

# **KEK**連携コロキウム

Empirical approaches to study aesthetic  
experiences

-an introduction to neuroaesthetics-

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Neuroaesthetics, cognitive science of art

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**Dep. Bioscience**  
2009~2016  
2018~2020



**University of  
Vienna**  
**Dep. Psychology**  
2016~2018



**Kansai University**  
**Dep. Psychology**  
2020.4~



Choshu five





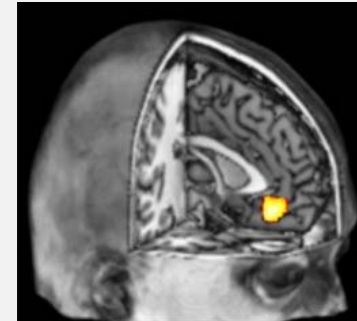
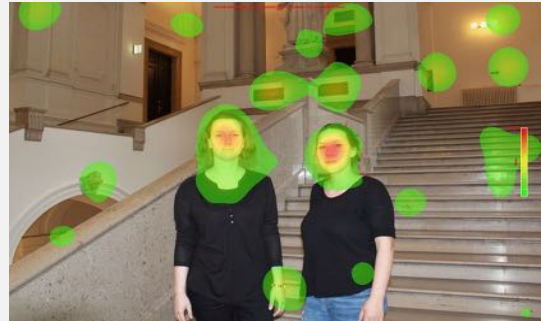


# Today's topics

- What is neuroaesthetics?
  - Definition, research areas, research objectives
  - Why beauty matters?
- Beauty (positive beauty) and its brain system
- Empirical studies on *negative beauty*

# What is neuroaesthetics? by definition

Studying workings of mind and brain with artistic activities and various aesthetic experience by using cognitive neuroscience methods



Empirical  
aesthetics

Psycho-  
physiology

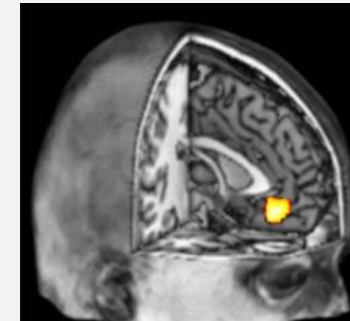
Brain imaging  
Brain  
stimulation

Machine  
learning  
Deep learning

# What is neuroaesthetics?

Appreciation, creativity, critique etc.

Studying workings of mind and brain with **artistic activities** and various aesthetic experience by using cognitive neuroscience methods



Empirical  
aesthetics

Psycho-  
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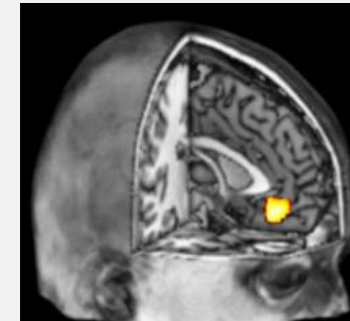
Machine  
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# What is neuroaesthetics?

Beauty, ugliness, sublime, nostalgia, moving, etc.

Appreciation, creativity, critique etc.

Studying workings of mind and brain with **artistic activities** and various **aesthetic experience** by using cognitive neuroscience methods



Empirical  
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Psycho-  
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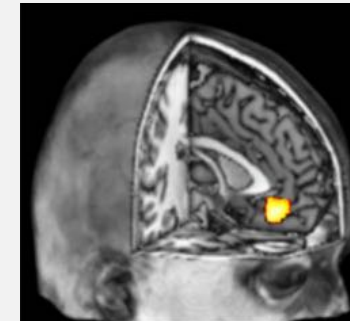
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**Cognitive model, brain systems, psychological effects etc.**



Empirical  
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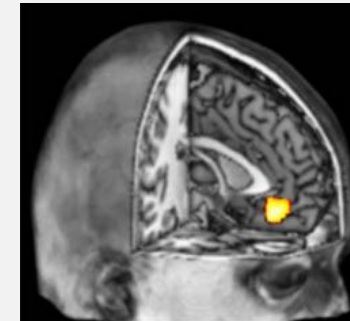
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**Cognitive model, brain systems, psychological effects etc.**



Empirical  
aesthetics

Psycho-  
physiology

Brain imaging  
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Machine  
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Deep learning

# What is neuroaesthetics? by research areas

Studying workings of mind and brain with artistic activities and various aesthetic experience by using cognitive neuroscience methods

## **Studies on aesthetics**

Cognitive processes and brain functions of aesthetic experiences

Cognitive  
Neuroscience of  
Aesthetics

Cognitive  
Neuroscience of Art

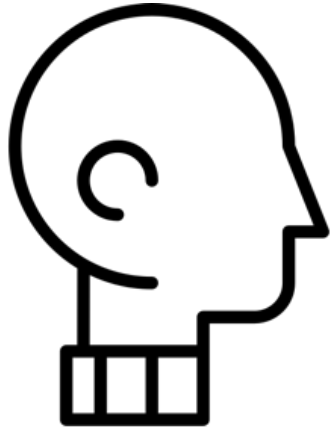
## **Studies on art/artworks**

Perception on artworks  
Artistic creativity  
Art, wellness, disease

Cognitive  
Neuroscience of  
Beauty

# What is neuroaesthetics? by objectives

“ How beautiful!! ”



Aesthetics from *below*

Aesthetics from *within*

Aesthetics from *above*

## Three levels in aesthetic judgements



# Aesthetics from above

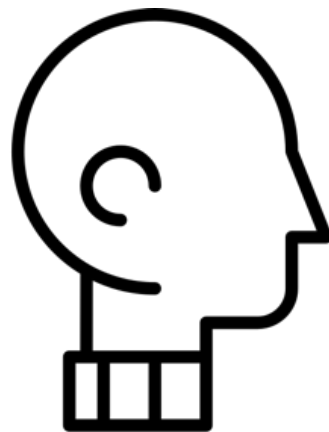
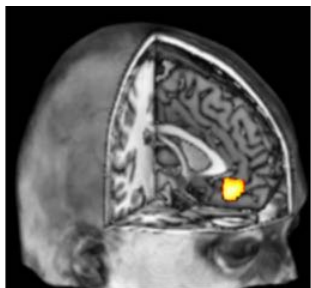
# Aesthetics from within

# Aesthetics from below

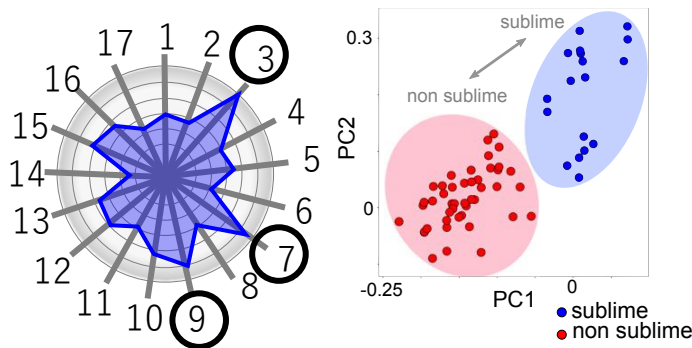
“ How beautiful!! ”



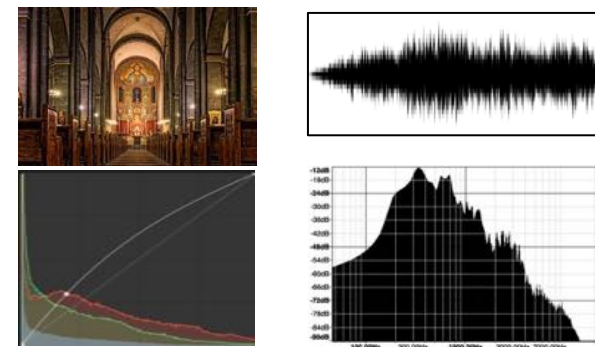
Neural profiles  
Brain response  
Physiological response



Psychological features  
Perception, cognition,  
emotion



Physical features  
Visual features  
Acoustic features



## Aesthetics from above

## Aesthetics from within

## Aesthetics from below



“ How beautiful!! ”



$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = -K T_{\mu\nu}$$
$$\begin{cases} \nabla \cdot \mathbf{B}(t, \mathbf{x}) = 0 \\ \nabla \times \mathbf{E}(t, \mathbf{x}) = -\frac{\partial \mathbf{B}(t, \mathbf{x})}{\partial t} \\ \nabla \cdot \mathbf{D}(t, \mathbf{x}) = \rho(t, \mathbf{x}) \\ \nabla \times \mathbf{H}(t, \mathbf{x}) = \mathbf{j}(t, \mathbf{x}) + \frac{\partial \mathbf{D}(t, \mathbf{x})}{\partial t} \end{cases}$$

Neural profiles

Brain response

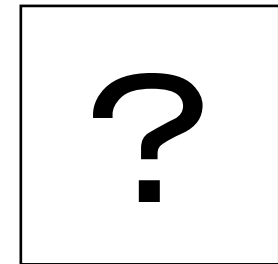
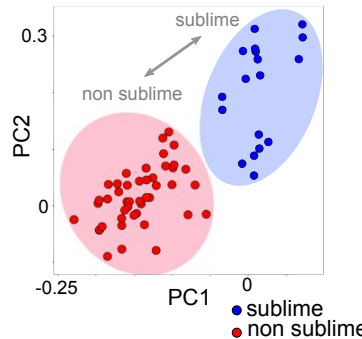
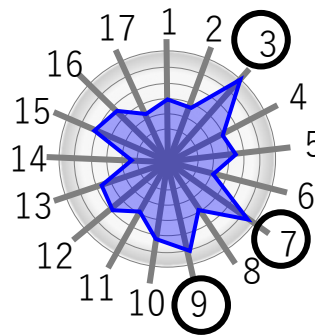
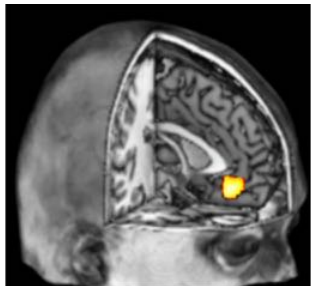
Physiological response

Psychological features

Perception, cognition,  
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Physical features

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Acoustic features

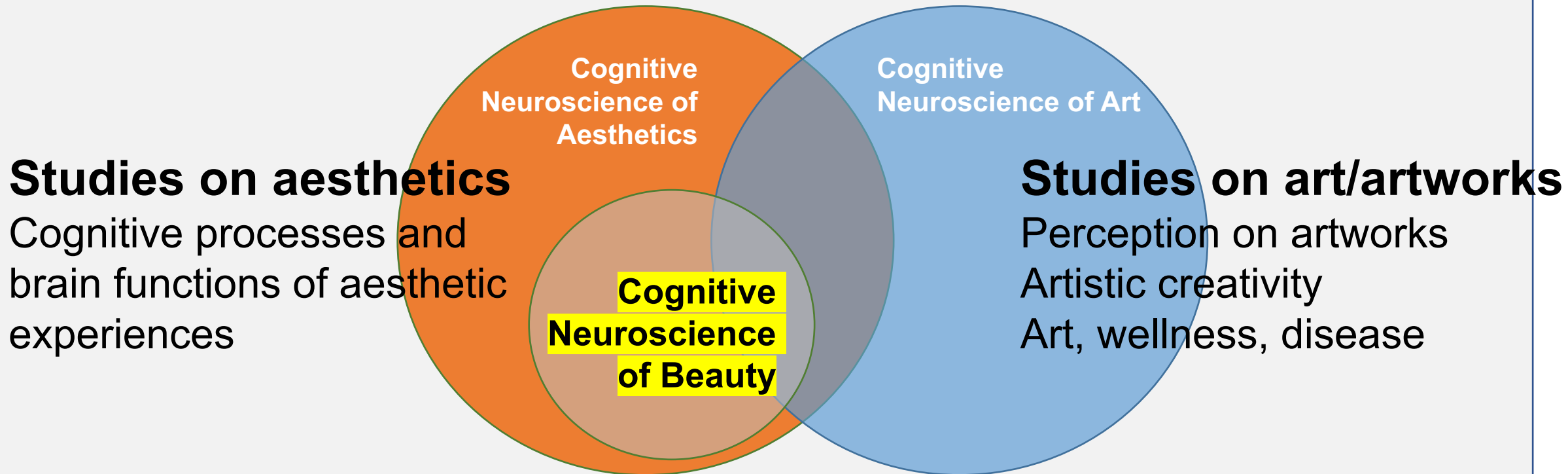


# Today's topics

- What is neuroaesthetics?
  - Definition, research areas, research objectives
  - **Why beauty matters?**
- Beauty (positive beauty) and its brain system
- Empirical studies on *negative beauty*

# Studies on beauty

Studying workings of mind and brain with artistic activities and various aesthetic experience by using cognitive neuroscience methods







Why beauty matters?



**£ 28bn**

economy



**6m**

visitors



**Double**

success rate

*“Beauty is not skin deep”*



Goodness

$$1 + e^{i\pi} = 0$$
$$\frac{1}{\pi} = \frac{2\sqrt{2}}{9801} \sum_{k=0}^{\infty} \frac{(4k)! (1103 + 26390k)}{(k!)^4 396^{4k}}$$

Mathematical truth

Truth, goodness, beauty  
rooted in the very foundations of humanity



---

*"My work has always tried to unite the True with the Beautiful and when I had to choose one or the other, I usually chose the Beautiful."*



Beauty is

not 'luxury' but 'necessity'

嗜好・贅沢

必需・必須

leading to a deeper understanding  
of human nature

# Today's topics

- What is neuroaesthetics?
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- **Beauty (positive beauty) and its brain system**
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Research question

What **brain response(s)** do the experience of beauty derived from different sources have **in common**?

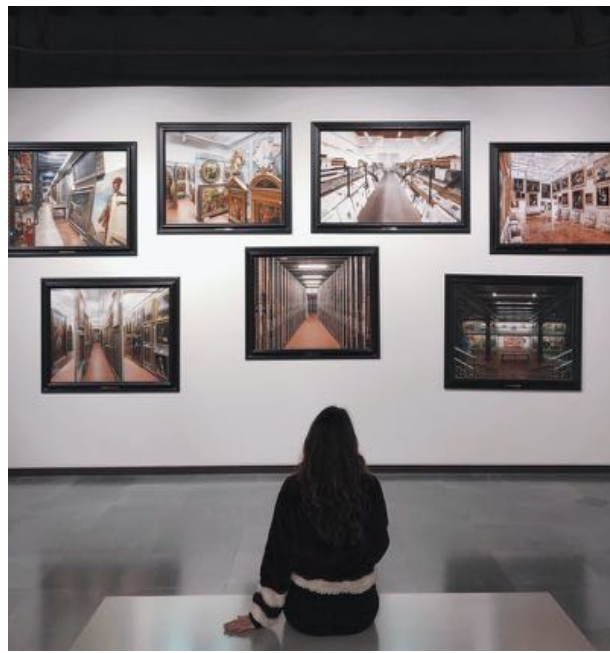


visual beauty



musical beauty

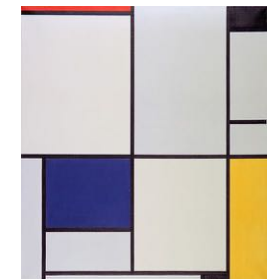




visual beauty



musical beauty





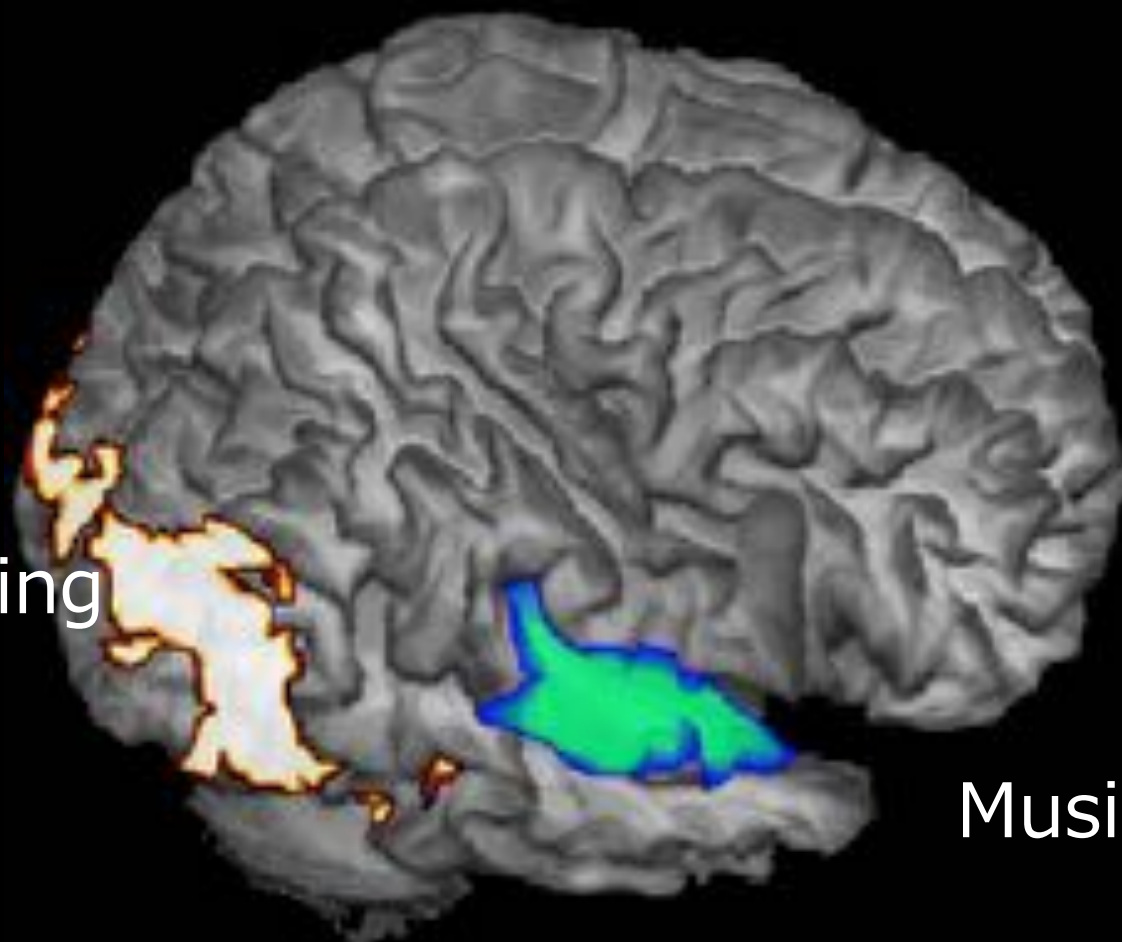
**Visual beauty**



**Musical beauty**

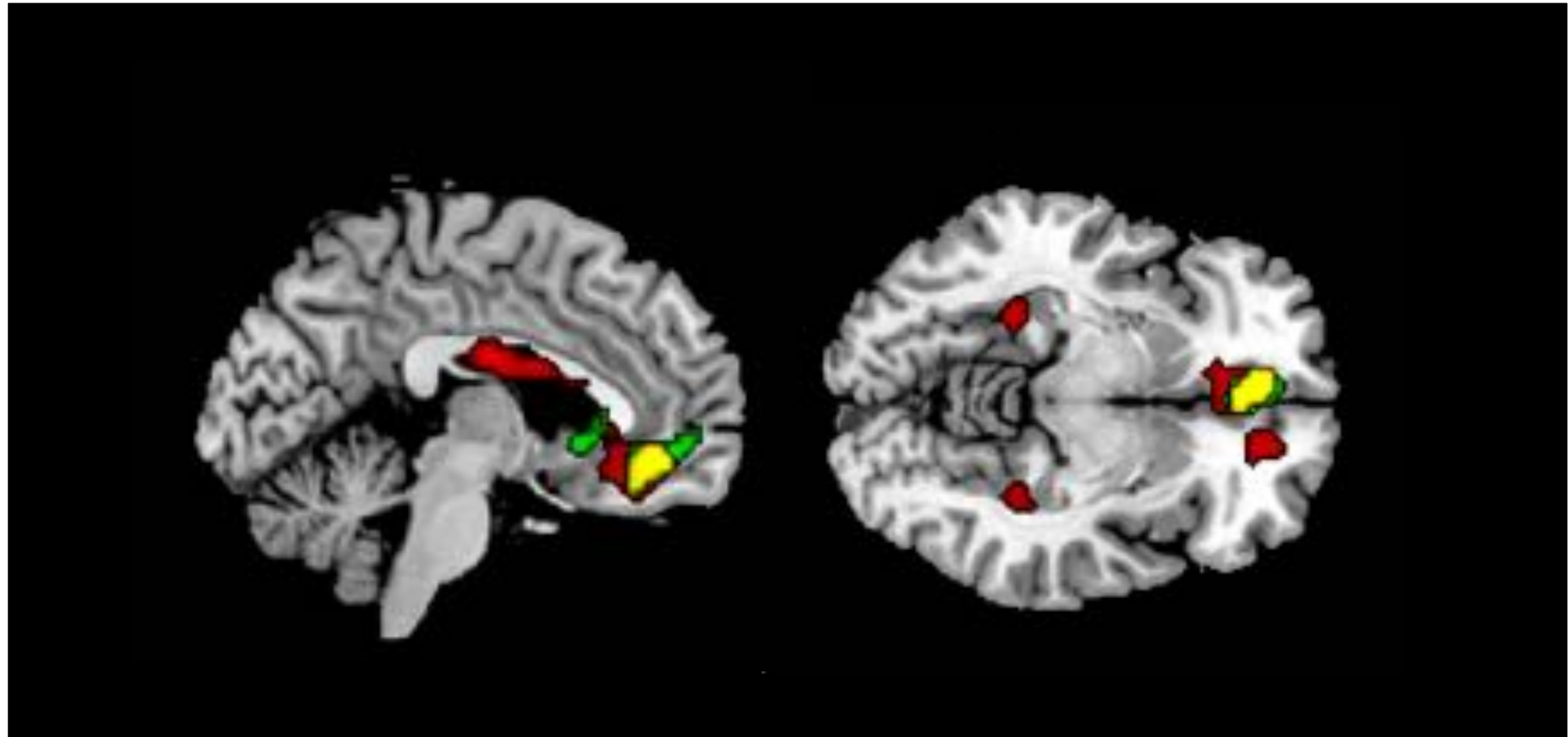
Is there common neural activity ?

Painting viewing



Music listening

# Music perception



VISUAL



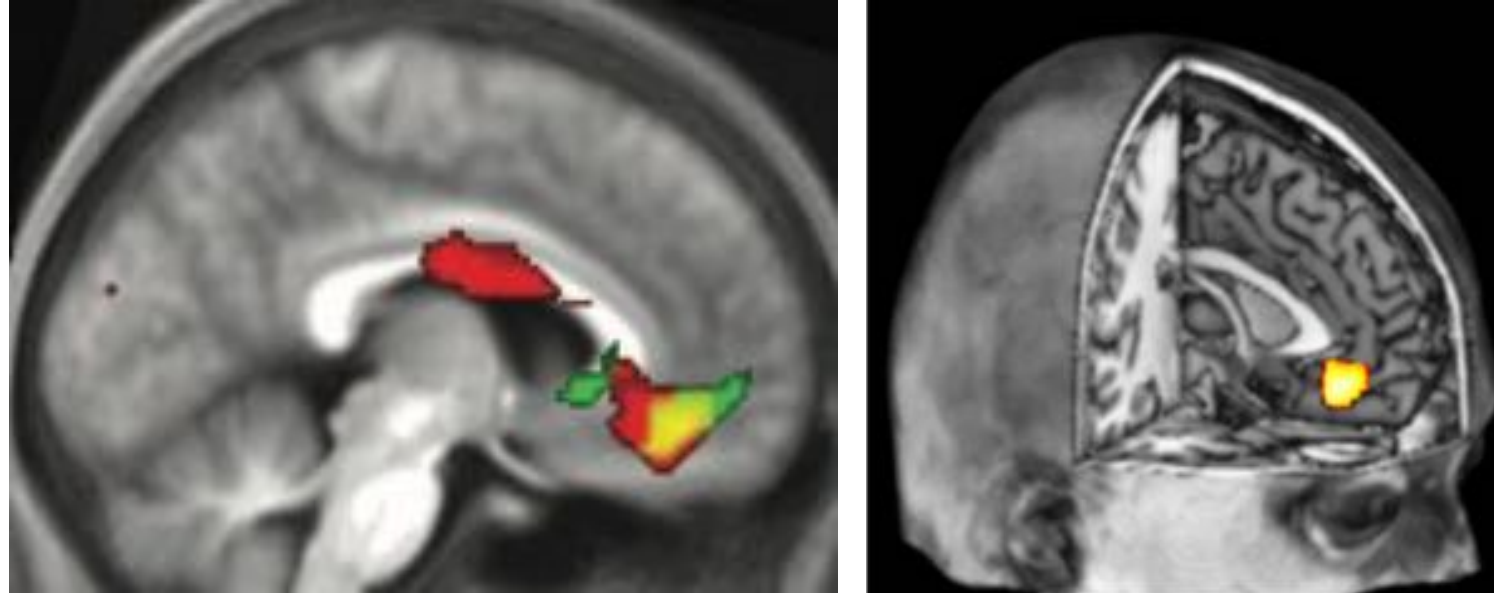
MUSICAL



COMMON

# Common response for experience of beauty

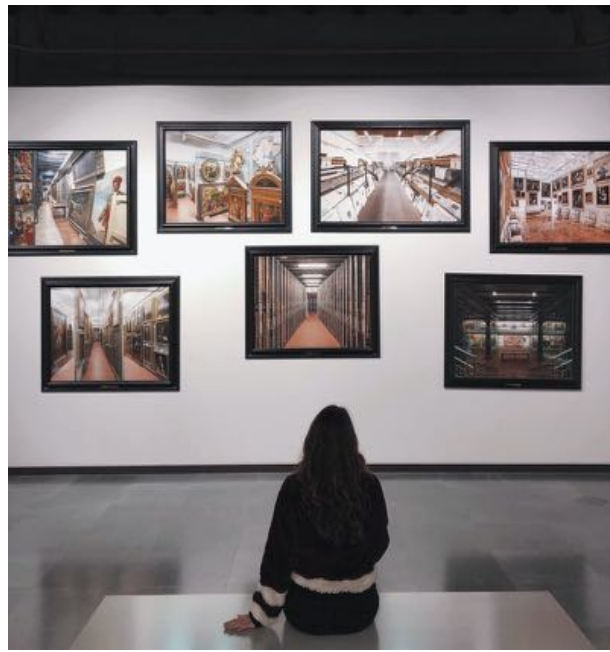
(at least for visual and auditory beauty)



(Ishizu & Zeki, 2011; 2013)

Medial orbitofrontal cortex (mOFC/vmPFC)





visual beauty



musical beauty





visual beauty

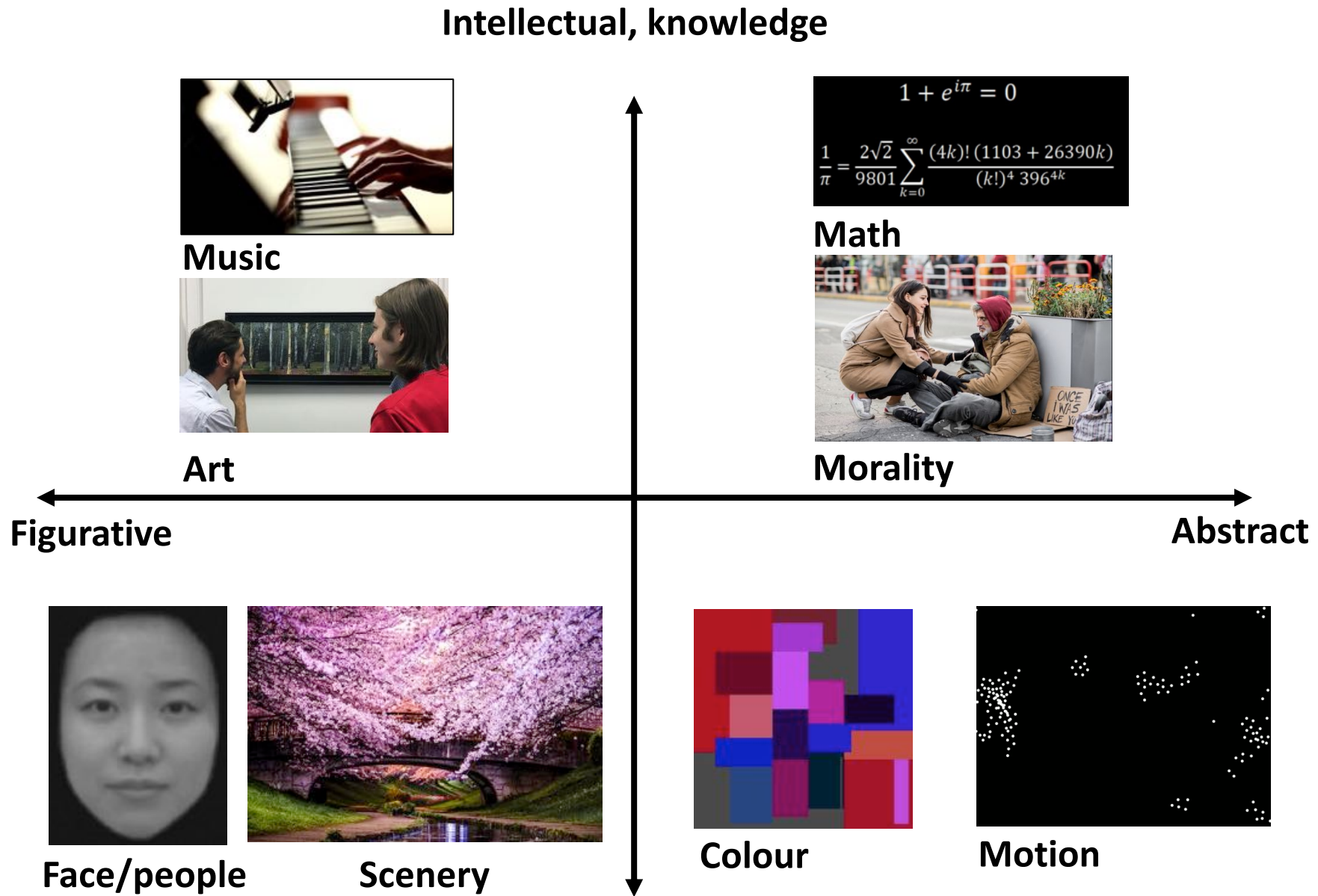


musical beauty



invisible beauty

$$1 + e^{i\pi} = 0$$
$$\frac{1}{\pi} = \frac{2\sqrt{2}}{9801} \sum_{k=0}^{\infty} \frac{(4k)! (1103 + 26390k)}{(k!)^4 396^{4k}}$$





# The experience of mathematical beauty and its neural correlates

Semir Zeki<sup>1\*</sup>, John Paul Romaya<sup>1</sup>, Dionigi M. T. Benincasa<sup>2</sup> and Michael F. Atiyah<sup>3</sup>

<sup>1</sup> Wellcome Laboratory of Neurobiology, University College London, London, UK

<sup>2</sup> Department of Physics, Imperial College London, London, UK

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Many have written of the experience of mathematical beauty as being comparable to that derived from the greatest art. This makes it interesting to learn whether the experience of beauty derived from such a highly intellectual and abstract source as mathematics correlates with activity in the same part of the emotional brain as that derived from more sensory, perceptually based, sources. To determine this, we used functional magnetic resonance imaging (fMRI) to image the activity in the brains of 15 mathematicians when they viewed mathematical formulae which they had individually rated as beautiful, indifferent or ugly. Results showed that the experience of mathematical beauty correlates parametrically with activity in the same part of the emotional brain, namely field A1 of the medial orbito-frontal cortex (mOFC), as the experience of beauty derived from other sources.

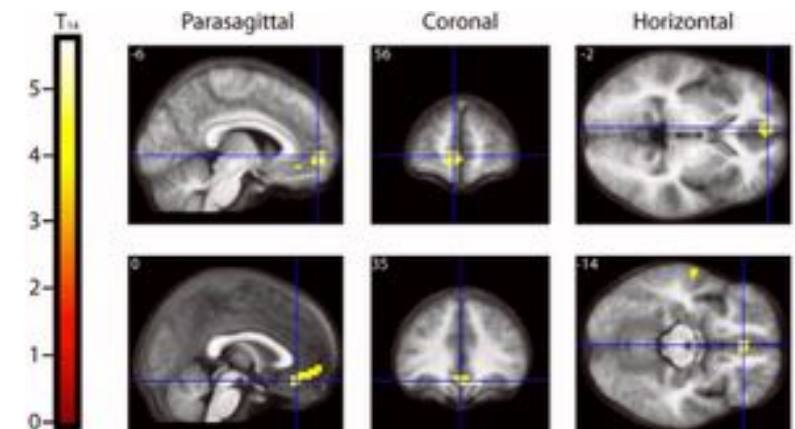
**Keywords:** mathematics, neuroaesthetics, fMRI, beauty, mofc

## 60 math equitions

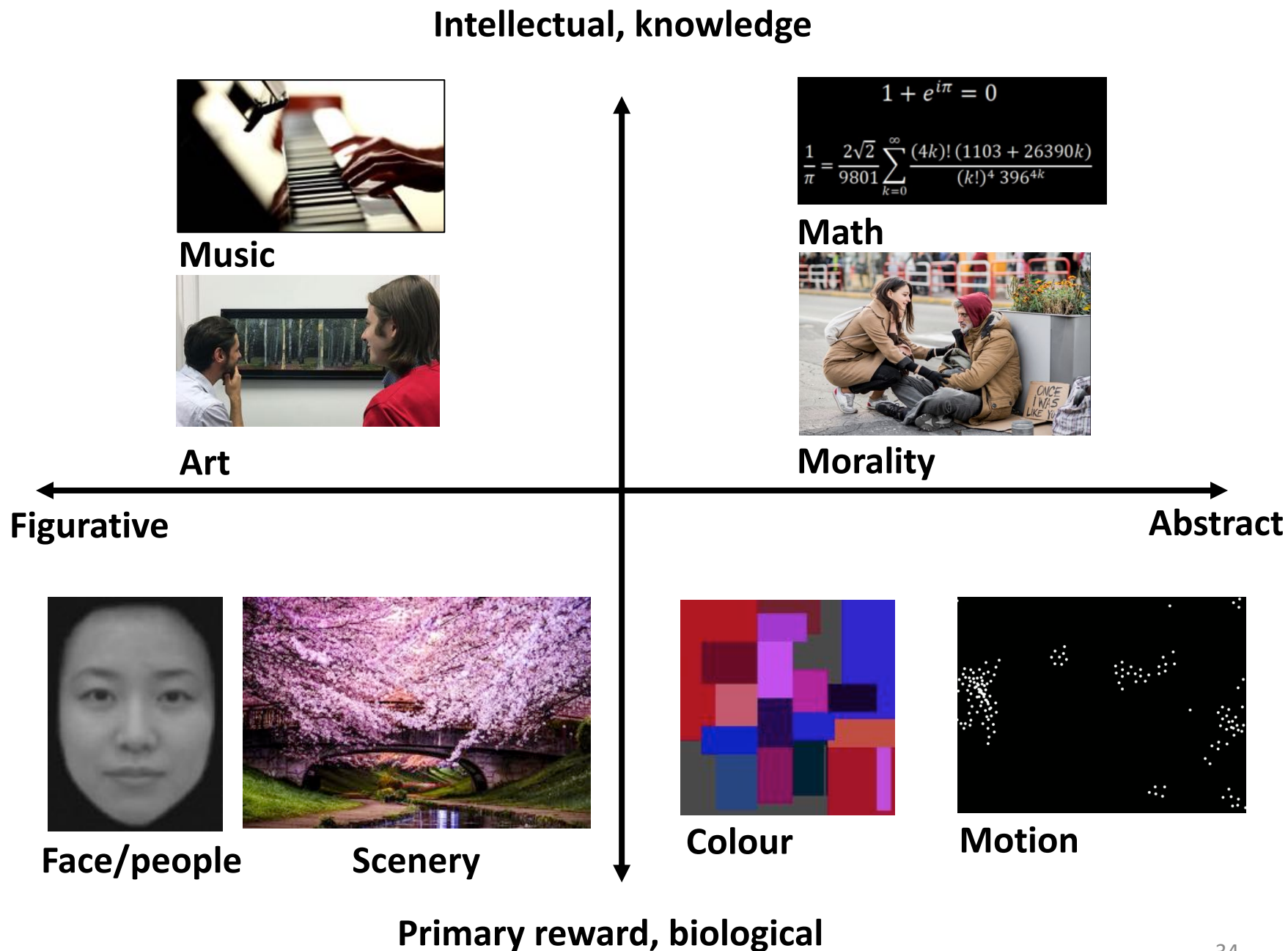
(e.g. Euler's identity, Pythagorean theorem, Gauss-Bonnet theorem, Cauchy's residue theorem, Taylor expansion of an analytic function, Ramanujan's infinite series and Riemann's functional equation)



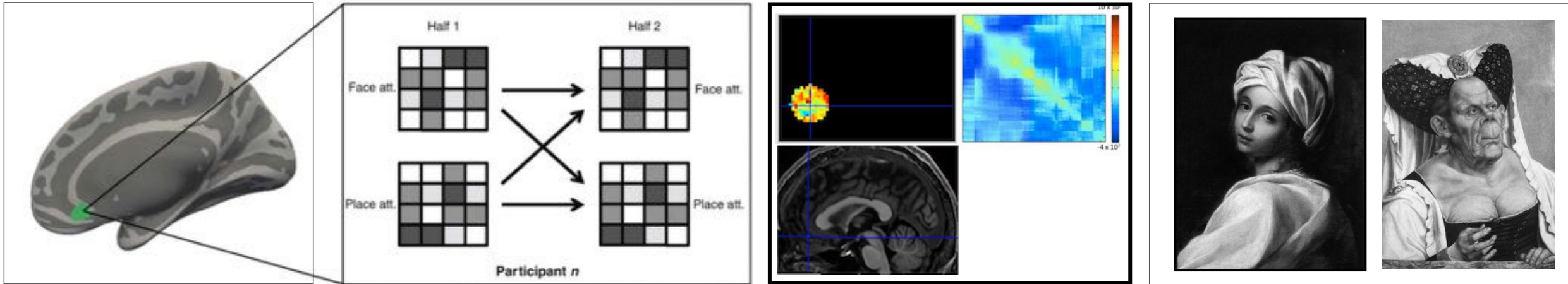
**Aesthetic evaluations  
(Degree of felt  
beauty/understanding)**







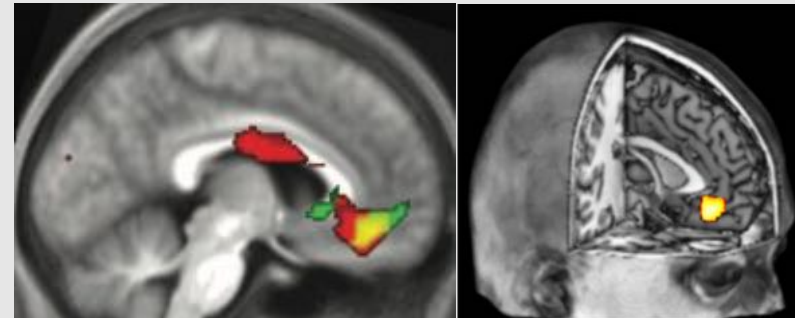
(e.g. Tsukiura & Cabeza, 2010; Ishizu & Zeki, 2011; 2013a; 2013b; 2014; Ikeda et al., 2014; Wang et al., 2015)



- Predicting individuals' aesthetic evaluations by decoding brain information
- The medial orbitofrontal cortex encodes (some) information about beauty

# One of neuroaesthetics findings:

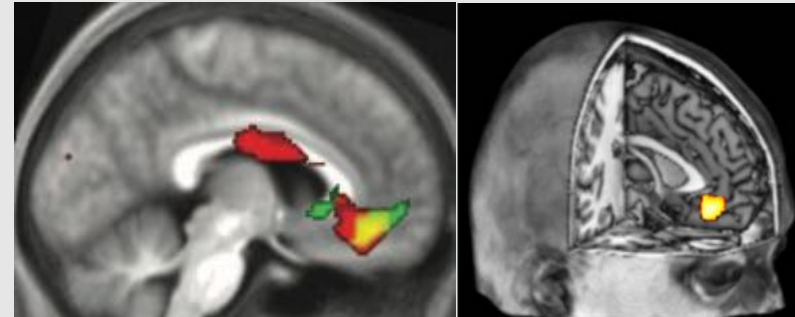
- mOFC may play an important role in aesthetic evaluation
- Independent of the media  
(supra-modal manner)
- *Common currency*





# One of neuroaesthetics findings:

- mOFC may play an important role in aesthetic evaluation
- Independent of the media  
(supra-modal manner)
- *Common currency*



Beauty with negatively valanced emotion

# Today's topics

- What is neuroaesthetics?
  - Definition, research areas, research objectives
  - Why beauty matters?
- Beauty (positive beauty) and its brain system
- **Empirical studies on *negative beauty***

What is

negatively valenced aesthetic experience ?

“Parting is such **sweet sorrow** that I shall  
say goodnight till it be morrow”

*Romeo and Juliet*









Positive valence +  
Positive aesthetic experience

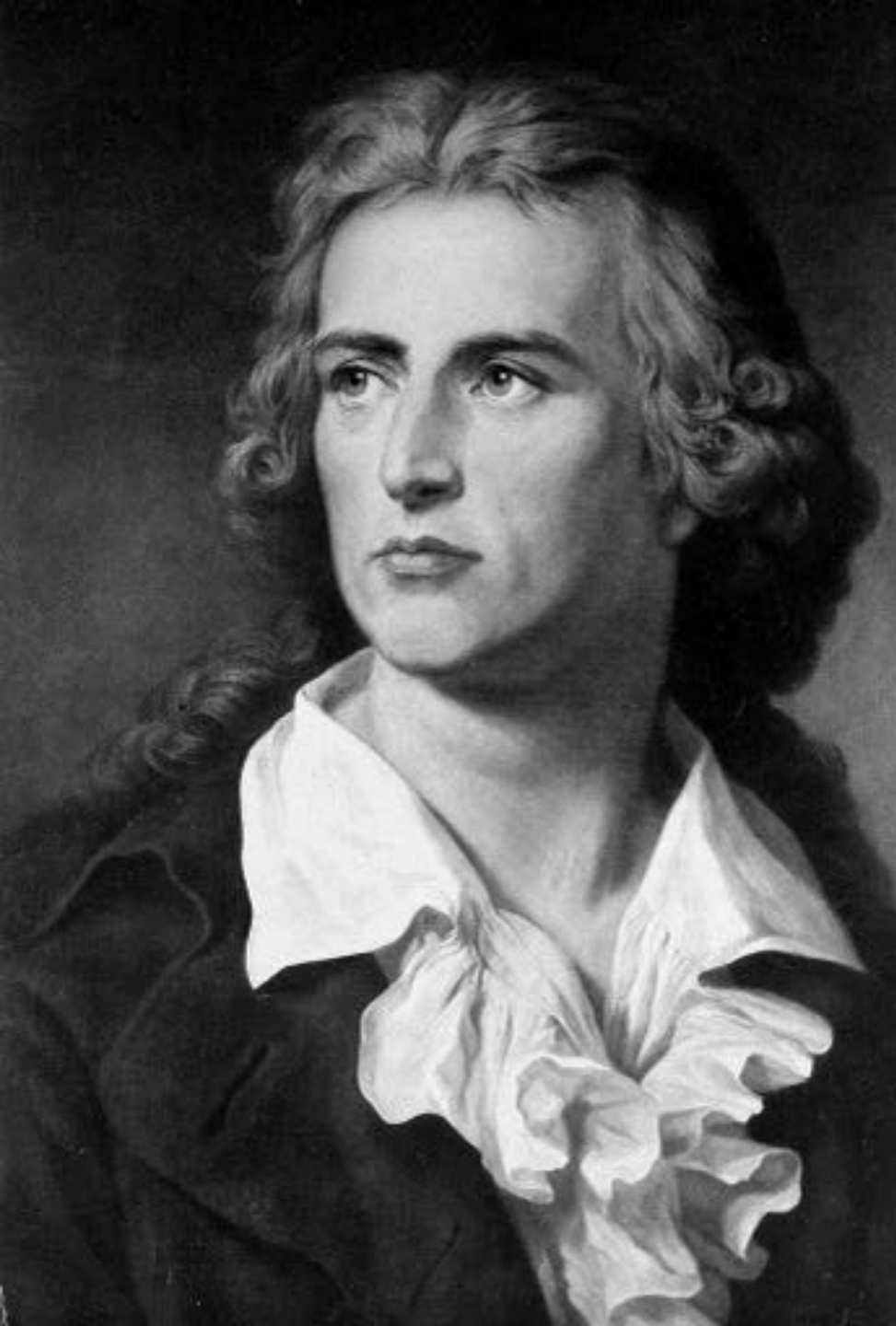


Negative valence +  
Positive aesthetic experience



Shutterstock

- Enjoyment of sad music and tragic stage play
- Morality, altruism, self-sacrifice  
= **involved in the foundations of humanity**



He discussed why we can enjoy tragedy in stage plays...

***“The pathetic (\*sorrow) is an artificial misfortune. The artificial misfortune of the pathetic... finds us in full armament, and... it is merely imagined”***

*Über das Pathetische*  
Friedrich von Schiller

- Artificial (imaginary) misfortune (F. Schiller, 18c)
- The fourth wall (D. Diderot, 18c)
- “The spectator is not sad but he *believes* he is sad” (P. Kivy, 1999)

**= Not real emotion but “imaginary emotion”**

Is negatively valenced emotion in art/aesthetics  
**imaginary emotion?**

Intriguing question in the humanities

↔ **hard to be tested by philosophical methodology**



sadness + beauty

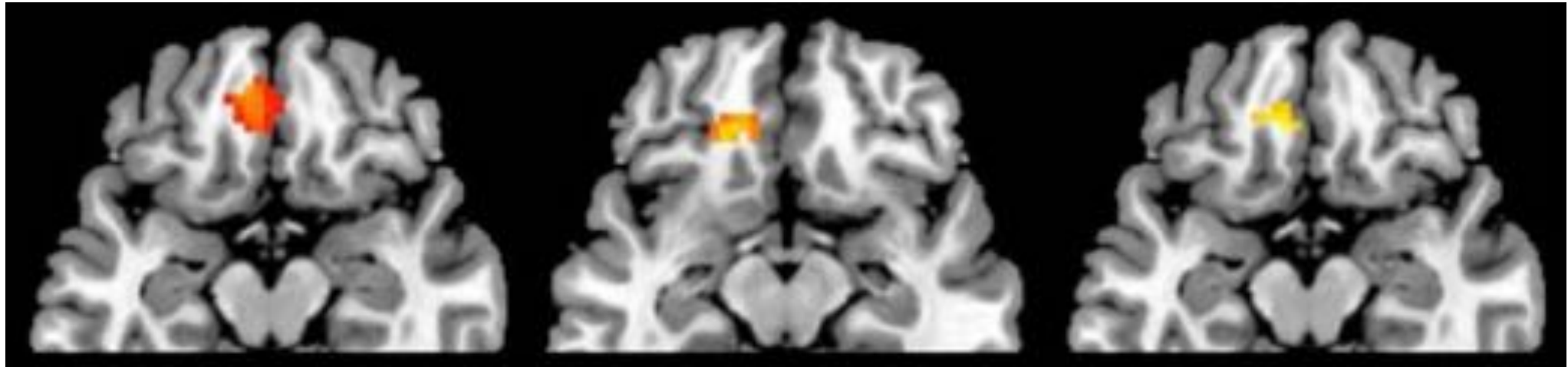


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joy + beauty

(aesthetic rating + emotion valence rating)

- **How the brain responds to sad beauty**
- **Comparison to pos. beauty**
- **Amygdala and ACC activity?**



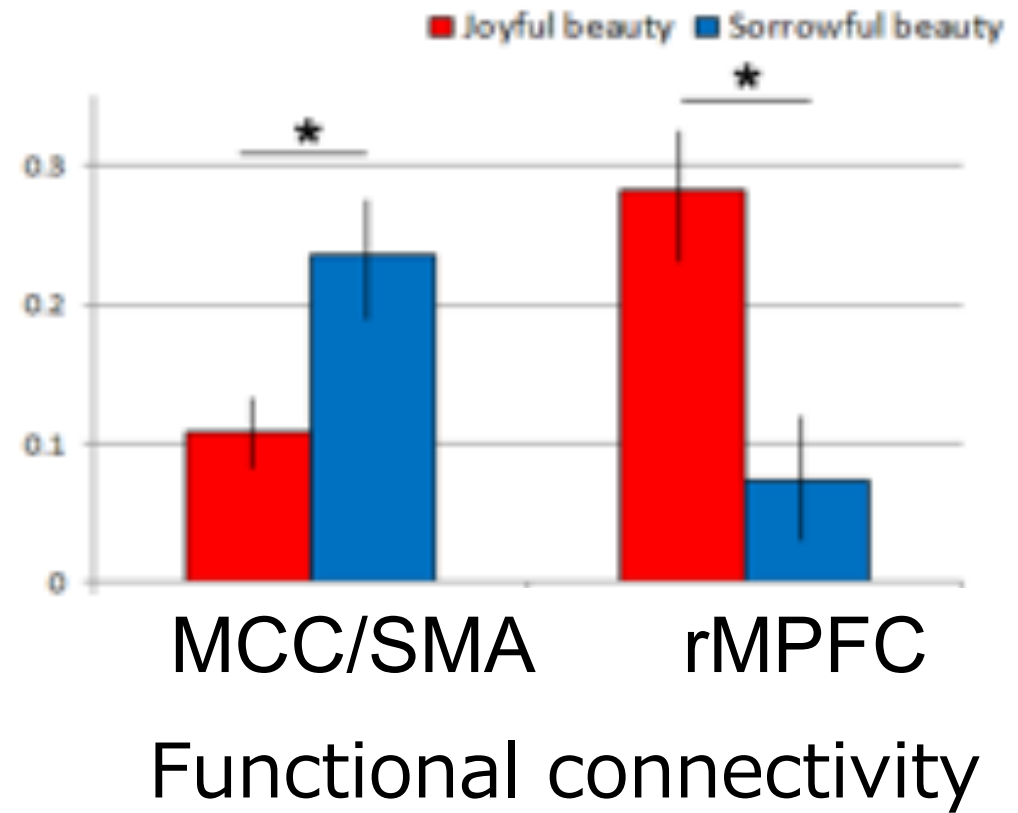
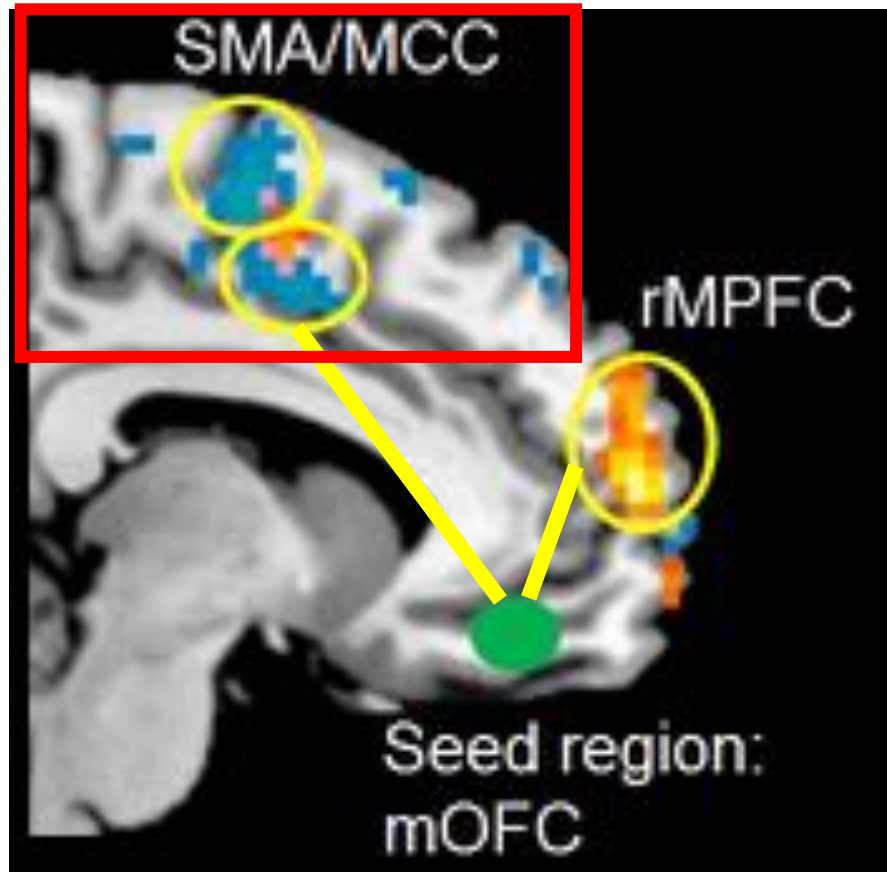
**Joy + beauty**

**Sadness + beauty**

**conjunction**

( $p < 0.05$  corr. SVC)

**Both types of beauty activate the mOFC**  
**mOFC: important for judgment of beauty**



## MCC/SMA, DLPFC

- **Empathy for pain/sadness** (Lamm et al., 2011)
- **Interpretation of others' intentions** (Fan et al., 2011)
- **No amygdala and ACC activity (ROI)**

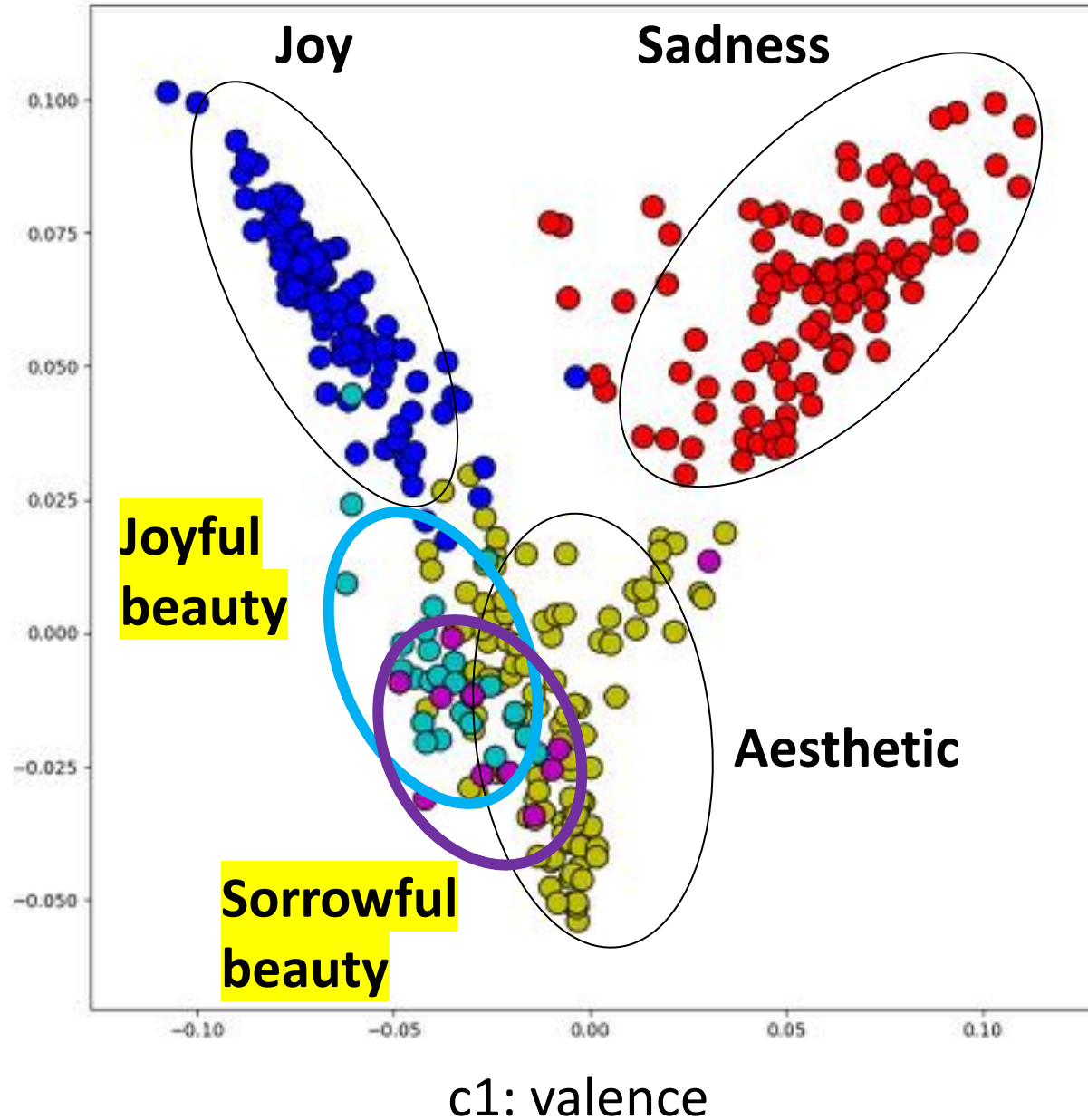


## Felt emotions in video viewing

(Original data derived from Cowen & Keltner, 2017)

c2: beauty +  
other components?

## Dimensionality reduction with PCA



PCA on each primal emotion and aesthetic experience

- Joy
- Sadness
- Aesthetic
- Joy + aesthetic
- Sadness + aes

Evaluating 366 videos using 34 emotions

How JA and SA are mapped in PCA

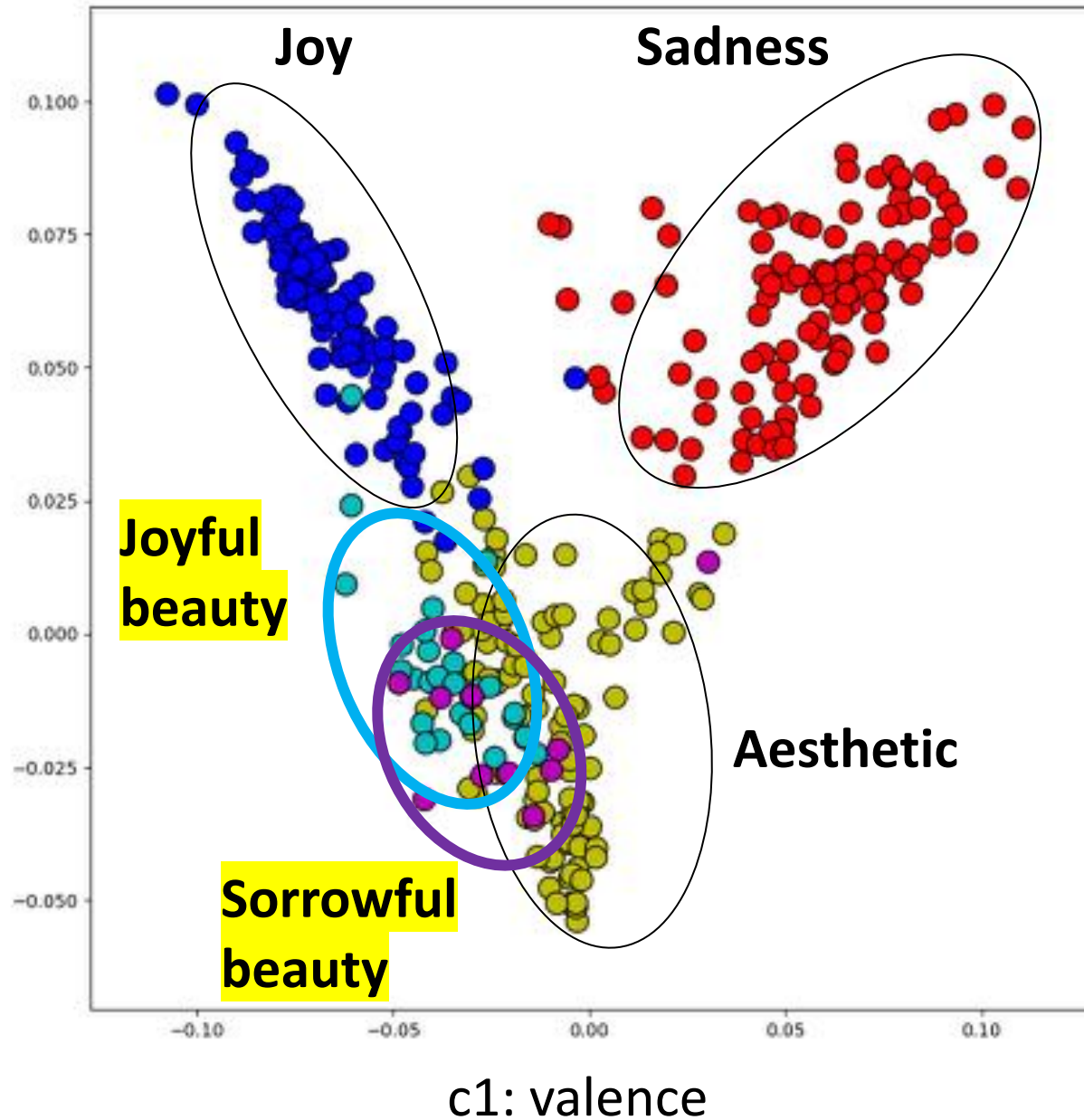
(Daikoku & Ishizu, under review)

# Felt emotions in video viewing

(Original data derived from Cowen & Keltner, 2017)

c2: beauty +  
other components?

## Dimensionality reduction with PCA



**The sad emotion of sad beauty may not be sadness with negative emotional valence**

Sad beauty may, in the end, have a pleasant experience (i.e. positive emotional valence)

Answering to the philosophical question from quantitative method

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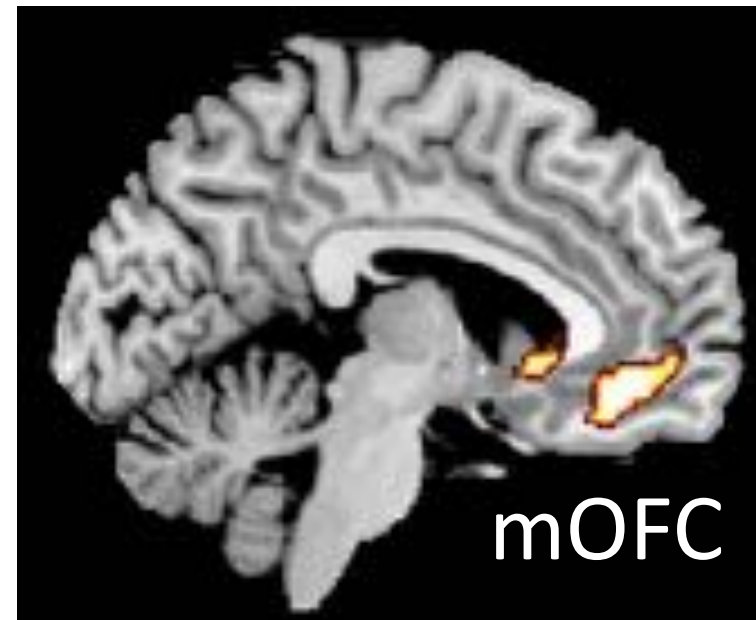
# Findings so far

- Beauty (visual, musical, morality, math, poetry)



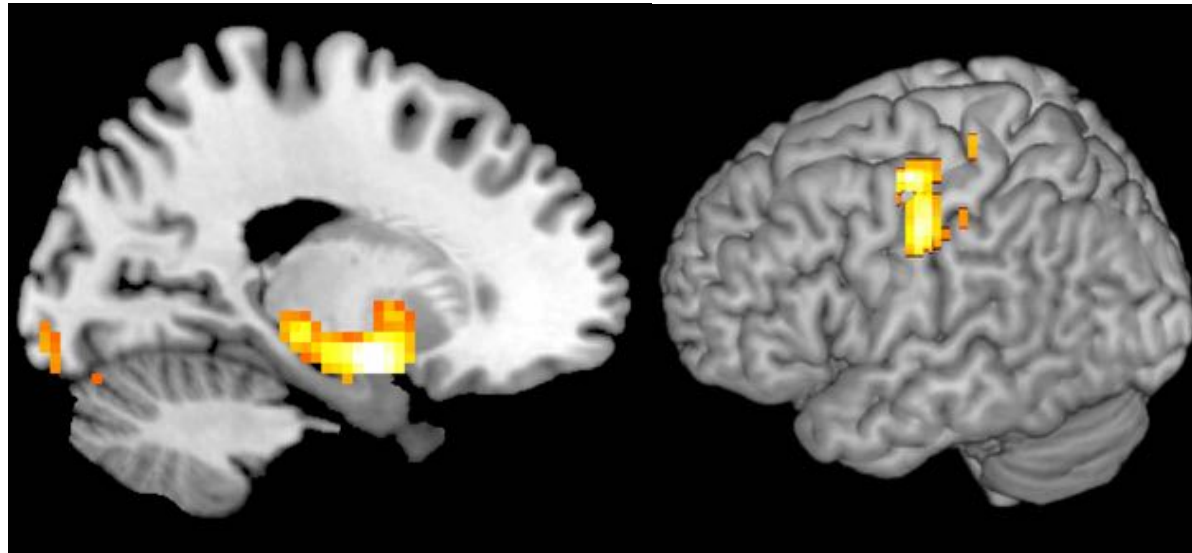
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# Findings so far

- Beauty (visual, musical, morality, math, poetry)
- Ugliness, aesthetic ugliness



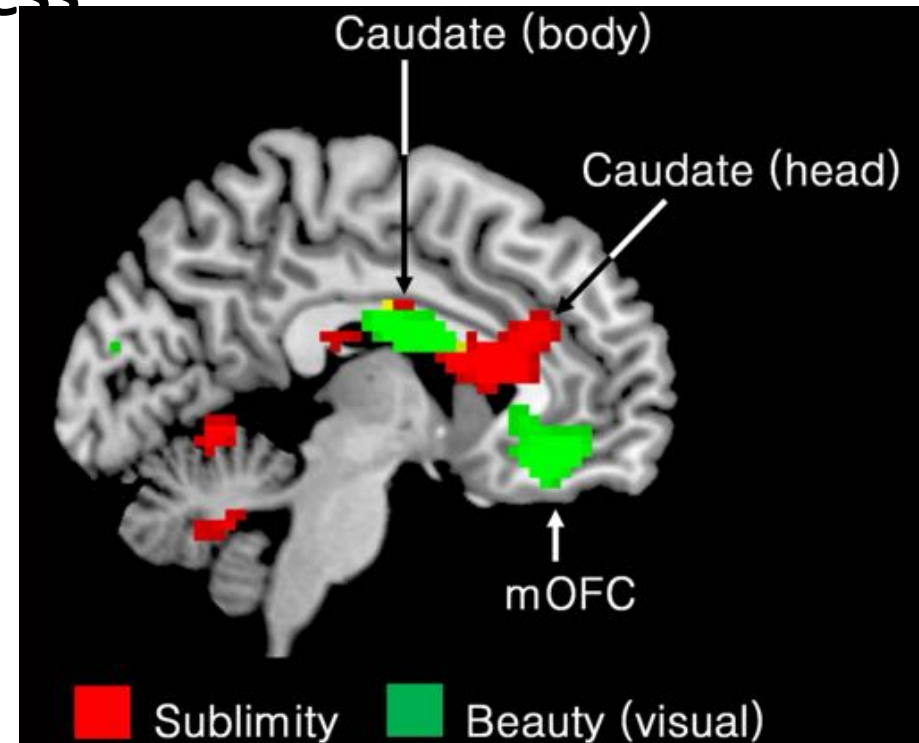
Amygdala

Motor cortex



# Findings so far

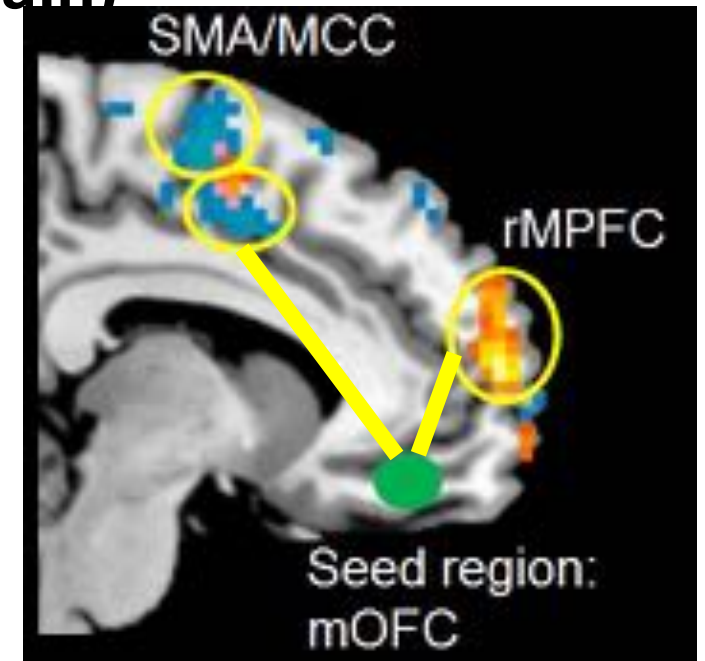
- Beauty (visual, musical, morality, math, poetry)
- Ugliness, aesthetic ugliness
- Sublime, awe





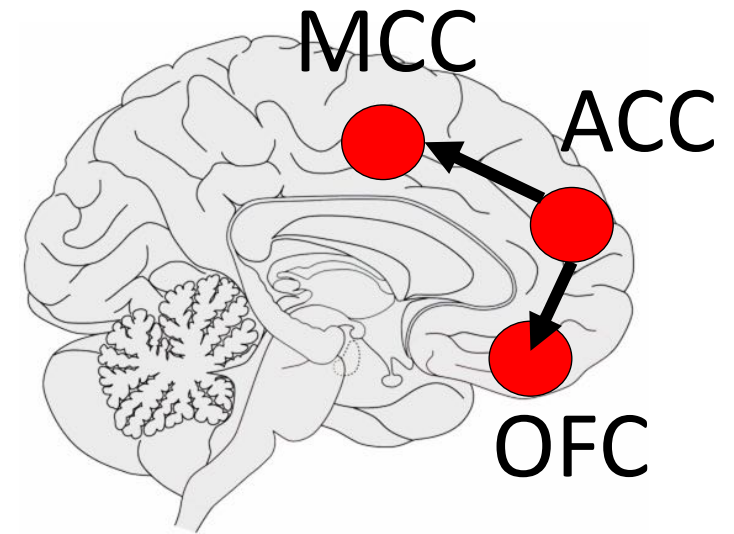
# Findings so far

- Beauty (visual, musical, morality, math, poetry)
- Ugliness, aesthetic ugliness
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- Aesthetic sadness (beauty in sorrow and pain)



# Findings so far

- Beauty (visual, musical, morality, math, poetry)
- Ugliness, aesthetic ugliness
- Sublime, awe
- Aesthetic sadness (beauty in sorrow and pain)
- How artistic values are socially shared

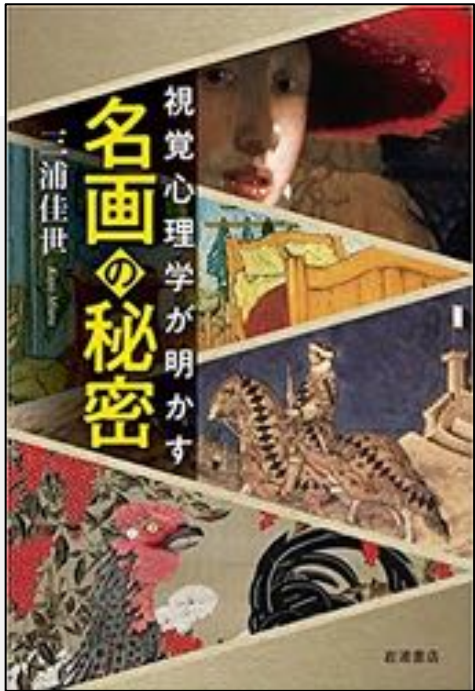


# Findings so far

- **Beauty (visual, musical, morality, math, poetry)**
- **Ugliness, aesthetic ugliness**
- **Sublime, awe**
- **Aesthetic sadness (beauty in sorrow and pain)**
- **How artistic values are socially shared**
- **Applications to social problems (well-being, pro-sociality)**

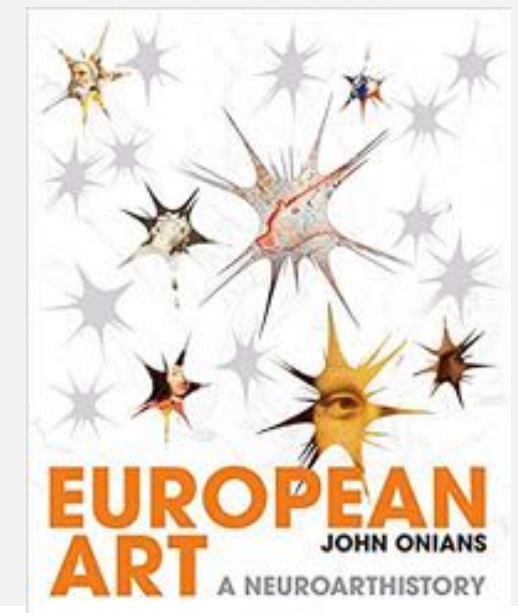
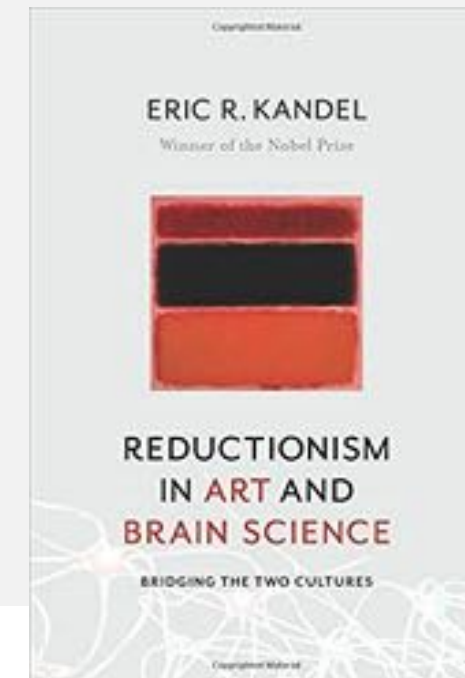
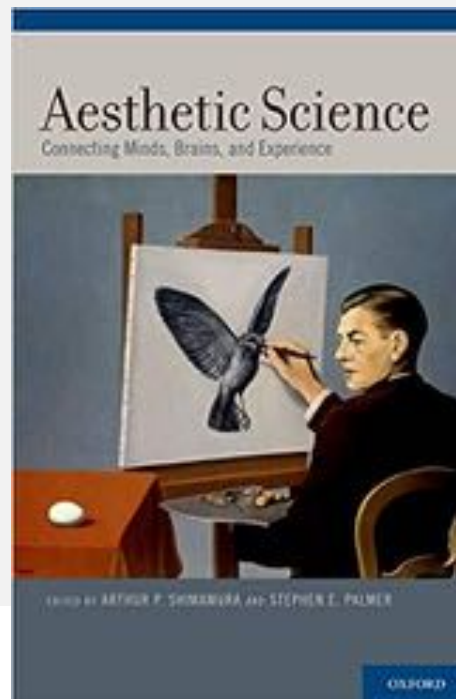
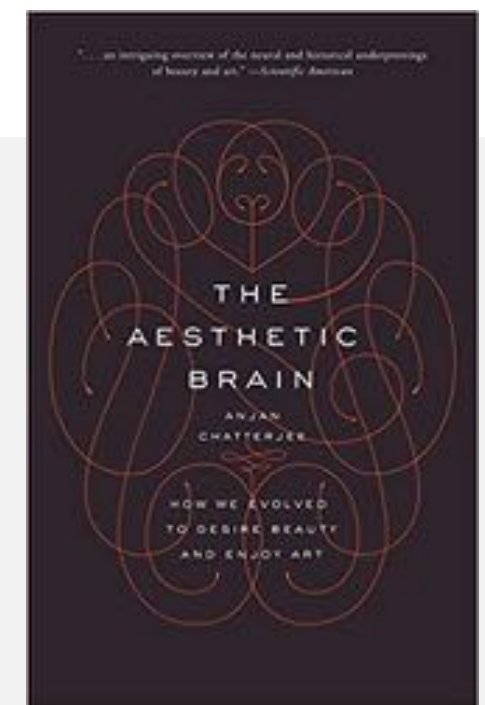
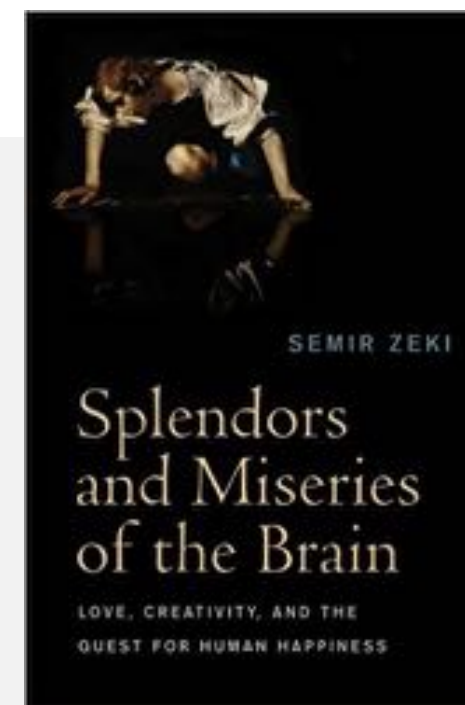
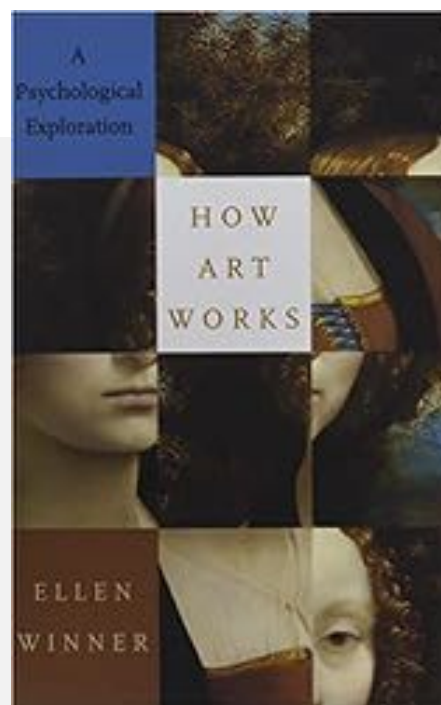


# Book & reading list





# Book & reading list



- About neuroaesthetics
- Studies on beauty with pos. emotions
- Negatively valenced aesthetic experience



サントリー文化財団 SUNTORY FOUNDATION

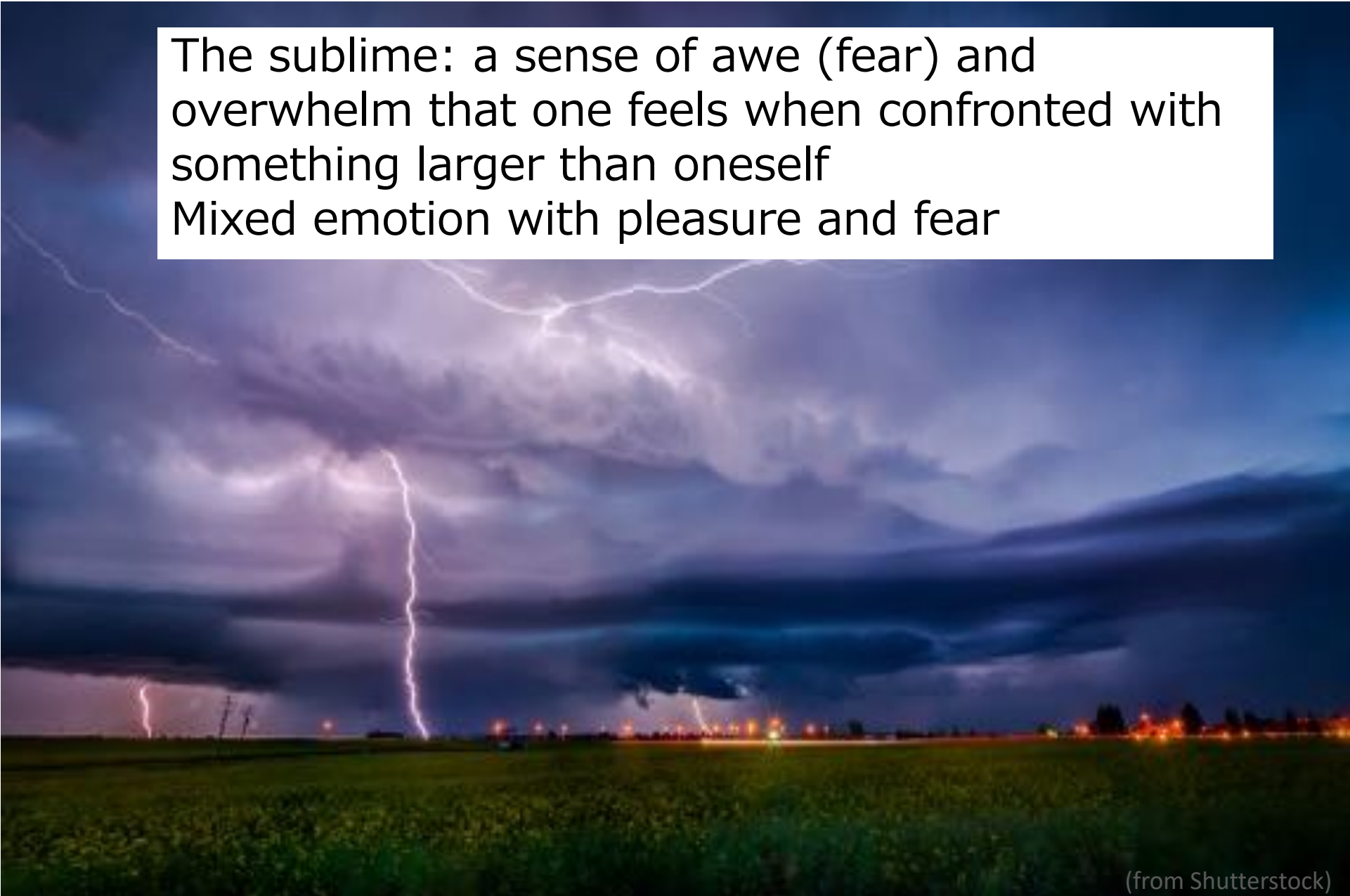
LEVERHULME  
TRUST





# *The sublime, awe*

The sublime: a sense of awe (fear) and overwhelm that one feels when confronted with something larger than oneself  
Mixed emotion with pleasure and fear

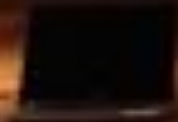




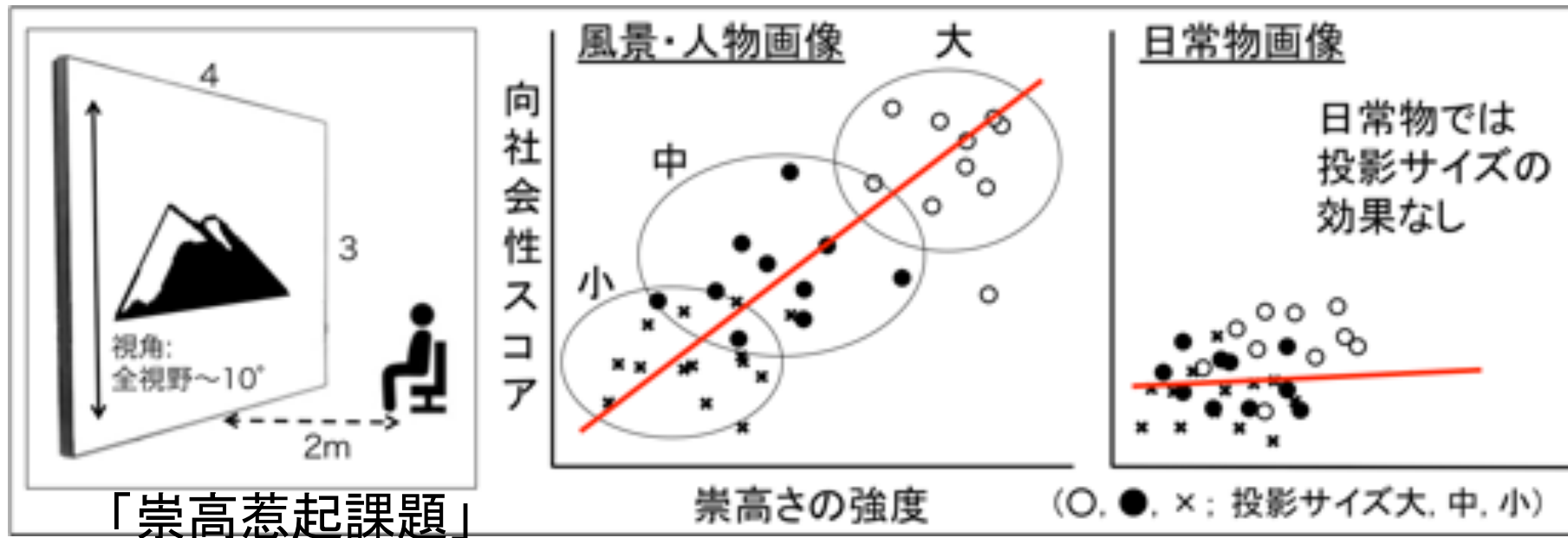


## Sublime experience enhances pro-social behaviours

- Increasing sense of belonging to the group one belongs
- Increasing cooperative behaviours
- Increasing altruistic acts





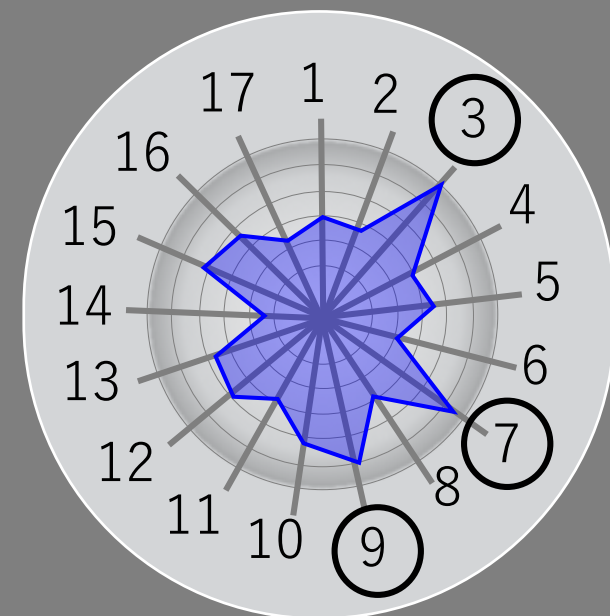


"Enhancing spontaneous social activities of residents and caretakers through 'sublime spaces and sounds' in homes for the elderly" project.

## 心理的因子の特定

崇高の主な  
構成情動

(3) 審美性  
(7) 恐怖  
(9) 覚醒度



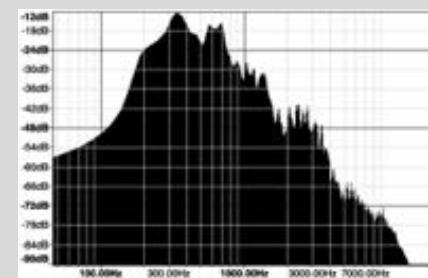
崇高の感情マップ

## 物理的特徴の抽出

崇高な音

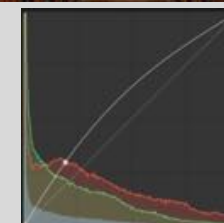


周波数スペクトル



各周波数帯域パワー  
倍音構造など

崇高な画像



各周波数帯域パワー  
コントラストなど