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Title:

Understanding the neuro-psychology of aesthetic paradox: the dual phase oscillation hypothesis

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Abstract:

Aesthetic delight is a unique and paradoxical psychological experience of simultaneous emotional exaltation and a state of serenity towards a percept when an individual experiences the percept with the approach of an art-experiencer or artist. The primary drawback of neuro-scientific investigation of art is that it fails to trace the functional coherence of the entire process of generation of aesthetic delight. At least two recent seminal works by Vessel et al., and Cela-Conde et al., tried to resolve this deficiency using two different neuro-imaging techniques (fMRI and MEG respectively) and assessed the relevance of the Default Mode Network (DMN) of the brain in the generation of aesthetic pleasure. However, their works are yet to precisely highlight what primarily separates aesthetic experience from similar psychological experiences. This article formulates the *'dual phase oscillation'* hypothesis based on the neural correlate of the paradox of aesthetic delight, explaining the precise logic behind linking aesthetic delight and DMN activity. The hypothesis focuses on two seemingly paradoxical unique attributes of aesthetic delight: the phenomenon of *suspension of disbelief* (SOD) whereby the person experiencing art temporarily suspends the belief of surface reality and the phenomenon of *introspective detached contemplation* whereby the same person, while experiencing the same art, reflects on the artistic phenomenon and is simultaneously aware of the surface reality. The hypothesis proposes that aesthetic delight is the dynamic, oscillatory balance between SOD and *introspective detached contemplation* and is orchestrated by the functional coherence of the DMN. The article integrates the two previous works with the fundamentals of this proposal and thus offers a unique neuro-psychological solution to the problem of aesthetic paradox.

Keywords: aesthetic delight; suspension of disbelief; introspective detached contemplation; Default Mode Network; *'dual phase oscillation'* hypothesis

1. Introduction:

Why is there a distinctly different psychological feeling between a person watching a live autopsy and the same person watching the painting of Rembrandt's 'The Anatomy Lesson of Dr. Nicolaes Tulp'? (Figure 1)

Figure 1: *The Anatomy Lesson of Dr. Nicolaes Tulp* by Rembrandt van Rijn, 1632. [Source: http://en.wikipedia.org/wiki/File:The_Anatomy_Lesson.jpg]

Aesthetic delight is a unique and paradoxical psychological experience of simultaneous emotional exaltation and a state of serenity towards a percept when an individual experiences the percept with the approach of an art-experiencer or artist. The experience of aesthetic delight is now explored through branches of cognitive sciences like neuroaesthetics. From the 1990s a radical outlook appeared in the field of aesthetics due to the advancement of cognitive neuroscience, especially in brain-imaging technology, which led to a significant level of cross-linking between the arts and the sciences. This neurobiological foundation has been laid by the ideas and works of several scientists (e.g., Changeux, 1994; Zeki, 1999; Ramachandran & Hirstein, 1999; Zeki, 2002; Cavanagh, 2005; Jacobsen et al., 2006; Di Dio & Gallese, 2009; Skov & Vartanian, 2009; Chatterjee, 2011; Nadal & Pearce, 2011). Semir Zeki was instrumental in coining the term 'neuroaesthetics' (Zeki, 1999) and proposes: *'the future field of what I call 'neuroaesthetics' will, I hope study the neural basis of artistic creativity and achievement, starting with the elementary perceptual process'* (Zeki, 2001).

However, the primary drawback of neuro-scientific investigations of art is that it fails to trace the functional coherence of the entire process of generation of aesthetic delight. Brain imaging studies have localised certain areas that respond to specific art attributes but have failed to offer a justifiable rationale how these regions work differently in cohesion outside their normal context to generate the distinctive feeling of aesthetic delight. [1]

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[1] To get an idea about the different brain regions that have been identified to be activated by different attributes of art like paintings, architecture, dance movements, faces, music, visual designs etc, I would suggest to go through the summary of works given in their review by Nadal & Pearce (2011) including works by Vessel, Skov, Ishai, Calvo-Merino, Koelsch, Brattico and Jacobsen. Several areas of Prefrontal Cortex (PFC) have been identified including Inferior Frontal Gyrus; Medial Prefrontal Cortex; Orbitofrontal Cortex; Superior Frontal Gyrus etc along with other cortical and sub-cortical regions. It needs to be explained here what is precisely meant by the terms 'working outside their normal context'. Many of the prefrontal regions identified play a role in the cognitive processing of executive functions and can be activated in response to both non-aesthetic and aesthetic activities. However, extant neuroscientific studies of aesthetics do not explain what specific coherent phenomenon takes place involving these regions to generate the unique experience of aesthetic delight.

As put forward by Anjan Chatterjee, the psycho-physical and brain imaging tests *'makes the tacit assumption that complex artistic and aesthetic experiences result from the interaction of simpler processes whose contribution to aesthetic experience can be investigated separately,...this may not be the case: it may be impossible to isolate the component processes without losing the aesthetic experience itself*' (Nadal & Pearce, 2011, referring to Chatterjee's contribution to the 'Copenhagen Neuroaesthetics Conference', 2009, entitled *'Visual neuroaesthetics: Principles and practice'*).

At least two recent seminal works by Vessel et al., (2013) and Cela-Conde et al., (2013) tried to resolve this deficiency in understanding the functional coherence of aesthetic delight using two different neuro-imaging techniques (functional Magnetic Resonance Imagery (fMRI) and Magnetoencephalography (MEG) respectively) and assess the relevance of the Default Mode Network (DMN) of the brain in the generation of aesthetic pleasure. Cela-Conde et al., (2013) published their MEG study on the dynamics of brain networks in aesthetic appreciation highlighting the role of DMN in aesthetic delight. Vessel et al., (2012; 2013) focused on the phenomenon of individual variability in art. By showing unfamiliar art-works, they compared the fMRI of brain activity during observation of visual art that elicited high levels of aesthetic appreciation compared to unappreciated artworks and stated the relevance of DMN activity in highly moving art forms.

The works of Cela-Conde et al., (2013) and Vessel et al., (2012; 2013) used two different technical approaches in understanding the neural correlate of aesthetic appreciation, namely: the predominantly temporal approach using MEG and spatial localization using fMRI, respectively. Both the works highlighted the limitations of their neuro-imaging techniques: moderate spatial resolution of MEG (Cela-Conde et al., 2013) and poor temporal resolution of fMRI (Vessel et al., 2013). However, more importantly, the works are yet to precisely highlight the attributes behind the uniqueness of aesthetic delight or specifically state what primarily separates aesthetic experience from similar psychological experiences. For example, why is there a distinctly different psychological feeling between a person watching a live autopsy and the same person watching the painting of Rembrandt's *'The Anatomy Lesson of Dr. Nicolaes Tulp'*? (Figure 1).

This article formulates the *'dual phase oscillation'* hypothesis based on the neural correlate of aesthetic paradox, explaining the precise logic behind linking aesthetic delight and DMN activity while re-evaluating the coherent phenomena which take place in the brain generating the feeling of aesthetic experience. The article also reviews the two above mentioned works by Cela-Conde et al., (2013) and Vessel et al., (2013) and highlights how their works can be integrated with the proposed hypothesis to attain a complete picture. Aesthetic delight is at once an emotional exaltation and a state of serenity (Chaudhury, 1964) representing a state of simultaneous attachment and detachment which seems paradoxical. The fundamental characteristics of aesthetic delight thus need to be determined first. This will highlight the uniqueness of the process and will separate it from other psychological activities (for example, experiencing an emotionally charged event in a real-life situation). If we analyse carefully the integral aspects of aesthetic delight, two characteristics stand out:

1. The phenomenon of *suspension of disbelief* (SOD) whereby the person experiencing art temporarily suspends the belief of surface reality [2].

[2] Belief or awareness of surface reality refers to accepting the art-form for what its surface properties declare. It can refer to a range of denotative and literal properties of the art form. For example, while observing a painting we initially temporarily suspend the awareness that this is a two dimensional represented image of an object and that the form is created by say, paint on canvas.

2. The phenomenon of *introspective detached contemplation* whereby the same person, while experiencing the same art, reflects on the artistic phenomenon being aware of the surface reality and the nature of representation.

The above two characteristics of aesthetic delight seem contradictory to each other and that is why it can be called the *aesthetic paradox* (how can someone simultaneously suspend and become aware of surface reality?). It is for this reason there is simultaneous emotional rapture and a state of calmness in art appreciation. It is because of the interplay of these two aspects that one having an aesthetic experience remains attached and simultaneously detached from the art.

The roles of SOD and detachment in aesthetic appreciation have been independently investigated by philosophers. The phrase *'willing suspension of disbelief'* was coined in 1817 by the poet and philosopher S.T. Coleridge, whereby he suggested that readers temporarily suspend the improbability of a narrative through poetic faith (Coleridge, 2009, p.239). The concept of *'detachment'* in aesthetic appreciation was chiefly emphasised by German philosopher Immanuel Kant who, in his *'Critique of Aesthetic Judgement'* (Kant, 2014) explains the aesthetic attitude of *'disinterest'*. The concept of *Rasa* in ancient Indian aesthetics (Chaudhury, 1964) also speaks about aesthetic detachment.

The recent philosophical debates on the paradox of fiction began primarily with the paper by Colin Radford and Michael Weston in 1975 (Radford & Weston, 1975). Since then several theories have been put forward regarding how people get emotionally involved in fiction despite knowing that *it is* fiction. Some of these concepts include the *make-believe* (or simulation) theory proposed by Kendall Walton (Walton, 1990), the concept of *imaginative resistance* (inspired by David Hume) by T. S. Gendler (Gendler, 2000), the *thought theories* by Peter Lamarque, Noël Carroll, and Murray Smith (Schneider, 2014) or the *Illusion theory* drawn from the original Coleridge's theory of *'willing suspension of disbelief'* (Schneider, 2014). Although the detailed evaluation of these theories is not the purpose of this article, it is evident that the notion of a paradox arises because of the apparently simultaneous occurrence of inconsistent events in aesthetic appreciation. [3]

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[3] The information-processing stage model of aesthetic processing by Leder et al., (2004) elaborated the five-stages of aesthetic processing and distinguished between aesthetic emotion and aesthetic judgments as two types of output.

The *'dual phase oscillation'* hypothesis based on the neural correlate of aesthetic paradox provides a neuro-psychological solution to this problem whereby it proposes with reference to recent neuro-scientific findings that the two apparently simultaneous events described above as SOD and *introspective detached contemplation* are *actually* temporally demarcated but the temporal difference may be unperceivable. Most importantly, the hypothesis further emphasises that it is the oscillatory balance between these two phases that actually generates aesthetic delight

2. How can these two phenomena be explained neuro-scientifically?

This *'dual phase oscillation'* hypothesis proposes that aesthetic delight is the dynamic, oscillatory balance between SOD and *introspective detached contemplation* and is orchestrated by functional coherence of the Default Mode Network (DMN) of the brain. It primarily focuses on the dynamics of the DMN, a concept which has attained significant relevance post 2000, especially highlighting the functional heterogeneity of the Medial Prefrontal Cortex (MPFC). Along with this I substantiate the role of two important concepts: the idea of Meta-representations (MR) which can be explained by the

Convergence-Divergence framework proposed by Antonio Damasio (Damasio, 1989; 2010) and secondly the relevance of information processing in art based on the works of Daniel Berlyne (Berlyne, 1970; 1971; 1974). The hypothesis suggested integrates these concepts to trace how aesthetic delight is generated. I believe this integrative approach offers a functional coherence not yet applied in neuroaesthetics.

3. The Default Mode Network (DMN):

Raichle et al., first introduced DMN into the neuro-scientific literature in 2001 (Raichle et al., 2001) and since then the concept of DMN attained increasing interest. The human brain is never physiologically at rest as there is evidence for ongoing intrinsic activity and a very high-energy consumption in resting, non-attention demanding states (example, daydreaming) that is comparable with the states of attention-demanding tasks (Raichle, 2010). There are brain regions which show increased activity during rest but are usually attenuated during task related activity. They together form the network known as the DMN (parts of DMN can however also show increased activity from baseline state during special types of goal-directed activity, as described in the subsequent section). This task-negative network (which generally shows decreased activity from baseline state during task-induced attention demanding activity, for example solving a puzzle) comprises chiefly the Medial Prefrontal Cortex, Posterior Cingulate Cortex/Retrosplenial Cortex, Inferior Parietal Lobule, Lateral Temporal Cortex and the Hippocampal formation (Buckner et al., 2008).

3.1 The DMN uniqueness: *functional heterogeneity of MPFC*

The DMN activity in major parts is decreased (but never stopped) during goal-directed tasks. The lowering down of its activity is thought to enable the re-allotment of attentional resources from internal processes to goal-directed behaviour (Gilbert et al., 2007; Mason et al., 2007). A major hub of the DMN is the Medial Prefrontal Cortex (MPFC) which lies along the frontal midline (Buckner et al., 2008). The MPFC region of DMN shows a high baseline metabolic activity at rest and is one of the key areas most prominently showing decreases in its baseline activity during task-induced goal directed activity (Gusnard et al., 2001). However, anatomical and imaging studies have provided evidence that there is a dorsal-ventral functional distinction within the MPFC (Gusnard et al., 2001; Buckner et al., 2008). While the activity of the ventral Medial Prefrontal Cortex (vMPFC) is attenuated during goal-directed tasks, the dorsal Medial Prefrontal Cortex (dMPFC) shows striking increases from its baseline activity during particular types of attention driven, goal directed task, which involve self-referential, introspective activities (Gusnard et al., 2001; Buckner et al., 2008; Vessel et al., 2013). It has been shown that regions of dMPFC, especially elements of Brodmann areas (BA) 8, 9, and 10 may contribute to self-referential introspection (Gusnard et al., 2001). It has also been suggested that the dMPFC is more associated with complex introspective operations and the vMPFC [BA areas 24, 10m/10 r/10 p, 32ac (Buckner et al., 2008)] with emotional or affective processes (Gusnard et al., 2001). [4]

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[4] It is to be noted that dorsal and ventral positions are relative terms which are often used variably (Buckner et al., 2008) and there is partial overlap of BA areas in dMPFC and vMPFC. To avoid confusion, the specific regions of dMPFC mentioned in Gusnard et al., 2001 and BA areas of vMPFC as mentioned in Buckner et al., 2008 are mentioned in this article.

Artistic appreciation involves both stimulus dependent goal-directed activity and self-referential, introspective activity with direct involvement of emotional processes (the role of vMPFC in emotion regulation will be discussed later). Interestingly, a majority of neuroimaging studies highlight the cross-modal involvement of Medial Prefrontal Cortex (MPFC) in art appreciation as is evident from the summary of works given in their review by Nadal & Pearce (2011) including works by Vessel, Skov, Brattico, Jacobsen and others. As mentioned before, Vessel et al., (2012; 2013) and Cela-Conde et al., (2013) specifically highlights the role of the DMN in aesthetic appreciation. Their works will be discussed separately later [section 6] since the works are relevant to the hypothesis proposed here.

4. The *'dual phase oscillation'* hypothesis based on the neural correlate of aesthetic paradox*:*

This hypothesis is based upon the fact that there is a temporal segregation of phases in art appreciation. It states that the initial stimulus-guided goal directed activity of artistic appreciation is non-self referential, non-introspective and the DMN (especially the MPFC) can show an overall decrease in its activity from the baseline state during this phase leading to *suspension of disbelief* (SOD) (how this leads to SOD is explained later). However, subsequent resolution of stimulus complexity by information processing activates the dMPFC turning the phenomenon of artistic appreciation into an attention driven, goal-directed yet self-referential, introspective process. The temporal transition between these two phases exists although the transition may be unperceived such that the feeling of aesthetic delight may *appear* as a uniform non-transitional activity (hence the apparent paradox is generated). With increasing information resolution, the activation of dMPFC and vMPFC can lead to full integration of emotional and cognitive processes. The entire process can be summarised as follows:

Stage 1: Suspension of disbelief (SOD): The phenomenon of SOD in this hypothesis is given a neuro-scientific explanation for which the functional architecture and heterogeneity of the MPFC region of DMN needs to be explained. As mentioned before, it has been shown that areas BA 8, 9 and 10 of dMPFC may contribute to self-referential introspection and that these regions show an increase in its activity from baseline during specific types of goal-directed yet self-referential activity (Gusnard et al., 2001). The vMPFC (constituting BA areas 24, 10m/10 r/10 p, 32ac, Buckner et al., 2008) shows a decrease in activity during goal-directed tasks and anatomically is composed of discrete areas that are heavily interconnected with the Orbito-Frontal Cortex (OFC) and the limbic structures such as the amygdala, ventral striatum, hypothalamus, midbrain periaqueductal gray region, and brainstem autonomic nuclei (Gusnard et al., 2001). The vMPFC is thus known to bridge the conceptual and affective processes (Roy et al., 2012).

In the initial phase of art appreciation the person experiencing art (any forms of art) comes in contact with a form of visual or auditory stimulus and there is a high demand for information processing. The entire activity at this phase can be regarded as a task-driven activity during which introspection and self-referential thoughts are absent. The observer is engrossed solely in information processing. During this phase the decrease of activity can take place in the DMN especially in entire MPFC in response to the attention-demanding task. vMPFC activity is decreased as a conventional response of DMN to task-directed behaviour. Since this attention demanding phase is non-introspective, it is proposed that dMPFC also shows task-induced attenuation. Since vMPFC is also attenuated, the complete integration of cognitive and emotional responses cannot take place. However, the fundamental patterns of the art form can influence the limbic system at this stage though the conscious representation of these emotional states may not have yet developed. It has been demonstrated that the amygdala and Orbito-Frontal Cortex (OFC) can be activated by emotional stimuli even without awareness (Hatzimoysis, 2007; Stanley et al., 2008). The pressure of information processing in a goal-directed task, the reduced activity of vMPFC and dMPFC, the absence of introspection and the generation of implicit emotions lead to this initial SOD phase whereby the person experiencing art temporarily suspends the belief of surface reality. It is to be noted that SOD not only refers to losing oneself into the maze of art; even the temporary act of suspension of the awareness that *'Monalisa'* is actually 'oil on canvas' is also a phenomenon of SOD.

The recent works of Cela-Conde et al., (2013) and Vessel et al., (2013) (both these works will be discussed in detail later) validate this proposal through two major findings in their studies. Cela-Conde et al., (2013) in their study found a fast aesthetic appreciative perception formed within 250-750 ms time window and Vessel et al., (2013) showed that overall MPFC was initially suppressed during all types of image representation.

Stage 2: Introspective Detached Contemplation: The pressure of information processing in an attention-driven task directly depends on the stimulus or form complexity and this attenuates the activity of the DMN in Stage 1. The information value in a stimulus is assumed to be an increasing function of the subject's difficulty in coding or establishing an identity for the stimulus (Faw & Nunnally, 1968). By form complexity I do not mean visual form complexity alone but it can extend to other domains like spectro-temporal complexity of sound (Samson et al., 2011), movement complexity (Aubry et al., 2007) and even the complexity of mathematical symbols (the recent paper by Zeki et al., 2014, suggests that the experience of mathematical beauty correlates with activity in the same part of the emotional brain – namely the Medial Orbito-Frontal Cortex (MOFC) – as the experience of beauty derived from art or music).

Through information processing and decoding, this form complexity is resolved. This concept was first proposed by psychologist Daniel Berlyne, who modified the Wundt's inverted-U curve (Figure 2) of 1874, relating stimulus intensity with its degree of appraisal.

According to Berlyne (1970; 1971; 1974) there is a phase in the curve where the increasing complexity of the form results in a conflict between appraisal and aversion and this is where new information accumulation can result in a reduction of uncertainty which results in renewed interest in the form.

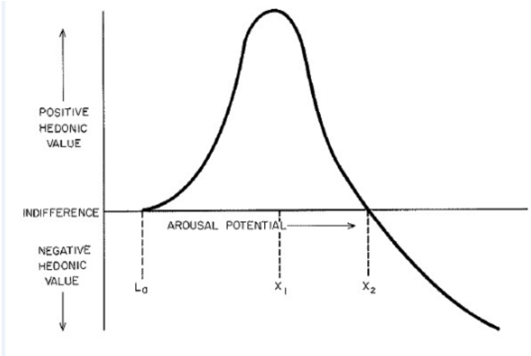

Figure 2: The Wundt curve; adapted from Wundt, 1874 (Source: page: 89; Berlyne, D.E. (1971). Aesthetics and psychobiology. New York: Appleton-Century-Crofts).

The DPO hypothesis states that the resolution of form complexity by information processing turns the non-introspective (till now) aesthetic phenomenon into an attention driven, goal-directed yet self referential and introspective process increasing the activity of the dMPFC from its baseline level. (According to the *'the gateway hypothesis'* developed by Burgess, Dumontheil & Gilbert (Burgess et al., 2007), the Rostral Prefrontal Cortex (RPFC) (BA 10, 47, 12) plays a crucial role in the switch between stimulus-oriented and stimulus-independent thought). As we have mentioned earlier, previous studies have shown that elements of BA 8, 9, and 10 of dMPFC contribute to self-referential or introspectively oriented mental activity (Gusnard et al., 2001). Since the dMPFC is also involved in understanding others' mental states (Ossandon, 2010; Frith & Frith, 1999) this activation can also generate the feeling of empathy keeping self-referential point of view intact. It is proposed that with decreasing information processing tasks, the vMPFC also shows increased activation. Since the vMPFC architecture is integrally connected with OFC and limbic areas (Gusnard et al., 2001), the full integration of emotional and cognitive processes now sets in. In a recent study by Cela-Conde et al., (2013), which shall be discussed later, a delayed aesthetic appreciation phase was also noted within a 1000-1500 ms time window.

Role of Meta-representations (MR):

Meta-representation here refers to the *representation of a representation*. It is also referred as Meta-cognition which refers to 'one's knowledge concerning one's own cognitive processes and products or anything related to them' (Flavell, 1979; Johnson et al., 2002; Sun & Mathews, 2012). MRs are generated when a second-order network observes and reproduces the states of the first-order network on its output units (Cleeremans et al., 2007, Damasio [5], 1989).

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[5] The fundamental role of Meta-representations in the generation of aesthetic consciousness can be understood if we understand the categorisation of 'self' by Antonio Damasio on the basis of 'the very different biological impact of three distinct although closely related phenomena: an emotion, the feeling of that emotion, and knowing that we have a feeling of that emotion' (Damasio, 1999, p. 8). This is correlated with his categorisation of proto self, core self and autobiographical self (Damasio, 1999; 2010). In his book *'The Feeling Of What Happens'* (Damasio, 1999, p. 230) Damasio states: 'the nonconscious neural signalling of an individual organism begets the proto self which permits core self and core consciousness, which allow for an autobiographical self, which permits extended consciousness' (Damasio, 1999).

MRs can be explained by the architecture of the higher order Convergence-Divergence Regions (CDRs) in the Postero Medial Cortex (PMC) which are hierarchically organized loops of axonal projections (Damasio, 2010). In his 2010 book *'Self comes to mind'* Damasio highlights the role of PMC in the generation of conscious mental representations and also categorically indicates its association with the DMN indicating that the PMCs, along with other CDRs are prominently activated in a variety of functional imaging tasks involving self-reference and that most of these regions especially the PMC are also part of Raichle's *'default network'* (Damasio 2010, p. 166). He suggests that the PMC assist in consciousness by contributing to the assembly of autobiographical self states.

It is proposed in this hypothesis that the activation of dMPFC and vMPFC which results in full integration of emotional and cognitive processes, forms MRs by its input to the higher order CDRs of the Postero-medial Cortex (PMC). The sense of *detachment* that comes along with introspective contemplation in aesthetic delight results from the integration of *at least* (there may be others) three types of MRs which can be produced in this stage:

MR1: This brings into conscious awareness that *it is 'I' who is feeling an emotional attachment towards the art.*

MR2: This reminds us that this is an object of representation. So MR2 partially counter-balances the initial SOD phase.

MR3: This is the aesthetic delight which makes us know that MR1 and MR2 are interlinked. We know that we are attached but simultaneously detached.

Stage 3: Dynamic Balance: The dynamic, oscillatory temporal balance between SOD (generated through task-induced information processing and through the overall decrease in activity of the DMN from baseline level) and *introspective detached contemplation* (the later phase of increased activation of dMPFC and vMPFC) maintains the aesthetic delight. If the SOD phase dominates too much, we may lose ourselves in the information web of the art form. If the introspective phase prevails over the SOD phase, information processing may be hampered and we may lose interest in the art form as excessive awareness of literal reality starts to act as an impediment.

For example, while observing a painting like the *'Three Musicians'* (Figure 3) by Picasso, if the observer is lost in the information web of the art form, the dynamic, oscillatory balance between these two phases may be lost. On the other hand, citing an extreme example, while watching the scandalous *'Fountain'* (Figure 4) by Marcel Duchamp if one is constantly reminded of nothing else but a urinal only, this habitual awareness of surface reality can become an obstacle too (no doubt it was out rightly rejected from exhibition in 1917!). Similarly, citing examples from audiovisual narrative art, while viewing a film like *'Avatar'* (made in 2009 by James Cameron), if one is constantly reminded that this is a work of Computer-Generated-Imagery (CGI), the same imbalance can ruin the aesthetic experience. This is a common complaint among artists who often fail to appreciate other art-works because of excessive technical introspection. For example, while analysing Leonardo's painting *'Virgin and Child'* (also known as *'Madonna of the Carnation'*, Figure 5), one artist commented on the marked wrinkling of the paint surface on the Virgin's flesh and attributed it to poor technique since Leonardo seemed to have added too much oil to the paint mixture! (Januszczak, 1987, p. 29).

The *'dual phase oscillation'* hypothesis is thus based upon the fact that the initial task-induced attention driven activity of artistic appreciation is non-introspective and the DMN (especially the MPFC) can show an overall decrease in its activity during this phase leading to *suspension of disbelief* (SOD). However, subsequent resolution of stimulus complexity by information processing activates the dMPFC and vMPFC turning the phenomenon of artistic appreciation into a task driven yet introspective process. According to this hypothesis, aesthetic delight is the dynamic oscillatory balance between SOD and *introspective detached contemplation* and is orchestrated by functional coherence of the DMN.

Figure 3: Decoding the *Three Musicians* by Pablo Picasso (created 1921) at Philadelphia Museum of Art. [Photograph source: by conxa.roda (cropped and converted to greyscale); https://www.flickr.com/photos/25730976@N06/5670014111/ and http://farm6.staticflickr.com/5107/5670014111_fc2da6846d_o.jpg]

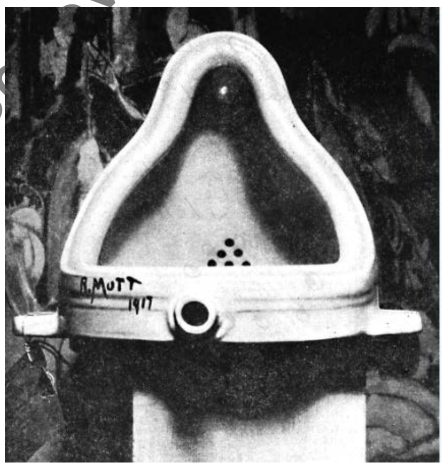

Figure 4: The original 'Fountain' by Marcel Duchamp, 1917, photographed by Alfred Stieglitz. [Source: http://en.wikipedia.org/wiki/File:Duchamp_Fountaine.jpg#filehistory]

Figure 5: *The Madonna of the Carnation* by Leonardo da Vinci, 1473-75.

[Source:http://en.wikipedia.org/wiki/File:Leonardo_da_Vinci_Madonna_of_the_Carnation.jpg]

5. Testing the hypothesis:

5.1 What kind of stimuli to be used?

The essence of the *'dual phase oscillation'* hypothesis is to understand the process of development of the unique feeling of aesthetic delight and to trace the spatial and temporal changes in the activity of the brain in relation to the DMN especially investigating the functional heterogeneity of the MPFC. Simple artificial laboratory stimuli cannot simulate art since the coherence of an art-form of any modality will be lost. Natural stimuli which are not restricted to artificial laboratory constructions but which are more behaviourally relevant (Kayser et al., 2004) have been shown by numerous studies to be coded more efficiently than artificial stimuli in both the visual and auditory systems (Lesica et al., 2008). It is obvious that exposure to complex natural stimuli will provide a more authentic account of this process. It is important to *'learn whether functional segregation is maintained during more natural, complex, and dynamic conditions when many features have to be processed simultaneously'* (Bartels & Zeki, 2004). However, working with complex natural stimuli is more challenging since the overlap of neural signatures can interfere with correct assessments. Hence, proper control measures need to be taken and psychophysical testing and scaling methods need to be integrated with the studies (Chatterjee et al., 2010; Ishizu & Zeki, 2011; Kawabata & Zeki, 2004). To investigate how the image signals correlate with visual search and information processing, additional help of eye-tracking technology can also be utilised (Quiroga & Pedreira, 2011). In current neuroaesthetic studies there are numerous instances of experiments using visual art-works like paintings (e.g., Kawabata & Zeki, 2004; Cupchik et al., 2009; Kirk et al., 2009; Augustin et al., 2011; Battaglia et al., 2011; Di Dio et al., 2011; Huang et al., 2011; Ishizu & Zeki, 2011; Cela-Conde et al., 2013; Vessel et al., 2013). Hence using art-works is an option for testing this hypothesis.

However, to extend the boundaries of the hypothesis the cross-modal involvements are necessary to investigate since the hypothesis does not restrict itself to static visual art but has the possibility of extending to other disciplines of art including *music, dance, theatre and film*. Form complexity is not only restricted to visual complexity but as mentioned earlier, can extend to other domains (explained in Stage 2 of the hypothesis) through which there is definitely a possibility of generation of SOD by the attenuation of DMN activity as proposed in this hypothesis. It is true that the cross-modal activation patterns may be different in films or other non-static art forms in relation to static visual art and each have to be understood on their own before comparisons can be made between them. Therefore working with complex, non-static, narrative audiovisual art forms like film is one of the most challenging among all experimental designs relevant to this study. The recent works of Cela-Conde et al., (2013) and Vessel et al., (2012; 2013) conducted their study with static visual art only. However, I believe, the hypothesis can be tested for other art forms too, especially since a significant amount of work has already been done on non-static narrative art forms (e.g., Hasson et al., 2008; Bartels & Zeki, 2004; Carvalho et al., 2011; Kauppi et al., 2010; Wang et al., 2012). During cross-modal investigations with paintings and music, Ishizu & Zeki's paper has highlighted that one cortical area, located in the MOFC was active during the experience of both musical and visual beauty (Ishizu & Zeki, 2011). The extensive connectivity of the vMPFC with OFC and limbic areas has been highlighted in my article. There is a possibility of extending the proposal of the hypothesis to other art forms.

5.2 Which imaging technique to adopt: fMRI/MEG?

The synchronous activity of the DMN can be assessed by measuring Local Field Potentials (LFP) recording integrative activity from cells within a few millimetres (Ossandon, 2010). In order to measure synchronous, spontaneous activity over a precise small unit of space, the fMRI offers a reliable measure of activity. However, as is evident in our proposal the extremely fast-paced change in neuronal activity is also another criterion to look into while observing how the activity changes over time in different parts of the task-negative and task-positive networks of the brain. Electro and Magnetoencephalography (EEG and MEG) have been used to record this behaviour in humans (e.g., Bhattacharya & Petsche, 2005; Belkofer & Konopka, 2008; Cela-Conde et al., 2013). However, these techniques again do not possess the fine spatial precision required to access the nuances of DMN activity as hypothesised in this study especially for measuring medial sections. Electrocorticography (ECoG) or intracranial EEG (iEEG) studies using depth electrodes are invasive and can be conducted only in highly specialised situations (for example in epileptic patients) and are not suitable for the use in art appreciation experiments. It is important to mention here that both the recent works by Cela-Conde et al., and Vessel et al., highlighted the limitations of their respective neuro-imaging techniques: moderate spatial resolution of MEG (Cela-Conde et al., 2013) and poor temporal resolution of fMRI (Vessel et al., 2013).

5.3 Combining EEG, MEG, fMRI:

In order to solve the problem of individual deficiencies of either MEG (/EEG) or fMRI, approaches currently in use combine the two neuroimaging techniques.

One of the earliest EEG-fMRI experiments was performed by Goldman et al., (2000) using special twisted dual-lead electrodes in a bipolar montage. Event-related fMRI with simultaneous and continuous EEG recordings was conducted by Lemieux et al., (2001). Implementation and evaluation of simultaneous video-electroencephalography recording without affecting the EEG and fMRI data quality was carried on by Chaudhary et al., (2010).

Horwitz & Poeppel (2002) categorised approaches in combining information from electrophysiological and hemodynamic neuroimaging methods (Korvenoja, 2007, p.31) chiefly by converging information from independent measurements, by data fusion from spatially more accurate imaging modality and temporally more accurate modality and by computational neural modelling. Since there is interference between the strong Magnetic Resonance field and the EEG system, there is possibility of interference during simultaneous EEG and fMRI recording. Hence, a concurrent EEG/fMRI experiment requires dedicated design and pre-processing methods for data analysis (Halchenko et al., 2005). For simultaneous measurements of EEG and fMRI, protocols such as triggered fMRI, interleaved EEG/fMRI and simultaneous fMRI/EEG were proposed (Halchenko et al., 2005).

5.4 Exploring other techniques: *TMS, tDCS, fNIRS*

Although the combination of electrophysiological (EEG/MEG) and hemodynamic (fMRI) neuroimaging methods appears to be the most appropriate means to test this hypothesis till date, I want to highlight the use of three other techniques that have been recently used in neuroaesthetic research.

In 2011, Battaglia et al., conducted a Transcranial Magnetic Stimulation (TMS) study whereby they analyzed the cortico-motor excitability during observation of an action in painting and observed the amplitudes of Motor Evoked Potentials (MEP) (Battaglia et al., 2011). TMS is a non-invasive method which uses electromagnetic induction to stimulate highly localised group of nerve cells in the brain. A test stimulus preceded by TMS can generate *Short-Interval Intracortical Inhibition (SICI)* or *Intracortical Facilitation (ICF)* and have been shown to be useful for probing inhibitory and facilitatory circuits in localised regions of the cortex (Battaglia et al., 2011).

By using for the first time transcranial Direct Current Stimulation (tDCS), Cattaneo et al., (2013) observed that aesthetic appreciation can be increased by applying excitatory transcranial direct current stimulation on the left Dorsolateral PFC. tDCS applies non-invasive, transcranial induction of weak direct currents able to induce focal, prolonged and fully reversible shifts of cortical excitability (Cattaneo et al., 2013).

TMS and tDCS can be explored because they do not heavily rely on correlational evidence or reverse inference (Cattaneo et al. 2013) like EEG or fMRI and permits highly selective observations.

Kreplin & Fairclough (2013) conducted a functional Near Infrared Spectroscopy (fNIRS) study to observe the functional heterogeneity of RPFC during the viewing of visual art which were viewed under two separate conditions of emotional introspection and external object identification. fNIRS measures changes in both oxy- and deoxy-Haemoglobin based on their differential absorbent properties of NIR light and have been used to investigate Blood Oxygen Level Dependent (BOLD) responses similar to fMRI. fMRI and fNIRS can show correlated results and fNIRS can also present some advantages over fMRI such as measurement of concentration changes in both oxygenated- and deoxygenated haemoglobin, finer temporal resolution, and ease of administration (Cui et al., 2011). However, two crucial disadvantages of fNIRS over fMRI are its poorer spatial resolution and decreased signal-to-noise ratio.

6. Integrating the recent studies with the fundamentals of the hypothesis:

6.1 The work by Cela-Conde et al., (2013):

The significant study conducted by Cela-Conde et al., (2013) deserves special mention in this article as this exclusively deals with the role of two different brain networks in aesthetic appreciation. Using Magnetoencephalography (MEG) studies they categorised two different phases of aesthetic appreciation: a fast aesthetic appreciative perception formed within 250-750 ms time window and a delayed aesthetic appreciation performed within 1000-1500 ms time window. They also stated that the activation of DMN is related to the delayed aesthetic network (Cela-Conde et al., 2013).

The work by Cela-Conde et al., (2013) segregated the phenomenon of aesthetic appreciation into two different phases (based on differential synchronisation patterns at different time windows) and explained them neuro-scientifically but it does not integrate or explain the functional relationship between these two phases and hence as mentioned before, does not explain the uniqueness of the phenomenon of aesthetic delight (the question at the beginning of Introduction is thus so essentially important). The feeling of *attachment and simultaneous detachment* is generated through aesthetic activity (whether the art form is 'beautiful' or 'sublime' – art can also be 'not beautiful' in the traditional sense of the term) making it uniquely different from similar psychological activities. In other words, the concept of aesthetic paradox explained in the *'dual phase oscillation'* hypothesis is vitally important in understanding aesthetic delight and this concept needs to be realized to undertake neuro-scientific experiments. As emphasised by the authors themselves in their discussion '…*the eventual relationship of this aesthetic Aha! moment with other episodes, such as that of problem solving, cannot be determined thus far* (Cela-Conde et al., 2013).' It is here that the concepts of task-induced attention driven generation of SOD and subsequent *introspective detached contemplation* need to be emphasised. It is to be noted that according to my hypothesis, the initial phase of SOD (generated through task-induced information processing and through the overall decrease in DMN activity from baseline level) and the later phase of the increased activation of dMPFC and vMPFC (which turns the aesthetic activity into a goal-directed yet self-referential process) are integrally linked and dynamically balanced. This marks their relationship.

‘The moderate spatial accuracy’ (Cela-Conde et al., 2013) of MEG makes it very difficult to specifically analyse the uniqueness of the DMN as explained in this article using *only* MEG, especially the activations of the different highly localised regions of the MPFC like the specific areas of dMPFC and vMPFC. Hence, the proposed combinatorial approaches with electrophysiological and hemodynamic neuroimaging methods can offer a more precise investigation.

Another important point needs to be mentioned here that the stages of artistic appreciation is not a linear process with one-off beginning and end of phases. The initial and later phases can interact and oscillate (that is why it can be called *‘dual phase oscillation’*) several times even in the course of experiencing a single art form and this is guided by the resolution of stimulus complexity which may occur in multiple spurts.

Lastly, as I have mentioned in my hypothesis, the activation of dMPFC and vMPFC forms MRs most possibly by its input to the higher order CDRs of the PMC which scientists like Damasio regard as the potential constructor of consciousness (Damasio, 1989; 2010). This phenomenon of coupling of neural networks links the SOD and introspective phases and generates the feeling that *we are attached but simultaneously detached* in appreciating art. This marks one of the important steps in understanding aesthetic delight.

<u>6.2 The work by Vessel et al., (2012, 2013):</u>

The work by Vessel et al., (2013) is an extension of their earlier work in 2012 (Vessel et al., 2012) which shows that intense aesthetic activity activates the DMN. Subjects were asked to rate each unfamiliar art work on a 4-point scale (participants rated how moving they found the images). The analyses of the fMRI results revealed that the reactions were highly individual and in contrast with the pattern of activity seen in ratings of 1, 2 and 3, DMN regions showed markedly less deactivation during highest-rated trials (ratings 4).

While explaining the self-introspective properties of highly-moving art works, they proposed that certain artworks can 'resonate' with an individual's sense of self in a manner affecting regions of the DMN by keeping it activated. The fMRI responses during task vs. rest periods were analysed and the fMRI signal time course in the MPFC for the lower-rated trials and the highest-rated trials was shown in the study. The result showed that the MPFC activity was different for highly moving art-works (rated 4) from those rated 1, 2 or 3. MPFC was initially suppressed during image representation for all the ratings. However, the MPFC started to become active and continued to rise above baseline for highly rated images. On the other hand, for the other ratings, it continued to remain suppressed.

The essence of these findings attaches a considerable amount of importance to the activation of MPFC as a whole (although the separate temporal activation patterns of dMPFC and vMPFC needs to be traced as per my proposition) and self-reference during intense aesthetic activity. However, it does not trace the importance of the initial stage of SOD which results from the decreased activity of dMPFC and vMPFC during initial information resolution phase. I think the initial phase of SOD is equally significant even in generating *'intense'* aesthetic delight since, too much dominance of introspection can ruin the entire aesthetic experience as explained before in the *'Fountain'*, *'Avatar'* or *'Virgin and Child'* examples (Section 4, Stage 3). Introspection has a dual role which, apart from making us relate to the art, can also make us conscious about surface (literal and denotative) reality. So rather than the rise of MPFC activity alone in highly appreciated art, I think the dynamic oscillation between the two phases involving dMPFC and vMPFC is an absolute necessity in generating aesthetic delight. This is all the more evident from their own findings which showed that MPFC was initially suppressed during image representation for all the ratings (Vessel et al., 2013). Hence, it is important to make further spatial and temporal analyses of both the highest and lower rated images described in the study. The problem though is that the poor temporal resolution of fMRI as mentioned by the authors themselves (Vessel et al., 2013) is an obstacle in trying to understand the temporal coherence of the entire process and as I have mentioned before, individual approaches with either fMRI or MEG are therefore not ideal to study the simultaneous spatial, temporal and functional integrity of the process. Hence combinatorial approaches need to be considered.

The balance between the phases of SOD and introspection during aesthetic delight, as I have mentioned in my hypothesis, is maintained through spurts of information resolution (task-induced, attention driven, non-introspective), confrontation with newer forms and the constant oscillation between the two phases of SOD and *introspective detached contemplation* (regulated by the decreased/increased activities of dMPFC and vMPFC) by which the observer simultaneously suspends and becomes aware of reality. Thus while observing a typical Hollywood action movie we may get engrossed in the chase sequence for a considerable period of time and then suddenly lose interest and start muttering that it is all nonsense and then again can generate renewed interest in a confrontational scene. Even in case of static visual art, the generation of renewed interest while observing the same art again and again explains why some observers need to look at a great piece of art for hours and even days.

The essence of the *'dual phase oscillation'* hypothesis is that the model fits not only in case of highly appreciated art but for any degree of art appraisal (irrespective of any ratings) starting from praising the '*Monalisa'*, praising any unfamiliar novel art-work or even temporarily getting interested in a Hollywood action movie. What changes in each aspect is not the model but the oscillatory balance between the phases described in the model.

In case of highly rated art work an optimal balance is observed. However, this balance too is created by the innate predispositions as well as experiential conditioning of the individual person giving rise to aesthetic variability. This explains why some people simply hate Picasso while some others are thrilled. It is obvious that the speed of information processing depends on how much the individual is familiar or aware of a particular form in the art-work. The introspective phases similarly are influenced directly by the prior acquaintance with socio-cultural-historical contexts and also by autobiographical memory. It is important to understand that the entire art-work itself need not be familiar; even in a completely unfamiliar art-work the observer may find acquaintance with a form or context. For example, if an observer is familiar with the typical visual motif of the *'base of a guitar'*-shape (Figure 6) in Picasso's *Guitar* series, his information processing will be much faster and he can easily find out how this repeated motif is used at different contexts: sometimes even to resemble a man's ear (Gersh-Nesic, 2011). Similarly, the introspective phase is guided by contextual familiarity. While observing the representation of a skull at the base of the cross of Christ (for example, in the '*The Descent from the Cross*' by van der Weyden (Figure 7)) if the observer knows that the skull represents Adam and that the place where Christ was crucified is the very place where Adam lay, then multiple layers of interpretations can set in.

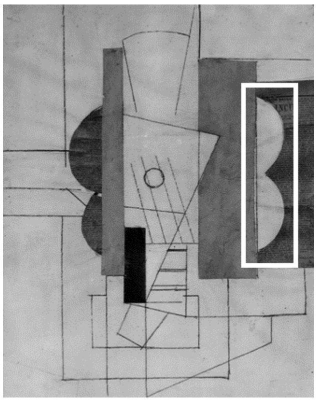

Figure 6: Pablo Picasso's *Guitar* (created before 1932). [The shape discussed is highlighted]; [Source: http://commons.wikimedia.org/wiki/File:Picasso_Guitar.jpg; In 1932 the work was given to City Museum of History and Art in Łódź by Stanisław Ignacy Witkiewicz. Owned by The J. and K. Bartoszewicz City Museum of History and Art in Łódź. Lost around: 1939/1945. Photograph source: Archive of the Art Museum in Łódź]

Figure 7: The *Descent from the Cross* (or *Deposition of Christ*) by Rogier van der Weyden, 1435. [The skull is highlighted].

[Source: http://en.wikipedia.org/wiki/File:Weyden_Deposition.jpg]

A review of art history also shows us that there were styles which played with the concept of manipulating this balance between these two phases. Starting especially from the *Post-impressionist* period we often see a deliberate attempt to make the viewers aware that they are experiencing work of art while also maintaining aspects of realistic illusionism. Paul Gauguin's use of colour, Paul Cezanne's distortion of perspective or Georges Seurat's experiments with *Pointillism* all strove to achieve this perfect balance. For example, an analysis of Seurat's *'A Sunday afternoon on the island of La Grande Jatte'* (Figure 8), in Stokstad and Cothren's *Art History* reads as follows:

'When viewed from a distance of about 9 feet, the painting reads as figures in a park rendered in many colors and tones; but when viewed from a distance of 3 feet, the individual marks of color become more distinct and the forms begin to dissolve into abstraction.' (Stokstad & Cothren, 2011)

Figure 8: *A Sunday afternoon on the island of La Grande Jatte* by Georges Seurat, 1884-1886.

[Source:http://commons.wikimedia.org/wiki/File:A_Sunday_on_La_Grande_Jatte,_Georges_Seurat,_1884.jpg]

Theatre and film later on adopted similar strategies following the concepts of Brecht's *alienation theory* (Willett, 1964).

An important aspect which needs to be addressed here to avoid confusion is that the *'apparent paradox'* of aesthetic appreciation mentioned in Vessel et al's., work (2012) refers to a completely different aspect of art appreciation: the phenomenon of aesthetic variability observed among individuals despite the universal ability to be aesthetically moved. The concept of *'aesthetic paradox'* discussed in my article refers to the apparently strange phenomenon of simultaneous attachment and detachment observed during art appreciation.

6.3 Other relevant works and contradictions:

Previous studies have shown contradictory results in the electrical activity of the brain detected through EEG while in the process of creating or appreciating art in the activity patterns of the higher and lower frequency bands (especially Beta and Delta activity) (Belkofer & Konopka, 2008; Bhattacharya & Petsche, 2005). I propose that these studies have not yet assessed the complete picture and if the transition between SOD and *introspective detached contemplation* is observed in the context of the DMN along with the change in the electrical activities then a clearer picture will emerge. This is because artistic appreciation is simultaneously a task-induced, attention driven as well as introspective activity which requires the involvement of both higher and lower frequency bands at different phases. EEG spectral neuro-feedback protocols have shown that Alpha/Theta wave training has consistently improved artistic imagination and enhanced creativity (Gruzelier, 2011).

Results by Ossandon and his group (Ossandon, 2010) showed that visual search is associated with transient task-induced Gamma band suppression (GBS) in Posterior Cingulate Cortex (PPC), Medial Prefrontal Cortex (MPFC), Ventrolateral Prefrontal Cortex (VLPFC), Lateral Temporal Cortex (LTC) and Temporal Parietal Junction (TPJ) which shows a conspicuous spatial correlation between GBS areas and DMN. Their GBS analysis showed that the duration and intensity of Gamma suppression is modulated by task complexity. Thus GBS activity can be a possible area of investigation while observing the electrical activity pattern during Stage1 (during the phase of SOD with task-induced attention driven information processing).

In order to test this hypothesis we should categorically demarcate the spatial-temporal states of the DMN during aesthetic activity tracing especially the functional heterogeneity of the MPFC along with studying the convergent-divergent circuitry involving the PMC.

7. <u>Postscript:</u>

During the preparation of this article, a symposium was held between February 6–7, 2014, presented by Columbia University and New York University titled *'The Default Mode Network in Aesthetics and Creativity'*. The symposium was primarily organised by David Freedberg, Director of the Italian Academy, Columbia University and G. Gabrielle Starr and Edward A. Vessel from New York University. I do hope, that a published account of the symposium will be available (just like the paper that Nadal & Pearce, 2011, published after the 2009 Copenhagen neuroaesthetics conference) since it is evident that there is increasing interest developing in the subject. However, an article based on the symposium is available in the website *'The beautiful brain'* which outlines the relevance of the symposium (Hutton, 2014). The article quotes David Freedberg's statements at the conclusion to the symposium as: *'the humanities don't really know about what happens in the brain—we can just look at the results from neuroscience about aesthetics.*' However, the advice to the neuroscientists was *'do tell, but tell us what we don't already know'* (Hutton, 2014). The significance of these words is undoubtedly invaluable since it highlights the basic need of conducting challenging neuroaesthetic research truly based on the fundamental questions on the philosophy of art rather than conducting so called art-experiments tailor-made for the neuroscience laboratory.

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