise. Dissertation, University of California

From metaphor to perception

Despite the diverse metaphorical timbre lexicon in orchestration books, taxonomies of musical instruments and the kinds of sounds they produce are usually based on the nature of the sound-producing material and mechanism.

Koechlin (1954–1959; cited in Chiasson et al. 2017, p. 113–114) proposed instead to organize instrument sounds for orchestration purposes on the basis of **volume** and **intensity**, and a third attribute of **density** vs transparency

There is evidence that in the later Middle Ages it was typical to think of musical instruments in terms of volume of sound (Bowles, 1954)

Chiasson F, Traube C, Lagarrigue C, McAdams S (2017) Koechlin's volume: perception of sound extensity among instrument timbres from different families. Music Sci 21:113–131
Bowles EA (1954) Haut and bas: the grouping of musical instruments in the middle ages. Music Discip 8:115–140

Schaeffer's typo-morphology of "sonorous objects"

Schaeffer P (1966) Traité des objets musicaux: essai interdisciplines. Editions du Seuil, Paris. English edition: Schaeffer P (2017) Treatise on musical objects: an essay across disciplines (trans: North C, Dack J). University of California Press, Oakland

FACTURE / SUSTAINMENT

		continuous			*impulse*	*iterative*		
		unpredictable	*nonexistent*	*formed*		*formed*	*nonexistent*	*unpredictable*
MASS	*tonal*	En	Hn	**N**	**N'**	N"	Zn	An
	complex	Ex	Hx	**X**	**X'**	X"	Zx	Ax
	varying	Ey	Tx/Tn	Y	Y	Y"	Zy	Ay
	unpredictable	E	T	W	Φ	K	P	A

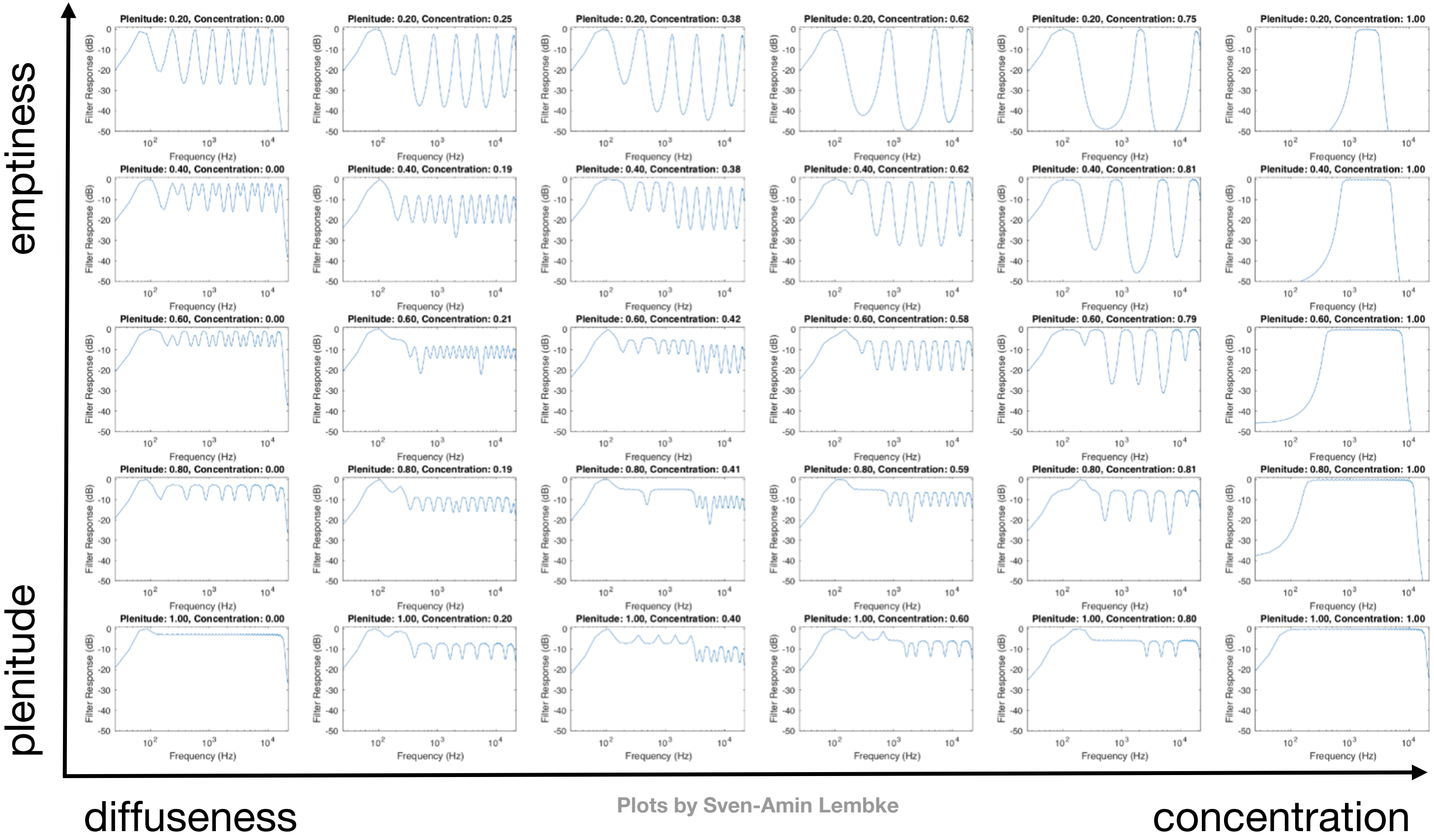
Mass: "the quality through which sound installs itself ... in the **pitch field**"

Can be **low–high** (location) and **thick–thin** (extensity)

Its **timbre** can be **dark–light** (location), **ample–narrow** (extensity), **rich–poor** (intensity)

Smalley’s “spectral space” (spectromorphology)

Smalley D (1997) Spectromorphology: explaining sound-shapes. Organised Sound 107–126



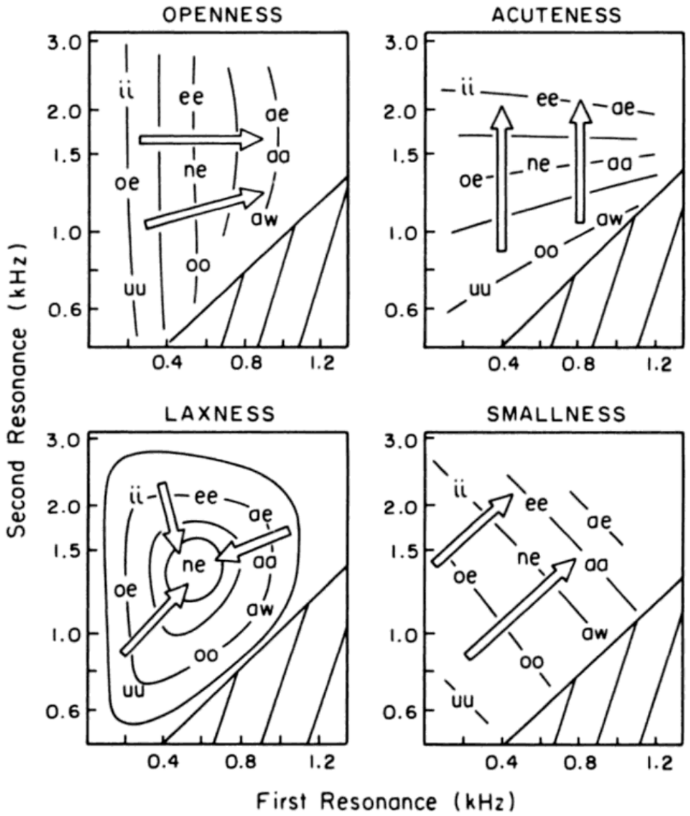
Plots by Sven-Amin Lembke

Slawson's dimensions of "sound color"

Slawson W (1985) Sound color. University of California Press, Berkeley

More open vowels have a higher first formant

Lax vowels have a lower total energy that is less spread out over the spectrum



Acuteness increases with increasing frequency of the second resonance

The lower the first and second formants are, the smaller the vowel sounds

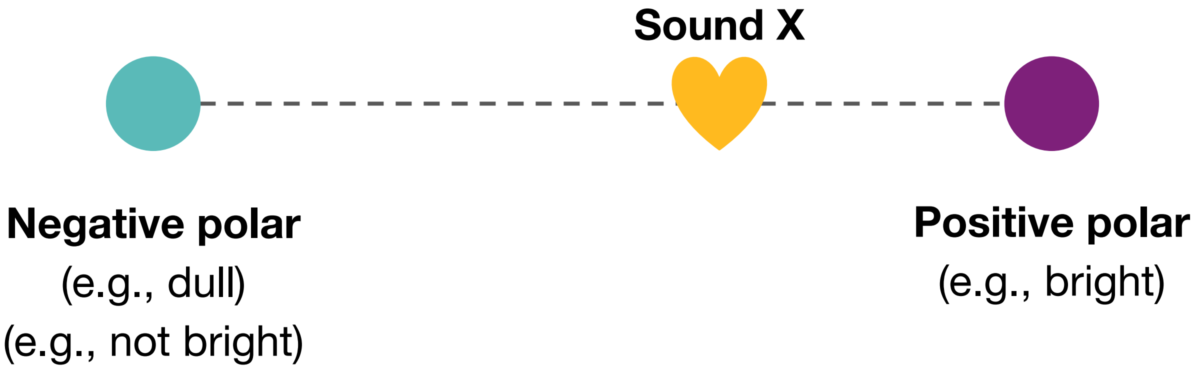
Early psychoacoustical ideas

Helmholtz (1877)	Simple Tones [...] have a very **soft**, pleasant sound, **free from all roughness** [...] and **dull at low frequencies**. [...] Musical Tones [...] are **rich** and splendid, while they are at the same time perfectly **sweet and soft** if the **higher upper partials are absent**. [...] If **only** the **unevenly numbered partials are present,** the quality of tone is **hollow** [...] **When partial tones higher than the 6th or 7th are very distinct,** the quality of tone is **cutting and rough**.
Stumpf (1890)	Most verbal attributes of timbre can be summarised by semantic proximity to **dark–bright** (dunkel–hell); **soft–rough** (weich–rauch); **full–empty** (voll–leer)
Lichte (1941)	**brightness**, **roughness**, and **fullness** (as defined by Helmholtz) form **independent attributes of sound** in addition to pitch and loudness

Helmholtz H (1877) English edition: Helmholtz H (1954) **On the sensations of tone as a physiological basis for the theory of music** (trans: Ellis AJ), 2nd edn. Dover, New York
Stumpf C (1890) Tonpsychologie (Psychology of sound), vol 2. Hirzel, Leipzig
Lichte WH (1941) Attributes of complex tones. J Exp Psychol 28:455–480

Modern empirical approaches

Osgood’s semantic differential (1952)



many semantic differentials → factor analysis → semantic space

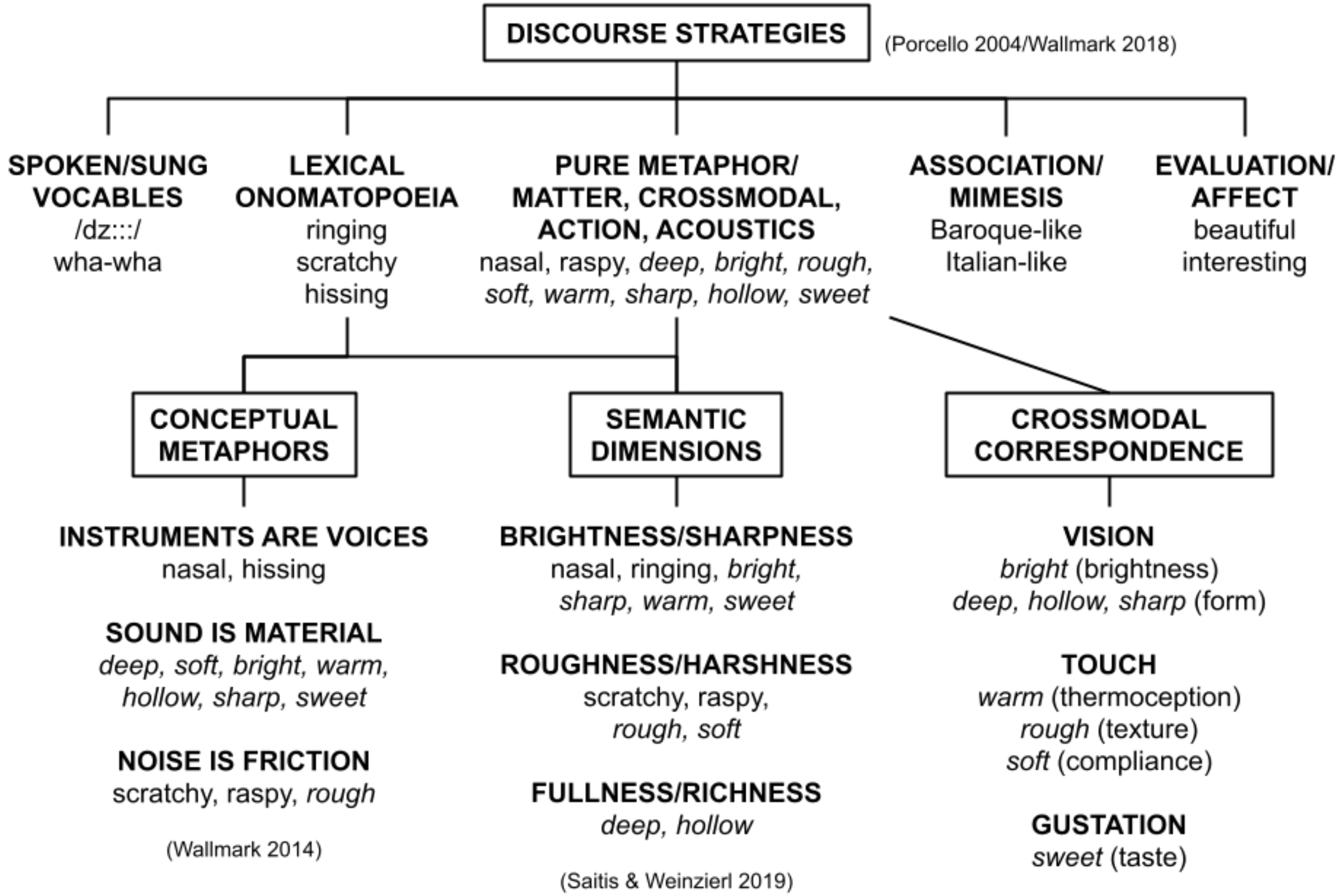
Osgood CE (1952) The nature and measurement of meaning. Psychol Bull 49:197–237

Modern empirical approaches

Von Bismarck (1974)	Used synthetic spectra that mimicked vowels and instruments **dull–sharp**; compact–scattered; full–empty; colorful–colorless
Zacharakis et al. (2014)	Used isolated notes from instruments and synths **bright/sharp** (luminance)**; rough/harsh** (texture)**; thick/light** (mass)
Reymore & Huron (2020)	**Interviews and rating tasks with "imagined" instrument sounds** rumbling/low/thick; soft/singing; watery/fluid; direct/loud; nasal/reedy; shrill/harsh/noisy; percussive; pure/clear; brassy/metallic; raspy/grainy; ringing/long decay; sparkling/brilliant; airy/breathy; resonant/vibrant; hollow; woody; muted/veiled; sustained/even; open; focused/compact

von Bismarck G (1974) Timbre of steady tones: a factorial investigation of its verbal attributes. Acustica 30:146–159
Zacharakis A, Pastiadis K, Reiss JD (2014) An interlanguage study of musical timbre semantic dimensions and their acoustic correlates. Music Percept 31:339–358
Reymore L & Huron D (2020) Using auditory imagery tasks to map the cognitive linguistic dimensions of musical instrument timbre qualia. Psychomusicology, 30(3), 124–144

Putting it together



Saitis C, Weinzierl S (2019) The semantics of timbre. In: Siedenburg K, Saitis C, McAdams S et al (eds) Timbre: Acoustics, Perception, and Cognition, Springer

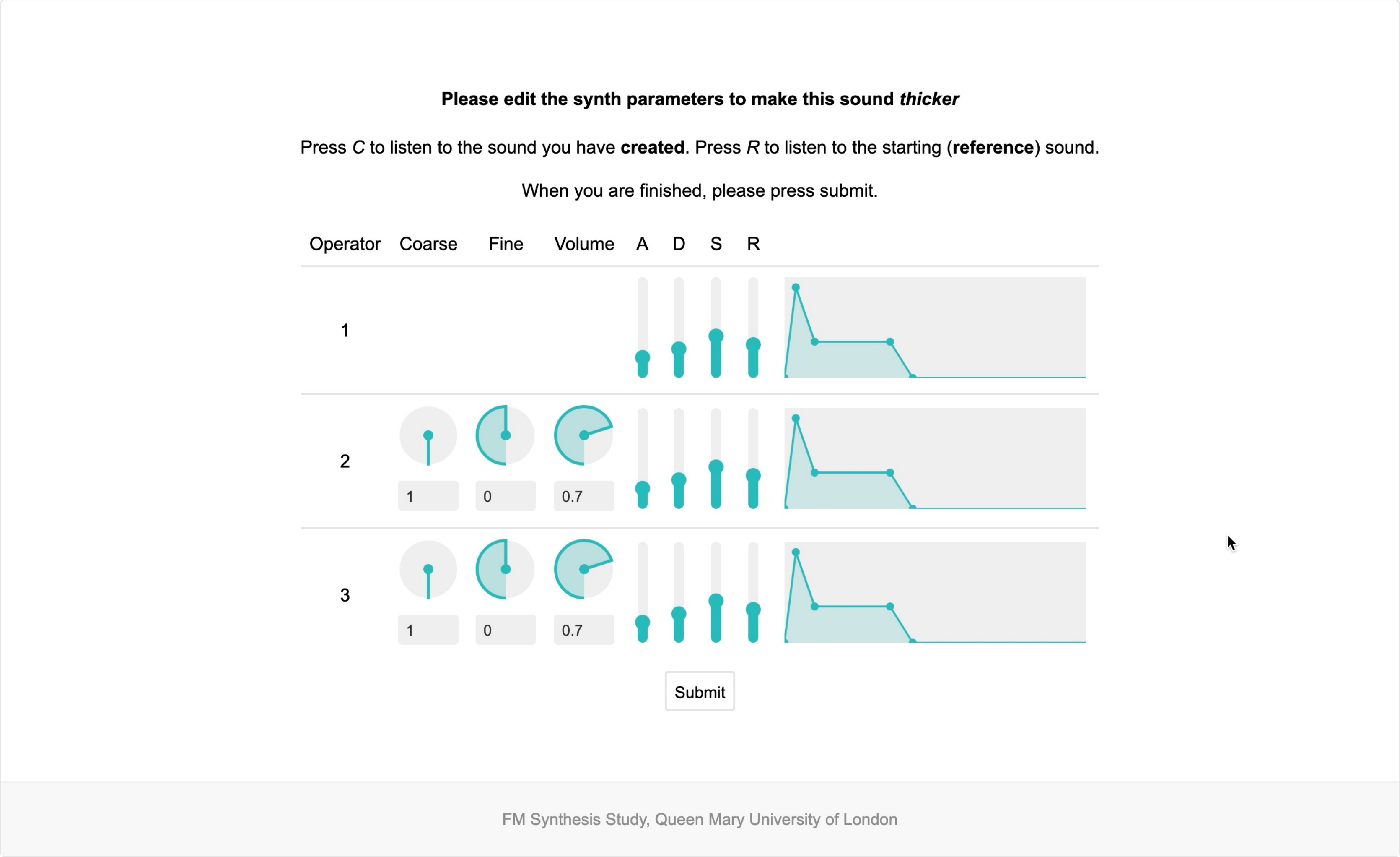
Beyond the orchestra: disembodied timbres

Our timbral world is increasingly populated by sounds with no discernible physical source, let’s call them *disembodied timbres*

How well do familiar-source semantic models generalise to more abstract and disembodied sounds?

The semantic differential helps understand how acoustical response modulates semantic associations, but not vice versa

How does the perceptual experience of timbre, through its semantic associations, relate to the creative process of sound synthesis and design?

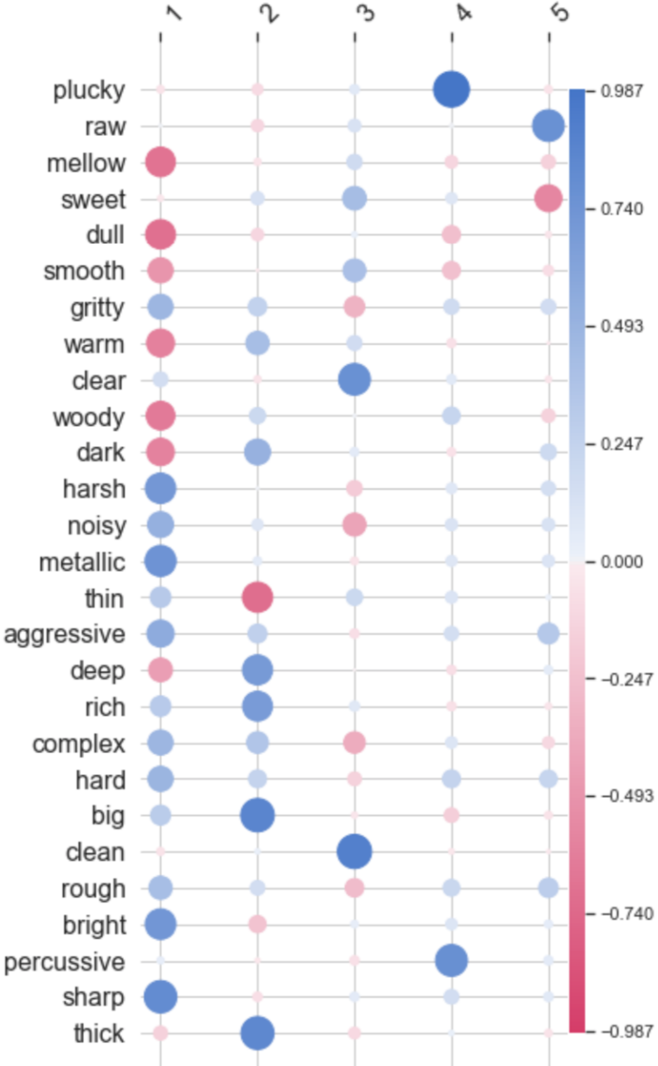

Please edit the synth parameters to make this sound *thicker*
Press *C* to listen to the sound you have **created**. Press *R* to listen to the starting (**reference**) sound.
When you are finished, please press submit.
Operator
Coarse
Fine
Volume
A
D
S
R
1
2
1
0
0.7
3
1
0
0.7
Submit
FM Synthesis Study, Queen Mary University of London

Study 1: prompted synthesis task

5 factors from Horn’s parallel analysis
74.36% of data variance explained
Moderate collinearity

Factor #1: sharp/bright/harsh
Factor #2: big/thick/deep
Factor #3: clear/clean
Factor #4: plucky/percussive
Factor #5: raw

Strong loadings for LTM-associated descriptors but also distinct structure in response to the specificities of FM signals



Hayes B, Saitis C, & Fazekas G (2022) Disembodied timbres: A study on semantically prompted FM synthesis. Journal of the Audio Engineering Society, 70(5), 373–391

Acoustic feature analysis

Table 4. Spearman rank correlation coefficients between semantic factors and acoustic feature principal components, as well as fundamental frequency.

	PC1 *Spectrotemporal (distribution) & spectral shape*	*PC2* *Temporal energy variation & spectral slope*	*PC3* *Spectrotemporal (flatness)*	*PC4* *Spectrotemporal (crest factor)*	*F0*
Factor 1 *(Sharpness)*	–.58***	–.37***	.49***	–.25***	–.01
Factor 2 *(Mass)*	.09	–.02	.09	.03	.08
Factor 3 *(Clarity)*	.29***	.17**	–.44***	.04	–.03
Factor 4 *(Percussiveness)*	–.24***	–.03	.31***	–.14*	–.02
Factor 5 *(Rawness)*	–.22***	–.10	.34***	–.10	–.05

* : $p < 0.05$; ** : $p < 0.01$; *** : $p < 0.001$

Only moderate correlations

Hayes B, Saitis C, & Fazekas G (2022) Disembodied timbres: A study on semantically prompted FM synthesis. Journal of the Audio Engineering Society, 70(5), 373–391

Semantic factors and FM parameters

	A1	D1	S1	R1	T2	V2	A2	D2	S2	R2	T3	V3	A3	D3	S3	R3
F1	−0.43***	−0.07	−0.05	−0.22***	0.58***	0.6***	−0.23***	−0.03	0	−0.12*	0.6***	0.55***	−0.26***	−0.02	0.06	−0.05
F2	0.13*	0.21***	0.31***	0.16**	−0.33***	0.06	0.15**	0.17**	0.11*	0.14**	−0.17**	0.02	0.19***	0.14**	0.15**	0.09
F3	0.25***	−0.02	−0.06	0.08	−0.2***	−0.42***	0.04	−0.12*	−0.03	0.01	−0.23***	−0.38***	0.09	−0.16**	−0.1	0
F4	−0.55***	−0.15**	−0.2***	−0.31***	0.34***	0.44***	−0.3***	−0.08	−0.08	−0.14**	0.37***	0.41***	−0.4***	−0.09	−0.06	−0.09
F5	−0.36***	0.04	0	−0.13*	0.23***	0.44***	−0.12*	0.05	0	−0.06	0.31***	0.42***	−0.2***	0.12*	0.03	−0.03

Increasing “sharpness”:

faster amplitude envelopes

wider spacing between sidebands

more energy distributed to sidebands

shorter sideband energy envelope

Increasing “mass”:

slower amplitude envelopes with more sustain

narrower spacing between sidebands

no change to sideband energy distribution

slower sideband energy envelopes with more sustain

Hayes B, Saitis C, & Fazekas G (2022) Disembodied timbres: A study on semantically prompted FM synthesis. Journal of the Audio Engineering Society, 70(5), 373–391

Study 2: perceptual and semantic scaling

12 FM sounds created in prompted synthesis study

Selected via k-means clustering of acoustic features

Synthesised from stored parameters at 1.25s length

Equalised in loudness using LUFS (ITU-R BS.1770-4 2015)

Collected dissimilarity and semantic ratings

2x2 *posterior* subgroups: musicality (GoldMSI); synthesis experience (self-reported)

Hayes B, Saitis C, & Fazekas G (2021) Perceptual and semantic scaling of FM synthesis timbres: Common dimensions and the role of expertise. ICMPC

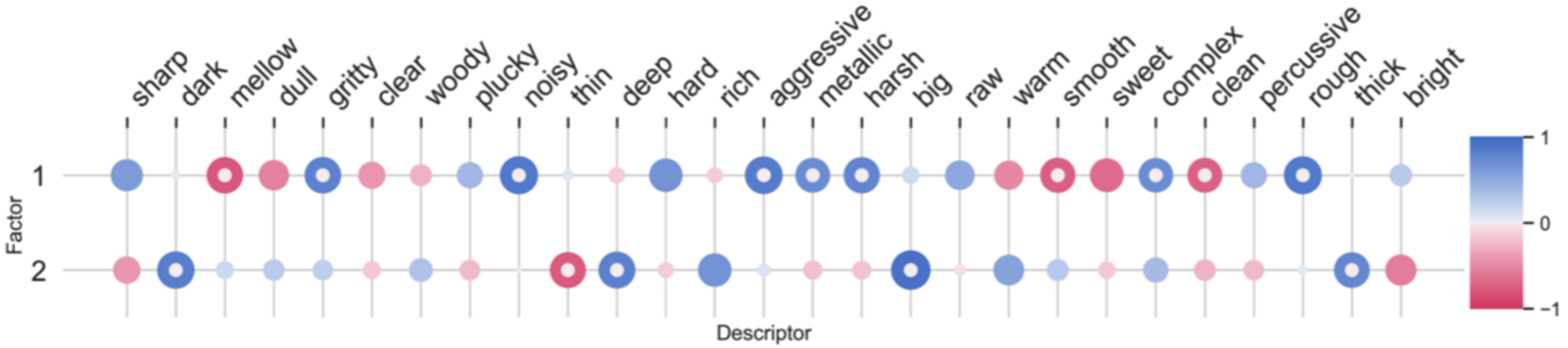
Study 2: perceptual and semantic scaling

2 factors from Horn's parallel analysis
Loadings > 0.7 shown with white dot

Factor #1: texture
Factor #2: mass / luminance (negative)

Differences between non-experts and experts in perceptual organisation of stimuli

"Mass" correlates strongly with first MDS dimension



Hayes B, Saitis C, & Fazekas G (2021) Perceptual and semantic scaling of FM synthesis timbres: Common dimensions and the role of expertise. ICMPC

Disembodied timbres: summary

Where do percussiveness, rawness, clarity come from?

Percussiveness congruent with Zacharakis & Pastiadis (2016)

Rawness & clarity — FM specificities? Textural nuance?

Difference between 5-factor and 2-factor models?

Priming effect of synthesis?

Larger (+ noisier) dataset?

Important variance missing from 2-factor dataset? (k = 12)

Effect of experience on organisation of perceptual space

“Mass” as first dimension — shared by all subgroups

Zacharakis A & Pastiadis K (2016) Revisiting the luminance-texture-mass model for musical timbre semantics: A confirmatory approach and perspectives of extension. Journal of the Audio Engineering Society, 64(9), 636-645

Disembodied timbres: outcomes

5 factor space with evidence for percussiveness dimension and FM specificities

Classical perceptual timbre spaces with evidence for effect of experience

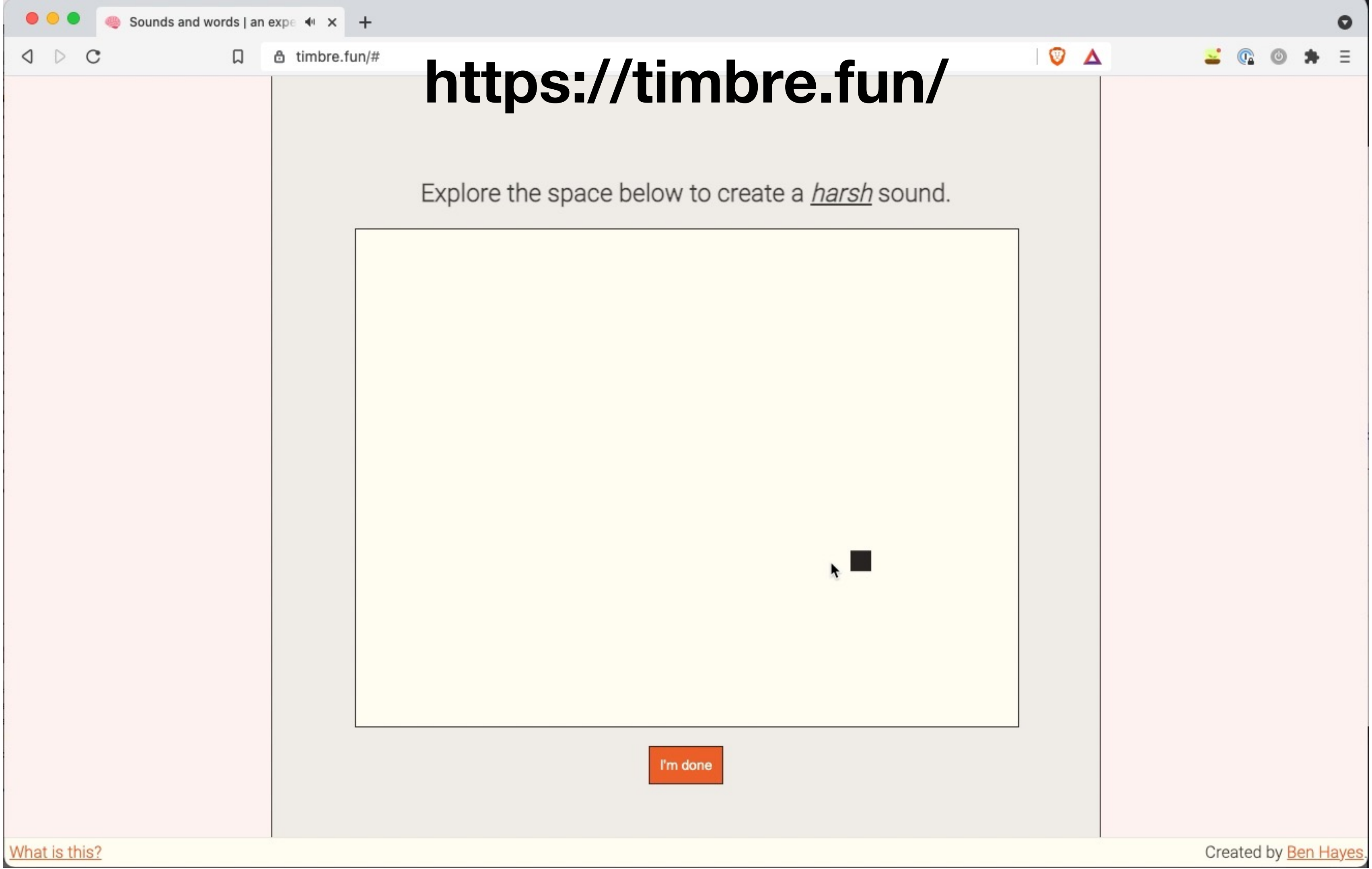
Evidence also for cross-group salience of “mass” in perception of FM sounds

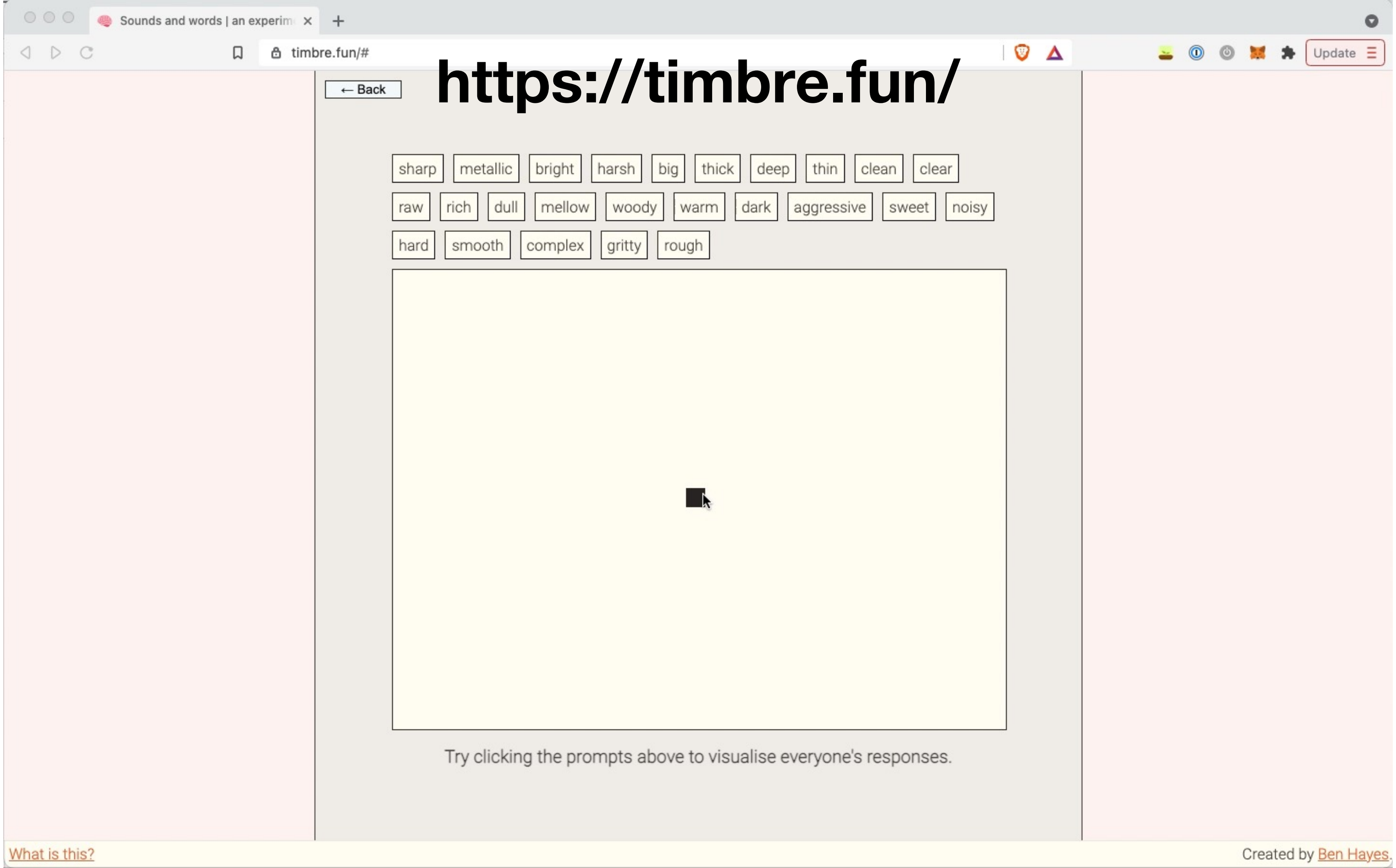
2 factor semantic space supporting LTM for FM sounds

Novel experimental paradigm for studying semantic associations of timbre

Semantically tagged dataset of FM synthesiser patches

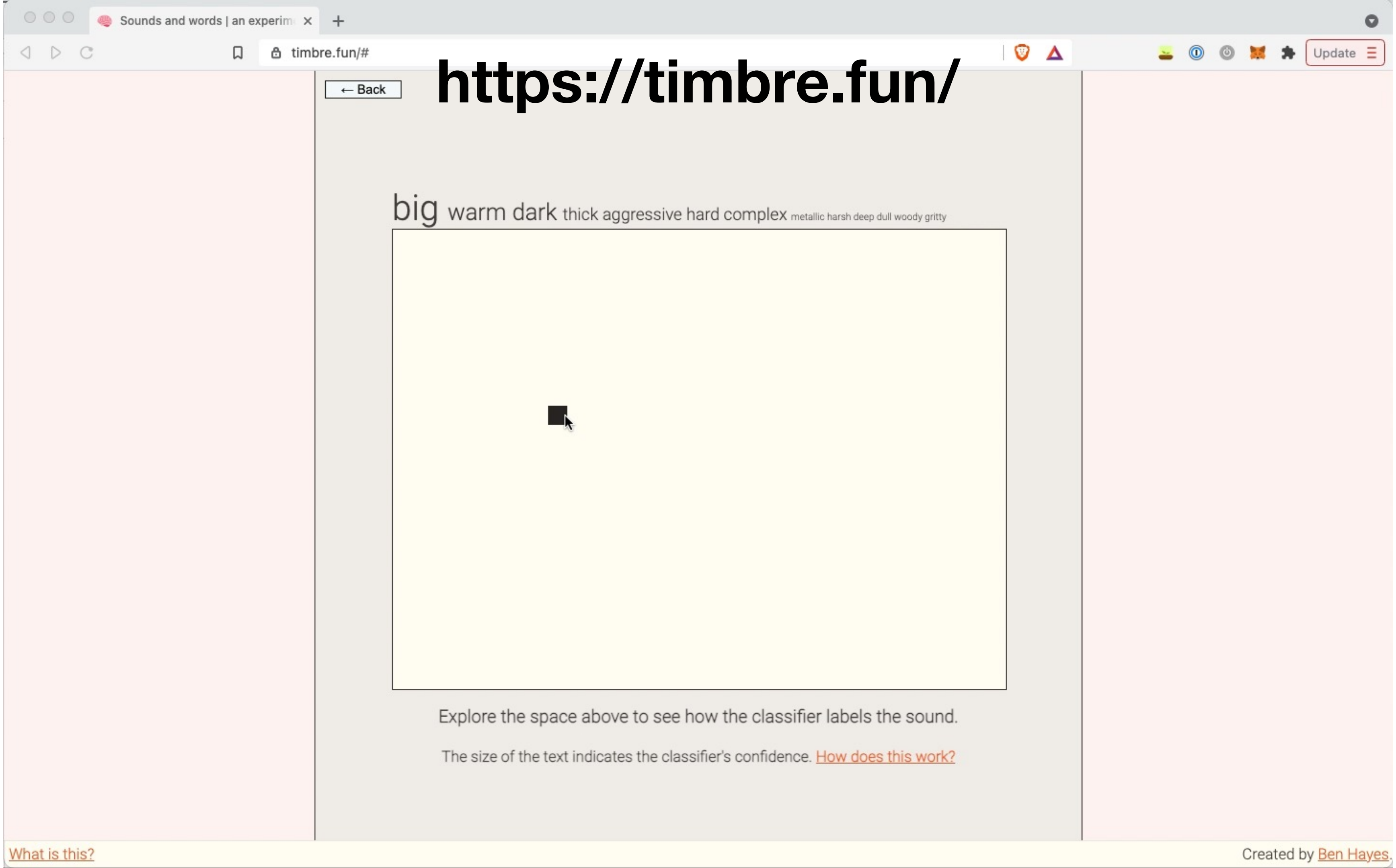
https://timbre.fun/



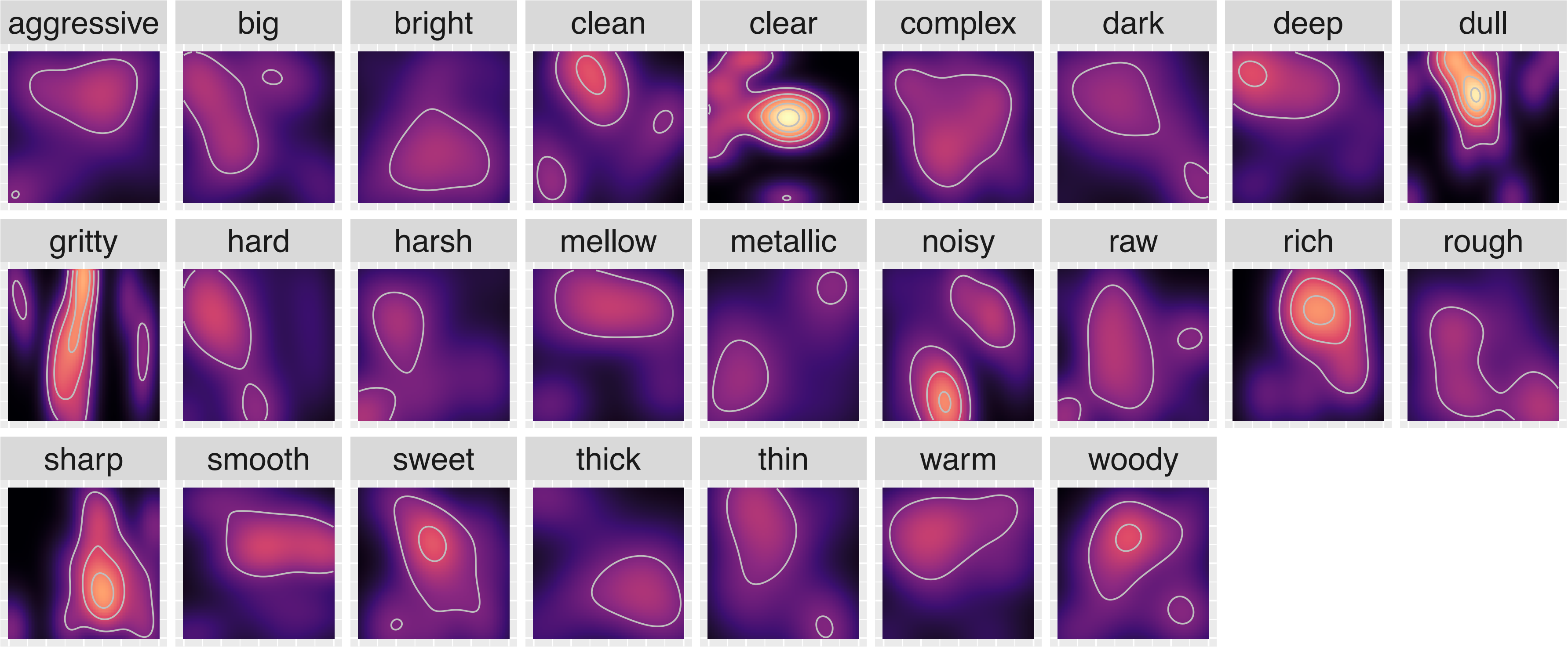


Sounds and words | an experim
timbre.fun/#
Update
https://timbre.fun/
← Back
sharp
metallic
bright
harsh
big
thick
deep
thin
clean
clear
raw
rich
dull
mellow
woody
warm
dark
aggressive
sweet
noisy
hard
smooth
complex
gritty
rough
Try clicking the prompts above to visualise everyone's responses.
What is this?
Created by Ben Hayes.

https://timbre.fun/

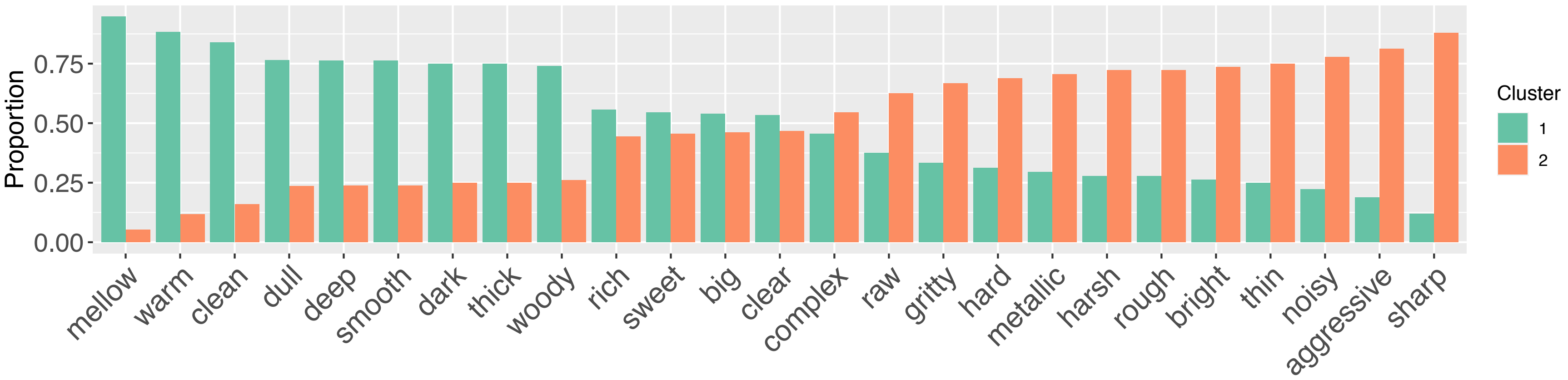


timbre.fun: exploratory analysis



Hayes B, Saitis C, & Fazekas G (2023) timbre.fun: A gamified interactive system for crowdsourcing a timbre semantic vocabulary. ICA

timbre.fun: exploratory analysis



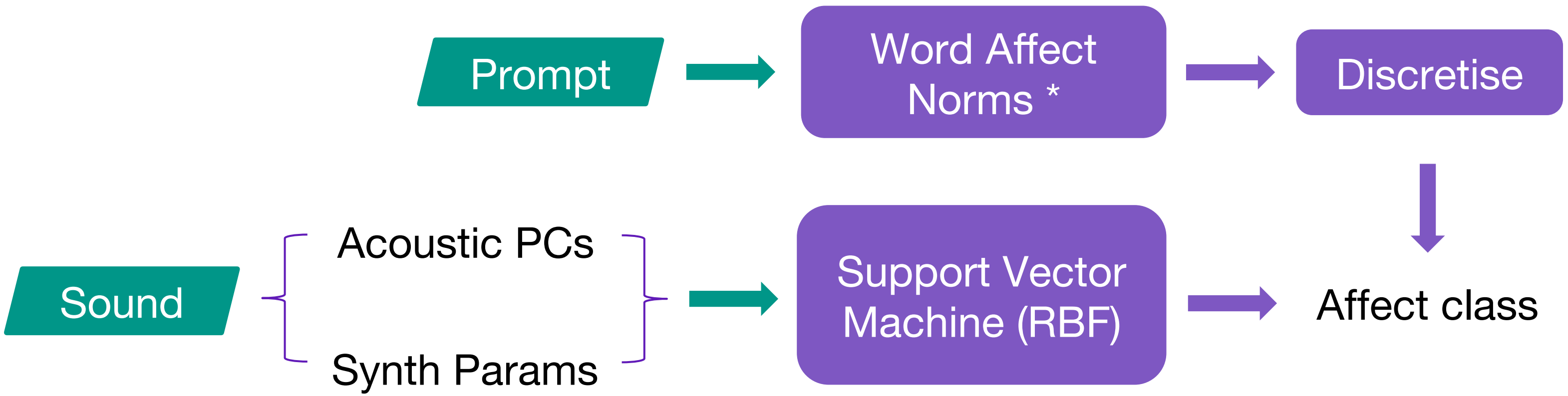
PCA and k-means clustering on audio features revealed two distinct clusters

cluster 1: more energy in low frequencies, and clear peaks in the spectrum
cluster 2: a flatter spectrum with more high frequency energy

These groupings very closely match correlations between semantic factors and acoustical principal components in studies 1 & 2

Hayes B, Saitis C, & Fazekas G (2023) timbre.fun: A gamified interactive system for crowdsourcing a timbre semantic vocabulary. ICA

timbre.fun: exploratory analysis



the model achieved particularly good performance when predicting word arousal

SVM Test Accuracy (%)

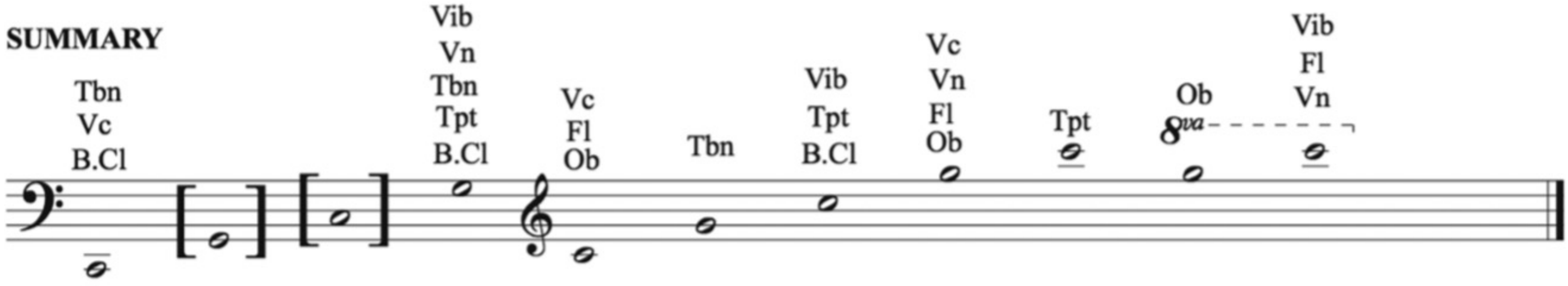
Dimension	Synth. Params	Acoustic PCs
Valence	61.3	62.4
Arousal	73.1***	71.0***
Dominance	53.8	62.4*

* **Warriner, Kuperman, & Brysbaert, 'Norms of valence, arousal, and dominance for 13,915 English lemmas'**, *Behav Res* 45 1191–1207

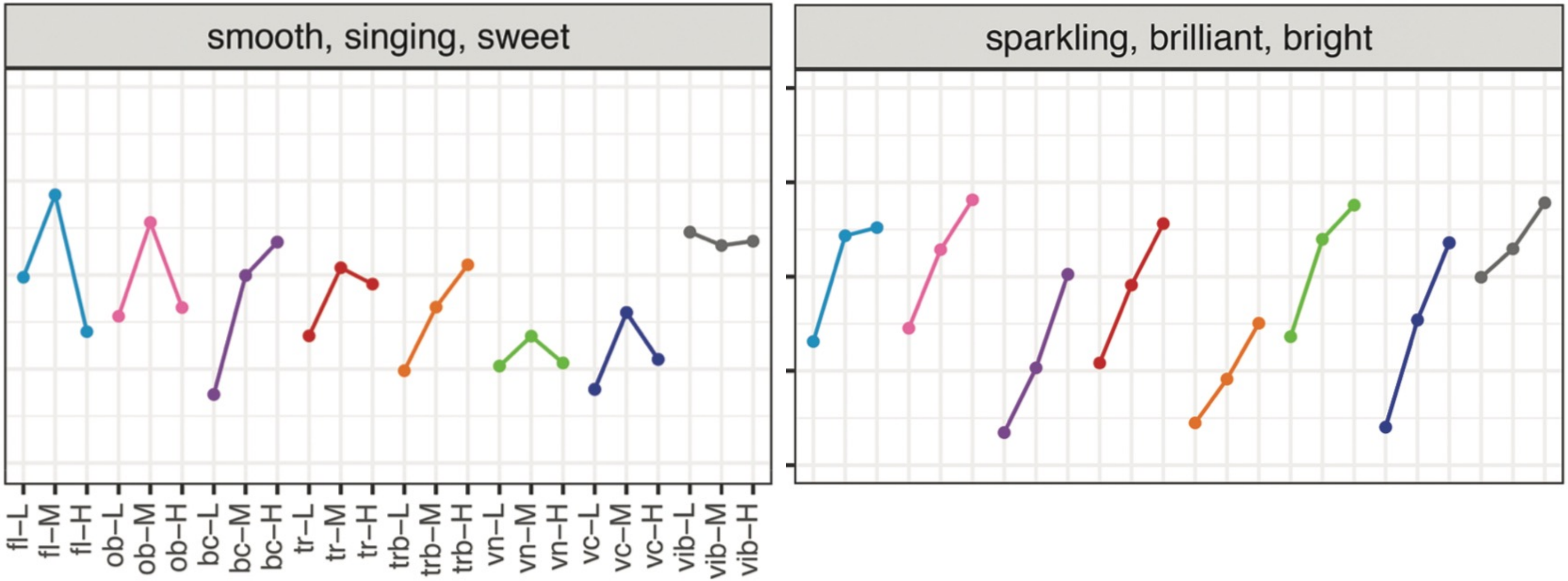
Hayes B, Saitis C, & Fazekas G (2023) timbre.fun: A gamified interactive system for crowdsourcing a timbre semantic vocabulary. ICA

Semantic pitch-timbre interactions

8 acoustic instruments
3 pitch heights (low, mid, high register)
varied across instruments
20 semantic scales (Reymore & Huron, 2020)
400+ listeners recruited via Prolific
About 80% non-musicians



Semantic pitch-timbre interactions



Semantic pitch-timbre interactions

	Marginal R^2	
Semantic Scale	Pitch height only	Register only
deep, thick, heavy	.54	.29
sparkling, brilliant, bright	.29	.16
shrill, harsh, noisy	.20	.12
raspy, grainy, gravelly	.20	.08
projecting, commanding, powerful	.13	.05
woody	.12	.05
pure, clear, clean	.09	.05
percussive	.09	.05
smooth, singing, sweet	.08	.04
hollow	.08	.04
muted/veiled	.06	.03
ringing, long decay	.06	.02
watery/fluid	.05	.02

Timbre Semantic Associations Vary Both Between and Within Instruments: An Empirical Study Incorporating Register and Pitch Height

Lindsey Reymore
Arizona State University

Jason Noble
University of Montreal, Montreal, Canada

Charalampos Saitis
Queen Mary University of London, London, United Kingdom

Caroline Traube
University of Montreal, Montreal, Canada

Zachary Wallmark
University of Oregon

clarify the influence of both instrument and relative register (and pitch height) on common timbre semantic associations.

Received: February 5, 2022, accepted October 13, 2022.

Key words: timbre, pitch, cognition, language, meaning

How do listeners associate musical sound qualities with extramusical concepts and descriptions? Researchers and musicians are increasingly interested in this question (Saitis & Weinzierl, 2019), with a particular focus on semantic associations related to timbre, or timbre semantics, which refer to verbal attributes describing timbral qual-

TIMBRE
THESSALONIKI 2023

The 3rd International Conference on Timbre

10–12 July 2023

Timbre and Orchestration Summer School

8–12 July 2023

A synergy with

ACTOR

ANALYSIS, CREATION + TEACHING OF ORCHESTRATION

Queen Mary
University of London

centre for digital music

Metaphors we listen with

Semantic (conceptual?) spaces of timbre

Charalampos Saitis

c.saitis@qmul.ac.uk