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SUMÁRIO

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EDITORIAL

EDITORIAL

Closing the 2023 year, this edition contains two papers and one supplement.

The first paper, " Hemicoreia na infância: Revisão da literatura com relato de caso" [*Hemichorea in childhood: Literature review with case report*], authored by Drs. Bruna Andrade de Oliveira and Luiz Felipe R. Vasconcellos, describes the complexities of diagnosing acute chorea in infancy, and reports one case with peculiar characteristics. The second paper, "Spinal cord: initial historical images" [*Medula: imagens históricas iniciais*], written by Prof. Eliasz Engelhardt, historical aspects on the anatomy of the spinal cord and spinal roots are provided, with pivotal information and images, which permitted further studies of this segment of the nervous system.

The added supplement "Neuroaesthetics and Pictorial Arts," by Prof. Marleide da Mota Gomes, consists of seven studies that provide a thorough examination of the relationship between the human brain and creativity. These essays examine the relationship between neuroscience and artistic expression, as well as the perspectives of neuroscientists, painters, and sufferers of neurological conditions, including migraine and epilepsy. They also look at how artists from the Renaissance onwards have represented dreams, sleep, and sleep disorders. This intersection of history, neurology, and the arts is proof positive of the importance of the arts, which great minds have long recognized and valued.

The editors of RBN and the Director of the INDC hope you enjoy this end-of-year academic and intellectual experience, and take this opportunity to thank the authors, administrators, associate editors, editorial board, and reviewers, and all those who have helped to keep RBN going in its 75th year.

Editors of the RBN

Hemicoreia na infância: Revisão da literatura com relato de caso

Hemichorea in childhood: Literature review with case report

Bruna Andrade de Oliveira[1], Luiz Felipe R. Vasconcellos[2]

RESUMO

O diagnóstico etiológico de quadros coréicos é amplo e algumas características da apresentação auxiliam no raciocínio diagnóstico, como o tempo de instalação do quadro (agudo/crônico), a distribuição corporal (focal/generalizada) e sintomas associados. Na infância, a principal causa da forma aguda é a coreia de Sydenham. Descrevemos o caso de uma paciente do sexo feminino de 13 anos que apresentou hemicoreia de instalação aguda relacionada a febre reumática, sendo a manifestação dimidiada atípica nesta condição.

Palavras-chave: coreia, febre reumática.

ABSTRACT

There are numerous causes of chorea, and some characteristics of the presentation of this symptom help in the diagnosis reasoning, such as the onset time of the condition (acute/chronic), body distribution (local/generalized), and associated symptoms. In childhood, the main cause of acute chorea is Sydenham chorea. In childhood, the main cause of the acute form is Sydenham chorea. We report a case of a 13-year-old female patient who presented with acute onset hemichorea, being diagnosed with Sydenham's chorea.

Keywords: coreia, febre reumática.

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INTRODUÇÃO

A coreia consiste em movimentos irregulares breves, variáveis, imprevisíveis, não estereotipados e não suprimiveis, que geralmente pioram na marcha, ao realizar movimentos voluntários e com o estresse. Esses movimentos podem ou não estar associados a labilidade emocional e hipotonia. Os movimentos coreicos podem afetar todo o corpo porém são mais comuns na cabeça, pescoço e membros superiores.[1]

Na abordagem diagnóstica das coreias, inicialmente deve-se considerar a forma de instalação do quadro: agudo/subagudo ou progressivo. No grupo das causas agudas/subagudas, as principais são: auto-imunes, vasculares, infecciosas, hipóxicas ou tóxicas. Já no grupo das causas progressivas, existem causas adquiridas ou genéticas.[2] Dentre as causas adquiridas, as mais comuns são estruturais (tumores p.ex), tóxicas, autoimunes, infecciosas e iatrogênicas. No grupo das causas genéticas, temos a coreia hereditária benigna, doenças neurodegenerativas (Doença de Huntington, acidúria glutárica, Doença de Wilson, encefalopatia associada ao GNAO1, doenças mitocondriais, síndrome de Lesch-Nyhan, fenilcetonúria, neuroacantocitose), síndromes atáxico-coréicas, dentre outras[1].

No grupo das causas infecciosas existem algumas particularidades geográficas. Apesar de uma drástica redução do número de casos de coreia relacionados a febre reumática (Sydenham) devido a ampla utilização de antibióticos, nos países subdesenvolvidos, tal condição ainda é a principal causa de coreia na infância e na adolescência de início agudo, sendo rara após 20 anos de idade[3-4] . A coreia de Sydenham é mais prevalente no sexo feminino, tendo em geral curso transitório, média de dois a três meses, podendo ter duração maior que um ano. Essa condição ocorre como uma manifestação tardia após uma infecção causada pelo estreptococo beta-hemolítico do grupo A, podendo ocorrer em até sete meses após a infecção aguda.[4] Em relação ao quadro clínico, a apresentação dimidiada, ou seja, hemicoreia, é raramente relatada nesta condição.

Relatamos caso de jovem com quadro de hemicoreia de instalação aguda relacionada a febre reumática, sendo discutida abordagem diagnóstica, tratamento e prognóstico. Trata-se de uma etiologia importante a ser considerada nos casos de coreia de início na infância/adolescência pois a instituição de antibioticoterapia profilática reduz a morbidade desta condição mesmo naqueles casos atipicos com apresentação dimidiada como apresentado por nossa paciente. A divulgação de informações sobre o paciente foi aprovada pelo Comitê de Ética em Pesquisa do INDC/UFRJ, sob o número: 6.284.811. A responsável pela paciente assinou o TCLE.

RELATO DE CASO

Adolescente de 13 anos, sexo feminino, estudante do oitavo ano do ensino fundamental. Iniciou 3 meses antes da avaliação em nosso serviço, quadro de movimentos involuntários de característica coreiformes em dimídio direito associada a irritabilidade. A instalação dos sintomas ocorreu em dias com posterior estabilização do quadro. Os movimentos atrapalhavam as atividades escolares, tanto pelo comprometimento de sua destreza manual quanto pelo constrangimento social. Procurou atendimento médico sendo prescrito biperideno 2 mg 2x ao dia, com relato de discreta melhora.

Apresentava história de quadro gripal caracterizado por coriza e odinofagia, sem febre associada e com melhora espontânea em poucos dias, precedendo em um mês o início dos sintomas neurológicos.

Histórico de puberdade precoce em uso de anticoncepcional oral há 9 meses. Negava história familiar de doenças neurológicas ou psiquiátricas.

Ao exame físico apresentava movimentos coréicos associado a hipotonia em dimídio direito, sem outras alterações.

Análise laboratorial revelou VHS elevado (30 mm/h - V.R: até 15mm/h), assim como do colesterol total (213 mg/dl - VR: até 170 mg/dl) e LDL (159 mg/dl - VR: até 100 mg/dl). Demais itens da investigação laboratorial encontravam-se dentro da normalidade, tais como, hemograma, eletrólitos, glicemia, creatinina, hepatograma, TSH, marcadores de doenças reumatológicas, VDRL e anticorpo anti-estreptolisina O.

Ressonância magnética de encéfalo e o ecocardiograma transtorácico sem alterações.

Recebeu diagnóstico de coreia de Sydenham, tendo sido orientada a fazer uso de penicilina benzatina na dose de 1.200.000 unidade intramuscular de 21/21 dias até 21 anos como tratamento profilático e para coreia foi substituído biperideno por ácido valpróico 250 mg 2x ao dia como tratamento sintomático. Reavaliamos a paciente um mês após início do ácido valpróico, sendo observada melhora expressiva da hemicoreia à direita.

DISCUSSÃO

Febre reumática é a causa mais comum de coreia aguda na infância-adolescência, estando relacionada a uma manifestação tardia, auto-imune, decorrente de infecção causada pelo estreptococo beta-hemolítico do grupo A.[4-5] Os pacientes relatam episódio infeccioso prévio, geralmente precedendo o início da coreia em até 6 meses, caracterizado por febre, tosse e/ou dor de garganta, podendo ser ainda oligossintomático.

Os títulos de antiestreptolisina O (ASO) e anti-desoxiribonuclease B (anti-DNAse B) devem ser interpretados levando-se em consideração o nível de suspeição da coreia de Sydenham, sendo que a ASO costuma manter-se positiva por mais tempo do que a anti-DNAse B[4]. O pico da ASO ocorre entre a 4ª e a 6ª semana, podendo manter-se elevada por até um ano após a infecção, e em até 20% dos pacientes com Febre Reumática não são documentados níveis elevados de ASO[2]. Como a coreia é uma manifestação tardia, é possível que os títulos da ASO já tenham normalizado no momento do teste.[5-6]

A coreia de Sydenham em geral tem curso autolimitado, tendo uma duração média de 2 a 3 meses, podendo em casos atípicos ter duração superior a 1 ano[3]. Em relação à distribuição corporal, menos comumente pode se apresentar como hemicoreia em 20-30% dos casos, como no caso relatado.[7-8]

Pacientes com uma história atípica ou com hemicoreia devem ser submetidos a uma neuroimagem (preferencialmente ressonância magnética de crânio) para exclusão de causas estruturais.[10] Outros diagnósticos diferenciais que devem ser considerados são lúpus eritematoso sistêmico (LES), síndrome do anticorpo antifosfolipídeo (SAF), causas tóxicas, uso de alguns medicamentos, tais como anticoncepcionais orais e anticonvulsivantes[5], e causas estruturais como AVC ou tumor, que devem ser consideradas principalmente se forem assimétricas/ unilaterais.[11]

No caso relatado, por se tratar de hemicoreia de início agudo na infância, foram aventadas inicialmente as seguintes hipóteses diagnósticas: coreia de Sydenham, doenças reumatológicas (Lúpus Eritematoso Sistêmico e Síndrome Anti-Fosfolipídeo) e medicamentosa (anticoncepcional oral). Os marcadores reumatológicos negativos afastaram a possibilidade de se tratar de uma doença reumatológica/colagenose. O uso de anticoncepcional não estaria relacionado ao quadro devido a ausência de relação temporal com seu uso. A coreia induzida pelo uso de anticoncepcional já foi descrita algumas vezes na literatura logo após início do mesmo e na maioria dos casos há reversão em até 2 a 3 meses após sua suspensão, podendo apresentar-se como coreia generalizada ou mais raramente como hemicoreia.[2,12]

Manifestações neuropsiquiátricas frequentemente estão presentes na coreia de Sydenham, como labilidade emocional, comportamento obsessivo-compulsivo, ansiedade e déficit de atenção, podendo inclusive anteceder os movimentos coreicos[9]. No caso relatado havia irritabilidade concomitantemente ao quadro hiercinético.

A paciente em questão recebeu diagnóstico final de coreia de Sydenham uma vez que segundo as últimas diretrizes brasileiras para febre reumática e a última revisão dos critérios de Jones a presença isolada de coreia, após exclusão de outras causas possíveis, é suficiente para o diagnóstico de febre reumática, mesmo sem outras manifestações associadas[3-4] .

CONCLUSÃO

A coreia de Sydenham deve sempre ser considerada no diagnóstico diferencial das coreias de início agudo na infância-adolescência por ser a causa mais frequente nessa faixa etária.[4] Neste contexto é fundamental uma busca ativa em relação à história de infecção de orofaringe prévia ao quadro neurológico.

Neste cenário o neurologista tem importante papel para o diagnóstico de febre reumática na fase inicial com a instituição precoce do tratamento profilático (penicilina benzatina) reduzindo significativamente a morbimortalidade relacionada a esta condição.

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Imagens em NEUROLOGIA

Spinal cord: initial historical images

Medula: imagens históricas iniciais

Eliasz Engelhardt[1] [https://orcid.org/0000-0003-4168-1992]

The spinal cord is mentioned in indirect manner since antiquity, as seen in the Edwin Smith papyrus, and Hippocratic writings, while the first direct mention may be credited to Aristoteles, and the first description to Galenus.[1] However, the first macroscopic description and depiction of the spinal cord (*dorsalis medulla*), and the related segmentary 'nerves' (roots), was presented by Andreas Vesalius (1514–1564), Flemish physician and anatomist, in Book IV of his 'On the Fabric of the Human Body' (*De Humani Corporis Fabrica*) (1543) (macroscopic image p 526, text pp 533-554).[2] The first meaningful study on the spinal cord is usually credited to Gerardus Leonardus Blasius (1625 – 1692), Dutch physician and anatomist, in his 'Anatomy of the Spinal Cord and its derived Nerves' (*Anatome Medullae Spinalis et Nervorum inde Provenientiur*) (1666), where the spinal cord (*medulla spinalis*) is described and depicted, regarding its macroscopic appearance, including its main fissures, the differentiation between the external white (*substantia albicans*) and the internal grey matter (*substantia cinericia*), the latter arranged in a peculiar way (later known as H shaped), and also the spinal nerve roots (anterior and posterior), the vascularization, as well as the meningeal covering, and vertebral encasing.[1,3,4] (Figure1 and Figure 2)

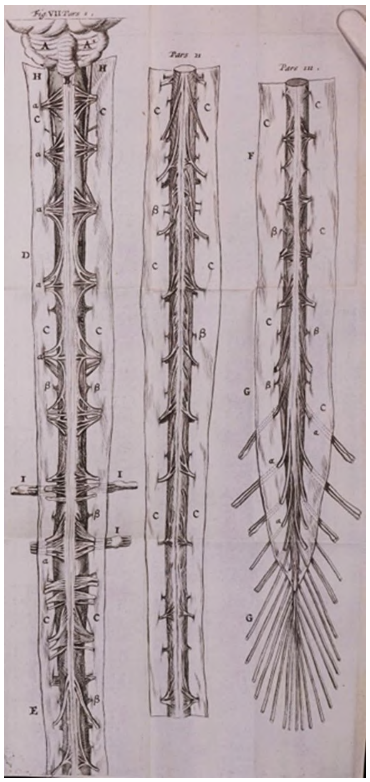

Figure 1. Spinal cord of dog with emerging roots, and dura mater, divided in three parts (part of plate - Figure VII).[4]
Part I=cervical, Part II=thoracic, Part 3=lumbar, sacral, and tail bones.
α=transit of root through the dura mater, β= union of the dura [dura mater] (C) with the thin meninx [pia mater] [denticulate ligament], I=extradural nodes developed from the convergence of several nerve fibers [spinal ganglia]

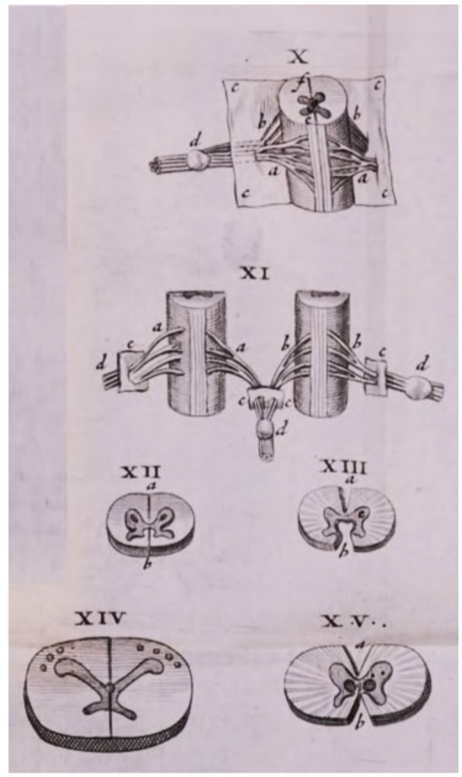

Figure 2. Spinal cord sections (part of plate – Figures X-XV).4
X. The emergence of nerves [roots] from the spinal cord, their origin from the anterior and posterior aspects, their passage through the dura mater, and their extradural junction.
a=nerves [roots] proceeding from the posterior aspect of the spinal cord, b=nerves [roots] from the anterior aspect, c=dura mater, d=extradural union of the roots [and spinal ganglion], g=internal reddish matter [grey matter].
XI. Hemisected spinal cord in order to display with more precision the a-b-c-d of the former figure.
XII.XIV. Transversal sections of the spinal cord. a=anterior fissure, b=posterior fissure.
XIII.XV. Transversal sections of the spinal cord. a=anterior fissure, b=posterior fissure, c=middle spinal matter [grey matter, spinal H]
XII-XV. Transversal sections of the spinal cord displaying the middle grey matter [spinal H shape], and the peripheral white matter

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Neuroculture and Aesthetics: Exploring the Multidisciplinary Ambiance of Art, Beauty and the Human Brain

Neurocultura e Estética: Explorando o Ambiente Multidisciplinar da Arte, da Beleza e do Cérebro Humano

To develop a complete mind: Study the science of art; Study the art of science. Learn how to see. Realize that everything connects to everything else.
Leonardo da Vinci

All religions, arts, and sciences are branches of the same tree. All these aspirations are directed toward ennobling man's life, lifting it from the sphere of mere physical existence and leading the individual toward freedom, 1937.
Albert Einstein

M. da Mota Gomes[1] [Orcid: https://orcid.org/0000-0001-8889-2573]

ABSTRACT

This narrative review addresses the intersection between neuroculture and aesthetics, exploring the intricate relationship between neuroscience and the perception of beauty. The presentation begins by mentioning the philosophical foundations of aesthetics and moves on to the neural basis behind the sensory and emotional processing of beauty. Progressing further, it presents the intricate networks involved in interactions and responses to art, elucidating the brain's mechanisms for appreciating artistic stimuli. Finally, it investigates the neural networks associated with deriving personal and symbolic meaning from art forms, shedding light on how our brains deduce meaning and value from aesthetic experiences. Thus, there is an integration of studies based on the connectome with neuroaesthetics, on how the complete network of neural connections in the brain influences and shapes the way we perceive, interpret, and appreciate beauty. Furthermore, the article addresses the impact of virtual reality and artificial intelligence on traditional concepts of creativity, challenging existing paradigms. Concluding, it explores the potential educational and therapeutic applications of 'Visual Thinking Strategies' in promoting artistic engagement with potential educational and therapeutic applications.

Keywords: Aesthetics, Art, Artificial Intelligence, Cognitive Processes, Perception, Neuroscience, Culture

RESUMO

Esta revisão narrativa aborda a intersecção entre neurocultura e estética, explorando a intrincada relação entre neurociência e a percepção da beleza. A apresentação começa mencionando os fundamentos filosóficos da estética e avança para a base neural por trás do processamento sensorial e emocional da beleza. Progredindo ainda mais, apresenta as intrincadas redes envolvidas nas interações e respostas à arte, elucidando os mecanismos do cérebro para apreciar estímulos artísticos. Por fim, investiga as redes neurais associadas à obtenção de significado pessoal e simbólico das formas de arte, esclarecendo como nossos cérebros deduzem significado e valor de experiências estéticas. Assim, há uma integração de estudos baseados no conectoma com a neuroestética, sobre como a rede completa de conexões neurais cerebrais influencia e molda a maneira como percebemos, interpretamos e apreciamos a beleza. Além disso, o artigo aborda o impacto da realidade virtual e da inteligência artificial nos conceitos tradicionais de criatividade, desafiando os paradigmas existentes. Concluindo, explora as potenciais aplicações educativas e terapêuticas das 'Estratégias de Pensamento Visual' na promoção do envolvimento artístico com potenciais aplicações educativas e terapêuticas.

Palavras-chave: Estética, Arte, Inteligência Artificial, Processos Cognitivos, Percepção, Neurociência, Cultura

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INTRODUCTION

This article, the first in a seven-part series about neuroaesthetics and visual art, sheds light on the intricate relationship between art, beauty, philosophy, neuroscience, and complex systems theories.

Leonardo da Vinci's and Albert Einstein´s quotes presented at the beginning of this article captures the essence of interdisciplinary learning, the interconnection of knowledge and the importance of observation and understanding, with Art being within this.

Within this path, we explore how art can be seen as a form of communication and how the sensation of beauty is experienced and understood through a multidisciplinary lens in a privileged aesthetics neuroscience-based approach. It begins by stating that art is a powerful form of communication and is a means by which artists convey ideas, emotions, and complex narratives to the public. However, the interpretation of art is not limited to the artist's intention but depends on the subjective experience and cultural context of the viewer. This perspective forms the basis for exploring the article.

Consequently, the appreciation of beauty can be examined across levels of increasing complexity within the brain, spanning from basic sensory and emotional processing to socio-affective and cognitive processes through 'social brain' networks, and finally reaching the complex brain networks associated with social behaviors and interactions. However, creativity, Neuroaesthetics, the Social Brain, and complex social behaviors and interactions are complex processes that involve various brain networks. Research in this field is ongoing, and advances in neuroimaging techniques such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) have allowed scientists to gain deeper insights into the brains of both artists and non-artists and compare brain activity in response to various visual stimuli, in this way researchers can identify regions associated with artistic production and appreciation in the general population. Also, they study how the brain networks function and interact during social interactions and emotional processing. These networks often work in concert and can vary in their specific contributions depending on the task or context and research in neuroscience on them is ongoing, and our understanding of these networks continues to evolve.

In the next sections, we examine aspects related to Neuroculture, Aesthetics, and the Social Brain (including increasing levels of complexity), which are fascinating and multidimensional endeavors and there are several important issues and interrelationships to be considered. These previous sections finally reach future perspectives, including aesthetics in the age of artificial intelligence and the use of Visual Thinking Strategies (VTS) for practical purposes.

Humanistic approach to aesthetics

First, we must understand that art is a form of communication, in fact, John Dewey (1859-1952), philosopher and reference in the field of education, called it 'the most universal and freest form of communication'[12]. However, it is not the aim of this article to study aspects related to communication in the arts, despite it being fundamentally linked to artistic expression and to aesthetics, which is the branch of philosophy that explores concepts of beauty, taste, and the perception of art.

The conceptions of aesthetics and aesthetic experience were clarified by European philosophers of the 18th century when art became separated from other spheres of human experience and aesthetic interests 'What is felt and imagined' moved away from the general purpose and the everyday pleasures.

The philosophical dimension of the study of beauty explores how thinkers from various schools of philosophy have dealt with its concept. As for semiotics, it concerns the study of signs and symbols and is presented as a tool for understanding how art communicates complex ideas and emotions. As for the study of beauty, there is a long history that precedes the formalization of aesthetics as a philosophical field. It dates back to ancient Greece and Rome, to ideas of beauty that were often associated with proportion, symmetry, and harmony, with beauty seen as an essential quality in art and the natural world. During the Middle Ages, religious and moral aspects of beauty became significant and beauty was often linked to spiritual and moral qualities. At that time, theologians such as Saint Augustine emphasized that beauty reflects the divine, highlighting the transcendent and moral aspects of beauty. During the Renaissance, we saw a revival of classical aesthetics, with a focus on humanism and the appreciation of beauty in art, architecture, and nature. In the Enlightenment, philosophers such as David Hume contributed to the development of aesthetics by exploring questions of taste and aesthetic judgment. However, German philosophers such as Alexander Baumgarten and Immanuel Kant formalized the study of aesthetics in the 18th century, with Baumgarten being the first to introduce the term 'aesthetics', while Kant provided a comprehensive framework for understanding beauty, the sublime, and judgment. aesthetics. Furthermore, Kant made significant contributions to the field of aesthetics, particularly in his 'Critique of Judgment' (1790), which had a profound influence on the development of modern aesthetics and is considered a cornerstone of this field. In particular, his notion of 'purposeless intentionality' is central to his aesthetics, as it suggests that in aesthetic experiences we perceive objects as if they were created for a specific (teleological) purpose, even if they were not. Consequently, the study of beauty has evolved, with diverse philosophical, cultural, and religious perspectives contributing to our understanding of this concept. However the formalization of aesthetics as a distinct philosophical field in the 18th century marked a crucial turning point in the systematic exploration of beauty, art, and the nature of aesthetic experience. These early foundations of aesthetics generated modern discussions about beauty, taste, and the philosophy of art.

Before the modern studies regarding aesthetics and the brain, there were the ones by Gustav Theodor Fechner, in 1876, who laid the groundwork for understanding the relationship between physical stimuli and the sensations they evoke, delving into the field of psychophysics—the link between sensations and the neural activities that produce them[2]. Over a century later, pivotal contributions by Semir Zeki and V.S. Ramachandran shaped the field of neuroaesthetics.

Semir Zeki's use of FMRI to investigate brain responses to visual art was instrumental in initiating neuroaesthetic research. His methods provided a foundational approach to studying the neural underpinnings of aesthetic perception. V.S. Ramachandran expanded our understanding of beauty's neural basis, exploring how specific visual features, like symmetry and composition, influence aesthetic preferences[2, 7, 10, 13]. Nadal and Chatterjee, 2019[6] addressed the combined view of the Nature of Art, Neural Mechanisms, Adaptability of the Brain, Universality, Diversity, Art Appreciation, and Cultural Influence. Ultimately, they concluded that although art is universal, its forms and content are shaped by cultural, temporal, and personal factors, offering a glimpse of the intersection between neurobiology, culture, and individual experiences.

A journey from beauty to aesthetic perception until Connectome-Based Neuroaesthetics

The sensation of beauty, and aesthetics, involves a combination of sensory stimuli, cognitive processing, emotional response, cultural influences, and individual variation.

The perception of aesthetics corresponds to a complex interaction between the human brain and society, as we feel aesthetics through the influenced combination of biological, psychological, and cultural factors. Consequently, it is a deeply subjective experience that can vary widely from person to person and across different contexts and cultures, intertwined with our sensory and emotional experiences of the world.

Research in this field often involves a combination of approaches that can provide valuable insights into the role of particular brain areas. The trajectory from initial studies on neurologically healthy individuals to the inclusion of diverse populations, including artists, non-artists, and individuals with varying levels of art training, reflects the field's commitment to understanding the universality and variability of aesthetic experiences. Besides, neuropsychological data from brain-damaged patients may be used to test causal hypotheses aside from the ones neuroimaging studies correlational data[2].

The term ‘neuroaesthetics,’ coined by Semir Zeki has transformed into an interdisciplinary field involving collaboration among neuroscientists, psychologists, art historians, and other experts. This cooperation emphasizes the need for diverse insights to achieve a comprehensive understanding of art aesthetics, favoring the exploration of neural mechanisms underlying a broad spectrum of aesthetic experiences closer to the cognitive neuroscience of aesthetic perception[7].

Furthermore, the integration of advanced neuroimaging techniques, cognitive sciences, and exploration of diverse populations, including those with neurological conditions, enriches our knowledge about the neural processes underlying aesthetic experiences. Overall, there is gradually a deepening appreciation of the complexity of art aesthetics through the lens of neuroscience and interdisciplinary collaboration. Thus, the field continues to evolve, offering new insights into the neural basis of creativity, aesthetic preferences, and the impact of cultural and individual differences on the perception and appreciation of art.

This section delves into the domains of Neuroscience, Neuroculture, and Neuroaesthetics to understand how the human brain processes and responds to art and beauty. Neuroaesthetics is a subfield of neuroscience that examines the neural basis of aesthetic experiences. Thus, it explores how the brain perceives and reacts to artistic stimuli, shedding light on the biological foundations of our aesthetic preferences.

Firstly, the concept of Neuroculture is presented, which unfolds the importance of Neuroscience innovations beyond the study limits of researchers in the area and reaches society as a whole. It is an emerging field that examines how cultural contexts shape our neural responses and aesthetic preferences. The article emphasizes the importance of understanding the dynamic relationship between culture and neuroscience in shaping our aesthetic perceptions. This discussion helps bridge the gap between the biological and cultural aspects of art appreciation. Therefore, neuroscientific knowledge is not restricted to laboratories alone but readily captures the attention of the general public even with some skepticism and rejection[8,9].

Since ideas, concepts, and images in neuroscience circulate widely in culture and are portrayed in literature, cinema, works of art, mass media, and commercial products, therefore shape social values and consumption practices. Thus, the interaction between art and science offers an opportunity to raise awareness among the scientific community and the public about the social and ethical implications of scientific advances in neuroscience.

This interrelationship is creating opportunities and a dire need for educational initiatives that broadly improve neuroscience literacy. Thus, neuroscience literacy is not only a desirable ideal, but a necessity so that society can maximize the potential benefits of neuroscience by effectively putting knowledge into practice. Therefore, responding to the growing need for communication that improves neuroscience literacy requires action on the part of neuroscientists at the institutional level and beyond.

Regarding this evolution, a quick search on Pubmed shows how the terms Neuroscience*, Neuroaesthetics, and Neuroculture have been used in articles registered in this bibliographic database under the title/abstract or in 'all fields', which deduces that the generic term neuroscience is widely used and there is a delay in the consecration of the more specific terms Neuroaesthetics and Neuroculture.

'Neuroscience*'		'Neuroaesthetics'		'Neuroculture'	
title/abstract	all fields	title/abstract	all fields	title/abstract	all fields
46,553 From 1967	623,976 From 1945	177 From 2008	217 From 2008	9 From 2009	9 From 2009

Consequently, Neuroculture and Aesthetics have several interconnections, as Neuroaesthetics investigates how the brain processes and responds to artistic and aesthetic experiences and explores the neural mechanisms underlying our perception of beauty, art, and aesthetics. Aesthetic judgment tasks, which involve evaluating the beauty or artistic qualities of various stimuli, engage a network of neural circuits in the brain. These circuits are responsible for processing sensory information, emotional responses, and cognitive evaluations. While the exact neural pathways can vary depending on the nature of the aesthetic judgment (e.g., visual art, music, literature), there are some common brain regions and networks that are often implicated in such tasks. It's important to note that aesthetic judgments are highly subjective and can vary greatly among individuals. Additionally, the specific brain regions involved can depend on factors like the type of aesthetic stimulus and personal preferences. Research in the field of Neuroaesthetics continues to shed light on the neural underpinnings of aesthetic experiences and judgments, but the interplay of emotion, cognition, and perception in aesthetic evaluations is a complex and ongoing area of investigation.

The foundations of aesthetic feeling are overviewed by Chatterjee and Vartanian as the triad that encompasses the sensorimotor, emotional evaluation, and meaning knowledge systems, as described in Figure 1[2].

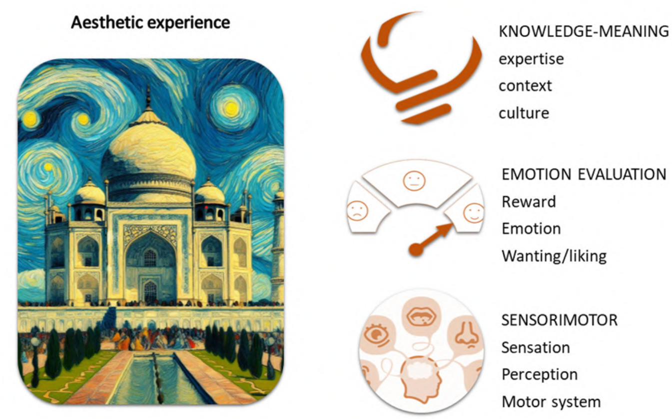

Figure 1. 'Aesthetic triad' based on Chatterjee and Vartanian 2 epitomized by 'Taj Mahal's Timeless Allure: Enigmatic Splendor' - from Image Creator of the DALL·E platform with recommendations given by the author of this paper.

Neuroaesthetics based on Zeki and Ramachandran has been undergoing current integration with connectome studies that took place in the late 2000s and early 2010s when the complete network of brain connections gained attention in neuroscience. Consequently, researchers delve deeper into understanding brain connectivity and network-level interactions, exploring how this pervasive network influences various cognitive functions. There is also growing interest in understanding the neural underpinnings of aesthetic experiences with an emphasis on the role of brain connectivity and network-level interactions in the perception of art and beauty.

The study by Alcalá-López *et al*. 2018[1], created the 'Social Brain Connectome' or 'Social Brain Atlas' which was later unfolded into the 'Artistic Brain Connectome' by van Leeuwen *et al*. 2022[13]. The first is based on a comprehensive meta-analysis of neuroimaging studies on social cognition, providing a systematic definition of the social brain through neural activity, while identifying thirty-six core social brain hubs spread across four hierarchical functional networks (lower sensory, limbic, intermediate, and high associative neural circuits). The 'Artistic Brain Connectome', extends insights from the 'Social Brain Connectome' to understand how the brain processes information related to visual art and creativity at the core social brain hubs and four networks: Perception, Animation, Interaction, and Construction, representing different stages of perceptual

Some Core 'Large-scale brain networks': [1]The salience network (SN) is key for switching between the default mode network (DMN) and the central executive network (CEN) depending on the task or stimulus salience, and they play crucial roles in different cognitive functions. These networks work in concert, dynamically interacting with each other to facilitate various cognitive functions for adaptive and flexible behavior in response to different environmental demands. Dysregulation or dysfunction in them has been implicated in various neuropsychiatric disorders and cognitive impairments

The SN which includes the ventrolateral prefrontal cortex (VLPFC) and anterior insula (jointly referred to as the fronto-insular cortex; FIC) and the anterior cingulate cortex (ACC) responds to the degree of subjective salience, whether cognitive, homeostatic, or emotional. It is involved in the detection and

and cognitive processing related to art and creativity. This conceptual framework aims to establish a bridge between social cognition and aesthetics and the cognitive processes associated with the visual arts. The interconnectivity of neural networks associated with both social cognition and the processing of visual arts is understood, aligned with the principles of social cognitive neuroscience, seeking to understand the neural basis of complex social behaviors and cognitive processes. The 'Artistic Brain Connectome' provides a theoretical framework for understanding how the brain engages in creative activities within a social context.

The following sections of this text propose a study of the first two networks of the 'Artistic Brain Connectome' in the context of the basic sensory and emotional processing of beauty. Furthermore, the third network (Interaction) is explored in terms of balancing internal states and sensory inputs for regulating social behavior, and the fourth network (Construction) in the context of multimodal knowledge synergy for personal and symbolic meaning in experience. Consequently, the next sections set the stage for a comprehensive exploration of the neural mechanisms underlying aesthetic experiences and visual arts processing.

Basic Sensory and Emotional Processing of Beauty

Aesthetic appreciation involves the brain's processing of sensory information to evaluate and derive pleasure from various forms of art, beauty, or visual stimuli. Consequently, aesthetics is, in part, a result of the way our brain processes sensory information, with certain neural pathways and structures being involved in the perception of beauty and aesthetics. This includes brain areas associated with visual processing, emotional processing, and reward systems. Visual aesthetics, for example, are processed in the visual cortex, while emotional responses to aesthetics involve brain regions such as the amygdala and prefrontal cortex. Consequently, aesthetic experience, mainly aesthetic perception, is reflected by the dynamic interaction between brain systems involved Lower Sensory Network and Limbic Network, by van Leeuwen et al., 2022[13] (Figure 2).

However, individual psychological factors such as personal preferences, experiences, and cognitive biases also play a significant role in how we perceive aesthetics. What one person finds aesthetically pleasing, another does not. This variation can be influenced by past experiences, cultural background, and personal taste.

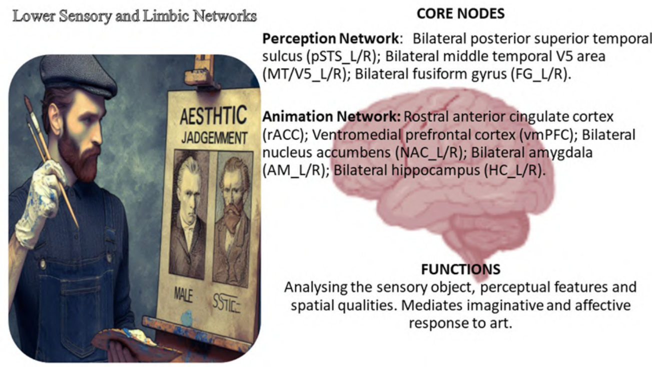

Figure 2. Schematic representation of the neural circuits implicated in aesthetic judgment tasks based on van Leeuwen et al., 2022[13]. The image source of 'Art's Alchemy: Contours of Perception and Emotion' is the Image Creator of the DALL·E platform with recommendations given by the author of this paper.

Balancing Internal States and Sensory Input for Social Behavior Regulation

The third processing level of the 'Social Brain Connectome', Interaction network, plays an important role in mediating between incoming, potentially significant sensory information and internal states and goals (Figure 3). This network contains the core areas (mainly, anterior insula (AI) and anterior mid-cingulate cortex (aMCC)) of the Salience Network[1] which weighs the significance and relevance of incoming sensory information against current homeostatic priorities in regulating social behavior. It also mediates mirroring behaviors and empathy.

The Interaction Network plays a key role in interpreting incoming sensory information based on current behavioral goals, and more particularly, in assigning salience (significance) to art and creative output. This network is therefore likely to be integral to the construction of significance in art, based on the perceived salience of artworks. Artworks tend to be highly valued in themselves, invested with emotional and cultural associations, and often encountered under conditions of 'ceremony' and heightened expectation; accordingly, they tend to be salient stimuli for many viewers. However, the salience of a particular artwork is heavily modulated by prior personal familiarity, the socio-emotional context in which we view it, and our behavioral stance toward it. Salience Network regions have functional connections to vmPFC and other core nodes from the Limbic (Animation) Network, enabling affective modulation of salience coding. Taken together, concerning art processing and visuospatial creativity, this network appears to play a key role in deciding whether to engage deeper or whether to disengage from an artwork.

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integration of salient stimuli from both the external environment and the internal state of the body and helps in determining what is personally relevant or important at a given moment and directs attention accordingly.

The DMN is a large-scale brain network that comprises the posterior cingulate (BA 23 and 31), posterior parietal cortex (BA 7, 39, and 40), and the ventromedial prefrontal cortex, which is active when the brain is not engaging in a specific task. It is often associated with self-referential thoughts, mind-wandering, daydreaming, and introspection.

The CEN comprises the dorsolateral prefrontal cortex and posterior parietal cortex and is engaged when a cognitively demanding task requiring attention is being performed. It is associated with higher cognitive functions such as working memory, problem-solving, decision-making, and cognitive control. It is engaged when an individual is actively focused on a task that requires attention and goal-directed behavior. The DMN and CEN are anticorrelated as activity within the first increases, and the other decreases[4].

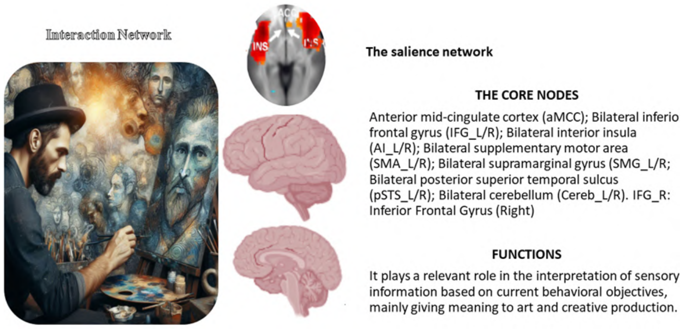

Figure 3. Simplified Interaction Network adapted from Leeuwen et al., 2022[13]. Images source: 'Art's Interpretive Power: Meaningful Nexus' from Image Creator of the DALL·E platform with recommendations given by the author of this paper, and The Salience Network from Wikimedia Commons.

Synergizing Multimodal Knowledge for Personal and Symbolic Meaning in Experience

There is a profound impact of society and culture on aesthetic sensibilities as cultural norms and values influence our perception of beauty, and cultural practices shape the development and functioning of the brain, possibly through neural plasticity. Besides, there is a cultural neurodiversity acknowledging that the brain can operate differently in different cultural contexts.

Also, there is a close relationship between complex social behaviors and social cognitive neuroscience, both focusing on understanding the neural and cognitive processes underlying intricate social interactions. Higher-order cognitive functions related to complex social behaviors, such as moral reasoning, social decision-making, and social norm processing. This level involves the integration of aesthetic experiences into broader social contexts, highlighting the interplay between aesthetics and social interactions.

The Construction Network of the 'Artistic Brain Connectome,' proposed as the fourth and highest processing level by van Leeuwen et al.[13] based on the 'Social Brain Connectome,' is introduced (Figure 4). This level corresponds anatomically with the Default Mode Network (DMN) and is crucial in creating internal models of ourselves and others about the world, besides, this Construction Network within this framework includes the semantic appraisal system, mediating associative knowledge about sensory objects and concepts, as well as vocabulary. This network plays a key role in the appreciation of art by integrating multimodal knowledge systems to assign personal and symbolic meaning to experiences, also this network is involved in generating and critically evaluating creative thoughts and artistic expressions.

Consequently, the 'Construction Network' as the higher level of the social brain connectome appears to align with the idea of complex systems described in the text 'The Social Connectome – Moving Toward Complexity in the Study of Brain Networks...' by Maliske and Kanske, 2022[5]. The text emphasizes a shift in neuroscience from a modular, isolated understanding of brain processes to a more interconnected, complex view. It highlights the importance of studying brain networks as interacting, complex entities, especially in the context of social cognitive neuroscience.

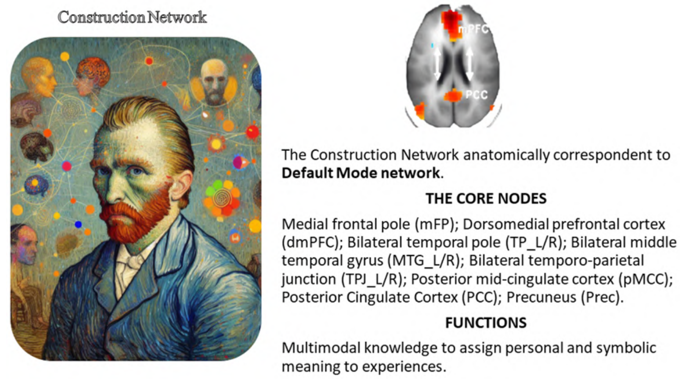

Figure 4. Moving towards the Complex Systems based on van Leeuwen et al., 2022[13]. Images source: 'Symbolic Realms: Interwoven Realities' from Image Creator of the DALL·E platform with recommendations given by the author of this paper, and The Default Mode Network from Wikimedia Common

From now on

Emerging technologies like virtual reality, artificial intelligence (AI), and brain-computer interfaces are likely reshaping the intersection of Neuroculture, aesthetics, and the Social Brain. The idea that creative activities are inherent to humanity is contestable as AI is already being used for this, and even in partnership with some artists[3].

Thus, AI can also have transformative potential in the creation of art, as AI algorithms can generate art autonomously, raising questions about creativity, authorship, and the evolutionary role of artists in a world increasingly influenced by technology.

Consequently, the long-term impact of cultural and aesthetic experiences on mental health, social bonds, and individual development is questioned. To better understand these connections, there is a need for interdisciplinary research in these areas, which has the potential to deepen our understanding of the human experience, shedding light on the profound ways in which culture, aesthetics, and the Social Brain are interconnected. It also raises important ethical questions about how this knowledge should be applied in society[15].

The integration of AI into the art world triggers a transformation of artistic paradigms, inviting us to reevaluate established concepts of creativity, authorship, and the role of artists. Promotes discussions about how technology can empower and challenge artists, redefine artistic practices, and influence the nature of art itself. As the relationship between AI and art continues to evolve, a world of possibilities is opening up, along with a set of profound questions and dilemmas for artists, academics, and society at large.

Art therapy is a field that uses creative expression as a means of promoting psychological healing, self-discovery, and well-being. Consequently, the role of AI in this context brings opportunities and challenges, and the incorporation of AI into art therapy must be done carefully, with a balance between the benefits of AI-enhanced accessibility and preserving the therapeutic, human-centered aspect of the practice[11].

The figure below was generated by artificial intelligence (AI) programmed to create images considered harmonized according to the sociocultural context. Thus, AI does not have a true ability to 'feel' beauty in the human sense, as it can be configured to create harmonized images based on different sociocultural contexts. This may involve selecting colors, patterns, styles, and visual elements appropriate to a specific culture or historical era, such as a landscape in the style of Van Gogh. Thus, AI can be used to create aesthetically pleasing images adapted to specific sociocultural contexts, but this creation is based on predefined algorithms and rules, rather than a true appreciation or understanding of beauty. Therefore, AI can be a powerful tool for creating visual content, but its success in generating harmonized images depends on the quality of training and programming carried out by humans!

Another question that concerns practical applications is related to VTS, an art-based technique for engaging individuals with works of art, emphasizing personal and social perspectives, linking artistic perception to social brain networks, and exploring how the VTS recruits these networks. Van Leeuwen *et al.*, 2023[14] study research investigates this as a method of artistic engagement, through an eye-tracking paradigm, shedding light on their influence on gaze patterns and personal resonance with works of art. The study, rooted in the concept of the social brain, reveals that VTS leads participants to focus more on highly salient social cues (animated elements) in works of art, as opposed to merely contextual information. Additionally, audio cues, especially personal reflections, intensify this effect. It is important to highlight that these results remain consistent across all ages and genders, highlighting the robustness of the method. However, it is noted that viewing condition does not have a significant impact on personal resonance with works of art, suggesting a nuanced relationship between gaze and emotional engagement. The findings contribute to the understanding of how VTS affects the social brain, offering insights for educational and therapeutic applications. The study highlights the potential of incorporating physiological and eye-tracking tools in evaluating behavioral and clinical outcomes in interventions that use art for personal well-being. However, there is a case for future research that adapts the experimental setup to real-world viewing conditions, emphasizing the broader applicability of the study's insights.

Figure 5. 'Sleepwalking among Almond Blossom Trees' (left) and 'Whispers of a Sleepy Elderly Man' (right), in the Van Gogh style, post-Impressionism from Image Creator on the DALL·E platform with recommendations given by the author of this paper.

CONCLUSIONS

In conclusion, the study of art aesthetics has undergone a significant evolution, progressing from philosophical reflections to a global vision that greatly values contemporary neuroscientific methods. The multidisciplinary approach, enriched by the 'Artistic Brain Connectome' framework, has deepened our understanding of the neural processes underlying aesthetic experiences, particularly in the context of social cognition and visual arts processing. The exploration of aesthetic judgments, regulation of internal states for social behavior, and integration of multimodal knowledge highlight the intrinsic connection between our appreciation of art and the interactions of neural networks.

The multidimensional perspective acknowledges the complex interplay of biological, psychological, and cultural influences, explaining the variations in aesthetic preferences across individuals and societies.

There is a need for further research using advanced neurophysiological tools and imaging to unravel the intricate neural array connecting art, aesthetics, and the human brain. The intertwining of Neuroculture, Neuroaesthetics, and the Social Brain has a profound impact on the perceptual dynamics of art and beauty.

The contributions of Semir Zeki and V.S. Ramachandran in the 1990s are highlighted as crucial milestones, with Zeki's use of fMRI laying the methodological foundation for neuroaesthetic research, and Ramachandran's work expanding our understanding of the neural basis of beauty.

The exploration of neuroappreciation of beauty spans at least three levels of complexity, as outlined by the 'Artistic Brain Connectome' and the 'Social Brain Connectome.' in their original four levels. Beginning with 'Aesthetic Judgment Tasks,' the investigation uncovers the neural underpinnings of aesthetic experiences, progressing to the 'Interaction' Network, which plays a central role in mediating responses to art, and culminating in the 'Construction' Network, revealing its involvement in deriving personal and symbolic meaning from art.

Besides, there is a transformative impact of emerging technologies, such as virtual reality and artificial intelligence, that has challenged traditional notions of creativity. Overall, there are profound insights into the intricate relationship between human cognition, cultural influences, and the continually evolving landscape of artistic and aesthetic perceptions.

To conclude, this article addresses VTS as a method of artistic engagement using eye tracking to understand its impact on gaze patterns and perhaps with pedagogical benefits and potential therapeutic applications.

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Unveiling the Dual Talents: The Artistic Gifts of Renowned Neuroscientists

Revelando os talentos duplos: os dons artísticos de neurocientistas renomados

Art is I; science is we.
Claude Bernard

The greatest scientists are also artists.
Albert Einstein

M. da Mota Gomes[1] [Orcid: https://orcid.org/0000-0001-8889-2573]

SUMMARY

This narrative review approaches four exceptional neuroscientists whose lives embody the convergence of scientific innovation and artistic expression. Jean-Martin Charcot (1825-1893), William Richard Gowers (1845-1915), Harvey Williams Cushing (1869-1939), and Santiago Ramón y Cajal (1852-1934) remain icons in the neurosciences. Not only did these four luminaries make groundbreaking advances in neuroscience, but they also possessed artistic abilities, especially Cajal. Their lives exemplify the harmony between scientific rigor and creative expression. Through their interdisciplinary talents, they illustrated how art and science are inextricably linked, enhancing their scientific endeavors through artistic skills. This article provides insight into the intriguing relationship between the arts and neuroscience, showing how these notable figures leveraged their artistic aptitude to advance scientific communication and understanding.

Keywords: Neuroscientists, Scientific Innovation, Art/history, Medicine in Art, Neurology/History, Interdisciplinary Studies, Creativity

RESUMO

Esta revisão narrativa aborda quatro neurocientistas excepcionais cujas vidas incorporam a convergência entre inovação científica e expressão artística. Jean-Martin Charcot (1825-1893), William Richard Gowers (1845-1915), Harvey Williams Cushing (1869-1939) e Santiago Ramón y Cajal (1852-1934) permanecem como ícones nas neurociências. Esses quatro luminares não apenas fizeram avanços inovadores na neurociência, mas também possuíam habilidades artísticas, especialmente Cajal. As suas vidas exemplificam a harmonia entre o rigor científico e a expressão criativa. Através dos seus talentos interdisciplinares, ilustraram como a arte e a ciência estão intrinsecamente ligadas, melhorando os seus esforços científicos através de competências artísticas. Este artigo dá uma ideia da relação intrigante entre as artes e a neurociência, mostrando como estas figuras notáveis alavancaram a sua aptidão artística para promover a comunicação e a compreensão científica.

Palavras-chave: Neurocientistas, Inovação Científica, Arte/história, Medicina na Arte, Neurologia/história, Estudos Interdisciplinares, Criatividade

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INTRODUCTION

In this article, the 2nd in a seven-part series about neuroaesthetics and visual art, there is the recognition that there is an interconnectedness between art, science, and medicine, showcasing how these disciplines intersect and complement each other. It acknowledges the symbiotic relationship between artistic expression and scientific inquiry, evident in fields like medical illustration and science communication.

The contrasting view points of Claude Bernard's and Albert Einstein's quotes presented at the beginning of this paper on the relationship between art and science offer intriguing insights. Bernard's emphasis on the individualistic nature of art and the collaborative essence of science, ‘Art is I; science is we’,contrasts Einstein's belief that the greatest scientists possess artistic traits, ‘The greatest scientists are also artists’. Yet, they converge on the presence of creativity and imagination bridging these distinct disciplines.

This paper focuses on renowned neuroscientists - Jean-Martin Charcot, William Gowers, Harvey Williams Cushing, and Santiago Ramón y Cajal - and underscores the intersection of art and neuroscience. These figures not only made pivotal contributions to neuroscience but also displayed artistic talents, emphasizing the profound synergy between the two realms. By exploring their lives and work, this paper aims to elucidate the significance of interdisciplinary approaches in scientific exploration and how artistic expression enriches scientific communication and comprehension.

Art and neuroscience

The symbiotic relationship between art and neuroscience, weaving together the perspectives of Semir Zeki6, Patrick Cavanagh2, and historic neuroscientists who had artistic talents exemplifies the harmony between artistic expression and scientific inquiry.

The parallels drawn between Zeki's concept of ‘the artist as neurobiologist’ and Cavanagh's idea of ‘the artist as neuroscientist’ effectively demonstrate the shared exploration of fundamental questions in both fields. Zeki's connection between the artistic endeavors of figures like Mondrian and Cubism with the pursuits of neuroscientists in understanding form constancy and essential shapes showcases the interconnectedness of their inquiries. Besides, highlighting the insights from kinetic artists about visual motion and how it parallels discoveries made by neurobiologists effectively underscores the interdisciplinary nature of art and neuroscience. Moreover, the emphasis on artists manipulating visual cues aligns seamlessly with historical neuroscientists' artistic talents, showcasing their shared pursuit of understanding perception and cognitive processes.

Artistic-Minded Scientists

Jean-Martin Charcot, a distinguished French neurologist regarded as the father of modern neurology, profoundly influenced neurology and psychiatry during his lifetime. Born on November 19, 1825, and passing away on August 16, 1893, Charcot's legacy is steeped in significant contributions to understanding neurological disorders, particularly hysteria and multiple sclerosis, fundamentally advancing the comprehension of these conditions and many others[3]. Educated at the University of Paris, Charcot received his medical degree before embarking on an illustrious career at the Salpêtrière Hospital in Paris. It was there that he conducted groundbreaking research that would shape the trajectory of neurology. However, Charcot's talents extended beyond the realms of medicine; he was an adept artist, utilizing his artistic prowess to document and illustrate neurological cases. His innovative teaching methods incorporated vivid drawings and engaging performances, revolutionizing medical education. Beyond his medical illustrations, Charcot found artistic expression in various forms, from sketches of colleagues during faculty meetings to landscapes and other subjects[1]. Despite his preference for conservative artistic tastes, Charcot's artistic skills were an integral part of his scientific work and, in addition, in 1853, he experimented with hashish in the company of a medical student to understand the effect of this drug. As a result, there was an intense visual hallucinatory state and a design that incorporated elements reminiscent of the surreal and often disturbing landscapes found in the works of artists such as Hieronymus Bosch (Figure 1)[11]. Consequently, Charcot´s artistic finesse, coupled with his scientific acumen, significantly enriched his scientific endeavors, allowing for a unique blend of art and neurology.

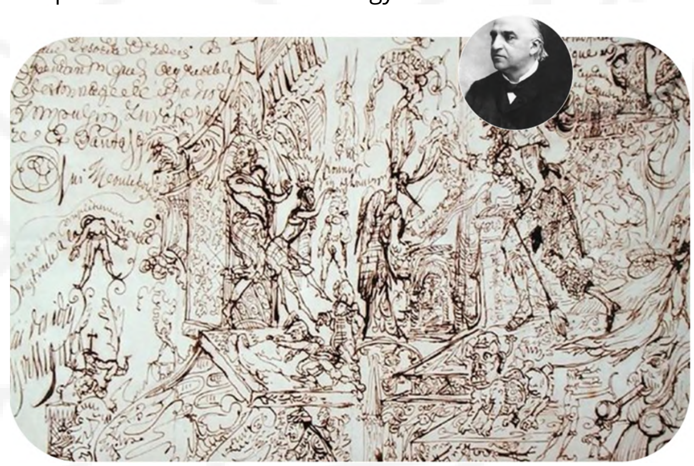

Figure 1. Drawing produced under the influence of hashish by Jean-Martin Charcot, http://www.wikigallery.org/

William Gowers, a celebrated British neurologist, left an indelible mark on the field of neurology. Born on March 20, 1845, and passing away on May 4, 1915, Gowers is remembered as a distinguished clinical neurologist who significantly advanced the understanding of epilepsy and various other neurological disorders4. His clinical descriptions and writings had a profound influence on shaping neurology as a discipline. Gowers received his medical education at University College London and practiced at the esteemed National Hospital for Neurology and Neurosurgery in London. He held various positions at University College London, contributing significantly to the institution. Beyond his contributions to neurology, Gowers' artistic talents were a unique facet of his multifaceted expertise, as he employed his artistic abilities to create meticulous medical illustrations, enriching textbooks and bridging the realms of medicine and art. His seminal work, 'A Manual of Diseases of the Nervous System,' stands as a testament to his proficiency in both medicine and art, playing a pivotal role in disseminating neurological knowledge to a wider audience (Figure 2). Regarding his artistic inclination, MacDonald Critchley noted Gowers' preference for etching and engraving, his delicate and intricate technique in these mediums. Additionally, Gowers utilized pencil drawings, especially for medical and pathological subjects, to illustrate his textbooks. Despite boasting that he never received formal drawing lessons, Gowers diligently studied handbooks on the subject and dedicated himself to practice, showcasing his commitment to refining his artistic skills alongside his medical expertise[9].

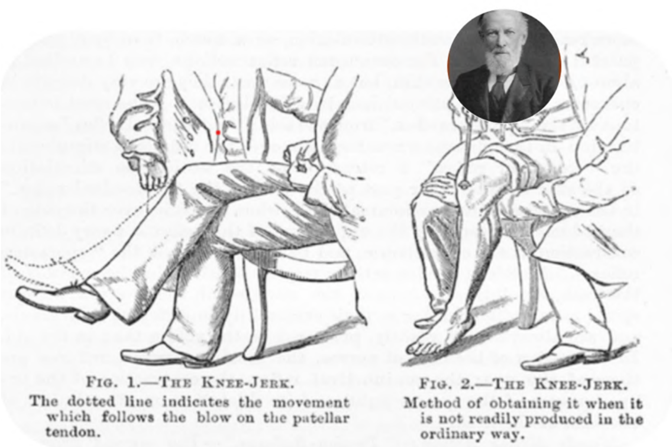

Figure 2. 'Knee Jerk' was drawn by William Richard Gowers for his 'Manual of Diseases of the Nervous System' published by J & A Churchill in 1886. From Wikimedia Commons.

Harvey Williams Cushing, an influential American neurosurgeon, is renowned as the pioneer of modern neurosurgery. Born on April 8, 1869, and passing on October 7, 1939, his transformative contributions reshaped brain surgery techniques, particularly in the realm of brain tumors, notably those involving the pituitary gland[5,8]. Cushing's groundbreaking innovations profoundly advanced the field of neurosurgery. His educational journey took place at Harvard Medical School, and his professional career spanned various esteemed institutions, including Johns Hopkins Hospital, Harvard Medical School, and the Peter Bent Brigham Hospital. Beyond his revolutionary surgical techniques, Cushing was notably meticulous in recording his surgical cases. His penchant for detailed documentation extended to creating intricate sketches and diagrams, serving as comprehensive medical illustrations. While recognized for his surgical prowess, Cushing also indulged in artistic pursuits during his leisure time, producing beautiful and intricate landscape paintings. In his admiration, divided with William Osler, for Andreas Vesalius, a pioneering figure in modern anatomy known for his groundbreaking work and illustrations in 'De Humani Corporis Fabrica,' Cushing found a kindred spirit with a shared appreciation for the fusion of science and art. However, it's important to note that Cushing's illustrations primarily aimed at documenting surgeries and anatomical findings, serving as meticulous medical records rather than artistic paintings (Figure 3). Despite this, Cushing's dual talents, bridging medical practice and artistic expression, undoubtedly enriched both his medical endeavors and his artistic pursuits.

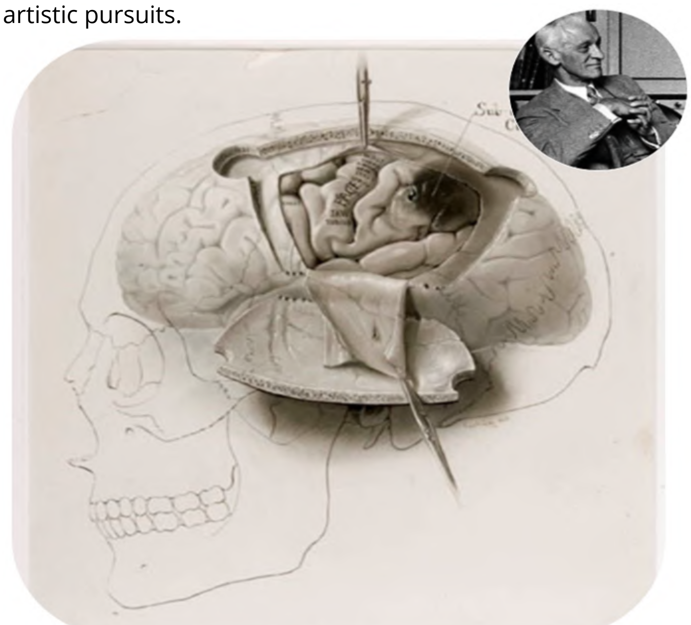

Figure 3. Medical Illustration by Harvey Cushing 1910. From: http://44377079.weebly.com/cushing-the-artist.html and Wikipedia.

Santiago Ramón y Cajal, a Spanish histologist, born on May 1, 1852, and died on October 17, 1934, is revered as the father of modern neuroscience through his pivotal work on the nervous system's structure10. Despite his brilliant scientific career, Cajal was torn between his aptitude for art and his father's insistence that he pursue medicine7. Cajal attended the University of Zaragoza for his medical studies where he received his degree in Medicine, and worked at the University of Valencia, where he held professorships and after he was appointed Professor of Histology and Pathological Anatomy in Barcelona, and successively in Madrid, where at the University and his Institute,he conducted his seminal research in neuroscience.

Cajal specifically his discoveries on neuron structure and the ‘neuron doctrine’, revolutionized the understanding of the nervous system and received the 1906 Nobel Prize, shared with Camillo Golgi (July 7, 1843-January 21, 1926) for Physiology or Medicine for establishing the neuron, or nerve cell, as the basic unit of nervous structure. Cajal stands out as a unique case among these four figures, as he was not only a brilliant neuroscientist but also a talented artist. His drawings are scientifically precise but also immensely eloquent, and famous artists were inspired by his work7. He created intricate and detailed drawings of neurons and brain structures through a technique called the Golgi stain, which allowed for the visualization of individual neurons (Figure 4). His drawings are not just scientific illustrations but are also considered artistic masterpieces due to their accuracy, detail, and aesthetic appeal. Cajal's artistic renderings of the brain's cellular structure have been recognized for their scientific significance as well as their artistic merit.

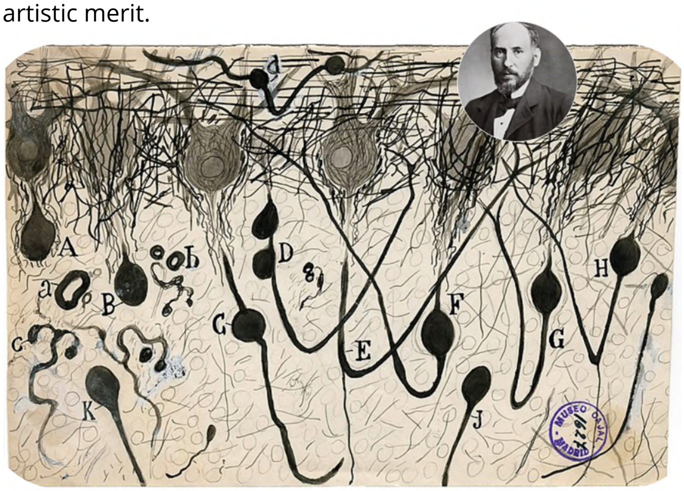

Figure 4. Axon of Purkinje neurons in the cerebellum of a drowned man, c. 1900, Santiago Ramón y Cajal, Cajal Institute (CSIC), Madrid. From Wikimedia Commons.

While Charcot's possible experiences with hashish/painting and Cushing's passion for landscape paintings are interesting aspects of their personal lives, their contributions to neurology and medicine are primarily remembered for their scientific and medical achievements rather than their artistic endeavors.

The enduring legacies of these neuroscientists indeed primarily stem from their groundbreaking contributions to neuroscience and medicine. However, their artistic talents and interests beyond their scientific pursuits highlight the depth of their personalities and the richness that interdisciplinary perspectives bring to scientific inquiry. However, Cajal remains the standout figure among them, renowned for his scientific illustrations that also hold artistic value. Cajal's ability to seamlessly merge scientific accuracy with artistic finesse stands as a testament to the profound impact of combining art and science. His work serves as an inspiration, illustrating how artistic expression can enhance scientific communication and comprehension while leaving a lasting imprint on both fields.

CONCLUSIONS

The intersection of art, science, and medicine is a rich amalgam of interconnected disciplines that complement and reinforce each other. The perspectives of Claude Bernard and Albert Einstein, though seemingly divergent, converge on the idea that creativity and imagination are central in bridging these distinct domains.

Focusing on eminent neuroscientists such as Jean-Martin Charcot, William Gowers, Harvey Williams Cushing, and Santiago Ramón y Cajal accentuates the profound harmony between art and neuroscience. These individuals not only significantly contributed to neuroscience but also showcased artistic talents, mainly Cajal, emphasizing the intrinsic synergy between these realms. Their lives and work serve as compelling examples of the value of interdisciplinary approaches in scientific exploration and highlight how artistic expression enhances scientific communication and comprehension.

The symbiotic relationship between art and neuroscience, as explored through the perspectives of Semir Zeki, Patrick Cavanagh, and historic neuroscientists with artistic talents, exemplifies the seamless blend of artistic expression and scientific inquiry. Zeki's connections between artistic endeavors and neurological pursuits, along with Cavanagh's views on artists as neuroscientists, vividly demonstrate the shared exploration of fundamental questions in both fields. The parallels drawn between artistic insights into visual motion and discoveries made by neurobiologists underscore the interdisciplinary nature of art and neuroscience, emphasizing their mutual quest to understand perception and cognitive processes. This interconnectedness reaffirms the profound links between art and neuroscience, illuminating their collective pursuit of understanding the human mind and perception.

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The Interplay Between Brain Lesions and Painter´s Creative Transformations

A interação entre lesões cerebrais e transformações criativas do pintor

Painting is just another way of keeping a diary.

Pablo Picasso

Every good artist paints what he is.

Jackson Pollock

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ABSTRACT

This narrative review addresses the complex relationship between neurological diseases and artistic expression, which can have a profound impact on a painter´s works. This exploration highlights the dynamic and ever-evolving connection between neuroscience and art, offering insights into the extraordinary ways in which the human brain and artistic expression intersect and evolve. Following brain damage, there may be the emergence of sudden artistic talents, intriguing changes in the styles of established artists, the paradoxical facilitation of artistic abilities despite the cognitive decline consequent to these injuries, besides coping strategies that artists adopt in response to the challenges of health. Therefore, this article investigates different scenarios where brain injuries and disorders have had a profound impact on artists, leading to the emergence of new talents, changes in artistic styles, and unexpected improvements in their work, as well as adaptations in their artistic practices, as represented by some painters such as Tommy McHugh (1949 -2012), Francisco Goya (1746-1828), Otto Dix (1891-1969), Willem de Kooning (1904-1997), William Charles Utermohlen (1933-2007) and Charles Meryon (1821-1868). Consequently, works of art can be valuable but understudied tools for understanding brain dysfunction, although they must be interpreted with great care.

Keywords: Neurological Disorders, Artistic Expression, Brain Injuries, Creativity, Cognitive Decline, Chronic Degenerative Diseases, Neurosciences

RESUMO

Esta revisão narrativa aborda a complexa relação entre doenças neurológicas e expressão artística, que pode ter um impacto profundo na obra de um pintor. Esta exploração destaca a conexão dinâmica e em constante evolução entre a neurociência e a arte, oferecendo insights sobre as formas extraordinárias pelas quais o cérebro humano e a expressão artística se cruzam e evoluem. Após danos cerebrais, pode haver o surgimento de talentos artísticos repentinos, mudanças intrigantes nos estilos de artistas estabelecidos, a facilitação paradoxal de habilidades artísticas, apesar do declínio cognitivo consequente a essas lesões, além de estratégias de enfrentamento que os artistas adotam em resposta aos desafios de saúde. Portanto, este artigo investiga diferentes cenários onde lesões e distúrbios cerebrais tiveram um impacto profundo nos artistas, levando ao surgimento de novos talentos, mudanças nos estilos artísticos e melhorias inesperadas em seu trabalho, bem como adaptações em suas práticas artísticas, bem como representado por alguns pintores como Tommy McHugh (1949 -2012), Francisco Goya (1746-1828), Otto Dix (1891-1969), Willem de Kooning (1904-1997), William Charles Utermohlen (1933-2007) e Charles Meryon (1821-1868). Consequentemente, as obras de arte podem ser ferramentas valiosas, mas pouco estudadas, para a compreensão da disfunção cerebral, embora devam ser interpretadas com muito cuidado.

Palavras-chave: Transtornos Neurológicos, Expressão Artística, Lesões Cerebrais, Criatividade, Declínio Cognitivo, Doenças Crônico Degenerativas, Neurociências

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INTRODUCTION

In this article, the third in a seven-part series about neuroaesthetics and visual art, there is the recognition that creating visual arts involves a complex interplay of motor skills, visual-spatial processing, emotional expression, cultural context, and creativity.

Picasso and Pollock´s quotes presented at the beginning of this article emphasize how an artist's work is an expression of their inner self and experiences, consequently, understanding the relationship between artistic production and brain disease is crucial, as neurological conditions can have a significant impact on an artist's ability to create across multiple domains.

This article presents reports of neurological disorders that have affected works by famous or lesser-known artists, mainly in situations such as the emergence of artistic talent, the complete change in the artists' style, the liberation of artistic expression through “paradoxical facilitation” and the health coping strategy.

Brain lesions and artists' styles and creative transformations

Many great artists have struggled with late-life impediments, from physical disabilities to cognitive decline, such as Monet's cataracts which were misery for him in his old age, but others have worse situations and surprises as will be presented[7].

Artistic expression can serve as a window into neurological disorders and deviations from an artist's typical style or behavior that may suggest emerging brain dysfunction. Thus, for example, compulsive artistic behavior, often emerging early in the illness, highlights a significant aspect of the neurological disorder and the basis of this behavior may include disruption of the frontotemporal-limbic-subcortical circuitry.

Sensory and emotional experiences, such as increased sensitivity or joy, can accompany this artistic impulse. Thus, sequential changes in an artist's work, observed through a series of images, reveal changes in style, form, or color choices, potentially reflecting underlying neurological changes. However, Schott[11] advises caution against an exaggerated interpretation of these changes as definitive indicators of brain dysfunction, emphasizing that such changes are not always warning signs for the onset of the disease. He points out that several renowned artists have evolved their styles without underlying neurological problems.

As for abnormalities, they can occur in various neurological conditions such as dementia, stroke, Parkinson's disease, autism, psychiatric disorders, epilepsy, migraines, and trauma. In these cases, artworks reveal underlying brain dysfunctions through abnormal context, evolving changes in style or content, compulsive elements, or emotional accompaniments that may result from involved brain regions, suggesting impaired inhibition that leads to paradoxical functional facilitation, especially in the hemisphere right hindquarters and individuals with an artistic inclination may be more prone to pathologically obsessive creativity[11].

The major review by Pelowski *et al*.[9] highlights the historical connections established between art and neurological issues, particularly neurodegenerative diseases. It emphasizes how notable artists such as Albrecht Dürer, Willem de Kooning, Vincent van Gogh, Georges Braque, William Utermohlen, and others were linked to potential neurological problems, presenting changes in their artistic expression. This review discusses how discussions arose in the 19th and 20th centuries linking the artistic expressions of renowned figures to neurological conditions. For example, Van Gogh's unique artistic style was potentially linked to epilepsy and psychotic episodes, while other artists such as the German painter Lovis Corinth (1858-1925) after suffering a right-hemisphere stroke, experienced changes in his artistic style, shifting from highly detailed and realistic portraits to a more expressive, impressionistic technique, and there were also instances of neglecting or omitting the left side of his paintings. Furthermore, cases such as those of Willem de Kooning and William Utermohlen have shown changes in artistic expression linked to later diagnosed Alzheimer's disease (AD). The aforementioned review also analyzes the emergence of case studies from the late 1980s, published in various journals specialized in neurology and neurosciences, which generally highlighted changes in artistic production attributed to specific neurodegenerative diseases, such as AD, Parkinson's disease (PD), and stroke. Pelowski *et al*.[9] observed several changes in formal artistic characteristics, such as color, line, and style of content, linking these changes to the appearance of the supposed disease. This review highlights that these case studies often lacked systematic assessments and relied predominantly on subjective assessments of artistic changes associated with neurodegenerative diseases. The authors identified different factors that indicate such disorders, including changes in the formal characteristics, quality, creativity, and emotions expressed in the artwork. However, there was some consensus among these reports, suggesting increased creativity for certain disorders such as frontotemporal dementia (FTD) and PD, while also indicating decreased creativity for AD and dementia with Lewy bodies.

Emergence of artistic talent

The emergence of artistic talent in certain neurodegenerative diseases, such as PD and FTD, has intrigued researchers. Despite declining motor skills, patients sometimes develop new artistic skills. In PD, higher doses of medication correlated with increased creativity8. One theory suggests that drug-induced increases in dopamine may trigger creativity, especially in individuals with low dopamine due to PD. Another theory proposes that as certain parts of the brain degenerate in these disorders, other areas become more active, allowing latent talents to surface. This phenomenon in PD patients parallels observations in individuals with FTD, where patients also display a sudden inclination toward art production. FTD sometimes triggers an unexpected surge of artistic creativity in individuals who experience language loss due to damage to specific brain regions. Typically expressed through visual art, this creativity stems from retained visuospatial skills and heightened interests. In FTD, damage to left-sided areas of the brain can increase activity in right-sided brain regions associated with visual perception, allowing artistic expression despite other cognitive impairments. This change in brain activity, already approached, and known as paradoxical functional facilitation, is a structural change in neurodegenerative diseases such as FTD, leading to greater artistic creativity despite other neurological challenges[6]. These intriguing cases have led scientists to explore how neurodegenerative conditions can unlock or activate artistic capabilities despite the general degeneration of cognitive and motor functions.

Tommy McHugh (1949-2012), figure 1, an artist and poet from Liverpool, England, initially worked in construction and was involved in minor criminal activities. After a stroke at age 51 that resulted in a coma for a week, McHugh acquired savant syndrome, demonstrating remarkable artistic abilities that he had not possessed before. His strokes, initially debilitating, unexpectedly opened a new chapter in his life, giving rise to a magnificent adventure that lasted 11 years[12].

Figure 1. Thinking Dreaming by Tommy McHugh (1949-2012), adapted from http://www.tommymchugh.co.uk/Picture%20Gallery/album/index.html#img=10S%20-%20Thinking%20dreaming.JPG.

Artists' Complete Change of Style

This section investigates cases in which established artists have undergone radical changes in their artistic styles, techniques, or subject matter due to neurological conditions. It involves comparative studies and case analyses to understand the neurological and psychological factors that contribute to transformative changes in the bodies of work of renowned artists.

Francisco Goya (1746–1828), figure 2, a Spanish painter, suffered a serious illness, potentially lead poisoning, that caused a significant change in his artistic style. Before his illness, his works tended to be more traditional, however, after this illness, his paintings took on a darker, more mysterious, and unconventional tone, reflecting a profound change in his emotions. Goya's artistic evolution encompassed several styles, from Rococo to Romanticism, presenting a broad spectrum of artistic expression.

Otto Dix (1891 - 1969), figure 3, a renowned German painter, experienced a diverse artistic journey marked by distinct phases. His early art, shaped by his World War I experiences, depicted grim war realities with detailed realism. Associated with the New Objectivity movement post-war, he continued portraying reality but with critical scrutiny, addressing societal issues. After a stroke later in life, his style shifted, embracing Expressionism's emotive, subjective approach. Departing from strict realism, his art became more emotionally charged and expressive. This likely evolution stemmed from personal experiences, evolving artistic trends, and potentially, neurological factors. Dix's stroke notably influenced his artistic expression, reflected in changes in his drawing style, including later self-portraits. He suffered a right hemisphere stroke in 1967, causing left-sided weakness, neglect, visual impairment, and difficulties with spatial tasks and arm movements. Initially unable to draw, he managed to make a simple tree sketch on the fourth day, demonstrating negligence by leaving the left side of the paper blank, in a week, a second tree sketch revealed considerable compensation for neglect. Dix's drawing style changed notably, obviously even in his later self-portraits[2].

Figure 2. Saturn Devouring His Son (from The Black Paintings), 1820-1823, by Francisco Goya (1746–1828), Romanticism (second half of 18th century–first half of 19th century), mixed technique and mural on the wall and canvas, Museo del Prado, from Wikipedia.

Figure 3. 'Otto Dix' (1891-1969) drawing style compared with his photo at the top left, with those in the bottom that share the absence of a resemblance to the painter adapted from Bäzner and Hennerici, 2007.

Liberation by "Paradoxical Facilitation"

Some stories highlight the profound and varied ways neurological damage can influence an artist's style, often leading to unexpected and aesthetically appealing transformations in their work. There is a common assumption that brain damage might permanently alter an artist's creative abilities, although there are instances where the effects are unexpectedly positive as some artists, despite neuropsychological deficits, demonstrate an enhanced artistic output, showcasing the remarkable resilience and adaptability of the human brain. This "paradoxical facilitation" challenges the conventional understanding of art production. When specific brain regions are damaged, other areas may compensate in unexpected and fascinating ways. For instance, individuals experiencing changes in perception due to brain injury have shown remarkable adaptations in their artistic style. An artist who developed achromatopsia after a traumatic brain injury, previously known for colorful, abstract paintings, adapted to working with a limited palette. This limitation led to a newfound appreciation for a pure form, resulting in striking black-and-white artworks. Similarly, artists affected by spatial neglect due to right hemisphere damage might exclude details from one side of their images, resulting in a style characterized by hidden facets and essence rather than realism. Left hemisphere damage has influenced artists' styles as well. Brain damage sometimes leads artists towards simplicity and abstraction, for instance, an artist with a left occipital lesion simplified their work, becoming more abstract with limited colors. Similar trends have been observed in some artists with AD, like Willem de Kooning, whose later works were simplified yet coherent, embracing a more straightforward and colorful palette[3].

William de Kooning (1904-1997), figure 4, a Dutch-American abstract expressionist painter, developed AD in his later years. His artistic style went through several transformations, alternating between representation and abstraction, after the "Woman" series, de Kooning moved more in the direction of abstraction. In 4 decades, de Kooning's art had traveled from concreteness to abstraction[1,4] . Kooming was diagnosed with dementia when he was almost 80 years old, but signs of the disease had already been noticed years before. However, in the following years, he painted more than 300 abstract paintings, glorified by art critics, with temporary interruption, but when he started again, his work had changed, as he became exuberant, carefree, and full of life, and paintings carried out in weeks rather than months. As his illness progressed, his art became progressively more abstract and difficult to understand, although he continued to attract critical attention. His career is indeed fascinating, especially the period in which he continued to produce art despite battling dementia. In his later years, his style underwent a noticeable transformation, becoming more abstract and challenging to interpret. Despite these changes, his work remained critically acclaimed, and his ability to express himself through art persisted even as his illness progressed. It's remarkable how he continued to create, evolving his style and captivating attention despite the challenges he faced due to dementia[4]. Despite his cognitive decline, his art underwent a transformation characterized by bold, expressive brushstrokes, reflecting a paradoxical facilitation of artistic talent.

Another painter also diagnosed with AD was William Charles Utermohlen (1933-2007), figure 5, an American figurative artist. In contrast to de Kooning's exuberant works, he followed the classical understanding that brain damage can permanently alter an artist's creative abilities. Utermohlen is known for a series of self-portraits that express his cognitive decline that followed his diagnosis of probable AD in 1995, at the age of 61, after a long and successful career as a painter. As the artist struggled to maintain contact with the world around him, his works became flatter and more abstract, with a greater loss of detail and spatial sense. Many of the stylistic changes are probably the result of the rapid decline of their visuospatial and motor skills over a few years.[4]

Figure 4. Woman 1, 1950 and Untitled XXVIII, 1983, by William de Kooning (1904-1970), adapted from https://www.theguardian.com/science/2016/dec/29/paintings-reveal-early-signs-of-cognitive-decline-claims-study.

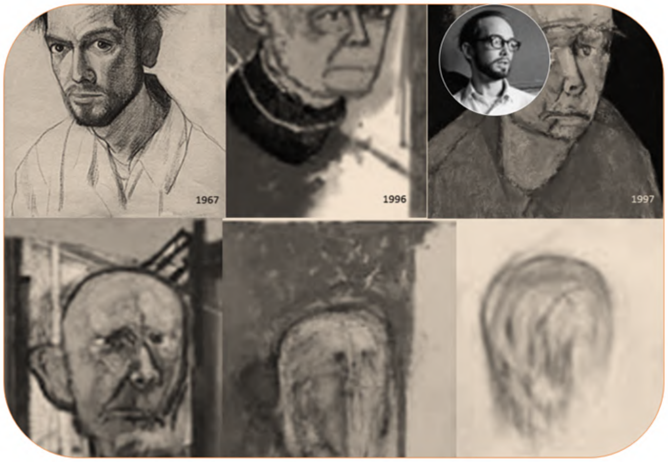

Figure 5. The impact of Alzheimer's disease on self-portraits by William Charles Utermohlen (1933-2007), adapted from https://digitalcommons.iwu.edu/utermohlen/1[13]

Coping Strategies Against Health Problems

This section discusses the multitude of factors that influence changes in painters' styles, encompassing personal evolution, life experiences, experimentation, market trends, and feedback from peers and critics. It also explores how artists use art as a mechanism for coping with the challenges posed by neuropsychological conditions.

Charles Meryon (1821-1868), figure 6, was a French artist, an illegitimate son of a Parisian opera dancer, and an English doctor, recognized for his etchings. After studying art, he realized that his congenital color blindness prevented him from being successful with oil paints, turned to etching, and also faced mental illness, apparently depression, and later developed hallucinations and persecutory delusions[5,10]. His art was deeply intertwined with his personal experiences and emotional responses, serving as a coping mechanism to address perception issues and lasting mental health challenges.

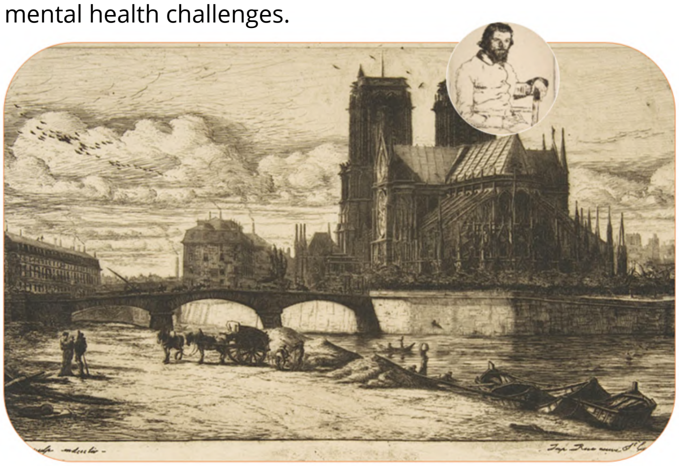

Figure 6. Abside de Notre Dame, 1854, the fourth state of nine, 1854, Charles Méryon (1821–1868), Etching with engraving and drypoint on laid paper, Metropolitan Museum of Art, from Wikipedia.

CONCLUSION

The intricate interplay between neurological disorders and artistic expression uncovers the exceptional adaptability and transformative power of the human mind. The cases presented reveal how brain injuries and neurological conditions shaped these artists' creations, transcending the forms and boundaries of conventional art. This exploration emphasizes the captivating and ever-evolving field of neuroscience and art, offering insights into the remarkable connection between the human brain and artistic creativity.

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Exploring the Art and Experiences of Painters with Epilepsy

Explorando a arte e as experiências de pintores com epilepsia

When I have a terrible need of - shall I say the word - religion. Then I go out and paint the stars.

Vincent Van Gogh

I dream of painting and then I paint my dream.

Vincent Van Gogh

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ABSTRACT

This narrative review addresses the world of artists who linked their creative journeys alongside their battles with epilepsy, a neurological condition engineered by recurrent epileptic seizures, with multifaceted implications in biopsychosocial domains. By examining the lives and works of celebrated artists such as Vincent Van Gogh and contemporary painters, particularly those possibly affected by epilepsy, a narrative transcends clinical elucidations, investigating historical contexts, artistic expressions, and therapeutic interventions. The focus is on uncovering the transformative influence of engaging in artistic activities for individuals struggling with epilepsy. It investigates the profound impact of artistic pursuits on people affected by epilepsy, showing the resilience of the human spirit in harnessing adversity as a source of creativity. This exploration illuminates the potential of art, not only as a means of self-expression, but also as a therapeutic medium in the setting of epilepsy and associated neurorehabilitation.

Keywords: Epilepsy, Art Therapy, Artists, Neurological Conditions, Creativity, Neurorehabilitation, Resilience

RESUMO

Esta revisão narrativa aborda o mundo dos artistas que associaram as suas jornadas criativas paralelamente às suas batalhas contra a epilepsia, uma condição neurológica caracterizada por ataques epilépticos recorrentes, com implicações multifacetadas em domínios biopsicossociais. Ao examinar as vidas e obras de artistas célebres como Vincent Van Gogh e pintores contemporâneos, particularmente aqueles possivelmente afetados pela epilepsia, a narrativa transcende as elucidações clínicas, investigando contextos históricos, expressão artística e intervenções terapêuticas. O foco está em desvendar a influência transformadora do envolvimento em atividades artísticas para indivíduos que lutam contra a epilepsia. Ele investiga o profundo impacto das atividades artísticas nas pessoas afetadas pela epilepsia, mostrando a resiliência do espírito humano ao aproveitar a adversidade como uma fonte de criatividade. Esta exploração ilumina o potencial da arte, não apenas como meio de autoexpressão, mas também como meio terapêutico no cenário da epilepsia e da neurorreabilitação associada.

Palavras-chave: Epilepsia, Arteterapia, Artistas, Condições Neurológicas, Criatividade, Neurorreabilitação, Resiliência

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INTRODUCTION

This article, the fourth in a seven-part series on neuroaesthetics and visual arts, is about the exploration of the representation of epilepsy in art, based on works by artists such as Vincent Van Gogh and contemporary painters that reveals a unique perspective on the experiences of people affected by neurological disorders.

Van Gogh's quotes presented at the beginning of this article illustrate the profound connection between his inner emotions and his art, and painting the stars during moments of spiritual need reflects how nature and art intertwined in his quest for solace and meaning, besides his dreamlike paintings were, in essence, a manifestation of his inner visions and aspirations.

However, the relationship between epilepsy and artistic production/creativity, despite expectations of a strong link between them, is known that a few renowned painters had epilepsy16. The historical context and artistic representations of epilepsy offer insights that transcend clinical descriptions, emphasizing the potential for art to play a significant role in therapy and neurorehabilitation.

The consequences of neurological disease on creativity

The artistic representation of epilepsy-related phenomena has been a topic in literature for a long time, often explored by epileptic writers like Dostoyevsky or by those who have observed seizures in others. However, the depiction of epilepsy by artists with the disease is a more recent trend. It was not until the 1990s that epilepsy became a declared source of inspiration for epileptic artists, notably through the experiences of Jennifer Hall as mentioned by Lambert[11].

Van Gogh's Enigmatic Disorder

Vincent van Gogh, figure 1, was a Dutch painter born on March 30, 1853, and died on July 29, 1890, and is one of the most celebrated creative artists of all time. His life and art continue to captivate scholars due to his special painting style, and speculated neurological or psychiatric conditions which remain a mystery to this day, and there are several debates surrounding his afflictions[2,3,15].

Van Gogh's art style is characterized by bold colors, expressive brushwork, and emotional intensity. He used these elements to convey his emotional and spiritual state rather than attempting to replicate reality accurately.[17].

During his life, van Gogh was influenced by various artistic movements and artists and was inspired by Impressionism and Post-Impressionism, particularly the works of artists like Claude Monet, Camille Pissarro, and Paul Gauguin. His time in Paris exposed him to Impressionist techniques and color theories.

Van Gogh's art, despite initially facing rejection and criticism during his lifetime,has had a profound impact on subsequent generations of artists. His emotionally charged works and distinctive style have influenced numerous artists and movements, including Expressionism and Fauvism. He left behind an extraordinary legacy, inspiring artists well beyond his era.

Many historians believe that he suffered from epilepsy based on characteristics such as hypergraphia, atypical sexuality, and viscosity of thought, suggesting the possibility of the Gastaut-Geschwind phenomenon, a known complication of complex partial seizures (focal impaired consciousness). He was supposedly addicted to absinthe liquor, which is known to cause xanthopsia, and many authorities argue that this was the reason for his penchant for the deep, bright yellow color in many of his paintings. Regarding his illness, other hypotheses were raised such as Ménière's disease, bipolar disorder, heatstroke, and acute intermittent porphyria. He explores the potential influence of these conditions on his artistic vision, examining his bold colors, emotive brushstrokes, and the tumultuous nature of his artwork. Although discussions link his conditions to his intense style, attributing specific aspects of his art solely to medical conditions remains speculative. The complexity of his creative process likely resulted from a mix of personal experiences, artistic influences, and his distinct perspective. His letters to his brother Theo offer glimpses into his thoughts and struggles, but definitive evidence linking his medical conditions to his artistic choices remains elusive.

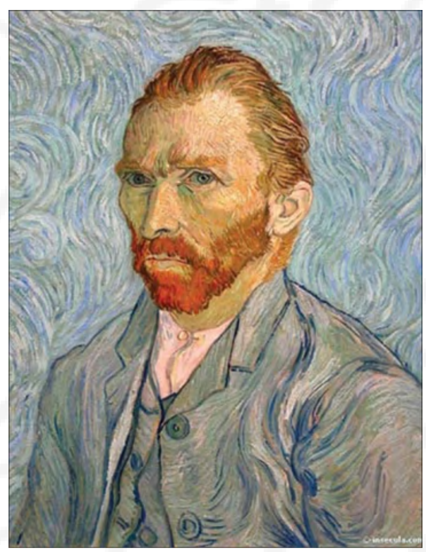

Figure 1. Self-portrait, 1889, Vincent van Gogh (1853–1890), oil on canvas, Musée d'Orsay, from Wikipedia.

Other Painters with Epilepsy and Artistic Representation of Epilepsy

In addition to Van Gogh, this section features lesser-known painters living with epilepsy. His diverse experiences and artistic styles present a rich expression of creative responses to the condition. Despite the challenges of finding documentation about these artists, their works highlight the broad spectrum of artistic talents influenced by epilepsy. Notable figures like Jennifer Hall exemplify this, demonstrating competence and artistic talent. However, due to limited documentation and recognition, detailed information about these artists may require more active and specialized investigation.

The story of resilience in people who have been diagnosed with epilepsy is remarkable, as in the case of Sir Kyffin Williams (1918-2006), a renowned Welsh painter whose artistic pursuits were precipitated by this disease. Initially pursuing a military career, Kyffin suffered seizures, which led a neurologist to suggest he dedicate himself to art. Despite his doubts, he enrolled at the Slade School of Fine Art, becoming a distinguished painter, known for his depictions of Welsh landscapes and people. His art resonated deeply with locals and gained national recognition, highlighting the transformative power of channeling personal challenges into creative pursuits[7].

Jennifer Hall, an artist with epilepsy and director of an artistic experimentation center in Boston, has put together an exhibition highlighting the work of twenty-seven painters with epilepsy, visually and visually exploring convulsive experiences and hallucinations associated with epilepsy. Hall herself uses performances like "Out of The Body Theater" to objectify these intense experiences, using automatons, digital animation, projections, and other tools to communicate experiences she cannot verbalize during a crisis.

More recently, individuals like Zach Beckemeyer are using art not only as a means of personal expression but also as a platform to raise awareness about epilepsy[13]. His trajectory, marked by surgeries and subsequent relearning of basic functions, shows the resilience and strength of those who live with neurological disorders. Beckemeyer's ability to channel his experiences into his art not only serves as a therapeutic outlet for him but also communicates a profound message to others. Her journey from diagnosis to surgeries and subsequent seizure-free period reflects a triumph of resilience and the human spirit. It is proof of the transformative power of art and overcoming personal challenges. Art exhibitions like these not only showcase the talent and creativity of individuals like Beckemeyer, but they also play a crucial role in promoting empathy, understanding, and support for those affected by epilepsy. They offer a platform for dialogue and awareness, ultimately contributing to a more inclusive and informed society.

These artistic works offer a unique and deeply personal insight into epilepsy-related experiences, highlighting how epileptic seizures can inspire and inform artistic creation, while also exploring the limits of communicating these intense experiences.

Finkelstein et al., apud Schott, 2012[16], presented a unique case of a mosaic artisan not previously known for artistic activity, diagnosed with left frontotemporal epilepsy based on clinical characteristics, EEG, SPECT images, and neuropsychological evaluation. During noncommunicative, aimless, and sometimes aggressive episodes lasting 40 minutes of sleep, this patient began to draw impulsively, demonstrating remarkable skill even during these attacks. The authors suggested that intact right hemisphere functions during a depression that spreads to the left hemisphere may lead to impulsive artistic creativity—a potential "release phenomenon" of the complex visuospatial abilities of the right hemisphere.

Carrizosa-Moog et al.[5] recognized that to date several professional artists and patients with epilepsy have described the disease through different forms of art, such as painting, sculpture, dance, etc., and the feelings and thoughts of those with seizures have been appreciated and reviewed in several articles demonstrating how art could display emotional, social and cultural aspects that other methods were not capable of. Art has been used as an expression of what cannot be said in words, as a healing instrument, and as a strategy for better empathy between patients, doctors, and society. Epilepsy researchers and specialists at LASSE XIII pictorially represented the feelings or challenges of persons with epilepsy, thus giving a multifaceted view of them[5]. These insights go beyond clinical descriptions, offering different perspectives on the experiences of individuals living with epilepsy. Themes of identity schism, loss of control, and complexity of the condition emerge in these artworks, reflecting the emotional, social, and clinical dimensions of epilepsy.

Neuroaesthetic Principles and Neurorehabilitation

Art therapy serves as a form of psychotherapy where art becomes a tool for healing and self-expression and trained art therapists guide patients, helping them create art to aid in emotional, psychological, and physical healing which is very important in epilepsy which is a bio-psycho-social disease[4,18]. This approach is especially valuable for individuals who find verbal expression challenging, and art therapy offers a safe space for nonverbal emotional expression being practiced in a variety of settings, including medical, psychiatric, educational, and social work. Visual art can serve as a preferred method of communication, especially for highly creative individuals, providing a safer avenue for emotional expression. Although research indicates the potential of art therapy in managing psychosocial challenges associated with epilepsy, its use remains limited. However, it holds promise in helping patients deal with the complexities surrounding epilepsy or psychogenic non-epileptic seizures (PNES). By allowing nonverbal expression, art therapy can reveal subconscious emotions and thoughts, helping patients understand their condition and improving coping mechanisms. Furthermore, artistic expression can reveal distinctions in the subconscious experiences of epilepsy and PNES, similar to insights derived from conversation analysis.

The neuroscientific foundations of art therapy elucidate the multi faceted mechanisms through which creative engagement positively influences neurological and emotional states. This covers the intricate neural tracts associated with creativity, shedding light on how the act of painting stimulates these pathways, thereby increasing cognitive flexibility and imaginative thinking. Emotional processing is also a key aspect, where artistic expression facilitates the interpretation and processing of emotions linked to the experiences of living with epilepsy. Furthermore, the therapeutic benefits of art extend to reducing stress, triggered by the meditative and calming aspects of the creative process. Through painting, individuals immerse themselves in a state of focused attention, promoting mindfulness that alleviates the stress and anxiety associated with epilepsy. Sensory stimulation derived from the tactile experience of painting and visual engagement with colors and shapes further amplifies this therapeutic effect, providing a rich sensory environment conducive to emotional release and relaxation. The neurological concepts of mirror neurons and empathy find resonance in art therapy, where creating or viewing art generates a shared emotional experience, promoting empathy and connection. This shared emotional resonance cultivates a sense of understanding and support, forming a vital component in the emotional rehabilitation of individuals navigating the complexities of epilepsy. Furthermore, the neuroplasticity of the brain is harnessed through art therapy, and practicing painting exercises the brain, promoting neural adaptation and flexibility. This process supports cognitive functions and problem-solving abilities and increases resilience to deal with the challenges posed by epilepsy. In summary, art therapy, particularly painting, is a multifaceted intervention that leverages neuroaesthetic principles to provide a holistic approach to the treatment of epilepsy. By integrating the intricate neuroscientific aspects with the expressive potential of art, this therapeutic modality offers individuals living with epilepsy a transformative journey toward self-discovery, emotional healing, and improved well-being.

Consequently, advances in the field of neuroscience can support best practices in art therapy, having a clear rationale for its practice[10]. The relevant neuroscientific basis for art therapy encompasses several crucial elements, such as the neural tracts of creativity; Emotional processing; Stress reduction and relaxation; Sensory stimulation; Mirror neurons and empathy; Reward paths; Cognitive functions: Problem solving, in addition to Neuroplasticity[1,6,8,9,12].

Understanding how creativity is processed in the brain involves exploring neural networks responsible for creative thinking, ideation, and imaginative processes. These tracts engage regions of the brain, emphasizing the interconnection of various brain areas to facilitate creative thought and expression.

The brain's mechanisms for processing emotions play a key role in art therapy. Exploring how emotions are perceived, interpreted, and expressed neurologically provides insights into how art can serve as a medium for emotional exploration and regulation.

Art therapy, especially painting, involves neural pathways associated with relaxation and stress reduction. This includes examining the brain regions implicated in mediating stress responses and understanding how artistic engagement can modulate these responses, promoting a state of relaxation and calm.

Sensory experiences derived from involvement in art, such as the tactile sensation of paint on canvas and the visual perception of colors and shapes, activate neural pathways linked to sensory processing. These sensory stimulations contribute to the therapeutic effects of art, involving various sensory regions of the brain.

The concept of mirror neurons, which fire when an individual performs an action and also observes another person performing the same action, supports empathy and shared emotional experiences. Art, as a means of expression and communication, involves these mirror neuron pathways, promoting empathy and emotional connection between individuals.

The brain's reward pathways, involving neuro transmitters like dopamine, play a role in reinforcing positive experiences. Creating art can activate these reward systems, contributing to feelings of accomplishment, pleasure, and motivation, thus reinforcing engagement in the creative process.

Art therapy involves cognitive functions related to problem-solving, creative thinking, and decision-making. It engages regions of the brain associated with executive functions, allowing individuals to navigate artistic challenges and express their ideas effectively.

This fundamental concept of neuroplasticity refers to the brain's ability to adapt, reorganize, and form new neural connections throughout life. Art therapy, by engaging the brain in creative endeavors like painting, harnesses neuroplasticity to facilitate learning, emotional processing, and adaptive changes in response to neurological conditions like epilepsy.

Understanding these neuroscientific elements provides a comprehensive framework for appreciating how art therapy, particularly through painting, influences neurological processes, emotional states, and cognitive functions, contributing to the holistic well-being of individuals, including those living with epilepsy. However, despite the potential of the arts to increase the cognitive and emotional engagement of patients in urgent need of neurorehabilitation, taking into account neuroaesthetic principles, there is a gap between the various protocols and the rigorous findings from the study of neuroaesthetics[14].

Figure 2 summarizes the relevant neuroscientific basis for art therapy, providing a visual demonstration of art therapy's transformative role in navigating the complexities of epilepsy. This convergence between art and neurological conditions not only broadens our perspectives but also highlights the immense potential of art in promoting resilience, expression, and healing for those affected by epilepsy.

Figure 2. The neuroscientific basis relevant to Art Therapy is symbolically represented by simulated Van Gogh´s paintings. Source: Image Creator of the DALL·E platform with recommendations given by the author of this paper.

CONCLUSIONS

This narrative journey about Van Gogh's enigmatic disorder to that of lesser-known painters with possible epilepsy highlights their artistic talent. It reveals contemporary interpretations that transcend clinical limits and the multifaceted nature of this condition. Furthermore, the comprehensive exploration of the neuroscientific foundations of art therapy demonstrates its transformative capacity in the treatment of epilepsy. Thus, the elucidation of neuroaesthetic principles illustrates how art therapy harnesses neural mechanisms linked to creativity, emotional processing, stress relief, sensory engagement, empathy, cognitive enhancement, and neuroplasticity. Understanding these intricate elements illuminates the multifaceted ways in which art therapy, particularly through painting, contributes holistically to the well-being of individuals affected by epilepsy.

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Journey through Artistic Eras depicting Dreams, Sleep, and its Disorders

Viagem por Eras Artísticas retratando Sonhos, Sono e seus Transtornos

Art is the Queen of all sciences communicating knowledge to all the generations of the world.

Leonardo da Vinci

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ABSTRACT

This narrative review presents a comprehensive examination of artistic periods since the Renaissance, paralleling the evolution of neurology and pictorial artistic expression about sleep, ending with the importance of the contemporary digital era. Over the centuries, artists have been drawn to the enigmatic themes of dreams, sleep, and their disorders, using them to explore the complexities of the human condition, emotions, and the interaction between reality and imagination. Thus, drawing references from diverse artistic eras, including their pictorial representations of sleep, alongside milestones in the history of neurology, this study reveals a rich interconnectivity between art, neurological advances, and social change.

Keywords: Sleep and its Disorders, Human Emotions, Symbolism in Art, Dreams and Dreaming, Artistic Eras, Neurological Advancements, Contemporary Digital Art

RESUMO

Esta revisão narrativa apresenta um exame abrangente dos períodos artísticos desde o Renascimento, em paralelo com a evolução da neurologia e a expressão artística pictórica sobre o sono, terminando com a importância da era digital contemporânea. Ao longo dos séculos, os artistas foram atraídos pelos temas enigmáticos dos sonhos, do sono e dos seus distúrbios, aproveitando-os para explorar as complexidades da condição humana, das emoções e da interação entre a realidade e a imaginação. Assim, extraindo referências de diversas épocas artísticas, incluindo suas representações pictóricas do sono, paralelamente a marcos na história da neurologia, este estudo revela uma rica interconectividade entre arte, avanços neurológicos e mudanças sociais.

Palavras-chave: Sono e seus Distúrbios, Emoções Humanas, Simbolismo na Arte, Sonhos e Sonhos, Eras Artísticas, Avanços Neurológicos, Arte Digital Contemporânea

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INTRODUCTION

This article, the fifth in a seven-part series on neuroaesthetics and the visual arts, addresses sleep in the artistic eras.

The quote from Leonardo Da Vinci presented at the beginning of this article reveres the profound impact of artistic expression and the ability of art to transmit knowledge across generations. In particular, artists over time have been captivated by the intricate aspects mainly of dreams, but also of sleep and its disorders, finding in them a rich theme that allows the exploration of the human condition, emotions and the interface between reality and dreams, delving deeper into the unconscious. This representation also reflects prevailing cultural attitudes towards sleep and related mental states in different historical periods.

This article, based on references such as Invaluable[5], Wikipedia[11], Agarwal et al.[1], Wikimedia Commons[9,10], and others related to sleep illustrations[2-8] embarks on a different exploration. The main objective is to present the artistic eras from the Renaissance onwards, outlining their defining characteristics and juxtaposing them with the evolutionary milestones of neurology. By interweaving advances in understanding the brain and its functions with the evolution of artistic expression, this examination seeks to illustrate how social, technological, and scientific developments have influenced both artistic creation and neurological achievements, especially concerning sleep as summarized in the Figures 1. Furthermore, this study emphasizes the fundamental role of today's digital era, both in its artistic and practical dimensions, for contemporary artistic expressions.

Exploring dreams in art opens up a world of symbolism, emotion, and exploration of the human experience. Dreams have left a significant mark on the pictorial arts, whether as a tool for self-expression, as a way to explore the frontiers of reality, or as a means of exploring the hidden corners of the mind.

Humanistic approach to aesthetics

This section explores a spectrum of artistic movements ranging from the Renaissance to contemporary art, covering crucial eras such as Renaissance Art, Mannerism, Baroque, Rococo, Neoclassicism, Romanticism, Realism, and avant-garde movements such as Impressionism, Post-Impressionism, Fauvism, Expressionism, Cubism, and Surrealism. Each is defined by distinctive traits that have left their mark on the history of art, often alongside the era of advances in neuroscience.

Throughout the history of art, sleep has emerged as a multifaceted motif depicted in both secular and sacred art. Sleep is often described as a state of restorative rest, providing solace and healing and symbolizing a break from the chaos of the waking world. Many representations explore the mysterious world of dreams, exploring the symbolism and hidden desires of the subconscious mind. Representations of sleep often reflect cultural attitudes towards sleep, its rituals, and the impact of sleep or its absence on mental health and well-being. Artists also portray sleep as a vehicle for spiritual enlightenment, prophetic visions, or as a symbol of rejuvenation and rest or of fear, from redemptive and magical fears to those evoked by nightmares. The presence of sleep in aesthetic art often involves figures such as young, seductive women, innocent children alone or with their caregivers, and, less commonly, men as a subject for simple contemplation. Artists also draw on mythology and religion, transforming sleep into rich sources of inspiration and symbolism. Thus, Berthe Morisot's serene portraits of Le Berceau and Jean-Francois Millet's Sleeping Peasants portray sleep as restorative, while others, such as Henry Fuseli's “The Nightmare,” explore its darker, more disturbing aspects. The Surrealists, influenced by Freud, delved into the subconscious realm, as seen in the symbolic works of Salvador Dalí.

Throughout the history of art, sleep has persisted as a multifaceted theme in both secular and sacred art. Portrayed alternatively as a central focus or background element, sleep has served as a channel for transmitting spiritual enlightenment, prophetic dreams, or as a symbol of rejuvenation and rest. Thus, the representation of sleep covers a spectrum of perceptions, ranging from its redemptive and magical aspects to the fears evoked by nightmares.

Throughout these artistic eras, each one brings specific characteristics that influence aesthetics, themes, and techniques, shaping the evolution of art over time. This evolution reflects simultaneous technological and neurological advances, highlighting the interaction between artistic expression and progress in science.

The representation and interpretation of dreams in art have evolved throughout different artistic eras, each movement bringing distinct perspectives and explorations that have served as a vehicle for artists to explore emotions, and human consciousness, offering interpretations that transcend conventional reality.

As we delve deeper into specific artistic periods, such as the surrealist exploration of the dream world realized by Salvador Dalí and René Magritte, or the romantic fascination with the symbolic qualities and mysteries of dreams epitomized in Henry Fuseli's "The Nightmare," we witness artists taking advantage of the power of dreams to create interesting and contemplative works of art. Surrealism delved into the subconscious, aiming to express the workings of the unconscious mind through dreamlike images, while romanticism embraced themes of the supernatural and mysterious, often incorporating dreamlike elements.

The timeline of art and neurology reveals their intertwined evolution. The milestones in neurology from

1857 to 1896 coincided with scientific discoveries about the structure of the brain and the doctrine of neurons, aligning with artistic movements exploring human expression, psychology, and introspection. Likewise, from the early 20th century, as neurology advanced in parallel with Psychoanalysis, several artistic eras emerged, reflecting evolving trends and movements in art. These connections suggest that neurological advances have also inspired artists to delve deeper into the human psyche, emotions, and introspection, manifesting in art that reflects a scientific understanding of the evolving complexities of the brain.

Furthermore, an exploration of the scientific understanding of sleep highlights its crucial role in restoring energy and maintaining bodily functionality. Understanding the brain's neural connections and the cyclical nature of wakefulness, slow-wave sleep, and REM sleep highlights the importance of sleep in our lives, with approximately a third of our existence dedicated to this essential process. This deeper exploration not only delves into the artistic significance of sleep but also sheds light on its physiological aspects, inviting a comprehensive understanding of this universal and indispensable human experience.

Renaissance Art (1400–1600) portrays a realistic portrait of human figures, linear perspective, classical themes, and the use of light and shadow (chiaroscuro). During this era, dreams were often depicted as symbolic narratives and painters presented dream scenes as allegories, representing moral lessons or religious visions. Artists like Rafael, with his ''Vision of a Knight'', e. g., incorporated dreamlike elements to convey messages. A sleep-related painting copy from this artistic epoch included in the Figures is 'Sleeping Venus', c.1510, by Giorgione (–1510), oil on canvas, located in the Gemäldegalerie Alte Meister. The focus of the Renaissance changed with Northern painters such as Hieronymus Bosch, who introduced disturbing and surreal dynamic elements into artistic representations of dreams, oniric art. The Renaissance saw a resurgence in anatomical studies, leading to more accurate representations of the human form in art, and artists such as Leonardo da Vinci and Michelangelo explored anatomy to create more realistic and developed human figures. Andreas Vesalius's publication on human anatomy laid the foundation for modern neuroanatomy and emphasized the systematic study of the human body through dissections. Thus, from the Renaissance through the 19th century, many profound advances were observed in both neurology and the arts, reflecting significant changes in knowledge and preparing society for the following centuries of major paradigm shifts.

Mannerism (1527 - 1580) features stylized compositions, elongated and exaggerated figures, unconventional poses, complex and intricate works of art, and a departure from classical ideals. A painting from this Era of Art included in the Figures is 'Water' (1566) by Giuseppe Arcimboldo - Arcimboldo (1526-1593). Arcimboldo's composite portraits, including the one representing "Water", often contain surreal elements and whimsical representations of natural elements and human figures, reflecting the imaginative and dreamlike qualities associated with sleep.

The Baroque (1600-1750) has dramatic use of light and shadow, grandeur, rich colors, ornate and elaborate works, emotional intensity, interest in the human intellect, and religious and mythological themes. Caravaggio and Rembrandt used chiaroscuro to create dramatic and otherworldly dreamscapes. Dreamlike elements were infused into mystical or divine scenes, depicting celestial visions or spiritual epiphanies. Baroque artists occasionally explored sleep as part of religious and allegorical themes and paintings such as José de Ribera's 'Jacob's Dream' illustrated biblical dream narratives. Furthermore, the Dream of St. Joseph continues to be a popular theme in religious art, often symbolizing divine revelation and guidance in the Christian faith, with Georges de La Tour, a French Baroque painter, known for his work "Dream of St. Joseph" (c. 1640-1645), which shows Saint Joseph sleeping with an angelic figure at his side, illuminating the scene with a soft, bright light. Another classic painting of the period is 'A Girl Sleeping', 1657, by Johannes Vermeer (1632-1675), and another included in the Figures is represented by 'Sleeping Girl', c. 1615, by Domenico Fetti (1589–), oil on canvas located in the Museum of Fine Arts, Budapest.

Rococo (1699–1780) has an ornate and decorative style, pastel colors, a love of nature, and an emphasis on cheerful themes. A notable painter of this era was Jean-Honoré Fragonard (1732-1806), and a representative painting of him is 'The Swing' – an iconic example of Rococo art. This painting captures a romantic and playful scene in a lush garden, which can be associated with the dreamy qualities of sleep and desire. A painting related to sleep from this artistic period included in the Figures is "Sleeping Bacchantes Surprised by Satyrs", 1760, by François Boucher (1703-1770).

Neoclassicism (1750–1850) emphasized classical themes and forms, clear, precise lines, and moral and political messages. A painting from this artistic period related to sleep included in the Figures is a dimly lit room where an old man sleeps sitting up, 'Sleep', by François Marius Granet (1775-1849), oil on canvas located in the Musée Granet.

Romanticism (1780 - 1850) emphasized individualism, imagination, and emotions over reason, appreciation for nature, passion and sensation, and the rejection of order and rationality. Romantic artists were driven by a fascination with the subconscious and the supernatural, sometimes incorporating dreamlike or nightmarish elements into their works. Romantic painters were fascinated by the emotional and imaginative aspects of dreams. Johann Heinrich Füssli, also known as Henry Fuseli or Fusely (1741-1825) was a Swiss painter, draftsman, and art writer based in Great Britain, with many of his works depicting supernatural experiences, inspired by dreams, with an emphasis on the sublime and the supernatural. Fuseli explored the emotional and psychological aspects of dreams in works such as 'The Nightmare' (1781), which showed a woman having a nightmare about a demon that depicts sleep paralysis and nightmares. Fuseli's Nightmare broke with moralistic narratives, presenting a mysterious and disturbing scene that anticipated Freud's psychoanalytic theories. Dreams have become a means of exploring the depths of human emotion and the unknown. This move away from moral logic aligned more with the ideals of Romanticism, emphasizing emotion and spirituality to the detriment of reason. A painting from this artistic era included in the Figures is 'The Sleep of Reason Produces Monsters', 1799, by Francisco Goya (1746-1828), an etching and other intaglio media, located at the Nelson-Atkins Museum of Art which explores the consequences of the absence of reason, potentially delving into the realm of nightmares and sleep-related imagery. Goya's engraving is part of his 'Los Caprichos' series. At this time, still, in the Enlightenment of the late 18th century, fundamental neurological achievements were growing, such as Luigi Galvani's experiments with frog nerves that contributed to the understanding of bioelectricity, in parallel with a growing interest in neural impulses and electrical activity in the nervous system. Furthermore, Phrenology emerged, which attempted to correlate brain structure with specific personality traits, although not scientifically accurate, stimulated interest in brain functions and inspired artistic interpretations of mental faculties. However, during the period of Galvani's discoveries in neurology and the rise of Phrenology, the art world was experiencing a transition from the Enlightenment era to Romanticism. The Enlightenment, characterized by rationality, reason, and scientific inquiry, influenced art by emphasizing clarity, order, and precision in artistic representations, and artists sought realism and precision, often depicting subjects in a precise and calculated manner. This period favored classical themes, historical narratives, and portraits that were more formal and controlled in their expression. However, the rise of Romanticism, which began to flourish around the end of the 18th century, marked a significant shift in artistic expression. By embracing emotions, imagination, and individualism, diverging from the strict rationality of the Enlightenment, artists of this period sought to evoke feelings and passions in their work, exploring themes of nature, the supernatural, and human emotions. The parallels between Galvani's neurological discoveries and the emergence of Phrenology in art are found more in the Romantic era. While Phrenology attempted to correlate personality traits with brain structures, artists delved deeper into exploring the human psyche, emotions, and mysterious aspects of the mind. This alignment may have inspired artists to depict subjects with greater emphasis on inner emotions, psychological depth, and the complexities of the human mind, aligning with the Romantic movement's emphasis on individuality and emotional expression.

Realism (1848 - 1900) depicts ordinary life and people with attention to detail, often addressing social and political issues with accurate depictions of everyday life, detailed and realistic depictions, moving away from romanticized or idealized subjects and focusing on as far as the eye could physically see. A notable painter of this era was Gustave Courbet (1819-1877), who portrayed everyday life, and a representative painting by him is "The Stonebreakers", a realistic portrait of workers addressing social issues and the human condition. A sleep-related painting copy from this artistic epoch included in the Figures is represented by 'The Sleeping Spinner', 1853, by Gustave Courbet (1819–1877), oil on canvas located in the Fabre museum. During this period, with the identification of the area of speech production by Broca and the discovery of the motor cortex by Fritsch and Hitzig, art began to explore expression and movement in profound ways. This aligns with artistic movements such as Realism and Impressionism. Realism sought to portray life as it was, emphasizing accurate representation that could reflect the scientific precision and localization evident in the discoveries of neurology. Impressionism, on the other hand, focused on capturing fleeting moments, emphasizing movement and sensation over precise details. This could be correlated with understanding motor skills and the representation of movement in art.

Art Nouveau (1890 – 1910) emphasized natural forms, sinuous lines, decorative and ornamental style, flowing lines, decorative motifs, a focus on decorative arts and the female form, and influence on applied arts, architecture, graphic design, and illustration. A notable painter of this era was Gustav Klimt (1862-1918), and a sleep-related painting copy included in the Figures is 'Night', 1890, by Ferdinand Hodler (1853-1918), on oil canvas, located in the Kunstmuseum Bern, Bern, Switzerland.

Impressionism (1865-1885) captures the fleeting moment, the use of light and color, and everyday scenes with rapid brushstrokes, an unfinished feel, modern life as a subject, and an emphasis on light and color. Impressionist artists often depicted scenes of leisure and everyday life, which may indirectly address the topic of sleep, but without a specific focus on sleep disorders. An example is 'Young Girl Dreaming', from 1881, by Paul Gauguin in his first works, impressionist genre. A sleep-related painting copy from this artistic epoch included in the Figures is 'The Artist's Son', c. 1868, by Claude Monet (1840–1926), located at the Carlsberg Glyptotek.

Post-Impressionism (1885-1910) with subjective views, symbolic and personal meanings, abstraction, and a focus on inner emotions, artists worked independently with similar ideals and emphasized the emotional and symbolic use of color, brushstrokes, and form. One notable painter was Vincent van Gogh (1853-1890) and his related painting, 'Starry Night' – one of the most famous paintings in the world, known for its emotional intensity and use of color. Many of his sleep works include 'Girl Kneeling by a Cradle', 1883, Mediumpencil and Charcoal highlighted with white, located in the Van Gogh Museum. Another painter from this time was Henri de Toulouse-Lautrec who became known for his depiction of cabaret scenes and nightlife, being able to indirectly address themes related to sleep and its disorders through his depictions of the night scene and for being an insomniac as portrayed in his painting 'Nuit Blanche'. A sleep-related painting copy from this artistic epoch included in the Figures is 'La méridienne' or 'La sieste', 1889-1890, by Vincent van Gogh (1853-1890), oil on canvas, located in the Musee d´ Orsay, Paris. As far as the intersection with neurology is concerned, the era of the Golgi staining technique and Ferrier brain mapping, which contributed to the understanding of specialized brain regions and the doctrine of neurons, correlates with the emergence of art styles more abstract and introspective. This period saw the rise of Symbolism and the beginning of movements such as Post-Impressionism and Art Nouveau. Symbolism emerged as a reaction against the naturalism and realism of the time, focusing on the use of symbols, imagination, and emotional content, reflecting the introspective nature of the neuron doctrine's understanding of the brain. With regards to Post-Impressionism and Art Nouveau, they emphasized the subjective and emotional aspects of art, exploring new forms, colors, and designs that echoed the evolving understanding of the inner workings of the mind.

Fauvism (1900 - 1935) has a bold and non-naturalistic use of color and simplified forms, consequently the use of intense colors, bold brushstrokes, flat compositions, a move away from the representative purposes of color, expressive use of color and line. A sleep-related painting copy from this artistic epoch included in the Figures is 'Still Life with Sleeping Woman', 1940, by Henri Matisse (1869-1954) - adapted, oil on canvas, located in the Collection of Mr. and Mrs. Paul Mellon.

Expressionism (1905–1920) emphasizes emotions, distortion, and raw personal expression, focusing on the unconscious mind and personal expression best represented by Edvard Munch (1863–1944) with his painting 'The Scream' - an iconic work reflecting anxiety and turmoil emotions. A sleep-related painting copy from this artistic epoch included in the Figures is ‘Sleeping Farmer’, 1936, by Hendrik Chabot (1894–1949), located in the Van Abbemuseum.

Cubism (1907–1914) with radical fragmentation of objects, abstraction, rejection of traditional perspectives, geometric shapes, multiple points of view, and often unidentifiable subjects. Furthermore, when it comes to sleep, there is the painting ‘Woman Sleeping at the Table’, 1936, by Pablo Picasso (1881-1973) located in the Museum of Modern Art in New York. A painting from this artistic era related to sleep included in the Figures is ‘Man in a Hammock’, 1913, by Albert Gleizes (1881-1953), oil on canvas, located at the Albright-Knox Art Gallery, Buffalo, New York.

Surrealism (1916-1950) explores the unconscious mind under the influence of Psychoanalysis and addresses the subconscious and the irrational, often with a detailed and realistic representation, consequently, there is a challenge to reason. Surrealism led by artists such as Salvador Dalí (1904-1989) and René Magritte (1898-1967) is perhaps the most famous movement that directly addresses dreams and the subconscious, and their works often feature bizarre, dreamlike, and boundary-pushing scenes. of reality. A notable painting by Dalí is “The Persistence of Memory,” known for its melting clocks and dreamlike quality. Thus, surrealism as an artistic movement often reached the world of dreams and the subconscious, and artists such as Dalí and Magritte created numerous works related to dreamlike and surreal images. More specifically, Surrealist artists delved deeply into the unconscious mind and freed art from conscious control, celebrating the absurd and the dreamlike. Dalí incorporated dream imagery into his works, interpreting dreams as windows into the unconscious mind. A painting from this artistic period related to sleep included in the Figures is "Dream Caused by the Flight of a bee around a Pomegranate a second before waking", 1944, by Salvador Dali belonging to a private collection. It is a dreamlike composition that portrays the chaotic and fragmented nature of many dreams. Surrealism's focus on the subconscious and dreams, aligned with revealing deeper insights into brain functions, parallels the development of EEG and cerebral angiography in the 20th century, which alongside psychoanalysis may have inspired artists to explore the depths of the human mind and the mysterious nature of the brain. On the other hand, as the 19th century progressed, artists such as Henri Rousseau (1844-1910), the greatest representative of the so-called ‘naïve’ art, had works highly valued by symbolist artists. His painting 'The Sleeping Gypsy' (1897), located in the Museum of Modern Art in New York, is a fantastic, almost surrealist depiction of a lion encountering a gypsy woman on a moonlit night. The 'Sleeping Gypsy' provoked questions about reality versus dreams, challenging viewers to interpret their meaning. Symbolist painters such as Gustave Moreau and Odilon Redon used dream motifs to convey psychological and spiritual themes, exploring the subconscious mind and its mysterious symbolism.

Although Abstract Expressionism, Op Art, Pop Art, Arte Povera, Minimalism, Conceptual Art, and Contemporary Art, including Digital Art, are artistic movements that introduced several innovative concepts and styles, in parallel with advances in technology and neurosciences, they are not typically associated with the direct exploration of sleep and dreams in the same way as some other movements except Surrealism. Characteristics of these movements are: Abstract Expressionism (1940s–1950s), emphasizing emotion and spontaneity in art, reflected revelations in memory studies; Op Art (1950s to 1960s), optical effects, illusions, use of shapes, colors and patterns that appear to move or blur, black and white contrast for maximum visual impact; Pop Art (1950s - 1960s), use of everyday and mundane objects, challenge of consumerism and mass media, identifiable images, shift from conventional modernism; Arte Povera (1960s), use of everyday materials, anti-elitist sentiment, focus on everyday elements, sculptural works with soil, stones, paper, rope, etc.; Minimalism (1960s to 1970s), emphasis on anonymity, materiality of works, order, simplicity and harmony, non-representational, focus on what is in front of the viewer; Conceptual Art (1960s to 1970s), focus on ideas about visual components, creating art in various forms such as performances, ephemera, exploration of language within art; Contemporary Art (1970-present), diverse and multifaceted, encompassing several schools and smaller movements, embracing skepticism, irony, philosophical criticism, the influences of technology and culture.

Contemporary artists have continued to explore sleep and dreams, some focusing on the disorienting aspects of modern life and their impact on sleep patterns, and this has been addressed through multimedia installations and conceptual art. The representation of sleep in contemporary culture reflects a complex interaction between scientific investigation, technological advances, social ideologies, and artistic expression. Contemporary perceptions about sleep, particularly through scientific research into circadian rhythms and neuroscience, have reshaped the understanding of its meaning in neuroculture society. Furthermore, contemporary artists approach sleep in a politically committed way, criticizing social norms and the effects of technological advancement on human rest. Themes of biodysregulation, images of insomnia, and pathologization of sleep are explored, reflecting the anxieties and disturbances caused by modernity. In essence, contemporary artistic representations of sleep interweave scientific discoveries, technological intrusions, and social critiques, providing a nuanced and multifaceted view of this fundamental yet enigmatic human experience[7].

Digital Art encompasses a wide spectrum of styles, themes, and artistic practices involving digital technology since the 1960s. Salvador Dalí's use of computational processing in artistic creation cemented his role as an early adopter and innovator of digital art and photomosaic art. Furthermore, Warhol's foray into digital art in 1985 marked a significant milestone in his artistic exploration. He used an Amiga computer, captured a monochrome image of Debbie Harry via a video camera, and then digitized it into a graphics program called ProPaint, allowing Warhol to engage in digital manipulation techniques. Specifically, digital painting is the process of creating paintings using computer software that simulates traditional painting tools and techniques, offering users customizable options for creating unique visual effects. Another aspect of digital art centers on the way artists have explored the use of artificial intelligence (AI) in creating works of art since the 1960s. More recently, the advent of generative adversarial networks (GANs) in 2014 has provided a framework for machine learning where two algorithms compete and iterate, enabling the generation of works of art. This technology allows computers to autonomously find optimal solutions and produce images that imitate traditional fine art. One significant aspect involves using text descriptions to ask AI to convert text into visual images. Through image generators, individuals can translate their language into paintings, essentially democratizing the creation of visual content, with some artists using image generators to produce foundational paintings rather than starting from scratch. They then refine these generated artworks, ultimately creating new digital paintings. This approach challenges the traditional boundaries of the art of painting, significantly lowering the barrier to entry into painting while incorporating AI-generated elements into the artistic process11. However, the presence of this theme would depend on the specific intentions and creative choices of the artist, in this case, the author of this paper made use of Digital Art Generated by DALL-E 3 for demonstrations on sleep disorders included in the Figures: 'Elaborate, vivid REM sleep, hallucinogenic and emotional', 'Non-REM sleep report of dreams when it occurs, more conceptual, less vivid and less emotional', 'The fat man sleeping snoring', 'The lady with insomnia', 'The boy with the nightmare' and ' The man with daytime drowsiness'.

Regarding the parallel between arts and neurology, just as computed tomography scans revolutionized neuroimaging, artists explored unconventional means and techniques. Video and installation art reflected a similar search for new forms of expression and perception. The diversification in advances in neuroscience during the Decade of the Brain resonated with the diverse expressions of Postmodernism. Initiatives such as the Human Connectome Project mirrored the exploration of interconnectivity in contemporary art. Stem cell research in neurology has inspired interdisciplinary collaborations in art, integrating technology and diverse approaches. The convergence of art and technology in the digital revolution echoed the interdisciplinary nature of the Human Brain Project and therapeutic advances in neurology, presenting an era of innovation and exploration at the intersection of multiple fields.

These are just snapshots of each artistic era, and many other artists and artworks contributed to these movements. Each era reflects the unique cultural and artistic trends of its time, and throughout these artistic eras, the representation of sleep and sleep disorders has evolved along with changes in artistic styles, cultural influences, and scientific understanding. Thus, artists used their creativity to convey the mystery, symbolism, and emotional depth associated with the realms of sleep and dreams.

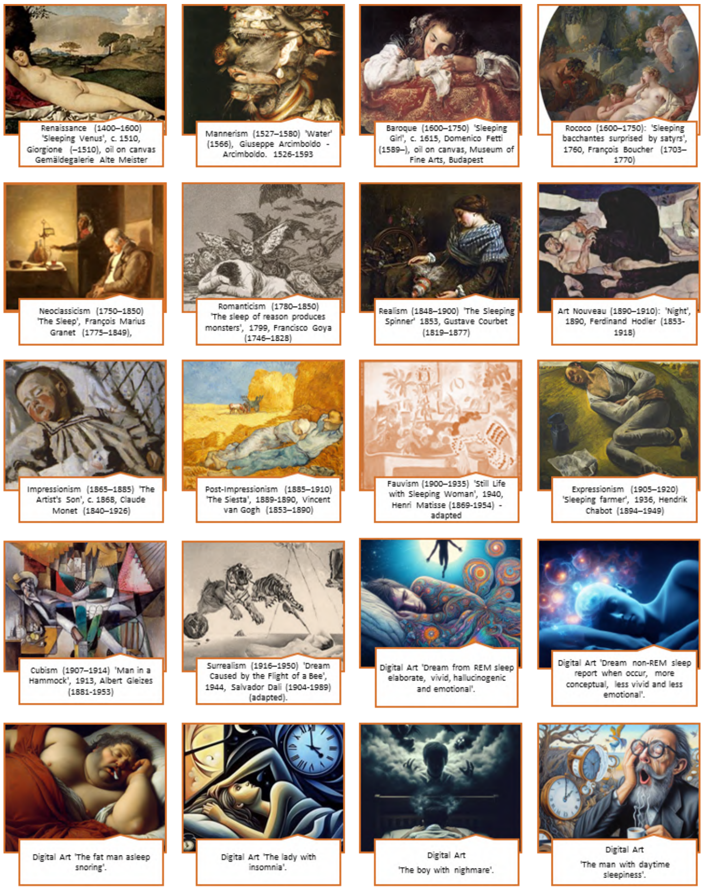

Figure 1. 'Evolution of Sleep in Art: From Renaissance to Digital Interpretations'. Sources: Wikimedia Commons and Digital Arts by Image Creator of the DALL·E platform with recommendations given by the author of this paper.

DISCUSSION

The depiction of dreams and sleep in art throughout history has been an enduring fascination, offering profound insights into human emotions and the enigmatic nature of the mind. Artists from the Renaissance to contemporary eras have approached these themes, and dreams have served as channels for creativity, blurring the lines between reality and the surreal, as they represent a means of conveying a spectrum of emotions, from tranquility to restlessness, and of probing intricate psychological states, often blurring the boundaries between the conscious and subconscious domains.

On the other hand, the advent of digital art opens up fascinating ways to delve deeper into these themes, as its dynamic and interactive nature aligns perfectly with the abstract and elusive nature of dreams. Furthermore, the incorporation of multimedia elements such as sound, video, and animation into digital art allows for more immersive experiences, potentially mirroring the sensory aspects of dreaming.

Notably, the emergence of AI Art Generators introduces new dimensions to this exploration, but while these tools help artists visualize dreamscapes and sleep-related experiences, they primarily serve as complementary tools. However, the essence of creative vision, storytelling, and emotional depth remains rooted in the artist's interpretation and choices. AI complements the creative process, facilitating experimentation and exploration, but does not replace the artist's unique perspective and creativity.

AI-generated art would add depth and nuance to the discussion about specific works of art or artists from different eras and cultures who engaged deeply with these themes. This expanded context emphasizes the multifaceted nature of dreams in art and highlights how digital art and AI present new avenues for artistic expression while preserving the essence of creativity.

CONCLUSIONS

The depiction of dreams and sleep in art throughout history has revealed the intricate nuances of human emotions and the mysterious landscape of the mind. From the Renaissance to contemporary times, the fascination with dreams resonated deeply with artists, blurring the boundaries between reality and the surreal. Artistic representations of sleep evolved alongside cultural changes in artistic movements such as Romanticism and Surrealism, which particularly explored dreams and the unconscious. The evolution of artistic epochs, intrinsically intertwined with neurological milestones, reflects the parallel progression of human expression and scientific understanding. As the artistic landscape continues to evolve into the digital realm, the integration of AI into artistic creation offers new dimensions to delve deeper into these themes, while preserving the essence of artistic creativity. This exploration sheds light on the multifaceted nature of dreams in art, and also of sleep and its disorders, highlighting the profound interaction between art, neuroscience, and the human experience.

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Epilepsy in Art: A Historical Exploration of Representations Across Eras

Epilepsia na Arte: uma Exploração Histórica de Representações através de Épocas

A painting without something disturbing in it – what's that?

Georges Braque

Art is not the application of a canon of beauty but what the instinct and the brain can conceive beyond any canon.

Pablo Picasso

M. da Mota Gomes[1] [Orcid: https://orcid.org/0000-0001-8889-2573]

ABSTRACT

This narrative review explores the diverse representations of epilepsy in art across different historical periods, examining the intersection of artistic expression with evolving cultural, medical, and societal perceptions. Beginning with ancient and medieval depictions intertwined with religious symbolism, the paper progresses through the Renaissance, and Baroque, and transitions into modern and avant-garde movements. Each period reflects changing attitudes towards epilepsy, from divine interpretations, and religious concerns to anatomical realism and, later, explorations of psychological themes. The contemporary lens focuses on inclusive and empathetic portrayals, utilizing digital media to challenge stigmas and foster understanding.

Keywords: Epilepsy, Art History, Cultural Evolution, Medical History, Societal Perceptions, Digital Media

RESUMO

Esta revisão narrativa explora as diversas representações da epilepsia na arte em diferentes períodos históricos, examinando a intersecção da expressão artística com a evolução das percepções culturais, médicas e sociais. Começando com representações antigas e medievais entrelaçadas com simbolismo religioso, o artigo avança através da Renascença e do Barroco, e transita para movimentos modernos e de vanguarda. Cada período reflete mudanças de atitudes em relação à epilepsia, desde interpretações divinas e preocupações religiosas até o realismo anatômico e, mais tarde, explorações de temas psicológicos. A lente contemporânea centra-se em representações inclusivas e empáticas, utilizando meios digitais para desafiar estigmas e promover a compreensão.

Palavras chave: Epilepsia, História da Arte, Evolução Cultural, História Médica, Percepções Societais, Mídias Digitais

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INTRODUCTION

This article, the sixth in a seven-part series about neuroaesthetics and visual art, sheds light on frames of epilepsy within the context of art, culture, and medical understanding, illustrating the multifaceted nature of the condition and its varying impact on individuals.

Georges Braque and Pablo Picasso developed a revolutionary style of art making known as Cubism, and their quotes at the beginning of this article emphasize the need for something beyond conventional aesthetics or beauty in a painting, suggesting that art isn't confined to prescribed standards but rather springs from imagination, instinct, and the boundless creativity of the mind. This holistic view is also useful for understanding the challenges faced by individuals with epilepsy that intertwine medical aspects and social implications, underlining the need for comprehensive approaches to the disease. The acknowledgment of the diverse experiences among patients emphasizes the importance of tailored treatments and ongoing research to enhance therapeutic options for all individuals affected by epilepsy. The depiction of epilepsy in art traverses centuries, encapsulating changing perceptions, cultural beliefs, and medical advancements. Epilepsy holds a unique position within the annals of medical history, serving as a foundational precursor to the field of neurosciences. Its historical trajectory illustrates a significant shift from religious and magical explanations toward scientific understandings. This transformation denotes an explicit evolution in cultural practices surrounding the condition, marking a pivotal moment in the demarcation between mystical beliefs, religious rituals, and the scientific study of neurological disorders[3]. William Richard Gowers (1845-1915), based at the National Hospital in London, was a notable junior colleague of John Hughlings Jackson (1835-1911), a formidable thinker and revolutionary in the field of epilepsy. Gowers' 1881 book on epilepsy was of great importance for propagating Jackson's revolutionary concepts on epilepsy in comprehensible and broadly consistent accounts of epileptogenesis[4].

This exploration investigates the multifaceted representations in various artistic movements according to Invaluable[10], highlighting the evolution from divine interpretations to realistic portrayals and abstract expressions. Epilepsy's artistic journey mirrors societal attitudes, offering insights into the intersection of art, culture, and the evolving understanding of this neurological condition. The illustrations of different art períodos regarding epilepsy depictions are from Wikimedia Commons or Wellcome Collection, and the Digital art painting by Image Creator of the DALL·E platform with recommendations given by the author of this paper.

There are varying approaches of artists across different periods, showcasing the evolving representations of epilepsy and its intersection with art, culture, and medical advancements.

Ancient and Medieval Depictions

Epilepsy in ancient times and the Middle Ages was often associated with divine or supernatural possession. Artists depicted seizures through symbolic or allegorical representations, often intertwining them with religious or mythological themes. The portrayal of epilepsy was shaped by the prevailing belief systems, where the condition was considered a manifestation of spiritual forces or divine intervention. These artistic renditions often depicted the dramatic nature of seizures but interpreted them within the context of religious or mystical experiences. In the Middle Ages and the Renaissance period, the visual arts were dominated by religious motifs. People often commissioned works of art and had the right to determine what was portrayed. The motivation to commission a picture was often gratitude for mercy and help given by God and the saints. The content and manner of portrayal enable us to make certain assumptions about the life of the person who commissioned the pictures[8].

Renaissance Realism

As medical knowledge advanced during the Renaissance, artists began to portray epilepsy more realistically. The emphasis shifted from purely symbolic representations to depicting the physical symptoms of seizures or surgical treatments associated with the condition. Renowned artists like One of the most striking representations is Raphael Santi's "The Transfiguration," completed just before his passing in 1520. In this masterpiece, a child experiences an epileptic attack amidst the transfiguration of the Lord, depicted with oculogyric crisis, hyperextension of the hands and fingers, and bodily torsion, witnessed by onlookers filled with wonder and anxiety. Raphael Sanzio depicted epileptic seizures in a dramatic and anatomically accurate manner, incorporating these episodes within religious or historical contexts[1]. The portrayal of saints associated with healing epileptics became a recurring theme, reflecting evolving cultural perceptions and medical understanding.

Baroque Dramatics

The Baroque period marked a significant evolution in the portrayal of epilepsy, characterized by intensified emotional and spiritual depictions within art. Notably, artists such as Caravaggio and Nicolas Poussin employed heightened drama and emotion to portray scenes related to epilepsy. Works like "The Miracle of Saint Francis Xavier" and "Conversion on the Road to Damascus" exemplify this, intertwining epileptic episodes into religious narratives to capture the intense emotional and spiritual dimensions of these events. Moreover, epilepsy held a substantial position in pictorial art during this period. Artists depicted epileptic seizures with profound expressiveness, capturing the essence of the condition in their works. Another significant artwork is Peter Paul Rubens' "The Miracles of St. Ignatius of Loyola" from 1620[6]. Within this altarpiece, among the patients seeking mercy and treatment, epileptics during seizures are also prominently featured. These artworks serve as powerful visual testaments to the artists' interpretation of epileptic episodes, portraying the condition's physical and emotional dimensions with profound insight and depth.

Transitioning Art Movements

During the eras of Neoclassicism, Romanticism, and Realism, explicit depictions of medical conditions, including epilepsy, became less prevalent as artists turned their focus toward exploring emotional and psychological themes rather than directly illustrating specific health conditions.

Jean Duplessi-Bertaux, an artist active during the late 18th and early 19th centuries, worked primarily in the artistic style associated with the Romantic period[5]. This work embodied elements of Romanticism, characterized by an emphasis on emotions, individualism, and dramatic scenes, this specific artwork leans more towards visual documentation or medical illustration rather than adhering to a particular artistic style.

This shift allowed for a deeper exploration of human psychology and emotions, leading to artworks that touched indirectly on aspects of epileptic experiences.

Vincent van Gogh's artistic legacy is intricately entwined with his tumultuous inner struggles and speculated health conditions, among which epilepsy remains a prominent conjecture. While epilepsy is often associated with his artistic genius, other disorders such as manic-depressive disease, Meniere´s disease, acute porphyria, or absinthe intoxication have been considered in the discourse surrounding his health[6]. The use of vivid yellow colors in Van Gogh's paintings has been connected to xanthopsia, a disorder that impairs vision and is frequently associated with the consumption of drugs such as absinthe or digitalis[9]. Van Gogh experienced periods of self-mutilation and severe emotional upheavals throughout his life; these themes are poignantly depicted in his artwork. His paintings not only portrayed the physical aspects but also delved into the emotional and perceptual experiences linked to epilepsy. Among his celebrated works, the renowned "Self-Portrait with Bandaged Ear" from 1889, exhibited at The Courtauld Gallery in London, immortalizes a significant event in van Gogh's life. Despite artistic interpretation regarding the bandaged ear on the right side (while in reality, he mutilated his left ear), the self-portrait resonates vividly with his disfigurement and the psychological torment he grappled with due to his mental state. Through his art, van Gogh revealed his distinctive perspective on the challenges posed by his condition, leaving an indelible mark on the artistic and medical realms alike.

Avant-Garde and Modern Art

In the 20th century, avant-garde movements like Expressionism and Surrealism offered artists a platform to experiment with abstract and dreamlike representations. While not explicitly focused on epilepsy, artworks from these movements often conveyed a sense of disorientation, altered perception, or psychological states that might parallel aspects of epileptic experiences.

Contemporary Perspectives and Digital Art

Ultimamente many artists declared themselves as having epilepsy such as Jennifer Hall, as mentioned by Engelsen[6], uses “the imagery of performances called; out of the body theater, drawn from the world in which I exist during seizures”, and the artist Juliane Ahrens called one of her pictures “seizures like a dream”. As said by Engelsen[6], during her seizures, her vision flourished and she had indescribable smells.

Modern representations of epilepsy aim for precision, empathy, and inclusivity. Artistic endeavors seek to portray epilepsy sensitively, shedding light on the experiences of individuals living with the condition. Through visual representation, artists might aim to depict brain activity during seizures, the neurological underpinnings of the condition, or the impact of epilepsy on cognitive and emotional processes. This allows for a creative exploration of the complex neurological aspects of epilepsy.

Digital art epilepsy representation

The artistic interpretations expressed in Figures 1 in the Art Nouveaux Style offer an appreciation of the multifaceted aspects of living with epilepsy, with general well-being or depression, e.g., in addition to being able to suffer from some of the types of seizures as exemplified by four of them according to the ILAE Classification, 2017[12].

Therapies

There are varying degrees of effectiveness in drug treatments and the challenges faced by the 30% deemed drug-resistant, some had surgical options and the absence of treatment for some cases, highlighting the complexity and limitations in managing epilepsy. These patients also face Adult epilepsy patients are confronted with psychological and psychosocial burdens[11].

The journey of epilepsy treatment and the incorporation of art therapy in its management reflects a multifaceted approach aimed at addressing the psychosocial dimensions of the condition. From ancient beliefs tied to crude surgical practices to modern therapeutic art, the evolution of treatment paradigms has been profound.

The integration of psychological therapies, specifically art therapy, emerges as a promising avenue to enhance the quality of life for individuals with epilepsy. The

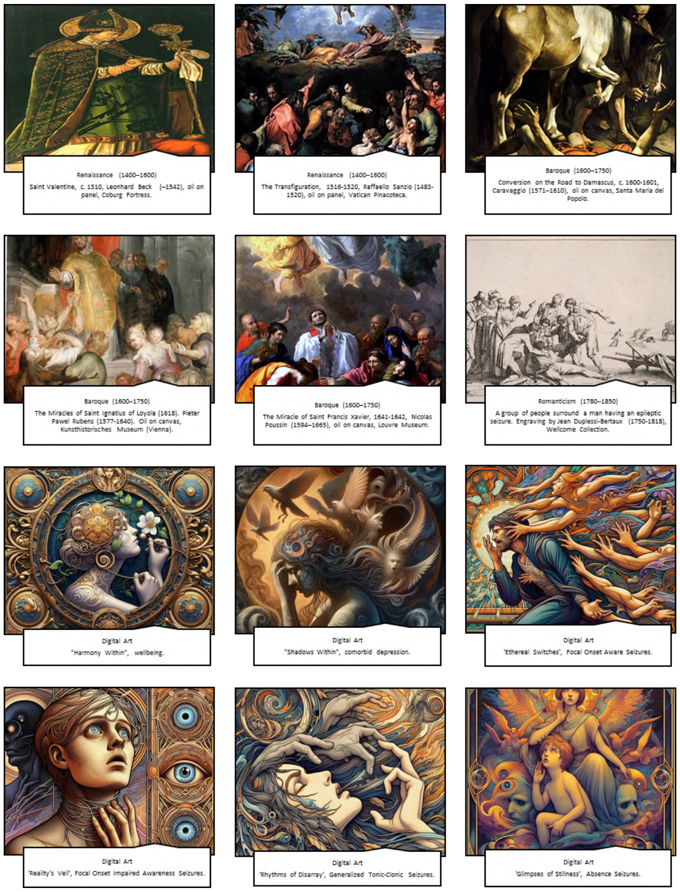

Figure 1.'Artistic Odyssey Through Time and Neurological Realms from Digital Interpretations'. Sources: Wikimedia Commons / Wellcome Collection and Digital Arts by Image Creator of the DALL·E platform with recommendations given by the author of this paper.

The supposed neuroscientific basis is presented in the paper about painters with epilepsia of this series[2].

Programs such as Studio E: The Epilepsy Art Therapy Program[13] and scratch art therapy in Japan[11] underscore the potential benefits of bolstering self-esteem, aiding emotional expression, and facilitating social adaptation. The utilization of art as a therapeutic medium opens avenues for self-expression and emotional regulation among patients facing difficulties in social adaptation or expressing their emotions.

Moreover, a pioneering endeavor led by Téllez-Zenteno and artist Eduardo Urbano Merino signifies a pivotal shift towards using art to elucidate the journey of epilepsy surgery. The painting 'Epilepsy, leaving behind the nightmare' visually narrates the transition from darkness and affliction to hope and recovery post-surgery. Placed at the Royal University Hospital in Canada, this artwork serves as a beacon, elucidating the potential benefits of epilepsy surgery through the universal language of art, bridging the gap between medical science and patient comprehension[14].

CONCLUSION

Artistic representations of epilepsy, ranging from medieval allegories to modern digital media, mirror the changing public perception of this neurological disorder. The numerous depictions highlight evolving medical advancements, changing social attitudes, and expanding artistic expressions. They vary from ancient symbolic interpretations to Renaissance physical realism and emotional explorations in modern art. A notable shift is the emphasis on empathy and inclusivity now prevalent, which aims to raise knowledge and acceptance of epilepsy by demystifying the condition and eliminating stigma through innovative creative methods.

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Migraine as a Source of Artistic Inspiration

Enxaqueca como fonte de inspiração artística

Presiding over the entire attack there will be, in du Bois Reymond's words, 'a general feeling of disorder,' which may be experienced in either physical or emotional terms, and tax or elude the patient's powers of description.'

Oliver Sacks, Migraine

M. da Mota Gomes[1] [Orcid: https://orcid.org/0000-0001-8889-2573]

ABSTRACT

This narrative review explores the intricate relationship between migraines and art, tracing historical examples and contemporary interpretations of how migraines, especially those with a visual aura, have influenced artists. Highlights how migraines may have shaped artistic inspiration, delving into notable, questionably migraine-infected figures such as Hildegard of Bingen, Giorgio de Chirico, Pablo Picasso, and Salvador Dali, examining how their experiences may have influenced their works. Furthermore, it addresses the emergence of 'migraine art' sponsored by the pharmaceutical industry, presenting the intersection between art, neuroscience, and public engagement. The diagnostic complexity and differentiation of migraines from epilepsy are also discussed, with a special focus on the symptoms of the visual aura and how this has been portrayed through various artistic representations, thus inviting further exploration of the relationship between neurological conditions and creative expression.

Keywords: Migraine Disorders, Art, Visual Phenomena, Aura, Art History, Creative Expression, Pharmaceutical Industry

RESUMO

Esta revisão narrativa explora a intrincada relação entre enxaquecas e arte, traçando exemplos históricos e interpretações contemporâneas de como as enxaquecas, especialmente aquelas com aura visual, influenciaram os artistas. Destaca como as enxaquecas podem ter moldado a inspiração artística, investigando figuras notáveis e questionavelmente infectadas pela enxaqueca, como Hildegard de Bingen, Giorgio de Chirico, Pablo Picasso e Salvador Dali, examinando como suas experiências podem ter influenciado suas obras. Além disso, aborda o surgimento da "arte da enxaqueca" patrocinada pela indústria farmacêutica, apresentando a intersecção entre arte, neurociência e envolvimento público. A complexidade diagnóstica e a diferenciação entre enxaquecas e epilepsia também são discutidas, com especial foco nos sintomas da aura visual e como esta tem sido retratada através de diversas representações artísticas, convidando assim a uma maior exploração da relação entre condições neurológicas e expressão criativa.

Palavras-chave: Transtornos de Enxaqueca, Arte, Fenômenos Visuais, Aura, História da Arte, Expressão Criativa, Indústria Farmacêutica

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INTRODUCTION

This article, the seventh in a seven-part series on neuroaesthetics and the visual arts, sheds light on the intricate relationship between migraine and art, investigating historical examples and contemporary interpretations of how the visual experiences that accompany migraine may have manifested in the works of many artists.

The quote from Oliver Sacks at the beginning of this article gives an idea of the migraineur´s overwhelming experience, of an intricate balance between physical and emotional turmoil, leaving those affected with difficulty conveying the complexity of their migraine attacks. However, the link between neurological disorders and artistic expression has long fascinated scholars and enthusiasts in the field of art history. In addition to dreams, hypnagogic hallucinations, or drug-induced phenomena, migraine can also be a source of artistic inspiration[1].

Chatterjee[2] in his review on 'The neuropsychology of visual artistic production' considers that several neurological conditions influence artistic expression and the unique talents of artists allow them to portray these deficits remarkably. Among neuropsychological syndromes, migraine auras inspire surreal works of art, and analyses from the Migraine Art Competition show how artists incorporate personal visual experiences into their work. Thus, although in principle neurological conditions may not create artistic talent, they expand artists' visual forms, leading to unexpected and visually intriguing changes in their art.

Migraine, often characterized by complex visual phenomena, has silently but profoundly influenced numerous artists throughout history, shaping their creative expressions and artistic motifs exemplarily in Hildegard of Bingen, Giorgio de Chirico, Salvador Dalí, and perhaps Pablo Picasso[1,6,7] . Furthermore, this article aims to explore not only the historical context but also the contemporary emergence of 'migraine art' supported by exhibitions and competitions sponsored by the pharmaceutical industry, which sits at the intersection of art, neuroscience, and public engagement. Thus, by examining the conscious or subconscious integration of migraine experiences into artistic expressions, this study seeks to unravel the captivating relationship between neurological conditions and the imaginative world of art.

Visual aura

Although epilepsy has attracted considerable attention for its influence on artistic creation, the widespread impact of migraine, particularly that accompanied by visual aura, has remained a relatively understudied but compelling subject. However, the intertwined relationship between migraine and epilepsy reveals complex connections[3] and clinically distinguishing between them can be challenging due to overlapping symptoms. Postictal headache is common, while the diagnosis of ictal epileptic headaches is more complex. The pathophysiology of seizure-triggered headaches and the similarity between migraine aura and epilepsy symptoms, especially visual aura, contribute to incorrect diagnosis. Furthermore, both migraine with aura and epilepsy can coexist, and the differential diagnosis between migraine with visual aura and occipital epilepsy depends on specific clinical characteristics. Migraine aura often presents with several visual symptoms, including bright lights, spots, blurred vision, zigzag lines, and scotomas. Notably, the duration of visual symptoms differs significantly as in epilepsy it lasts from seconds to minutes, whereas migraine aura lasts from 5 to 60 minutes. A distinctive indicator is the stereotypical lateralization and horizontal shift of visual symptoms in epilepsy, contrasting with the more heterogeneous presentation in migraine aura. Furthermore, migraine aura usually has a gradual onset, epilepsy has a sudden onset. Colored aura can also appear in both, but other associated symptoms such as migraine characteristics such as nausea, vomiting, or sensitivity to light and sound can help differentiate, but postictal headaches after epilepsy can mimic migraines.

Oliver Sacks (1933 - 2015), British neurologist, naturalist, historian of science and writer, also a migraine sufferer, wrote about the nature of visual hallucinations, as cited by Aguggia and Grassi[1]: 'What we can say, in general terms, is that these hallucinations reflect the tiny anatomical organization, the cytoarchitecture, of the primary visual cortex, including its columnar structure – and how the activity of millions of nerve cells organizes itself to produce complex, ever-changing patterns. We can actually see, through such hallucinations, something of the dynamics of a large population of living nerve cells and, in particular, the role of what mathematicians call deterministic chaos in allowing complex patterns of activity to emerge throughout the visual cortex. This activity operates at a basic cellular level, far below the level of personal experience. They are archetypes, in a way, universal of the human experience.' Furthermore, this profound connoisseur of migraine, apud Ferreira[4] recognized that 'from the migraine aura, one can map, through experience, exploration and reflection, an entire world - the cosmography of an individual'.

In essence, these auras usually occur before the onset of the headache phase and can vary in duration and intensity for each individual. According to Shankar et al.[9] the visual aura in migraine can be represented by a flickering and irregular arc of light, bright lines, or a blind spot in the visual field. Consequently, visual auras in migraines can manifest themselves in several ways, presenting a spectrum of visual disturbances as suggested in the images in Figures 1. Concerning the first image, 'A Brushstroke of Migraine', depicts a painter suffering a migraine attack, holding his head amidst a surreal atmosphere, and integrates several elements of the visual aura - such as sparkling lights, patterns in zigzags, palisaded structures and empty patches in the visual field, to convey the struggle, disorientation, and sensory overload amidst this neurological storm.

The other interpretations regard: Sparkling aura, 'star point', encapsulates the fleetingness of lights flickering and visualizes these indescribable and ghostly flickers, showing their transitory and ethereal quality; The Jagged Arc of Light, 'Luminous Fractals', representing jagged, fractured arcs of light and incorporates sharp, angular lines and radiant tones, creating a sense of dynamic movement and instability; Bright Lines Aura, 'Radiant Streaks', encapsulates the vivid and intense glowing lines that seek to capture the vibrant and striking nature of these glowing streaks, highlighting their intensity and brilliance against the visual field; Blind Spot Aura, 'Voided Sightlines', illustrates the visual phenomenon of blind spots as areas of emptiness within the visual field, emphasizing their absence and the disturbance they cause to vision.

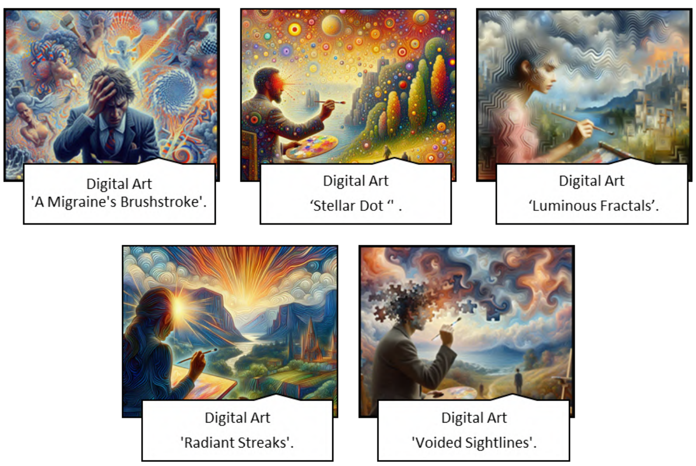

Figure 1. 'Fractured Illusions' from Digital Interpretations. Sources: Image Creator of the DALL·E platform with recommendations given by the author of this paper.

Migraine with Visual Aura in Art History

Some historical moments of migraine that influenced art include renowned artists such as Hildegard de Bingen, Giorgio de Chirico, Salvador Dali, and supposedly Pablo Picasso. These artists, with their unique styles and perspectives, may have channeled their personal experiences with migraines, particularly the visual aspects, into their works. His creations serve as testimony to the potential influence of migraines on the creative process, demonstrating the interaction between neurological phenomena and artistic expression.

Interpretations of his works may reflect his visual experiences of migraine and these works of art have been interpreted by scholars as potentially influencing or portraying elements related to migraine experiences, particularly visual aura or perceptual disturbances. These artists known for their unique styles may have incorporated their personal experiences with migraines into their work. Although there is no definitive proof of his diagnoses, historical accounts, interpretations of his artwork, and descriptions of his experiences point to a potential connection between his creative expressions and the visual phenomena associated with migraines especially in the cases of Hildegard of Bingen, Giorgio de Chirico and Salvador Dali.

Hildegard of Bingen (1098 – 1179), a prominent German mystic, composer, and visionary, is believed to have suffered migraines based on historical records describing her intense visions[1]. Scivias is an illustrated work that describes various religious visions she experienced, often described as vivid and otherworldly, in line with the visual phenomena associated with migraines, including flickering lights, geometric patterns, and fortifying specters. These visual disturbances were interpreted as influencing her artistic expression and the content of her visionary writings. According to Sacks, apud Haan et al.[6] these reports leave no doubt as to its migraine nature.

Pablo Picasso (1881-1973) was a Spanish painter, sculptor, engraver, ceramist, and set designer, co-founder of the Cubist movement and pioneer of several artistic styles throughout his career. His supposed migraines are speculative as there is a lack of concrete evidence in biographies or contemporary sources supporting his migraine condition, however, the 'illusory division' in the drawings of migraine patients suggests correspondence with Picasso works such as 'La femme qui pleure' and 'Portrait de femme au chapeau' which displays facial division[6]. There is a discussion around Cubist representations of vertically divided faces, linking this technique to Picasso and other Cubists, with this artistic choice possibly resulting from medical conditions such as migraine auras, eye diseases, or inspirations such as African masks. However, Picasso's art may not have been directly shaped by migraine auras due to their subjective and transient nature, in contrast to the visual problems caused by eye diseases.

Giorgio de Chirico (1888–1978), an Italian, known as the 'Father of Surrealism' and founder of the 'scuola metafisica art movement', is believed to have drawn inspiration from his personal experiences with migraines in his art, such as geometric patterns, distortions, and metamorphosis, dark shapes, scotomas that were included in his paintings. It is assumed that migraine with aura served as the basis for his 'Pittura metafisica', because of its various unusual aspects, and because he suffered from 'certain abdominal pains and migraines', and it appears that not only typical visual auras were depicted, but also sensations of kinesthetic pain with atypical aura[1]. His works such as 'The Return to the Castle', 'Spettacolo Misterioso', and 'The Enigma of the Day', often portray surreal, dreamlike landscapes and distorted perspectives, recalling the visual distortions and altered perceptions experienced during migraine auras. . De Chirico's artistic style, characterized by mysterious atmospheres, elongated shadows, and enigmatic architectural forms, has been associated with the disorienting and hallucinatory nature of migraine experiences.

As for the Spanish Salvador Dali (1904 – 1989), a self-proclaimed migraineur[1], known for his surreal and dreamlike works, had personal encounters with migraine, which may have significantly influenced his artistic creations. A notable piece often associated with migraine-like visual auras is 'The Persistence of Memory,' which features melting clocks. However, his painting 'Hallucinogenic Toreador' exemplifies his distinctive style, featuring fused forms, distorted perspectives, and fragmented images reminiscent of the visual disturbances experienced during migraine auras. Dalí's fascination with distorted reality, symbolism and the subconscious aligns with the altered subjective perceptions often associated with migraines, suggesting a possible link between his artistic vision and his experiences with this neurological condition.

Figure 2. "'Migraineurs or supposed to be". Source: Wikimedia Commons.

Artistic Expression and Migraine Manifestations Until Migraine Art

Artists portray their migraine experiences in their art, with some explicitly recognizing their visual migraine aura as part of their artistic inspiration, citing examples of recurring visual motifs and symbolism in their works. In this wave, the British Migraine Association organized a series of migraine art competitions in the 1980s to share the diverse experiences of people with migraines. Analyzed artworks submitted to the first National Migraine Art Competition, sponsored by the British Migraine Association and WB Pharmaceuticals, of over 200 entries, 70% showed spectral appearances, 48% showed fortifications, 16% showed visual

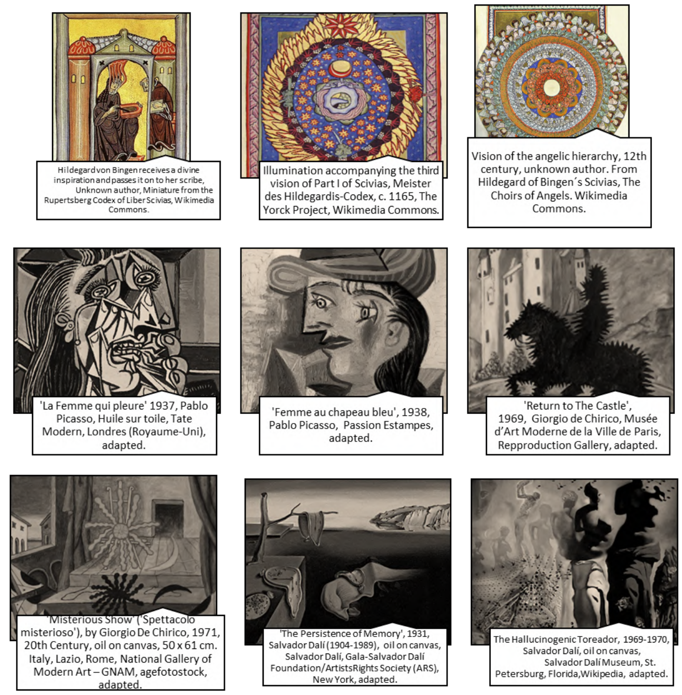

Figure 3. "Artistic Insights: Migraine, Vision, and Creativity

Artists portray their migraine experiences in their art, with some explicitly recognizing their visual migraine aura as part of their artistic inspiration, citing examples of recurring visual motifs and symbolism in their works. In this wave, the British Migraine Association organized a series of migraine art competitions in the 1980s to share the diverse experiences of people with migraines. Analyzed artworks submitted to the first National Migraine Art Competition, sponsored by the British Migraine Association and WB Pharmaceuticals, of over 200 entries, 70% showed spectral appearances, 48% showed fortifications, 16% showed visual loss and 2.5 % showed mosaic views[2,5]. The Migraine Art Competition Collection is made up of 545 paintings submitted to the four Migraine Art Competitions of 1980-1987[8,10]. Thus, there is the emergence of 'migraine art' as a recognized genre with the participation of pharmaceutical industries to sponsor exhibitions and competitions centered on migraine art, which shows the intersection between art, neuroscience, and public engagement, in addition to the profound influence of migraines on artistic creation. Thus, over time, there has been a transformative change in the way society and medicine view migraines. Starting with the creation of the British Migraine Association and evolving into specialist clinics and greater research efforts, perceptions about migraines have changed significantly, from the initial belief that migraines were purely vascular issues, to recognizing their neurological complexities.

The struggles faced by migraine sufferers, including misunderstanding and social contempt, have been challenged through advocacy, research, and specialist health services. Diverse approaches, from hormonal therapies to dietary studies, have contributed to a more comprehensive understanding of migraines.

In the 21st century, the digitization of the Migraine Art Collection and the shift to online communities reflect the evolution of how people communicate and engage with their migraine experiences, with the emergence of the term 'migraineur' indicative of the integration of migraines. in personal identity, emphasizing the profound impact of the disease on various aspects of life. Furthermore, art therapy and outsider art provided a unique way of expressing the subjective experiences of migraine sufferers, highlighting the importance of creative expression in healthcare. However, despite advances in understanding and treatment, migraines continue to be a significant challenge for many individuals.

CONCLUSION

The confluence of migraines and artistic creation offers a captivating insight into the way neurological conditions intertwine with the imaginative realm of art. Furthermore, the emergence of 'migraine art' as a recognized genre signals the growing recognition of the intersection between neurological disorders and creative expression, with pharmaceutical sponsorships for the convergence of art and neuroscience. This study illuminates the intriguing interplay between neurological phenomena and artistic inspiration, inviting greater investigation and appreciation of the profound ways in which migraines have shaped artistic creation throughout history and contemporary contexts.

In short, this comprehensive overview not only investigates the historical context of migraines but also emphasizes current challenges and the need for ongoing awareness, research, and support for those affected by migraines. The artworks in the Migraine Art Collection offer poignant insights into the multifaceted experiences of migraine sufferers, portraying the role of medication in their lives and the challenges they face.

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3. Texto:

a. Artigos originais: até 3.000 palavras, sem contar as referências, contendo: Introdução e objetivo; métodos (sujeitos e procedimentos), referência explícita quanto ao cumprimento das normas éticas aplicáveis, incluindo o nome da comissão de ética que aprovou o estudo e a obtenção do Consentimento Informado assinado; resultados; discussão; conclusão; agradecimentos; referências (até 40). Evitar repetir no texto dados que constem de tabelas e ilustrações;

b. Artigos de revisão: até 5.000 palavras, sem contar as referências, contendo análise de dados de outros autores ou metanálise, avaliação crítica dos dados da literatura e considerações baseadas em sua experiência pessoal, outras informações semelhantes ao item anterior, referências (até 100);

c. Nota histórica: até 2.500 palavras e até 30 referências;

d. Relato de caso: até 1.000 palavras e até 15 referências. Deve conter referência explícita quanto ao cumprimento das normas éticas aplicáveis, incluindo o nome da comissão de ética que aprovou o estudo e a obtenção do Consentimento Informado assinado. [Sugere-se seguir o roteiro do CARE. https://www.care-statement.org]

e. Imagens em neurologia: até 150 palavras, com resumo dos dados pertinentes e comentários sobre as imagens, referências (até 5).

4. Tabelas:

a. Artigos originais e de revisão: Até cinco, apresentadas em páginas separadas, constando: número de ordem, título e legenda;

b. Nota histórica: Até duas, com formato semelhante ao dos artigos.

c. Relato de caso: Uma, com formato semelhante ao dos artigos.

5. Ilustrações:

a. Artigos originais e de revisão: até seis gráficos e/ou fotos (excepcionalmente mais, a critério dos editores), de qualidade adequada para impressão, com legendas em páginas separadas;

b. Nota histórica: Até duas, com formato semelhante ao descrito para os artigos;

c. Relato de Caso: Até duas;

d. Imagens em neurologia: Até quatro, em uma única página.

Obs.: Todas as figuras devem ser submetidas em formato JPG ou TIFF (300 dpi) . Reproduções de ilustrações publicadas – informar sobre a autorização do detentor do direito, e caso se encontre em domínio público, citar a fonte.

Obs.: O local de inserção de tabelas e figuras deve ser assinalado no texto.

6. Referências:

Seguir o estilo Vancouver baseado no NLM http://www.nlm.nih.gov/ bsd/ uniform_requirements.html; as referências devem ser ordenadas de acordo com sua citação no texto (preferencialmente); incluir todos os autores quando até cinco; quando seis ou mais, listar os três primeiros seguidos de “et al.”.

RESPONSABILIDADES

Autores: Estudos envolvendo seres humanos devem conter menção da aprovação por Comitê de Ética em Pesquisa e o número desta, e da obtenção de assinatura de Consentimento Informado pelo participante ou responsável legal. Os estudos conduzidos com animais experimentais deverão também conter aprovação ética adequada. Os autores assumem plena responsabilidade intelectual e legal pelo conteúdo do artigo, incluindo texto, tabelas e figuras. O consentimento do participante (ou responsável legal) para a elaboração do “relato de caso” é essencial e deve ser obtida PREVIAMENTE à publicação ou divulgação, por meio de termo de consentimento livre e esclarecido (TCLE), acompanhado do termo de assentimento quando necessário.

LISTA DE VERIFICAÇÕES DE SUBMISSÃO

Esta lista pode ser usada para realizar uma verificação final do seu manuscrito antes de submetê-lo à Revista Brasileira de Neurologia.

1- Títulos em português, inglês e curto;

2- Autores e filiação;

3- Assinatura com a cessão de direitos sobre a publicação à Revista Brasileira de Neurologia, associada à declaração de conflito de interesses e financiamento;

4- Autor designado como correspondente, com detalhes de contato, máxime o seu e-mail:

5- Resumo com palavras-chave e abstract com key-words;

6- Todas as citações de figura e tabela no texto correspondem aos arquivos fornecidos;

7- Indispensável revisão ‘ortográfico’ e ‘gramatical’.

8- Todas as referências mencionadas na lista de referências são citadas no texto e vice-versa

9- Obtida permissão para uso de material protegido por direitos autorais de outras fontes (incluindo a Internet).

10- Cuidados especiais referentes a estudos envolvendo seres humanos (vide RESPONSABILIDADES)..

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