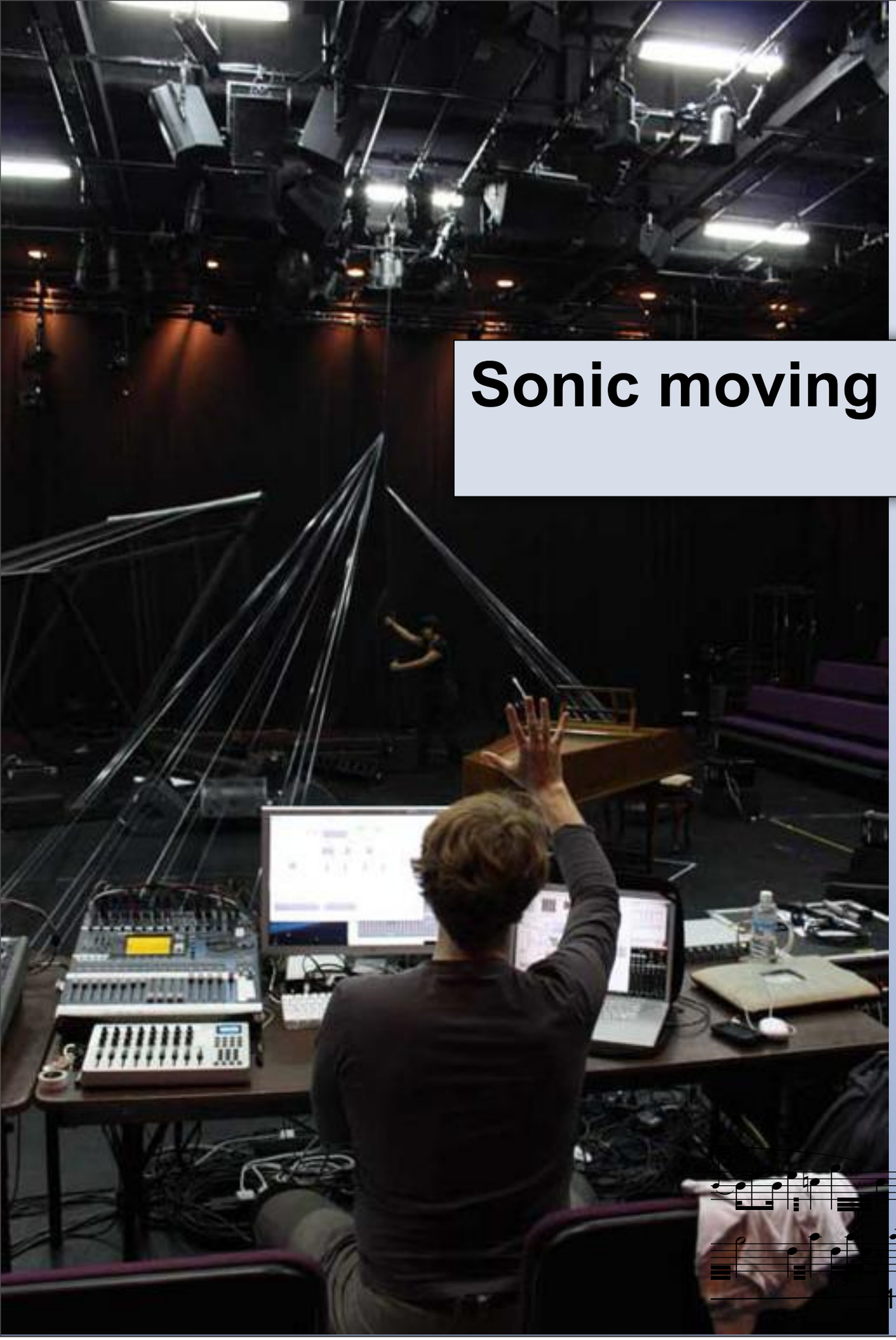


Sonic moving images – how sounds move us

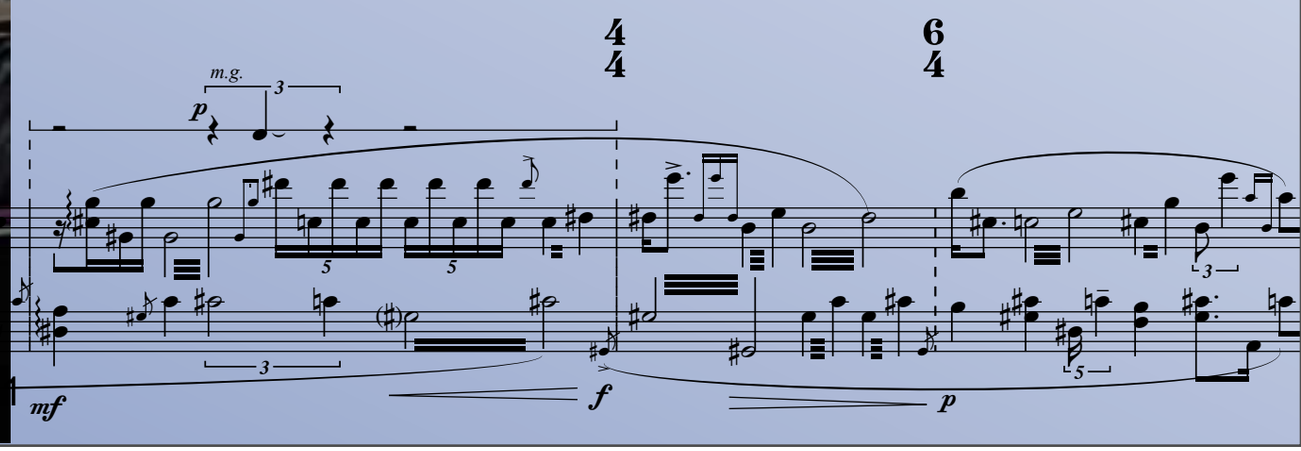
(and how we move sounds)

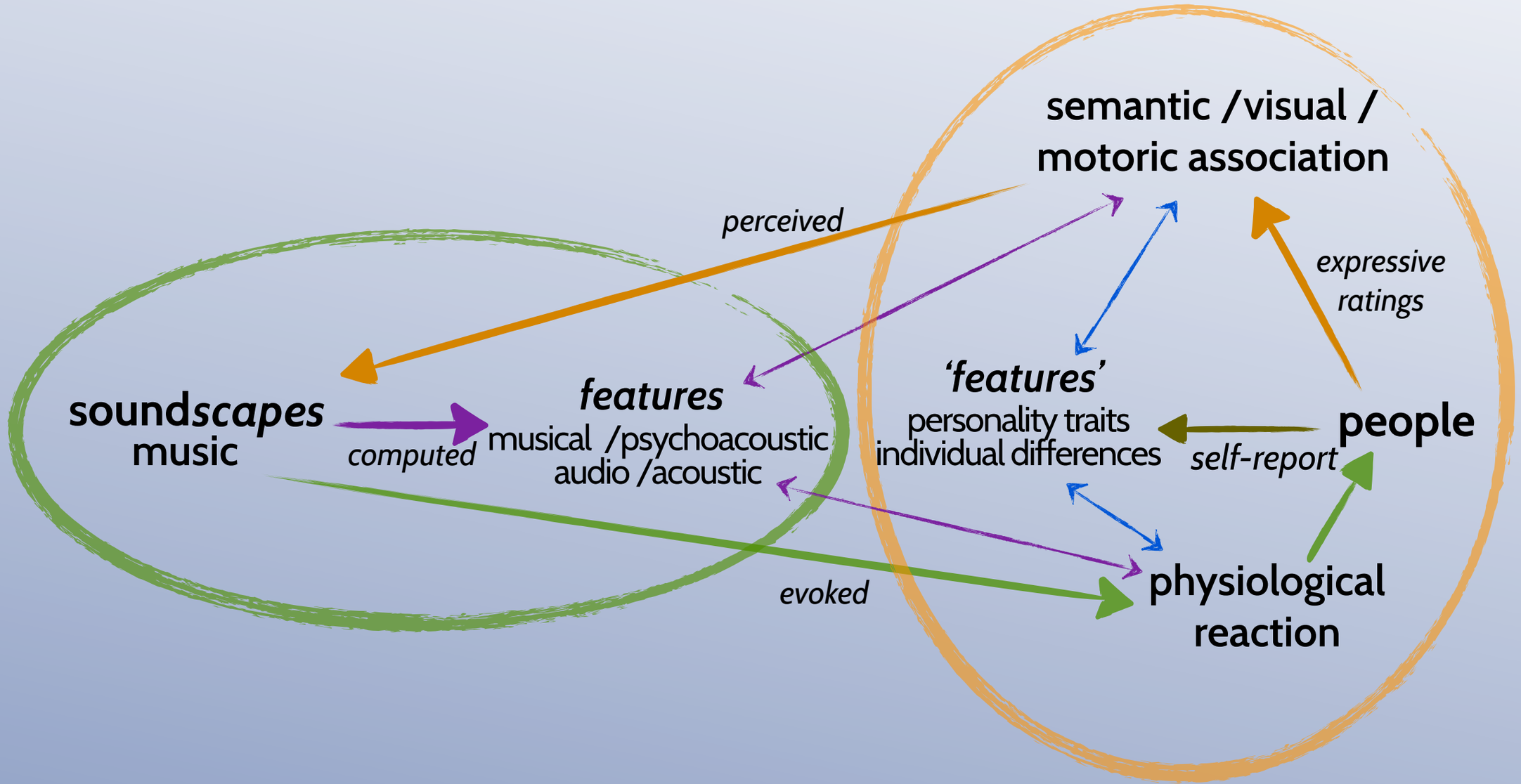
PerMagnus Lindborg, PhD

Si17 Symposium on Sound and Movement

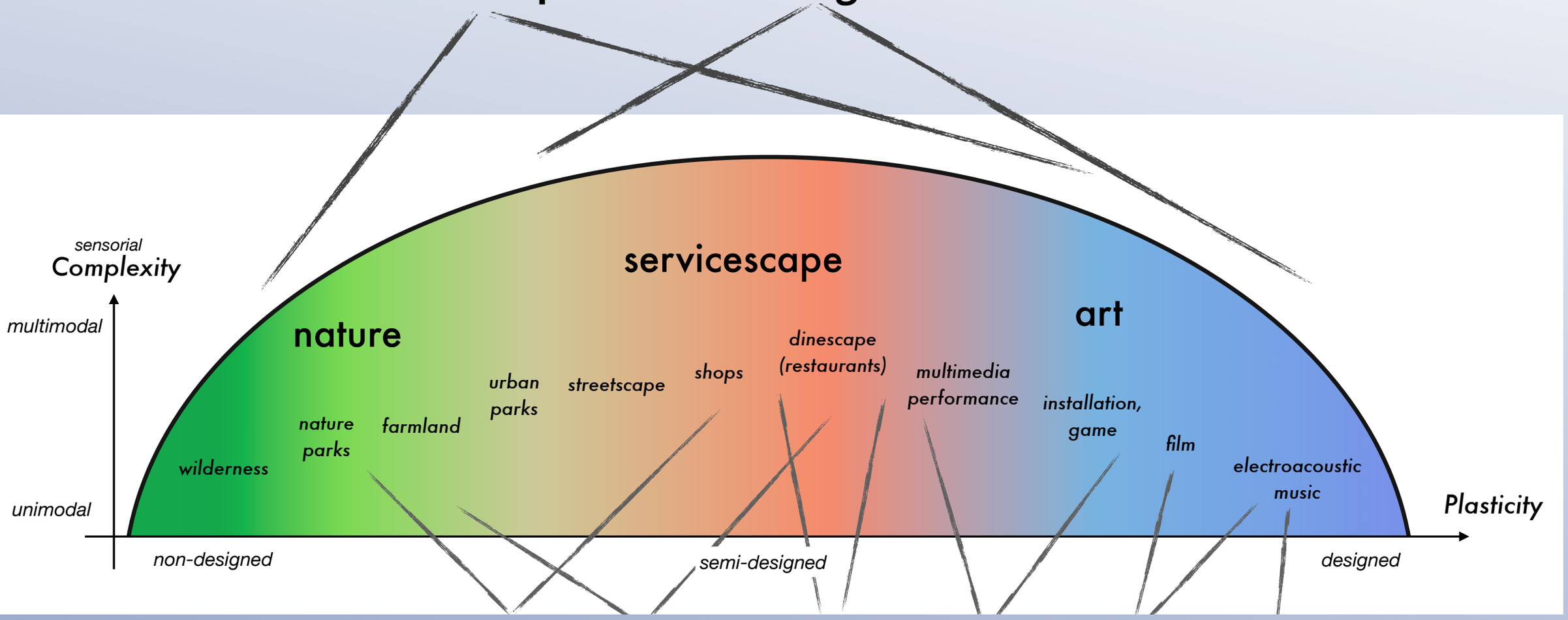
Soundislands Festival

8 March 2017




semantic /visual /
motoric association
perceived
expressive
ratings
'features'
personality traits
individual differences
people
self-report
soundscapes
music
computed
features
musical /psychoacoustic
audio /acoustic
evoked
physiological
reaction

Sound Perception *and Design* in Multimodal Environments



Sound Perception *and Design* in Multimodal Environments

Sound Perception *and Design* in Multimodal Environments

Perception

Information processing stages (Schnupp et al. 2011; Mesulam 1998)

Sensation physio-neurological, mainly reflexive (Moore & Linthicum 2011).
brain stem = ancient brain structure, subserves auditory perception
crucial to survival, "active 24/7"

Perception neurological
mediates between sensation and cognition (cf. afferent & efferent innervation)

Cognition psychoacoustic models (Fastl & Zwicker 2007)
neuro-psychological
"computation in mentalese" (Fodor 1975)

Affect

auditory cognition, e.g. BRECVEMA (Juslin & Västfjäll 2008; Juslin 2013)
all evaluative mental states (emotion, mood, preference… Juslin & Västfjäll 2008).

Emotion affective states = valenced (Osgood et al. 1957; Mehrabian & Russell 1974; Russell 1979)
relatively brief duration (cf. mood)

Appraisal distinction induced vs. perceived emotion ≈ blurred (Gabrielsson & Lindström 2010)
most emotions encountered in everyday listening, especially music (Juslin 2013)
Swedish Soundscape Quality Protocol (Axelsson, Nilsson & Berglund 2010; Axelsson 2011)

Individual differences broad personality traits (John & Srivastava 1999; Russell & Mehrabian 1977)
narrow construct: noise sensitivity (Weinstein 1978; Belojevic et al. 2012)

BRECVEMA

Brain stem reflex

Rhythmic entrainment

Evaluative conditioning

Contagion

Visual imagery

Episodic memory

Musical expectancy

+ Aesthetic judgement

Juslin, P. N., & Västfjäll, D. (2008). Emotional responses to music: The need to consider underlying mechanisms. Behavioral and brain sciences, 31(05), 559-575.

Juslin, P. N. (2013). "From everyday emotions to aesthetic emotions: towards a unified theory of musical emotions". *Physics of life reviews*, *10*(3), 235-266.

Mechanisms of emotion induction are regarded as *information-processing devices at different levels of the brain, which utilize distinct types of information to guide future behavior*

mechanisms ⟷ **mental representations**

physical state that conveys some meaning or information about the state of the world within a specific processing system

emotions… are embodied phenomena that serve to guide action
continuous **interaction** between the perceiver and the ecology
sensori-motoric links… essential – see *Action-Sound Couplings*

Juslin, P. N. (2013). "From everyday emotions to aesthetic emotions: towards a unified theory of musical emotions". *Physics of life reviews*, *10*(3), 235-266.

BRECVEMA

Brain stem reflex

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Evaluative conditioning

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Musical expectancy

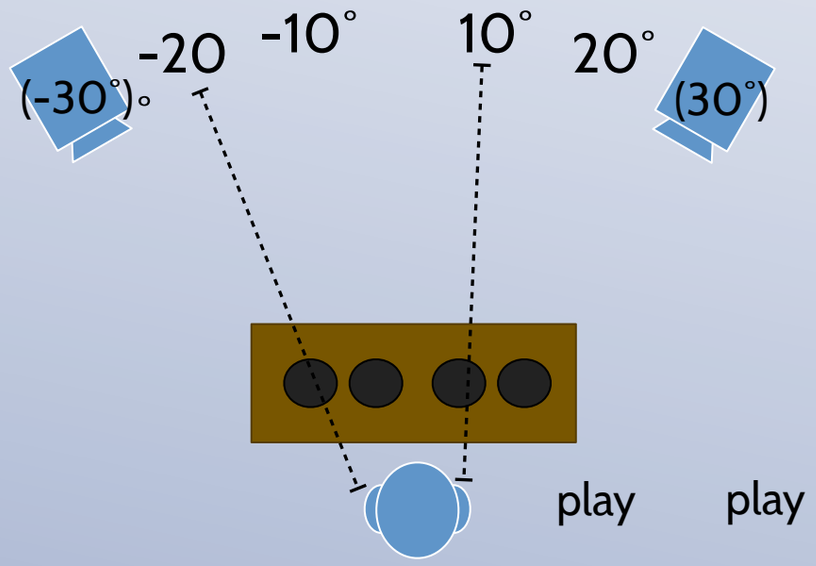
Aesthetic judgement

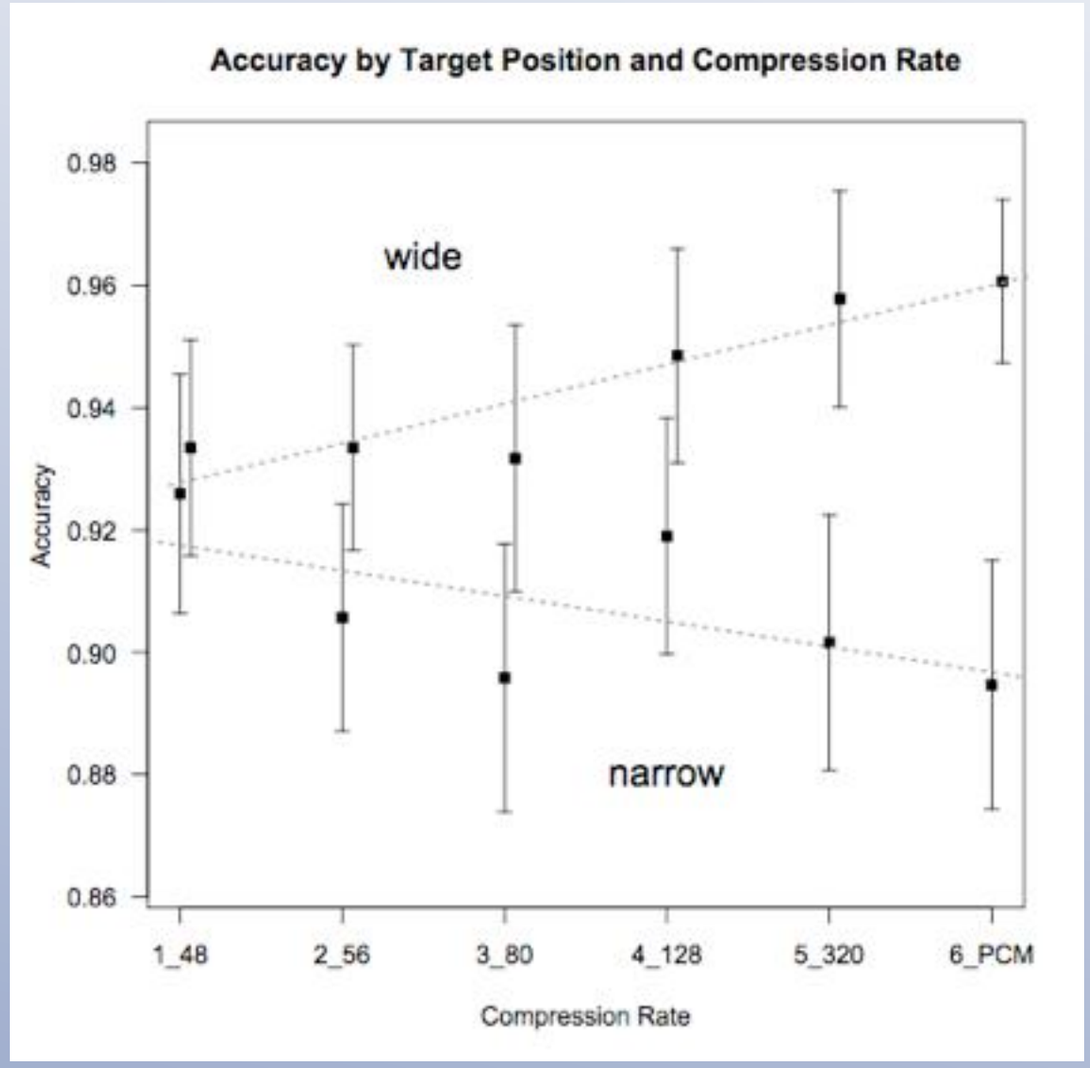
Brain stem reflex… fundamental acoustic characteristics of the music are taken by the brain stem to signal a potentially important and urgent event that needs attention… sudden, loud, or dissonant, or that feature accelerating patterns.

Juslin, P. N. (2013). “From everyday emotions to aesthetic emotions: towards a unified theory of musical emotions”. *Physics of life reviews*, *10*(3), 235-266.

Lindborg PM & Kwan NAK (2015, May). "Audio Quality Moderates Localisation Accuracy: Two Distinct Perceptual Effects?". *AES Conv.*

Does audio quality affect the perceived auditory space?





Crossmodal effect

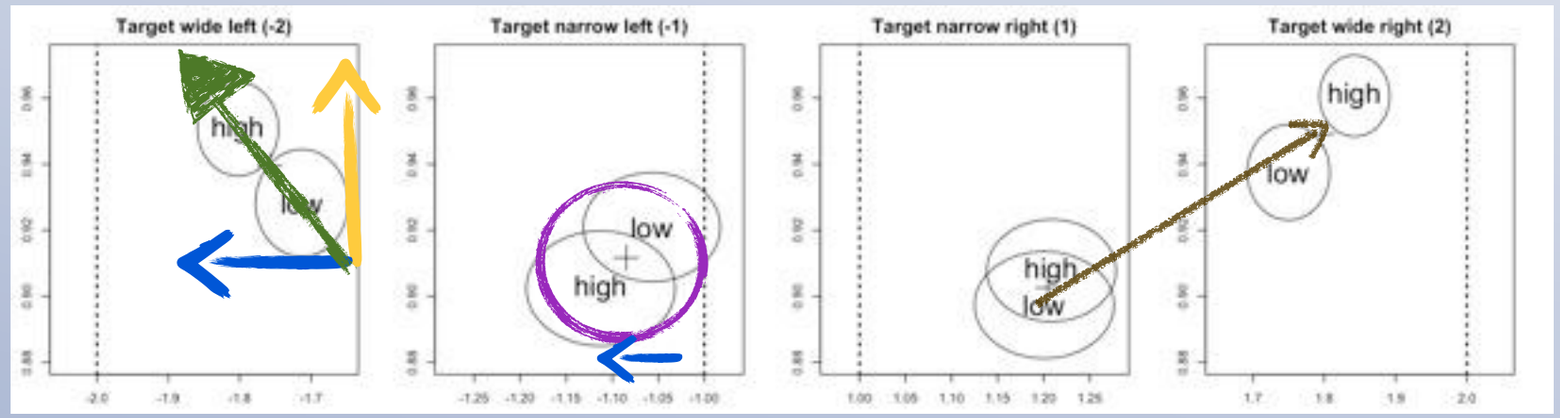
audio 'clarity' → space

higher audio quality { enables *higher localisation accuracy*
causes a *widening of the soundstage*

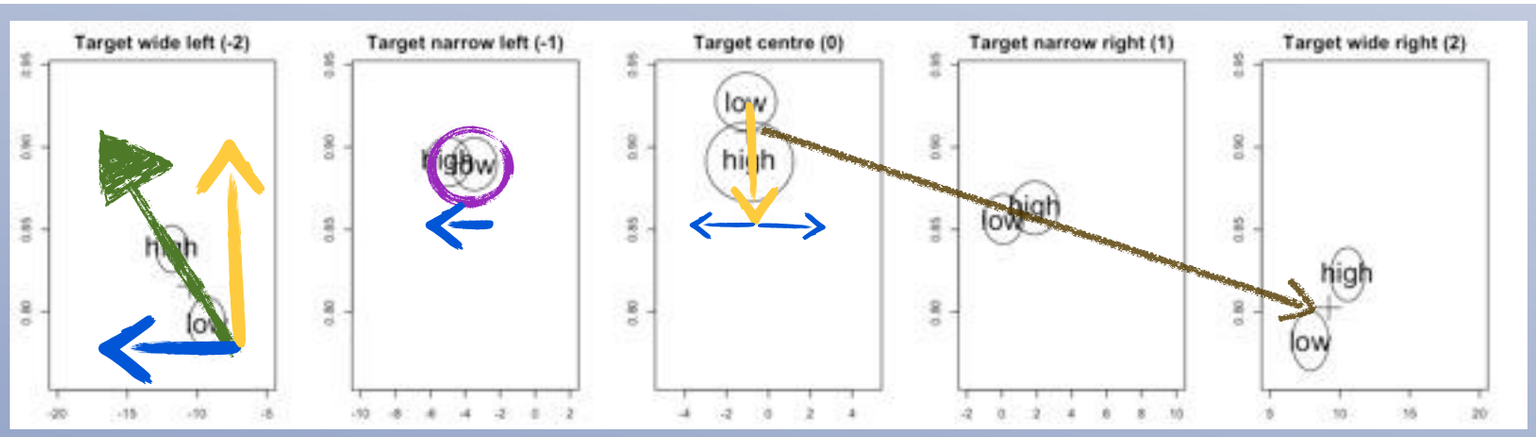
Lindborg PM (in preparation). "Audio quality influences perceived spatial image"

What aspects of audio quality provoke the image widening effect?

Exp. 1



Exp. 2



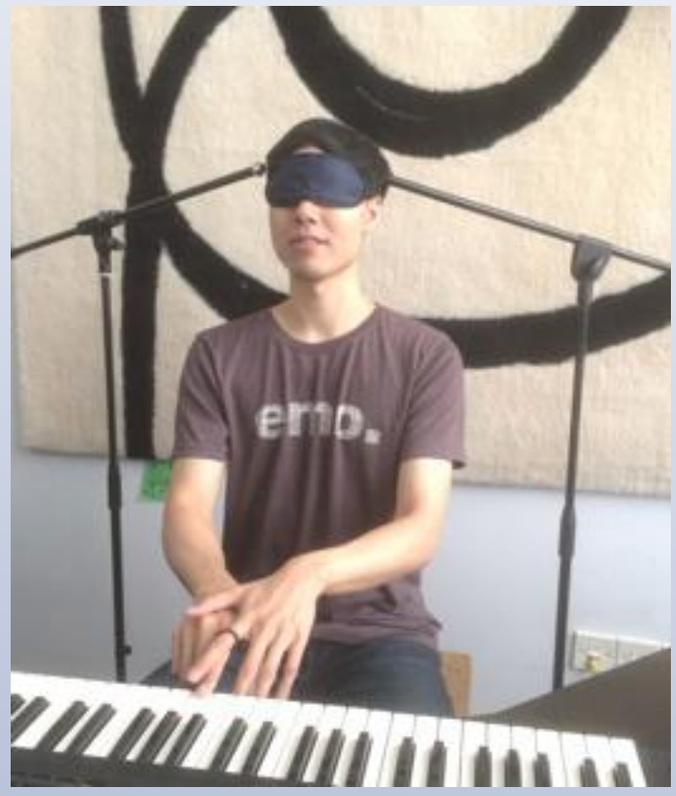


Fig. Participant in source localisation experiment 2. Note blindfold, head fixation, and joining of left-right indeces.

BRECVEMA

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Aesthetic judgement

Rhythmic entrainment… powerful, external rhythm in the music influences some internal bodily rhythm of the listener (e.g., heart rate), such that the latter rhythm adjusts toward and eventually 'locks in' to a common periodicity.

Juslin, P. N. (2013). "From everyday emotions to aesthetic emotions: towards a unified theory of musical emotions". *Physics of life reviews*, *10*(3), 235-266.

Lindborg PM (2013, June). "Physiological measures regress onto acoustic and perceptual features of soundscapes". *ICME3.*

How is the body affected by the sonic environment?

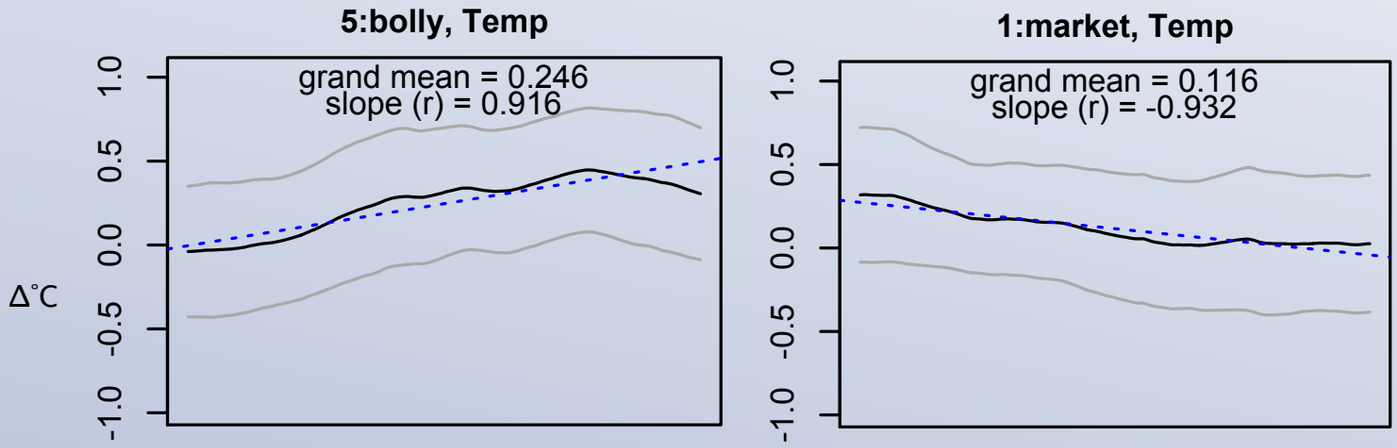
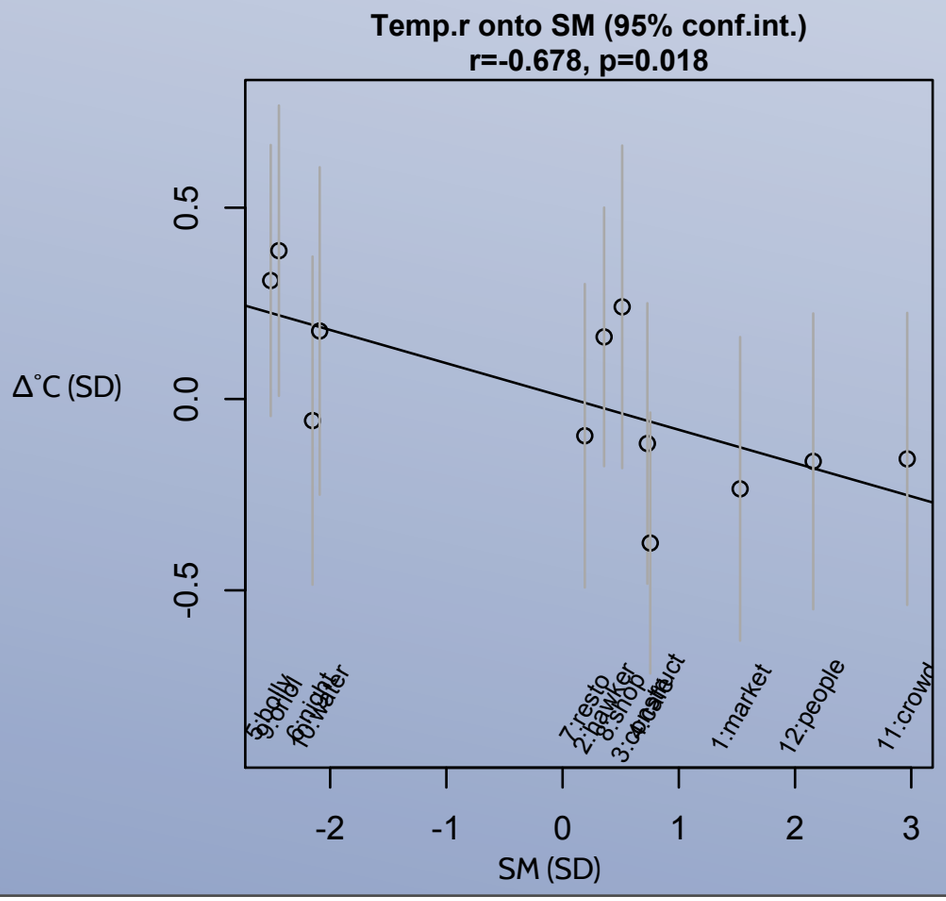


Fig. A blind-folded participant in the 3D sound installation listening to reproductions of Ambisonic recordings. Note sensors and "backpack" with wireless transmitter.



Sensation / involuntary reaction

Analysis revealed relationships between audio features and Autonomic Nervous System activation.

Example: SoundMass (≈ loudness) caused change in Peripheral Temperature.

BRECVEMA

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Aesthetic judgement

Evaluative conditioning (EC)… stimulus has often been paired with other positive or negative stimuli – i.e. statistically salient over time

Juslin, P. N. (2013). “From everyday emotions to aesthetic emotions: towards a unified theory of musical emotions”. *Physics of life reviews*, *10*(3), 235-266.

Proceedings of the 3rd International Conference on Music & Emotion (ICME3), Jyväskylä, Finland, 11th - 15th June 2013. Geoff Luck & Olivier Brabant (Eds.)

HOW MUCH DOES EARPHONE QUALITY MATTER WHILE LISTENING TO MUSIC ON BUSES AND TRAINS?

Miracle J.Y.J. Lim[*], PerMagnus Lindborg[†]

[*]Information Engineering & Media, Nanyang Technological University, Singapore
[†]School of Art Design Media, Nanyang Technological University, Singapore
miraclejoseph.lim@gmail.com

Abstract

We report results from an investigation into the relationships between acoustic performance, price, and perceived quality of earphones. In Singapore today, the most common situation where people listen to music is while commuting, however such environments have generally high ambient noise levels. A survey (N=94) of listener habits on buses and trains was conducted. Results showed that people use a wide range of earphones, both in terms of price and measurable acoustic performance. Five typical earphone models were identified and employed in a perceptual experiment (N=15). Volunteers rated various aspects of earphone quality while listening to music under two conditions: studio silence and a reproduced commuter environment. Results showed that participants displayed a strong preference towards in-ear earphones and this can be attributed to these having better *acoustic isolation* than on-ear earphones. People tend to describe the music listening experiences in terms of sonic clarity and noise isolation. We believe that these results can inform development of an ecologically valid model of how noisy environments affect people's perception of audio quality, and through that, of music experience. Such a model could inform consumers as well as manufacturers.

Keywords: earphones, sound quality, perception

Design of an Interactive Earphone Simulator and Results from a Perceptual Experiment

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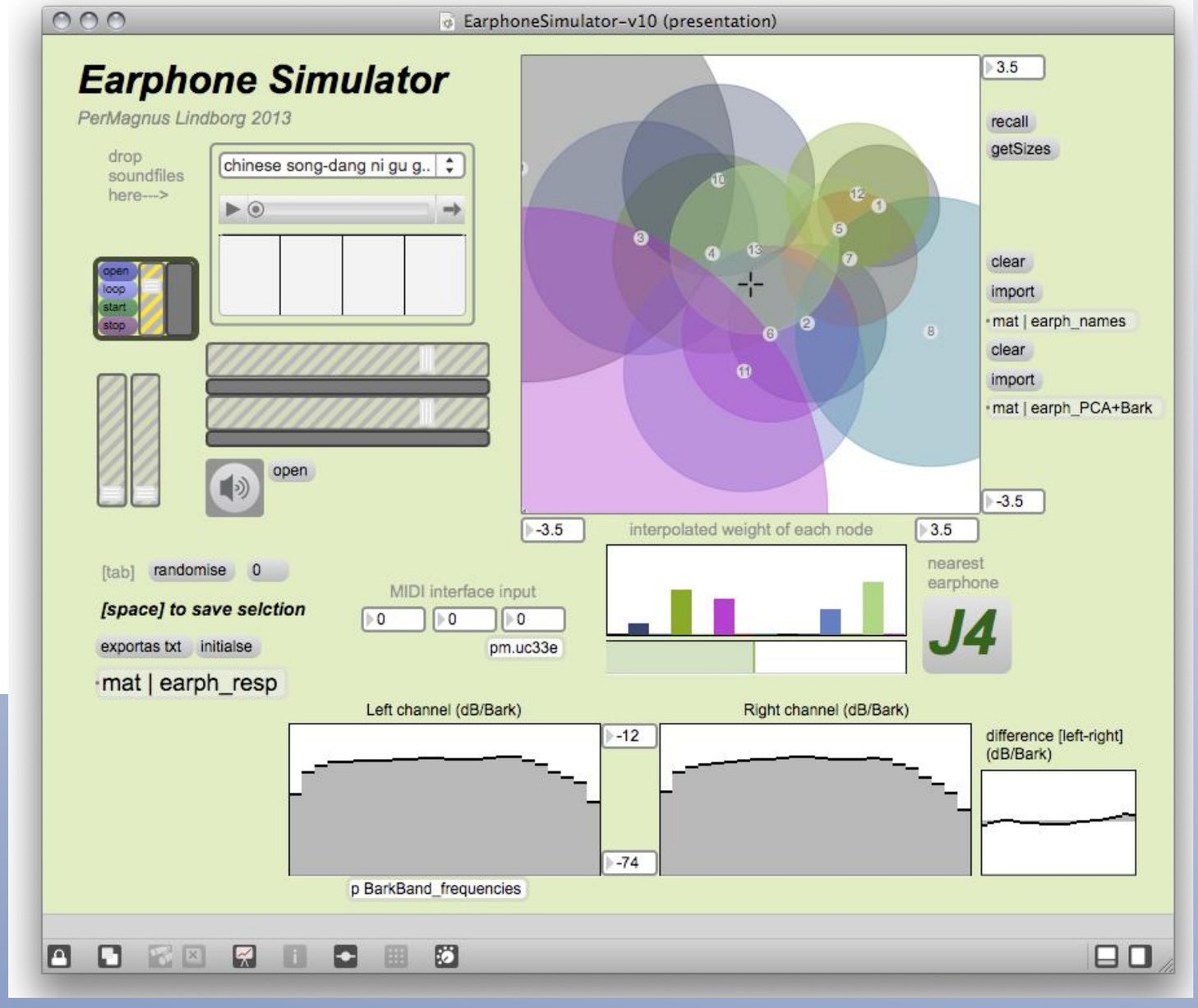
ABSTRACT

The article outlines a psychoacoustically founded method to describe the acoustic performance of earphones in two dimensions, *Spectral Shape* and *Stereo Image Coherence*. In a test set of 14 typical earphones, these dimensions explained 66.2% of total variability in 11 acoustic features based on Bark band energy distribution. We designed an interactive *Earphone Simulator* software that allows smooth interpolation between measured earphones, and employed it in a controlled experiment (N=30). Results showed that the preferred 'virtual earphone' sound was different between two test conditions, silence and commuter noise, both in terms of gain level and spectral shape. We dis-



BRECVEMA

Brain stem reflex

Rhythmic entrainment

Evaluative conditioning

Contagion

Visual imagery

Episodic memory

Musical expectancy

Aesthetic judgement

Emotional *contagion*… listener perceives the emotional expression of the music, and then 'mimics' this expression internally… 'brain module' responds automatically to certain stimulus features *as if* they were coming from a human voice expressing emotions …'mirror-neuron system'…pre-motor representations for vocal sound production.

Juslin, P. N. (2013). "From everyday emotions to aesthetic emotions: towards a unified theory of musical emotions". *Physics of life reviews*, *10*(3), 235-266.

PLOS | ONE

RESEARCH ARTICLE

Colour Association with Music Is Mediated by Emotion: Evidence from an Experiment Using a *CIE Lab* Interface and Interviews

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OPEN ACCESS

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Editor: Xiaoang Wan, Tsinghua University, CHINA

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Published: December 7, 2015

Abstract

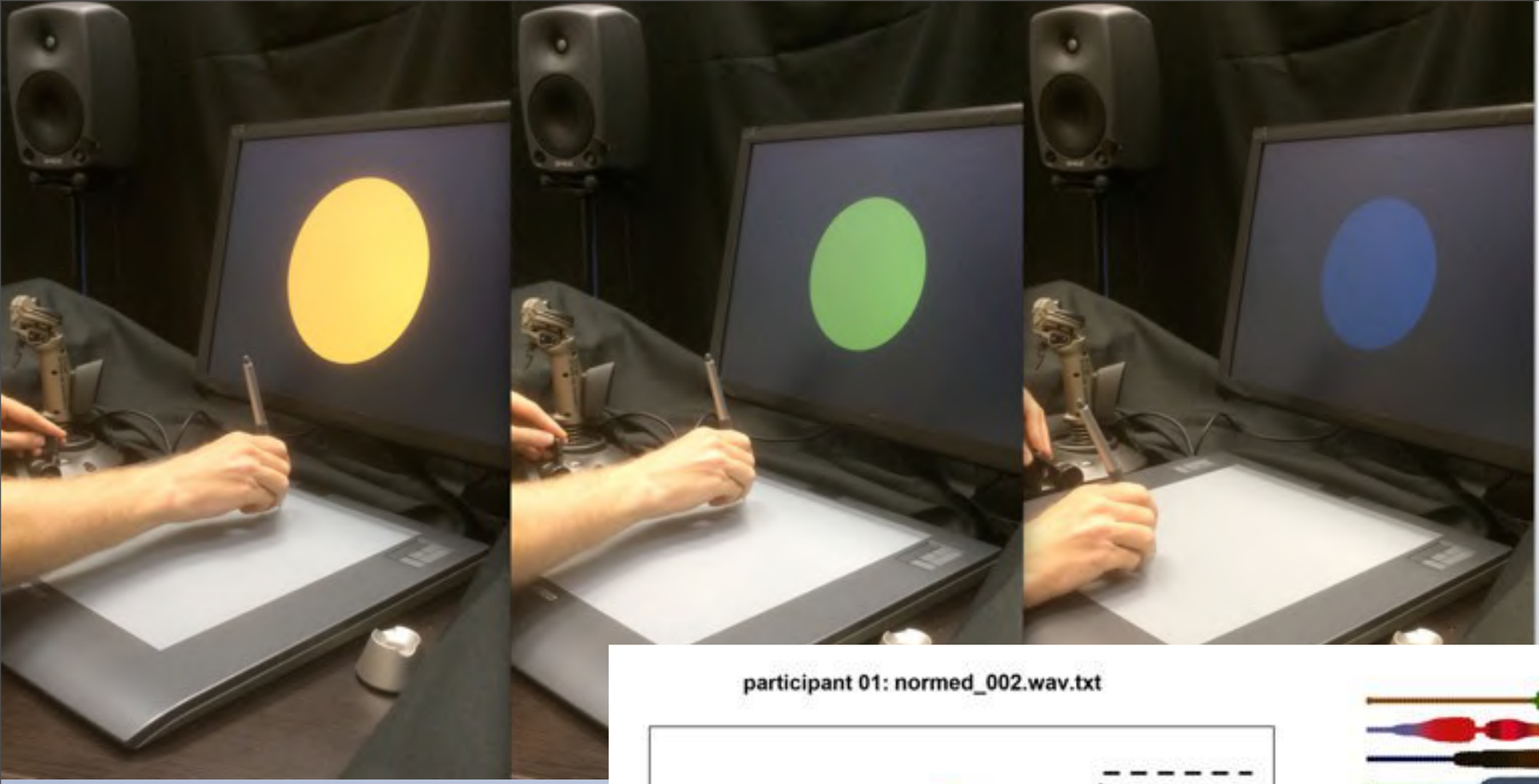
Crossmodal associations may arise at neurological, perceptual, cognitive, or emotional levels of brain processing. Higher-level modal correspondences between musical timbre and visual colour have been previously investigated, though with limited sets of colour. We developed a novel response method that employs a tablet interface to navigate the *CIE Lab* colour space. The method was used in an experiment where 27 film music excerpts were presented to participants (n = 22) who continuously manipulated the colour and size of an on-screen patch to match the music. Analysis of the data replicated and extended earlier research, for example, that happy music was associated with yellow, music expressing anger with large red colour patches, and sad music with smaller patches towards dark blue. Correlation analysis suggested patterns of relationships between audio features and colour patch parameters. Using partial least squares regression, we tested models for predicting colour patch responses from audio features and ratings of perceived emotion in the music. Parsimonious models that included emotion robustly explained between 60% and 75% of the variation in each of the colour patch parameters, as measured by cross-validated R^2. To illuminate the quantitative findings, we performed a content analysis of structured spoken interviews with the participants. This provided further evidence of a significant emotion mediation mechanism, whereby people tended to match colour association with the perceived emotion in the

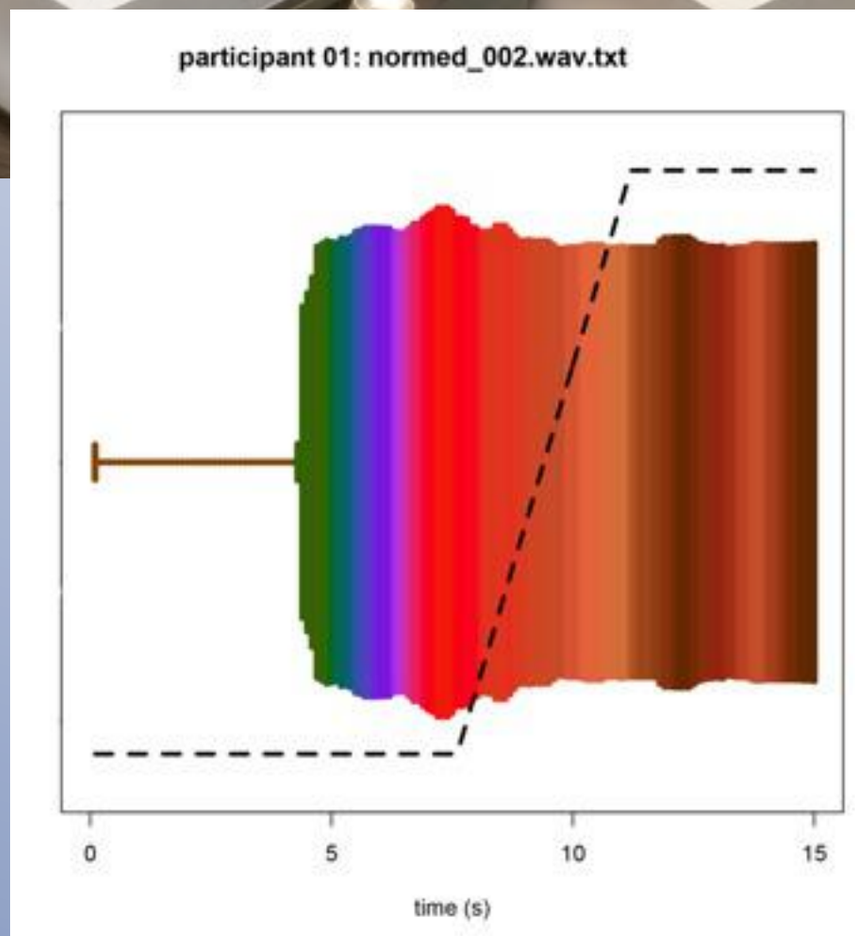
Table 1. Overview of methods used in recent studies of colour association with music.

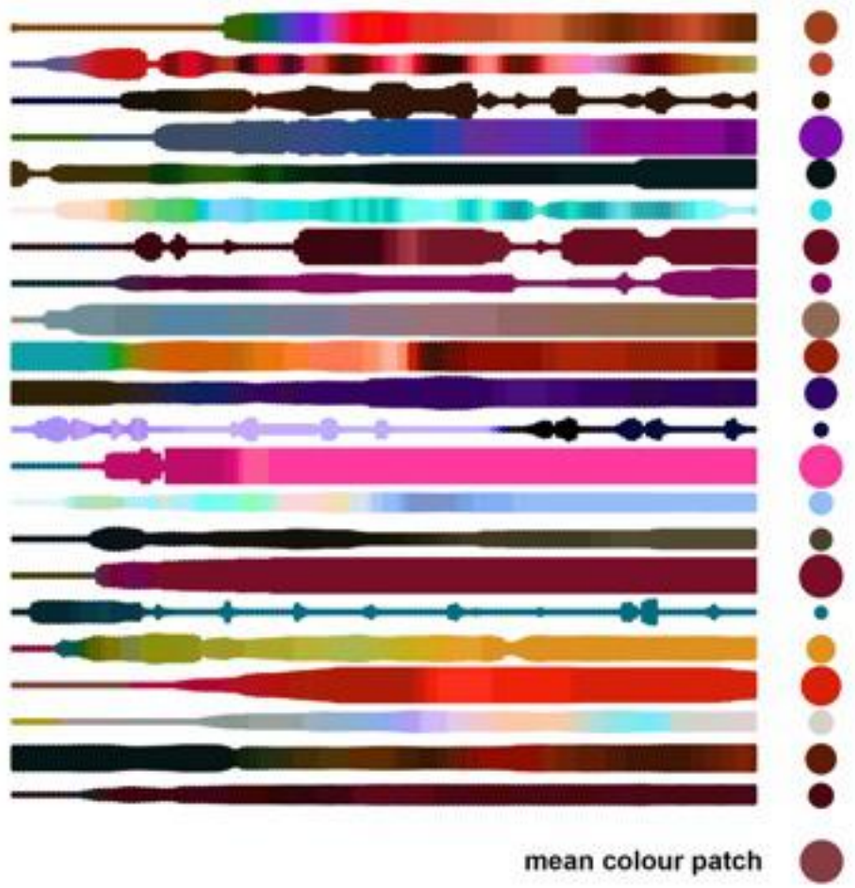
Authors	*Year*	*Colour model*	*Number of colours*	*Colour selection*	*Colour presentation*	*Number of sound stimuli*
Giannakis & Smith	2001	*HSV*	216	approx. equally spaced	parallel patches	33 (or 72, the description is unclear)
Datteri & Howard	2004	-	7	arbitrary	parallel patches	8
Lipscomb & Kim	2004	-	9 (48)	systematic selection	(rating of composites)	48 (tones)
Bresin	2005	*HSL*	24	approx. equally spaced	parallel patches	72 (2 pieces x 3 instruments x 12 emotions)
Barbiere et al.	2007	-	0 (7 words)	arbitrary	parallel word labels	4
Holm et al.	2009	-	12 (10+b/w)	arbitrary	parallel patches	0 (18 genre labels)
Palmer et al.	2013	*HSL*	37	systematic selection	parallel patches	18 (classicist music)
Lindborg	2013 (unpublished pilot)	*HSL*	>100,000	quasi-continuous	swatch colour picker	27 (soundscapes)
Lindborg	present article	*CIE Lab*	98,553	dimensions perceptually linear, orthogonal & continuous	physical interface (tablet & throttle)	27 (film music)

doi:10.1371/journal.pone.0144013.t001

Lindborg, P., & Friberg, A. K. (2015). Colour association with music is mediated by emotion: Evidence from an experiment using a CIE lab interface and interviews. PloS one, 10(12), e0144013.

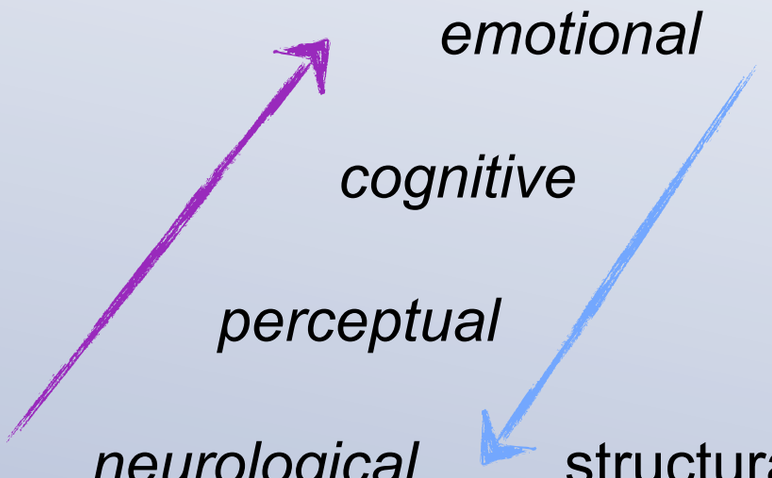






Lindborg, P., & Friberg, A. K. (2015). Colour association with music is mediated by emotion: Evidence from an experiment using a CIE lab interface and interviews. PloS one, 10(12), e0144013.

Crossmodal associations at different levels of brain processing:



conscious learning (language)

statistical co-occurrence in environment (ecological perception)

structural correspondences (encoding, locality)

Stimuli features

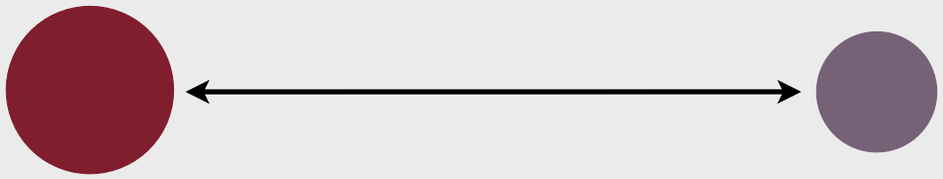
‘modal’ = specific to a single sensory modality,
(the timbre of sound / the colour of light)

‘amodal’ = not domain-specific
(e.g. *intensity, size*)

Lindborg, P., & Friberg, A. K. (2015). Colour association with music is mediated by emotion: Evidence from an experiment using a CIE lab interface and interviews. PloS one, 10(12), e0144013.

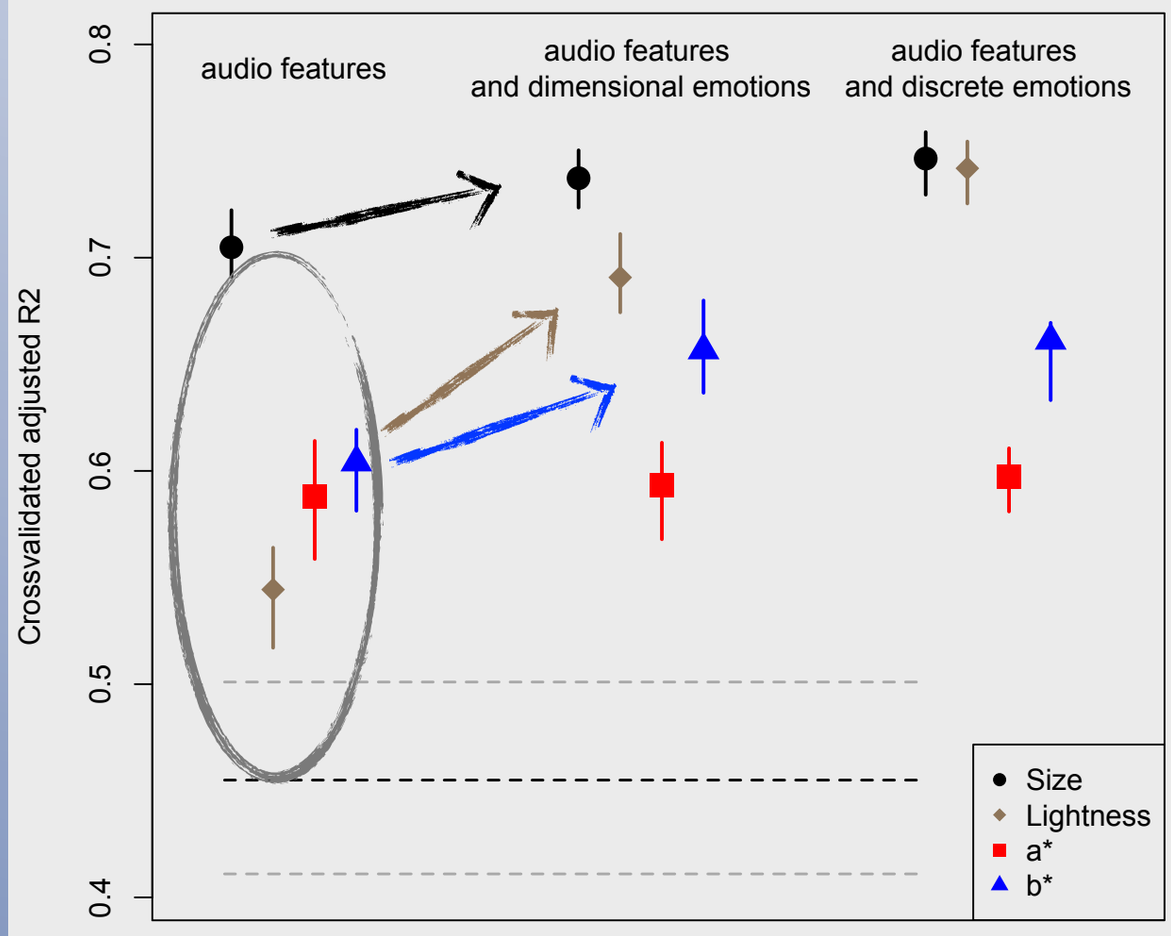
Lindborg PM & Friberg AK (2015, Dec.). "Colour Association with Music is Mediated by Emotion: Evidence from an Experiment using a CIE Lab Interface and Interviews". *PLoS one.*

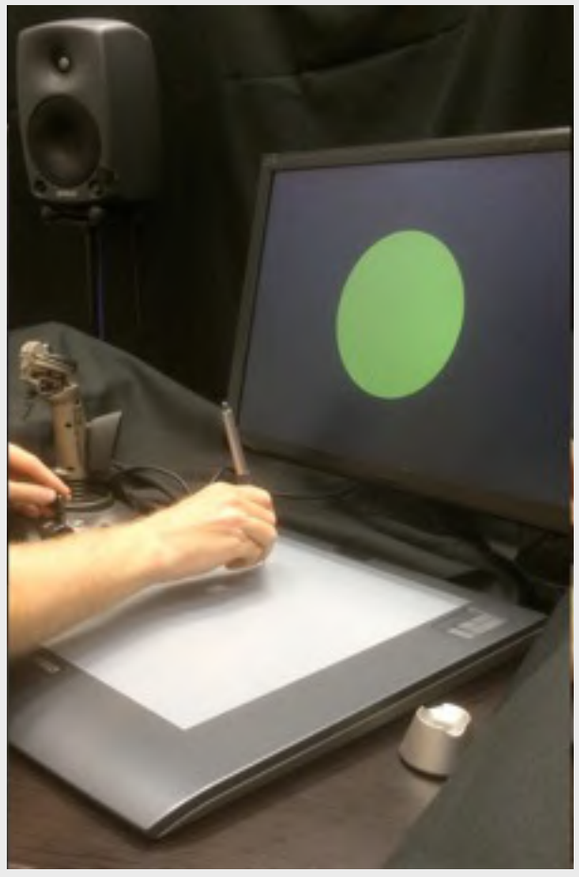
How does perception of music relate to colour?



colour = audio + emotion + Ɛ

PLS models predicting colour patch parameters





Crossmodal correspondence

emotion contributed to explaining colour responses, over & above music features;

mixed methodology strengthened emotion mediation hypothesis.

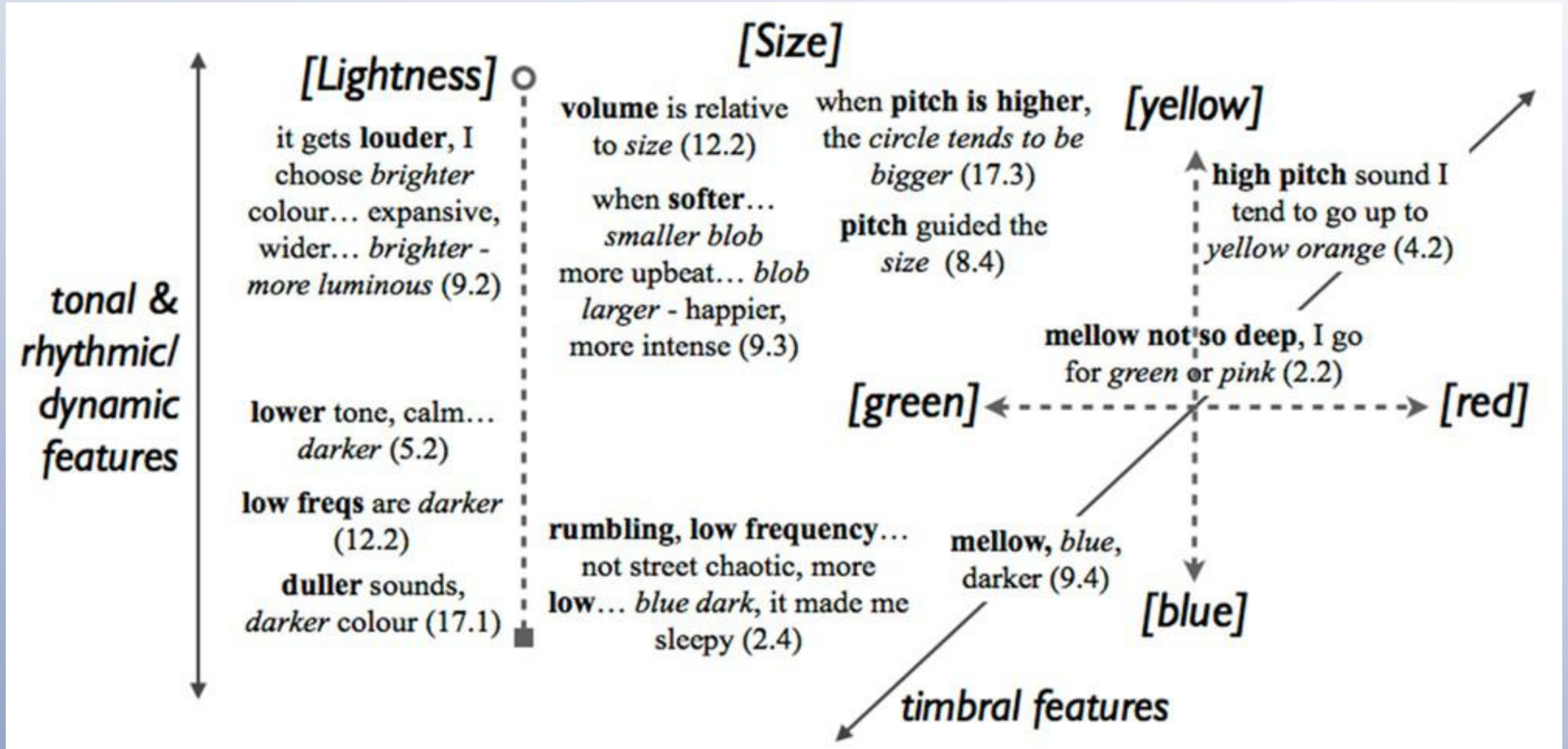
Lindborg, P., & Friberg, A. K. (2015). Colour association with music is mediated by emotion: Evidence from an experiment using a CIE lab interface and interviews. PloS one, 10(12), e0144013.

		Colour Patch Parameters			
Type	***Variable***	***Size***	***Lightness***	***a****	***b****
Psychoacoustic	***Loudness***				
	Sharpness	0.63***		(0.48*)	(0.56**)
	Roughness				
	Fluctuation strength	(0.44*)			
Rhythmic & Dynamic	***Tempo***				
	Attack_time	(0.5**)	(0.44*)		(0.4*)
	Lowenergy		(0.39*)		
Timbral	***Spectral centroid***	(0.53**)		(0.44*)	(0.51**)
	Brightness	0.63***		(0.44*)	(0.59**)
	Spectral spread			(-0.42*)	
	Rolloff (85%)	(0.6**)		(0.51**)	(0.51**)
	Spectentropy	0.69***		(0.61***)	(0.57**)
	Spectral flatness	(-0.45*)		(-0.52**)	
	Irregularity		(0.41*)	(-0.43*)	
	Zerocross rate	(0.53**)			(0.57**)
	Spectralflux	0.73***		(0.42*)	(0.61***)
Tonal	***Chromagram (PeakPos)***			(0.43*)	
	Chromagram (Centroid)				
	Keyclarity		(0.56**)		
	Mode		(0.41*)		

Lindborg, P., & Friberg, A. K. (2015). Colour association with music is mediated by emotion: Evidence from an experiment using a CIE lab interface and interviews. PloS one, 10(12), e0144013.

mechanism	***directed to***	***response fragments indicating crossmodal association***
structural	audio spatialisation	*panning demanded zig-zag (6.2) left-right… strong panning effect (8.2) panning… move left-right (16.4)*
structural	physical tapping	*rhythm… I tap the pen (16.2) giddy-giddy sounds… speccles of colours [makes tapping gesture] (17.4)*
structural	movement (imagined)	*sound pushing others away (13.3) tripping… catch[ing] up (1.2) running around (5.4)*
ecological	water	*blue water (1.3, 21.2) water blue (4.4, 5.2, 8.2, 11.2, 16.2)*
ecological	nature, birds	*nature blueish/greenish (17.2) nature green (5.2, 11.2) birds green (1.3) animals green, forest (16.2)*
cognitive / semantic	tactile feel	*this area [of the colour response interface] warm… muddy… cold (19.1)*
cognitive / semantic	audiovisual	*noise white (7.2) noise vocals machines white (4.4) mechanical… gray (21.4) singing red (11.2)*
emotional	memory	*memory childhood (13.1)… strong memories (13.4) [memories of] walking in Colombia… crowds brownish-red (8.3)*
emotional	imagery	*I imagine myself on the beach (6.2) sound of water…I visualise a beach (21.2) film (10.4) movie (11.2)*

Lindborg, P., & Friberg, A. K. (2015). Colour association with music is mediated by emotion: Evidence from an experiment using a CIE lab interface and interviews. PloS one, 10(12), e0144013.



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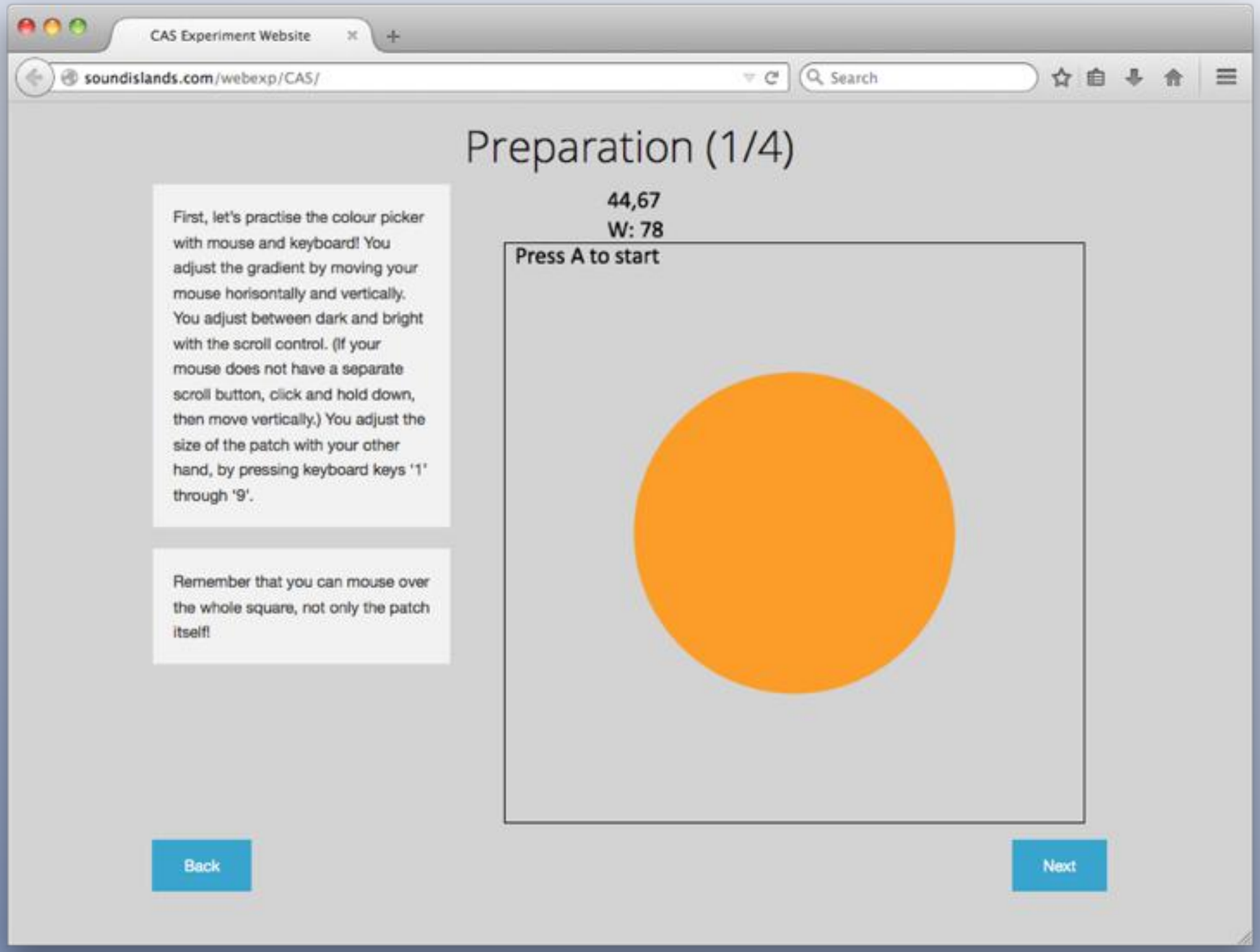
Lindborg PM, Hendinata J, Friberg A (2017). "Colour Association with Music: a web experiment"

Can personality traits predict crossmodal association?



http://soundislands.com/webexp/CAS/

BRECVEMA

Brain stem reflex

Rhythmic entrainment

Evaluative conditioning

Contagion

Visual imagery

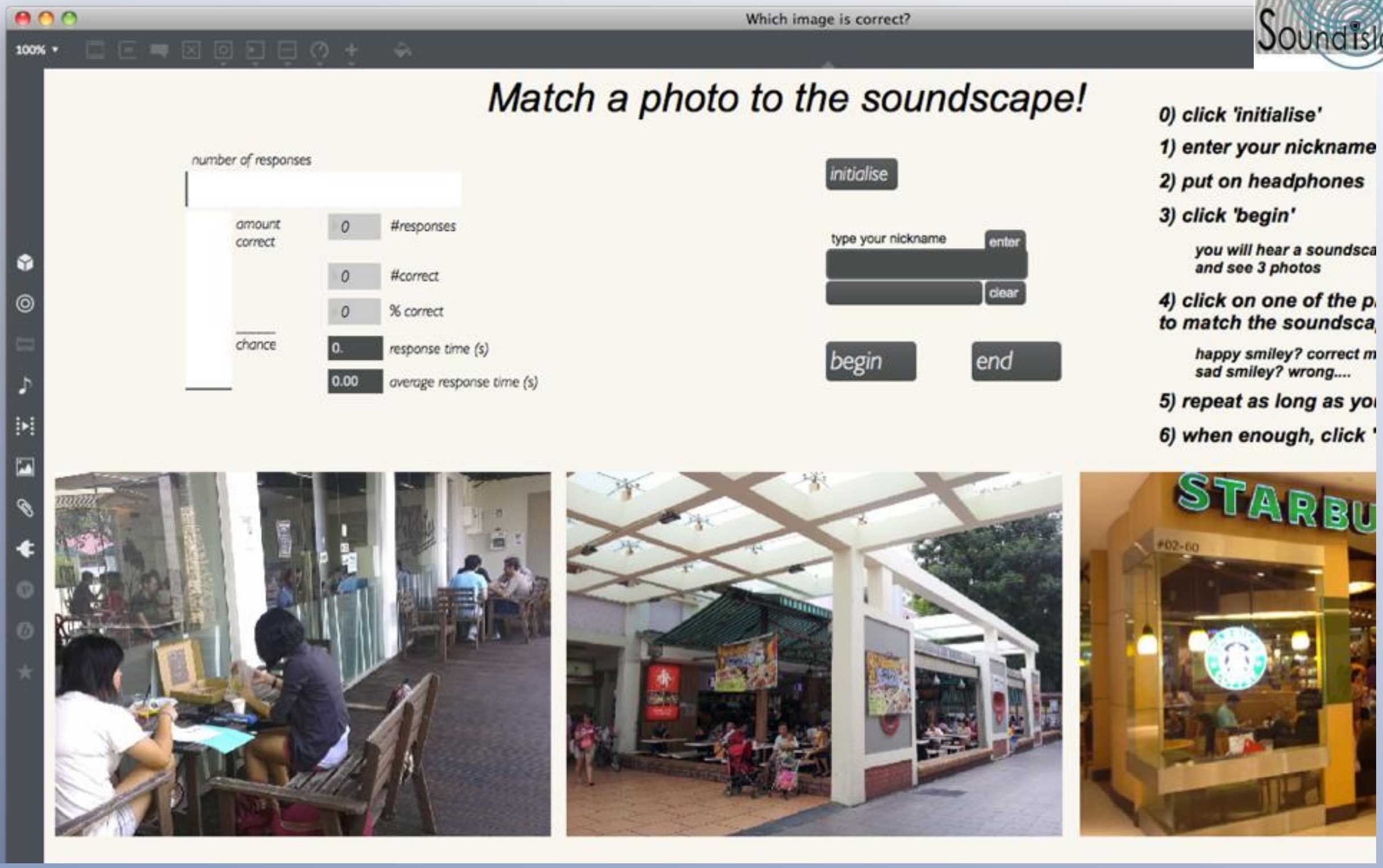
Episodic memory

Musical expectancy

Aesthetic judgement

Visual imagery… listener…conjures up inner images (e.g., of a beautiful landscape)…conceptualizing the musical structure in terms of a nonverbal mapping between the metaphorical 'affordances' of the music and 'image-schemata', grounded in bodily experience.

Juslin, P. N. (2013). "From everyday emotions to aesthetic emotions: towards a unified theory of musical emotions". *Physics of life reviews*, *10*(3), 235-266.


Which image is correct?
100%
Match a photo to the soundscape!
number of responses
amount correct
chance
0
#responses
0
#correct
0
% correct
0.
response time (s)
0.00
average response time (s)
initialise
type your nickname
enter
clear
begin
end
0) click 'initialise'
1) enter your nickname
2) put on headphones
3) click 'begin'
you will hear a soundsca
and see 3 photos
4) click on one of the p
to match the soundsca
happy smiley? correct m
sad smiley? wrong....
5) repeat as long as yo
6) when enough, click
STARBU
#02-60

BRECVEMA

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Juslin, P. N. (2013). “From everyday emotions to aesthetic emotions: towards a unified theory of musical emotions”. *Physics of life reviews*, *10*(3), 235-266.

emotions cannot be reduced to preferences

"not all music experiences should be properly regarded as 'aesthetic'"

"the aesthetic judgment process begins with *an initial classification* of the music as 'art', which will lead the listener to adopt *an **aesthetic attitude*** (see Leder 2004; also Tuuri & Eerola 2012)

aesthetic framing

"Once a piece of music is treated as art, the process of aesthetic judgment may begin."

Juslin, P. N. (2013). "From everyday emotions to aesthetic emotions: towards a unified theory of musical emotions". *Physics of life reviews*, *10*(3), 235-266.

aesthetic judgments of
music are *multi-dimensional*

Beauty

Expression

Novelty

Emotion

Skill

Message

Style

The sublime

Juslin, P. N. (2013). “From everyday emotions to aesthetic emotions: towards a unified theory of musical emotions”. *Physics of life reviews*, *10*(3), 235-266.

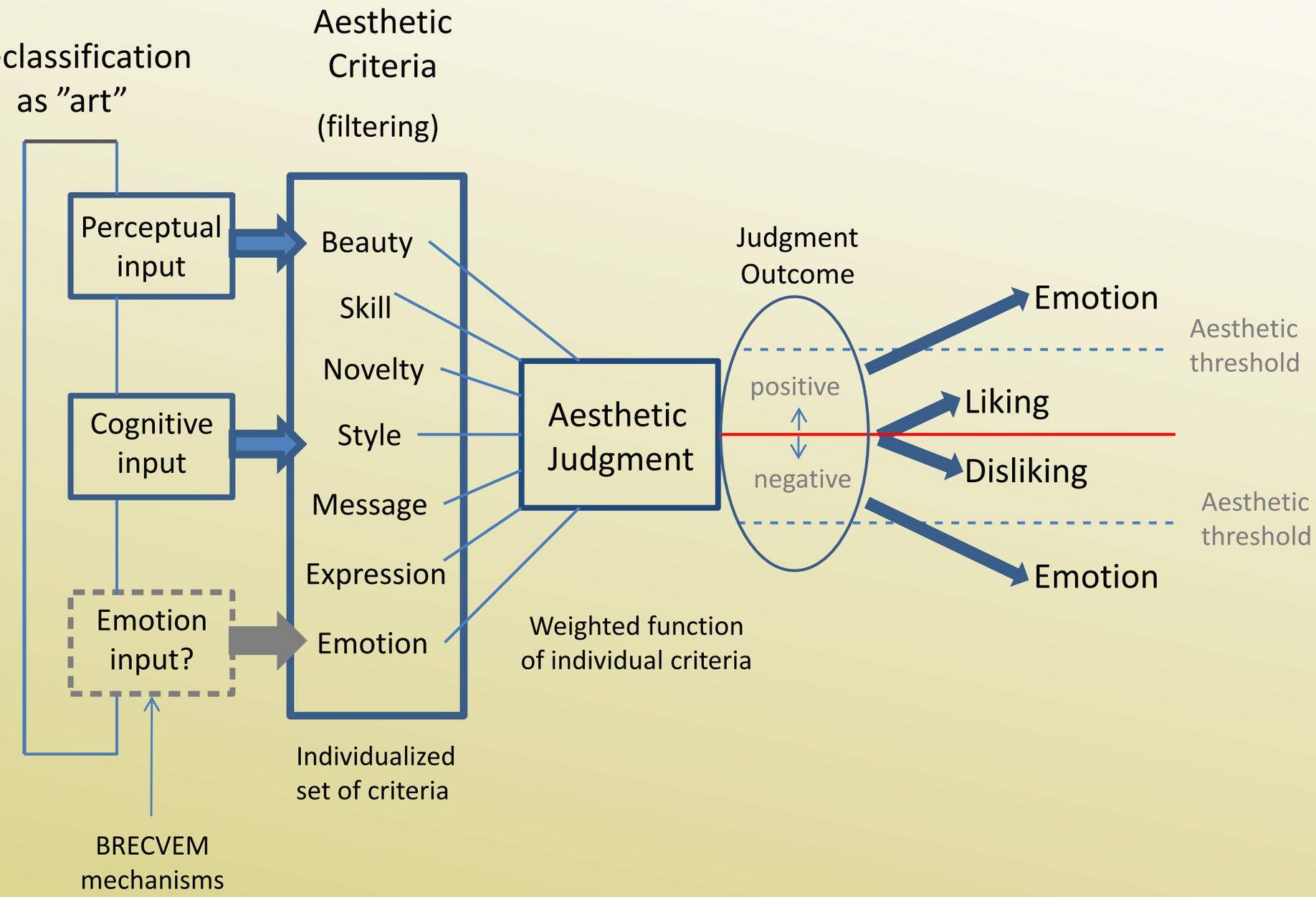
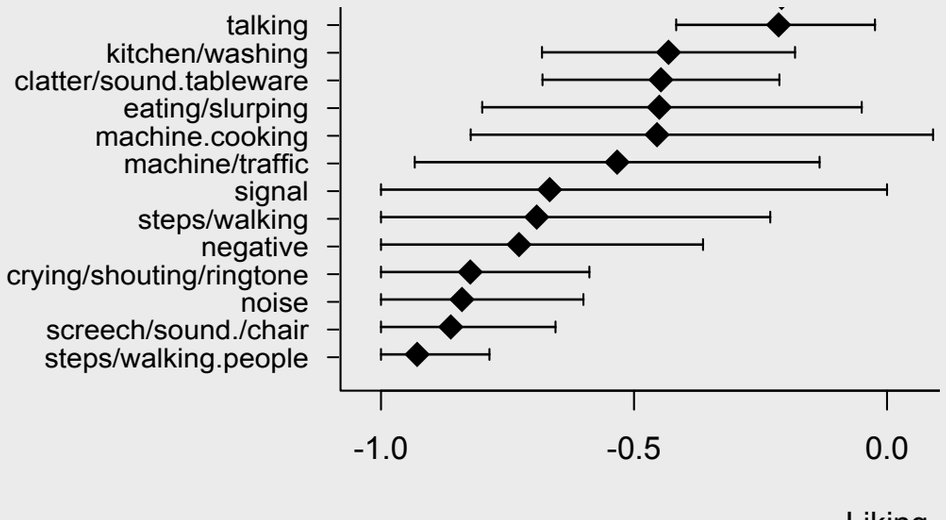


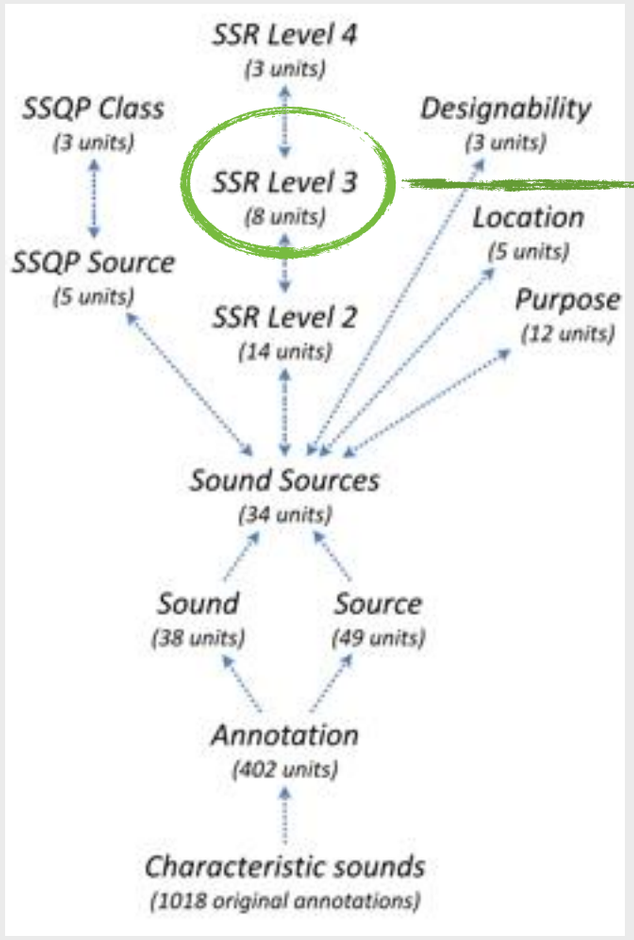
Fig. 1. Schematic description of the aesthetic judgment process in music listening.

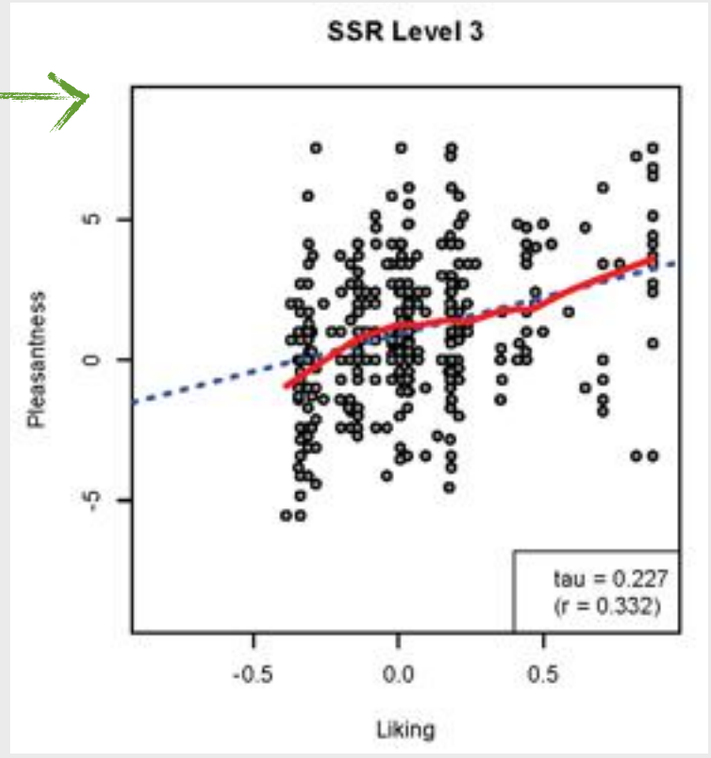
Juslin, P. N. (2013). “From everyday emotions to aesthetic emotions: towards a unified theory of musical emotions”. *Physics of life reviews*, *10*(3), 235-266.

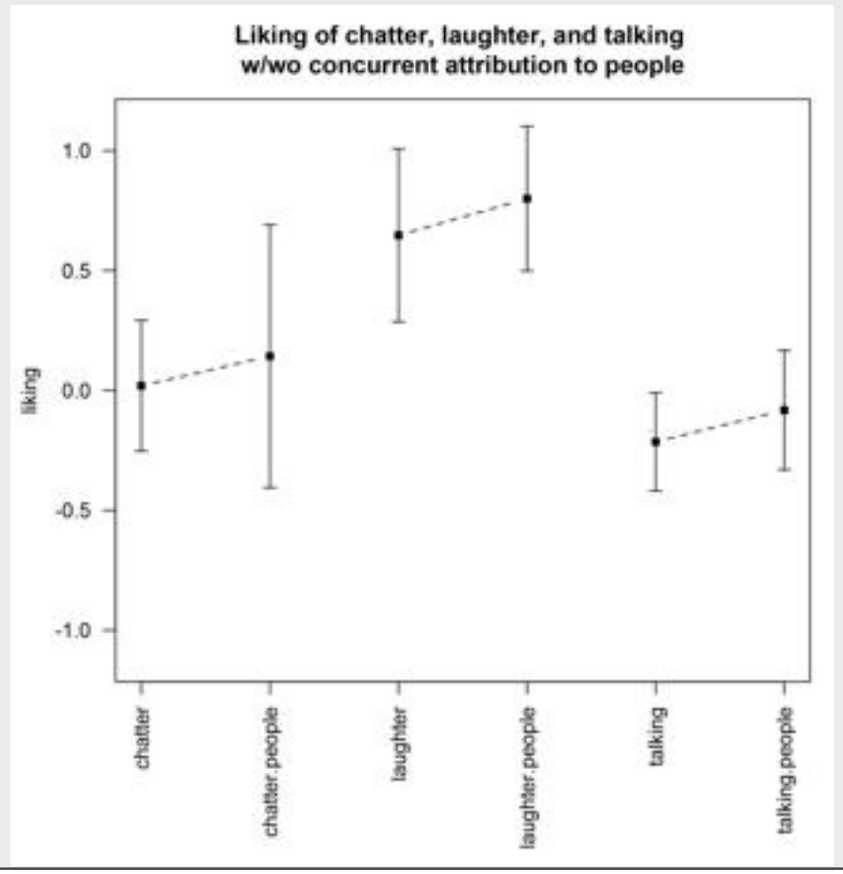
Lindborg PM (2016). "A taxonomy of sound sources in restaurants". *Applied Acoustics.*

Which sounds are liked or disliked in restaurants?









Restaurant sonic environment

Systematic classification of free-form annotations of characteristic sounds yielded a taxonomy (+validated).

Analysis revealed perceptual and crossmodal effects.

Example: voice-related annotations of characteristic sounds where 'people' was included as a specifier were more liked: possible emotional crossmodal association mechanism.

Lindborg PM & Friberg AK (2016). "Personality traits influence perception of soundscape quality". *Applied Sciences, special issue on soundscape*

Can personality explain how people perceive the urban sonic environment?

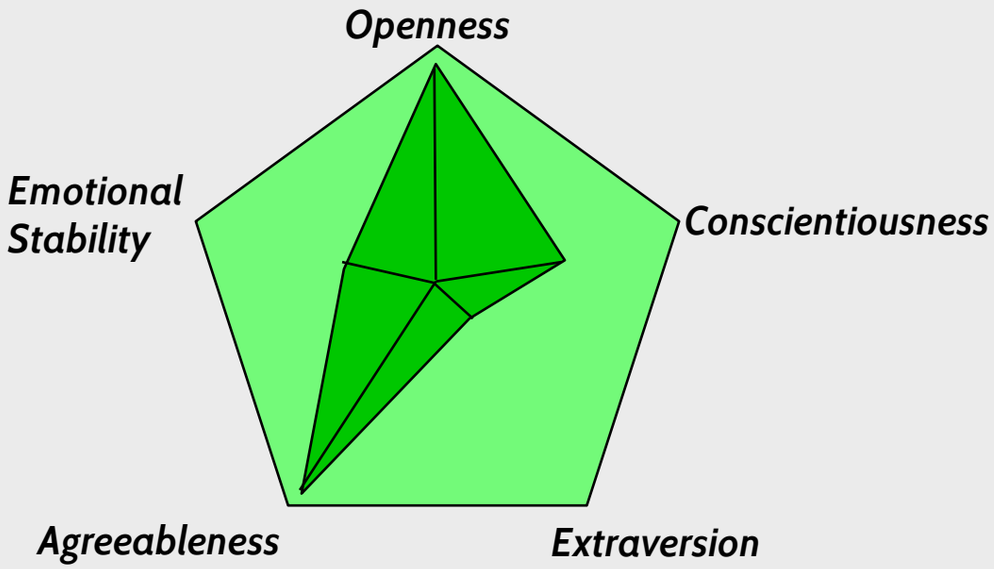


Fig. Big Five dimensions (e.g. McCrae & Costa 1997)

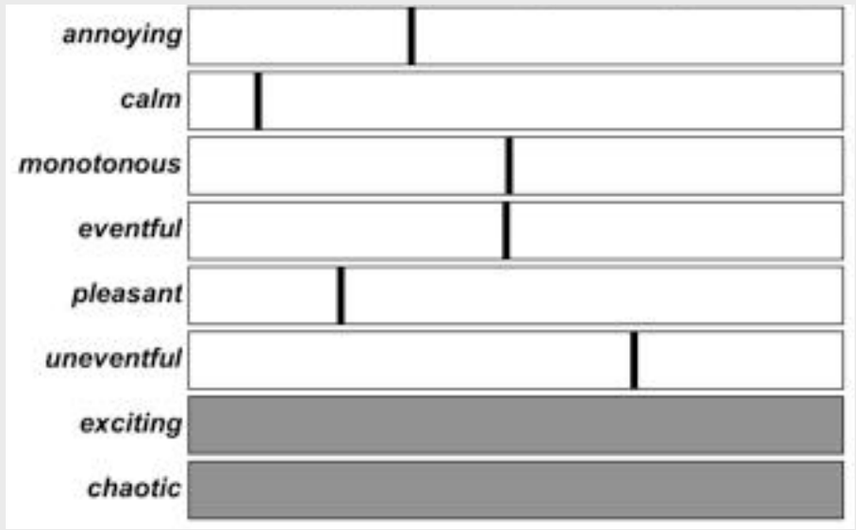
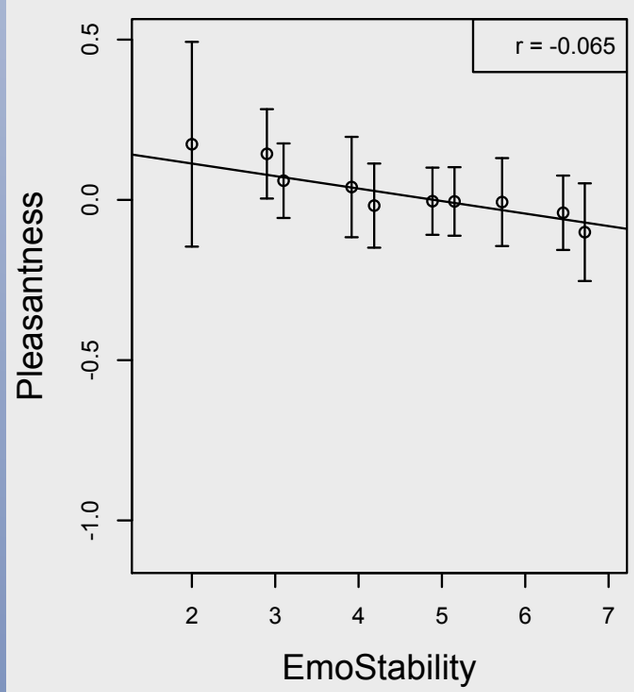
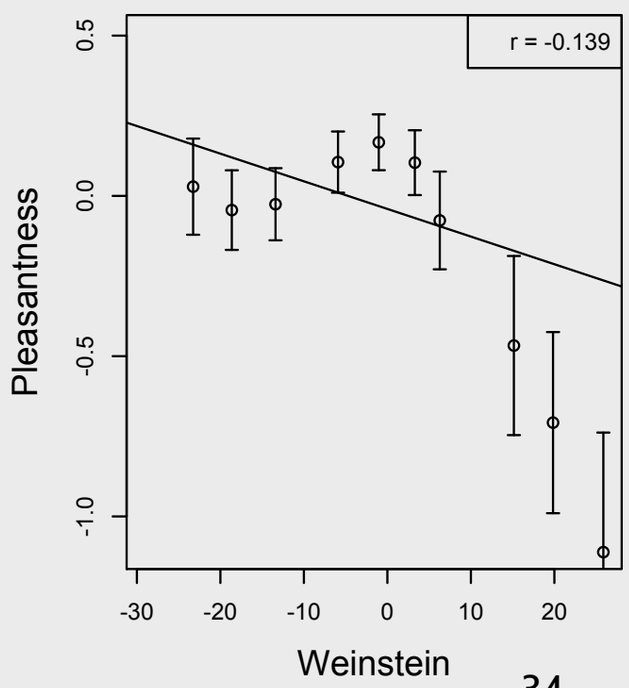


Fig. Part of screen-based rating interface for Swedish Soundscape Quality Protocol (Nilsson, Axelsson, Berglund 2010)





Analysis revealed the influence of personality traits on quality ratings.

Example: effect size of personality traits was up to one-tenth of psychoacoustic descriptors.

Sonic moving images – how sounds move us

Thanks for listening!

… questions?

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Si17 Symposium on Sound and Movement

Soundislands Festival

8 March 2017

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