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# The unconscious emotions that art evokes

*Neuroscience research into the impact of a  
museum visit*

Final Report

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## People involved

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# How our brain responds to art

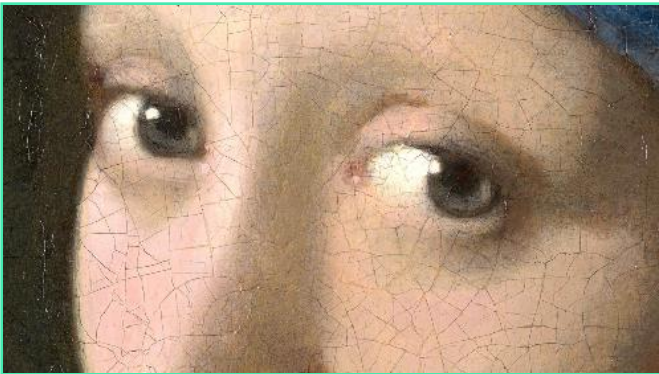


Fig. Top: the Mauritshuis. Bottom: the eyes of the Girl. Photo: Margareta Svensson.

*Making and appreciating art is the ultimate form of conscious behaviour. It has no value other than activating our emotions, and yet...*

Art has a profound impact on our emotions and perceptions. When we look at art, various parts of the brain are activated with a particular emphasis on the frontal cortex, which is crucial for aesthetic appreciation and value judgements.

But the amygdala is activated, too. This part of the brain is involved in emotional responses, allowing art to evoke a variety of emotions such as joy, sorrow, and a sense of calm.

The human brain has evolved to understand and interpret social interactions through direct, face-to-face communication. Neurological research shows that physical proximity to other people plays a unique role in social cognition (Shin et al., 2019). When we meet someone, brain regions related to social connection, empathy and emotional processing are activated, such as the tempoparietal junction, the prefrontal cortex and our mirror neuron system.

Many of these same social processes are also

activated when we see people via a screen (Derks et al., 2008).

It is logically plausible that art, and specifically artworks that feature people (e.g. portraits and tronies), also activate the mirror neurons in our brain – neurons that have a crucial function in empathy.

The Mauritshuis, an iconic museum in The Hague, houses a treasure-trove of masterpieces, including some of the world's most famous paintings from Dutch art. Including 'Girl with the Pearl Earring' painted by Johannes Vermeer.

This research, inspired by the Mauritshuis' wish to gain deeper insights into how visitors respond to artworks, in relation to images, aims to explore the neurological mechanisms and emotions underlying the appreciation of perception in art.

# The emotions behind the art experience

The questions the Mauritshuis has regarding neural activation when viewing works of art, with a specific focus on the 'Girl with a Pearl Earring', translate into the following research questions:

- *Is there a difference between looking at real paintings and images/reproductions of them?*
- *Is this potential difference mainly cognitive, or are there also emotional (affective) considerations?*
- *Which (if any) emotional considerations are involved, and what extra value does this give to a museum visit?*
- *Which emotions are responsible for this behavioural intention?*
- *Do these behaviour-steering emotions differ per work of art and what does 'Girl with a Pearl Earring' add to this?*

The research aims to find out how the physical presence of an authentic work of art in a museum evokes different emotional responses and what this may reveal about how people become emotionally involved with, and respond to, art..

The research aims to show why the 'Girl with a Pearl Earring' is not only consciously acknowledged as one of the most famous paintings in Dutch art history, but that this work owes its status as a masterpiece to largely unconscious processes and, precisely because of this, motivates people to visit the Mauritshuis to see this painting.

A unique research approach was devised: EEG measurements during a museum visit, combined with MRI analysis of the emotions underlying an art experience. Never before has research into the impact of art been conducted in this way, combining EEG and in-depth MRI research.



*Fig. Foto's of the Girl with a Pearl Earring. Images are the property of the Mauritshuis.*



# Research design

## PHASE 1: MUSEUM VISIT (EEG)



N=20



Girl with a Pearl Earring  
versus other paintings

Paintings  
versus posters

## PHASE 2: EMOTIONAL IMPACT OF ART (fMRI)



N=20



Girl with a Pearl  
Earring  
versus other paintings

To answer the research question, we used a combination of EEG, fMRI, both in combination with eye-tracking. For both techniques, a sample size of N=20 is sufficient.

The fact that MRI, like EEG, is a direct brain measurement of mainly unconscious processes in a controlled environment, makes this sample of sufficient size to make reliable statements about the perception of the population (*Berns & Moore, 2012; Lamme & Scholte, 2013*).

### Phase 1

For a direct and reliable evaluation of brain activity elicited by *real paintings*, an EEG measurement met eye-tracking was taken from test subjects who followed a set route through the Mauritshuis. The

measurement was taken from 20 test subjects who viewed five different paintings in the museum in a randomised order. To assess the effect of a real work of art in a museum, the same subjects, also saw, in random order, a poster version, full size, of the same paintings, during an EEG measurement.

### Phase 2

In search of the emotions underlying the EEG results, in part two of the study, MRI scans were taken while the participants saw the same paintings in random order.

Eye-tracking was used in both measurements. Eye-tracking registers what someone is looking at, for how long, and in what order.

# Rationale & Results



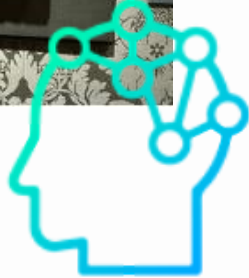
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PHASE 1:

*The museum visit*



# EEG as a research tool: Analysis of attention and approach needs



Electroencephalography (EEG) is a widely used neuro-technique that measures the immediate brain response and provides insight into the cognitive processing of stimuli, in this case the 5 paintings.

Via the cranial surface, EEG measures the activity of brain cells that are synchronously active at the same time. Electrical voltage, generated by the brain, is picked up in the process through a cap - a kind of bathing cap with electrodes - placed on the head.

## What does EEG measure?

We measure different types of brain activity through electrodes:

- Attention: the level of cognitive involvement;
- Approach/avoidance: indicates the extent to which certain stimuli tend to elicit approach or avoidance behaviour.

To analyse the attention levels, we used the alpha part (8-13 Hz) of the EEG signal for the visual channels, particularly the channels at the back of the head and the parietal channels.

Approach/avoidance is measured using brain activity in the prefrontal cortex. This area is involved in emotion regulation and decision-making.

With approach, there is generally more activity on the left side, while with avoidance there is more activity on the right side.

By measuring the asymmetry in activity, researchers can work out whether an individual experiences a positive or negative response towards a stimulus – in this case, a work of art.

## Why EEG

Although we can use fMRI to measure the same brain activity and more (the underlying emotions), EEG offers valuable advantages.

The portability of the equipment means that test subjects can look at real paintings in a museum environment, which creates a natural and contextual environment compared to looking at reproductions.

# Art appreciation in the brain: EEG measurements in the Mauritshuis



*Fig. Stimuli such as those used in the research. The formats have been adapted for layout reasons and the proportions don't correspond to reality. Images are property of the Mauritshuis.*

In Phase 1 we conducted a study using EEG and eye-tracking measurements on 20 participants who followed a set route through the Mauritshuis. 5 paintings were included on this route:

- Girl with a Pearl Earring (Johannes Vermeer)
- The Violin Player (Gerrit van Honthorst)
- Self-portrait (Rembrandt van Rijn)
- The Anatomy Lesson of Dr Nicolaes Tulp (Rembrandt van Rijn)
- View of Delft (Johannes Vermeer)

The same participants were exposed to poster versions of the 3 (self-) portraits and tronies, and EEG and Eye-tracking measurements were taken again. The poster versions were of the same size as the real artworks and were presented in the library of the Mauritshuis.

To ensure variability, the order of viewing the real paintings and posters, the route through the museum (following or going against the direction) and the order in which the posters was presented, were randomly assigned.

This research was possible thanks to a wearable kit. The participants wore an eye-tracker and EEG-cap, the latter of which was connected to an amplifier (carried in a backpack) and a tablet, all operated remotely by the researcher.

The participants were accompanied along the route by the researcher. At every painting, they performed a sequence of actions: eyes closed, followed by a benchmark measurement (with eyes closed) and an EEG and eye-tracking-measurement after opening their eyes. The benchmark measurement is intended to establish basal brain activity and serves as a reference point for analysing and interpreting the experimental stimuli, the paintings.

The results of this study shed light on the neurological processes involved in art appreciation in a museum. The flexible design, in which the portability of the equipment was crucial, enabled this research and provides valuable insights for the understanding of art appreciation.



# The added value of a museum visit

In our initial analysis, we examined the impact of authentic versus replica, What sets apart a museum visit and what makes a physical museum experience invaluable?

To find out, we used EEG to research the approach/avoidance-effect of paintings and posters by looking at the signal of the prefrontal cortex. The results show that real artworks, compared to posters, evoke an extremely powerful positive emotional reaction.

The approach effect of the posters differs in comparison to almost all the paintings (see fig.). The poster of the 'Girl with a Pearl Earring' differs significantly from all the paintings; the poster of the 'Self-portrait of Rembrandt' differs significantly from the 'Violin Player' and the 'Anatomy Lesson'; the poster of the 'Violin Player' differs significantly from all the paintings, except for the 'View of Delft'.

The participants experienced a strong

approach effect when looking at the real paintings: they experienced a 10 times greater approach effect when looking at real paintings compared to the poster versions: the average approach effect of the posters (0.03) versus the average approach effect of the (self-)portraits and tronies (0.35).

This indicates the powerful emotional reactions that real art, including the immediate surroundings (frame, lighting, etc.) evoke in the viewer.

When we compare the paintings to each other, we don't see any significantly differences. The 'Girl with a Pearl Earring' gets an average score. The 'Violin Player' and the 'Anatomy Lesson' score higher.

The 'Anatomy Lesson' and the 'Violin Player' are large-scale works, which may explain the relatively large approach effect.

Of all the paintings – including these two – we will examine the 'approach effect' more closely in Phase 2 with MRI.

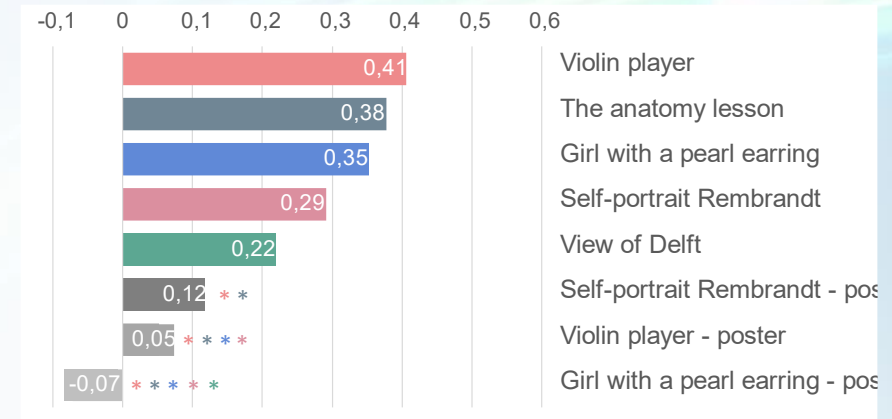


Fig. Approach/avoidance for the paintings and poster versions. A positive score reflects an approach; a negative score reflects avoidance.

## The masterpiece: Girl with a pearl earring attracts attention

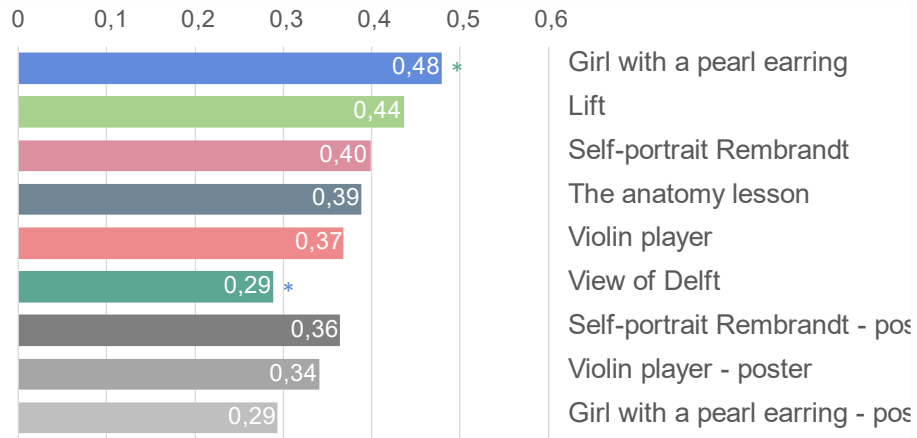


Fig. Attention score for the paintings and posters based on a comparison between benchmark- and experimental measurements. The alpha signal of the visual channels was used for this score.

Next, we examined the degree of cognitive engagement while viewing real works of art versus posters.

Compared to all other paintings and posters, the 'Girl with a Pearl Earring' attracts by far the most attention (see fig.), with the difference in attention compared to the 'View of Delft' being significant. The status of this painting as a masterpiece in the Mauritshuis is reflected in viewers' brain activity.

The degree of attention people pay to the 'Girl with a Pearl Earring' is incredibly powerful. She even attracts more attention than the lift to the museum – a measurement we included because of its

interesting aspects in terms of attention.

The lift stops halfway – the marble floor slab is connected to the lift – which sometimes causes people to want to get out halfway.

Noting this situation and responding to it requires a degree of attention for potential danger. However, less attention than the 'Girl with a Pearl Earring' demands.

When we look at the differences between real and reproduction, we see that the effect is somewhat smaller when participants viewed a poster version: 1.16 times more attention for paintings (0.38 average) versus posters (0.33 average).

# The secret behind the incredibly intense attention

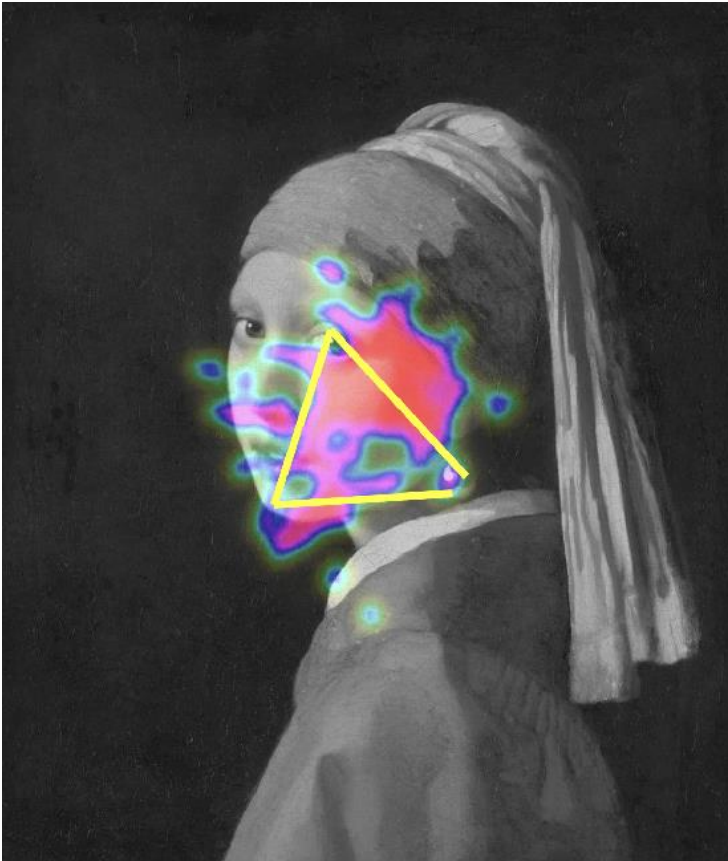


Fig. Heat map of the Girl with a Pearl Earring.

The secret behind the intense attention of the 'Girl with a Pearl Earring' is a neurological phenomenon.

The 'Girl with a Pearl Earring' is a painting that not only captures your gaze but holds you in a triangle of 'sustained visual attention'; the viewer's attention is held captive, so to speak, creating a 'loop'.

People are naturally focused on faces, as the brain instinctively tries to decipher the emotional context of a situation (Langton et al., 2008). Vermeer skilfully used this human attention mechanism.

Our eye-tracker analyse reveals a fascinating pattern. Normally, facial features such as the eyes and mouth dominate the attention. But, in

the case of the 'Girl with a Pearl Earring', we see a unique interaction. After looking at the eyes and mouth, the pearl captures the viewer's attention. Then leads their gaze back to the facial features, then back to the pearl, and so on.

*With the 'Girl with a Pearl Earring', Vermeer has created a visual loop that holds the viewer captive.*

This subtle choreography of attention makes the 'Girl with a Pearl Earring' not only a masterpiece by Vermeer, but a captivating experience for anyone who admires her.

This admiration also has a cause than can be explained with the sustained attentional loop.



## We love the 'Girl'

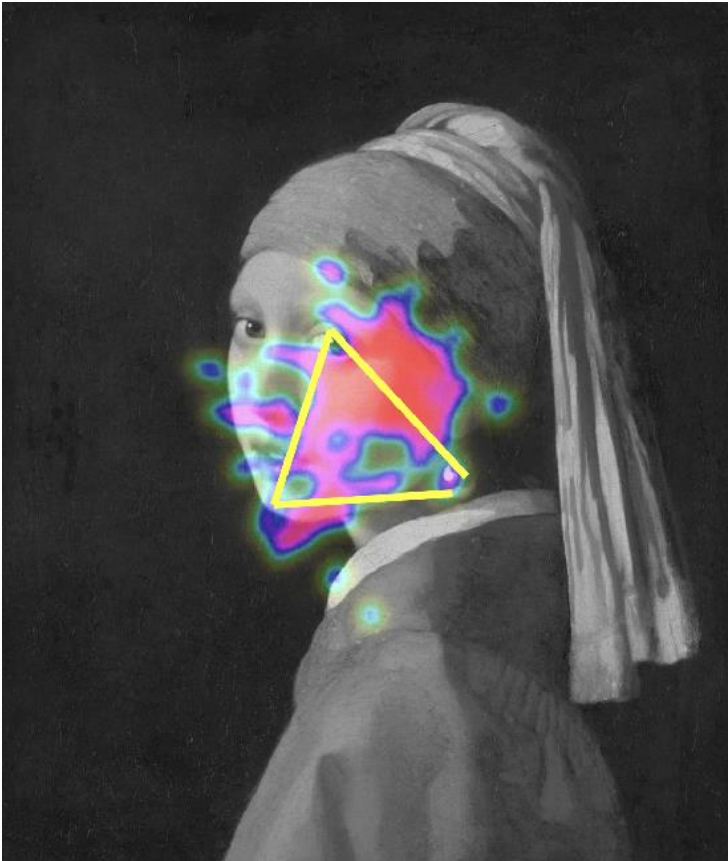


Fig. Heat map of the Girl with a Pearl Earring.

The sustained attentional loop, captures the attention in a 'loop' of eyes, mouth and pearl.

This prolonged need to look at the face sets in motion another psychological effect known as the Mere Exposure effect. (Robert Zajonc in 1964).

Mere Exposure is a psychological phenomenon that describes our tendency to develop preferences for things simply because we are familiar with them.

The core of the effect is that exposure to a

stimulus (such as a person, object, sound, or idea) causes us to like that stimulus more, without being aware of it.

This applies to both negative and positive stimuli.

Knowing that the 'Girl' arouses more positive than negative emotions, what happens in this case is the 'Girl' becomes more beautiful, intriguing and attractive the more often we look at it.

In the museum at the real painting, but also at the reproductions.





# Rationale & Results

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Phase 2:

*The emotional impact of art*

# MRI scanning: in search of the emotion behind the art experience



*Fig. The Philips MRI scanner such as the one at the UvA that was used for the study.*

A limitation of EEG is that it cannot capture the emotions that underlie the approach/avoidance effect. This is because these emotions are processed deep in the brain.

To measure the emotional impact of a stimulus, in this case a painting, MRI scanning was used.

An MRI scanner is – in simple terms – a large magnet with which the blood flow, and thus the energy consumption of the brain, is measured. Thus, we see where in the brain activity occurs when seeing a stimulus, here the 5 paintings,.

A brain scan generates a lot of data; the MRI scanner measures hundreds of thousands of voxels (three-dimensional pixels) in our brain. To give meaning to this data, Neurensics uses the 3D

Brain Rating analysis.

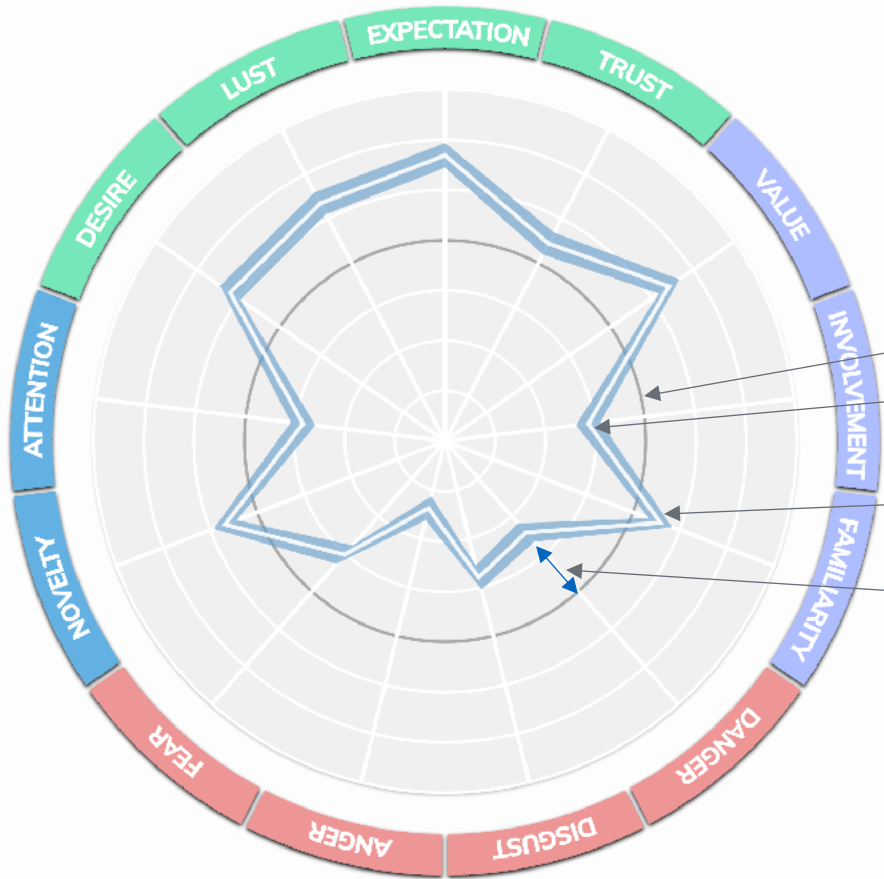
This method analyses 13 dimensions relevant to behavioural intentions, divided into four main categories: positive and negative emotions, attraction, and impact.

These include primary emotions such as value, desire, expectation and trust, as well as fear, danger and aversion (see appendix).

Each experience is composed of a combination of these emotions as the brain unconsciously values them. When the ratio of this valuation is more positive than negative, there is an intrinsic valuation of the stimulus (approach vs avoidance).



# Interpreting the spider diagram



The diagram can be read as follows:

- The grey circle is the indexed average score per emotion.
- The white line in the coloured band is the average activation on the given dimension.
- The coloured band around it indicates the standard error. This is used to calculate significances.
- If there is space between the grey circle and the coloured band, then there is a significant difference (at  $p < 0.05$ ) from the average.

# The Girl with a pearl earring in our brain

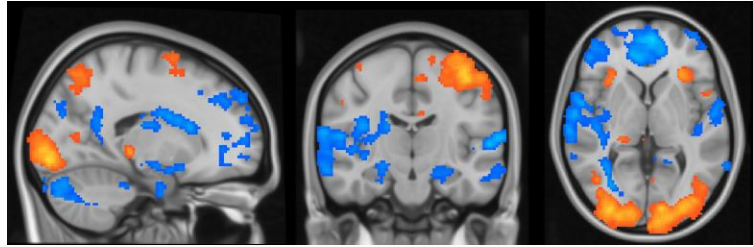


Fig. Visualization of the raw brain activity when viewing the 'Girl with a Pearl Earring'. Orange indicates increased activation compared to the average; blue indicates decreased activation compared to the average.

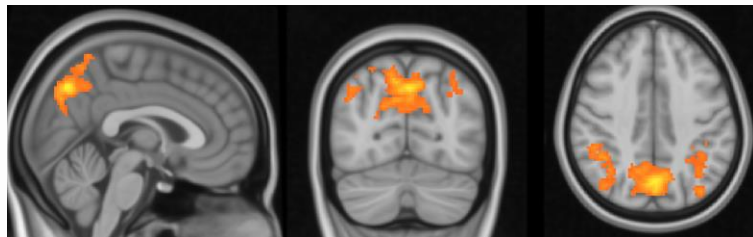
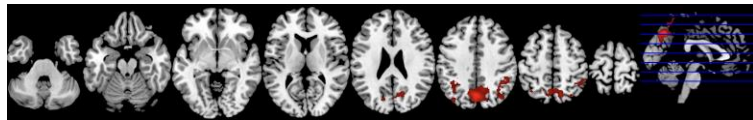


Fig. Visualizations of the contrast in brain activity between the 'Girl with a Pearl Earring' and the other paintings.

Top Fig. Transverse sections of the brain. Red indicates increased activation compared to the other paintings.

Bottom Fig. (left to right) sagittal, coronal, and transverse sections of the brain. Orange indicates increased activation compared to the other paintings.

In Phase 2 we used MRI scanning to measure the brain activity of 20 respondents as they looked at images of the paintings.

These paintings were the same as during the museum visit (Phase 1 of this research). As a control – as a benchmark – we included 5 other paintings from the Mauritshuis in the same block (see appendix). The order in which the images was presented was randomised.

The figure above left shows the basal brain activity when participants looked at the 'Girl with a Pearl Earring'. The activation of the visual cortex, which can be seen in the lowest orange activity in the figure at the top right, is striking. This activity corresponds with the degree of attention we observed in the EEG measurements.

Compared to other paintings in the Mauritshuis, the 'Girl with a Pearl Earring' causes a remarkable difference in brain activity (see fig. Below). The same contrast is visible in the brain, where the network involved in self-awareness and emotions is activated when someone is personally interested.

Specifically, the precuneus, normally associated with a richer grey mass among artists compared to non-artists (Chamberlain et al., 2014), is a crucial area that lights up when the viewer looks at the 'Girl with a Pearl Earring'. This suggests that the painting may promote deeper personal engagement and self-reflection compared to other artworks in the Mauritshuis.

# The magic of the 'Girl': a deep dive



Fig. Scatterplot of engagement score set off against the balance of positive and negative emotions. The coloured circles represent the standard error. In instances where they don't overlap there is a significantly difference

In the EEG results (Phase 1) it was noticeable that, compared with other artworks, the 'Girl with a Pearl Earring' generates heightened attention and a certain need to approach. The MRI results shed light on the *how and why* behind these remarkable responses to the 'Girl with a Pearl Earring'.

First, we compare the MRI data of all the paintings with a focus on engagement (x-as) and the balance between positive and negative emotions (y-as).

The figure on the left shows three results:

1. the 'Girl with a Pearl Earring', the 'Self-portrait of Rembrandt' and the 'View of Delft' score significantly higher than the 'Violin Player' and the 'Anatomy Lesson'. A

high engagement score reflects a positive involvement experienced when looking at the painting.

2. All the paintings, except for the 'Girl with a Pearl Earring' score average on the balance van positive versus negative emotions.
3. the 'Girl with a Pearl Earring' scores best of all the paintings: she is the only one that activates a significantly better balance of positive and negative emotions than average *and* scores significantly higher on engagement (positive involvement).

The emotions that underlie these results are shown clearly in the spider diagrams. In the following slides, we will discuss the spider diagrams of the 'Girl with a Pearl Earring' and the other paintings.



## The 'Girl': Activates a good balance in emotions with high scores on Value and Involvement

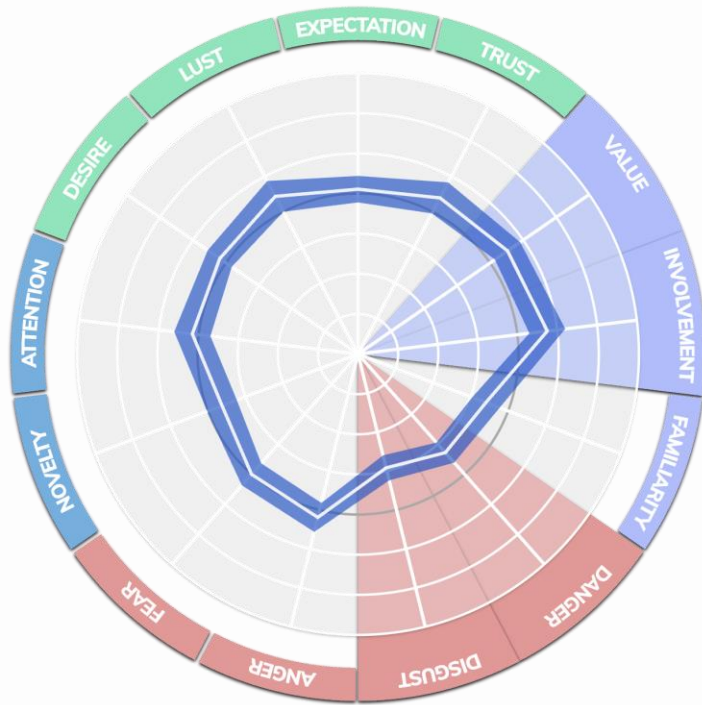


Fig. spider diagram of the Girl with the Pearl Earring. The grey circle in the middle is the average score of all images (inc. control). There is a significant difference if there is a space between the grey and blue line.

In the spider diagram of the 'Girl with a Pearl Earring', showing the score for the 13 emotions relevant to behavioural intention, the cause of the high engagement score is clear.

The 'Girl with a Pearl Earring' scores significantly high on value and involvement. People experience a rewarding feeling, a certain added value, because the 'Girl with a Pearl Earring' evokes a sense of involvement. The tronie is relevant to the viewer.

The 'Girl with a Pearl Earring' scores look significantly better than all the other paintings on

the balance of positive and negative emotions. This does not come from eliciting more positive emotions than average, but the 'Girl with a Pearl Earring' arouses almost no negative emotions and scores significantly lower than average on Danger and Disgust.

A good balance between positive and negative emotions contributes to behavioural intention. In the case of an artwork, this translates into a tendency to take a closer look at the painting, reflect on the meaning and/or decide to appreciate the work and share it with others.

A person is shown from the side, wearing a striped shirt, with their hand resting on a futuristic, metallic robotic arm. The arm is emitting several bright, glowing blue and cyan light trails that curve across the frame. The background is dark, and the overall lighting is dominated by the cool tones of the light trails.

| Conclusions

# Conclusions

- ✓ There is a difference in the experience between real artworks and their reproductions. The EEG results confirm that real paintings (compared to poster versions) elicit a strong need to approach. Reach art, including the surrounding ambience, lighting, frame, etc. – evoke an emotional reaction many times more powerful (10x more powerful according to this study).
- ✓ The 'Girl with a Pearl Earring' attracts the most attention by far. The EEG results confirm that the 'Girl' is a masterpiece in the Mauritshuis collection – the degree of attention it demands is reflected in the viewers' brain activity.
- ✓ With the 'Girl', Vermeer created a Sustained Attentional Loop that captures the viewer. The viewer first sees her eyes, then her mouth, and then is drawn to the pearl. Then he/she glances back at the eyes, mouth, pearl, etc.
- ✓ The 'Girl' stimulates the precuneus the most by far. When someone looks at the 'Girl with a Pearl Earring', more brain activity occurs, specifically in the precuneus, than when they look at any of the other paintings studied. This indicates a greater level of personal involvement and self-reflections, implying that emotional considerations make this work exceptional.
- ✓ The right balance in positive and negative emotions evoked by the 'Girl', comes from the absence of negative emotions. This, combined with a high involvement, makes this painting so special.
- ✓ The positive repeated attention creates a 'mere exposure effect' that makes us appreciate the 'Girl' more the more often, and longer, we see her. The many reproductions certainly contribute to this.



# Appendix

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Explanation of 13 dimensions, other spider diagrams, and references



## Explanation– 13 dimensions (fMRI), neural response to commercial stimuli

- Desire** The desire that is evoked, an emotion that serves to make people seek to satisfy their (mainly) primary needs. Such as wanting to satisfy hunger or accumulate possessions: the desire to buy.
- Lust** Also desire, but in a more sexual sense. Here, we see whether a stimulus is sexy, and often when there is a more generalised 'excitement' or sensation. This emotion also plays a role in ambition or other more long-term goals.
- Expectation** The brain expects to receive a reward (even though this uncertain). In the neuro-economic literature, we often see that this emotion has a strong positive correlation with buying behaviour.
- Trust** The brain trusts the stimulus. This is the importance of 'approach' behaviour because approach always involves a degree of risk (the stimulus can be dangerous, or disappointing). The presence of trust heightens the chance that actual conversion (off-the-shelf purchase, taking out a membership, etc.) actually takes place. This score is often low if there's something wrong with the stimulus: a proposition that doesn't fit the brand, a badly cast actor, photo, etc.
- Danger** The stimulus evokes a strong negative emotional arousal in the brain, which is often established based on primal evolutionary instincts and reflexes (spiders, snakes, predatory creatures). In the case of consumer behaviour, this usually involves stimulus that look morbid or ambiguous or that fall outside the peer group or generally accepted taste.
- Disgust** The stimulus evokes physical aversion, makes you nauseous, or 'hurts'. Spending money (price pain) also activates this emotion, as does losing someone close, or losing an object or a game, etc.
- Anger** Again, this is a strong negative emotional arousal, only in this case coupled with the tendency to react to it with aggression. Outrage, but also irritation, annoyance, etc.
- Fear** Fear, like 'Danger', but then less based on primitive instincts. Uncertainty or ambivalence about a proposition is often seen in this score.

## Explanation– 13 dimensions (fMRI), neural response to commercial stimuli

**Value** The stimulus is perceived as rewarding. It thereby reinforces the behaviour that preceded obtaining that reward (it is a positive reinforcer). An example of the good use of this emotion is demonstrating what's expected of the consumer (e.g. opening a bottle) followed by giving a reward (taking a refreshing sip). This value indicates the extent to which the rewarding aspect is portrayed / or registered as such in the brain of the consumer.

**Involvement** Also known as self-relevance: to what extent is what is shown relevant to the consumer? In the neuro-economic literature this emotion has been shown to be of great importance for eventual conversion or behavioural change in the test subject. Note that a high level of involvement can be both positive or negative, depending on the other emotions that are activated. Self-relevance is high in intense love, and acute hatred.

**Familiarity** To what extent is the viewer familiar with the material? This is primarily about the familiarity of the objects, persons or actions (and not: is the commercial itself familiar!). If this value is low, the images evoke a strong sense of alienation, and the viewer will distance themselves. The opposite is true: the more often you see something, the more you appreciate it (mere exposure effect).

**Novelty** To what extent is the material shown (images, objects, individuals, actions) surprising or new (and not: is the advert unfamiliar or new).

**Attention** To what extent does the material shown capture attention, or to what extent does it require a lot of attention to follow or understand. Quick editing or attention-grabbing images like faces generally ensure this value is high. A high level of attention strongly activates our working memory, which helps to better consolidate the memory. This is very important for the conscious opinion of the consumer, but of less importance for his (buying) behaviour.



## MRI scanning: control images



Fig. Control images for MRI scans. From left to right: Portrait of a Man (Frans Hals); Portrait of a Young Woman (Peter Paul Rubens and studio); Portrait of Anna Wake (Anthony van Dyck); Diana and her Nymphs (Johannes Vermeer); Portrait of a noble man with a hawk (Hans Holbein the Jonge).

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## Translations

This report was originally in Dutch and was translated by a company not specialized in scientific language. If you have any specific questions about the scientific terms in this translation, please don't hesitate to contact us.