Cortica
www.revue-cortica.net | ISSN : 2813-1940

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

SALIENCE AND EXECUTIVE NETWORK CONNECTIVITY ANALYSES IN SCHIZOPHRENIA DURING EMOTIONAL MEMORY TASKS

*Loïc Schollaert, [1,]

1. Master Thesis, Unit of Clinical and Health Psychology, Department of Psychology, University Fribourg, Fribourg, Switzerland

***Auteur correspondant** : Loïc Schollaert loic.schollaert@unifr.ch

Citation: Schollaert, L. (2025). Salience and executive network connectivity analyses in schizophrenia during emotional memory tasks. *Cortica,* *4*(2) 255-316. https://doi.org/10.26034/cortica.2025.8569

Résumé

Contexte : La schizophrénie est un trouble psychotique qui touche 1 % de la population (Morera-Fumero & Abreu-Gonzalez, 2013 ; Schultz et al., 2007). Il existe deux types de symptômes selon le DSM-5-TR : les symptômes positifs (hallucinations, délires, troubles de la pensée et comportement moteur anormal ou gravement désorganisé) et les symptômes négatifs qui correspondent à une diminution des fonctions comportementales normales. Le DSM-5-TR indique que deux symptômes négatifs sont prépondérants dans la schizophrénie : l'aboulie et la diminution de l'expression émotionnelle. Cependant, la schizophrénie se caractérise également par des symptômes cognitifs chez 98 % de la population atteinte de ce trouble (Keefe et al., 2005). L'objectif de cette étude est donc d'étudier la mémoire émotionnelle dans la schizophrénie et d'identifier les schémas de déconnexion sous-jacents.

Méthode : 70 participant·e·s (34 femmes et 36 hommes) ont été recrutés, dont 35 souffrant de schizophrénie (17 femmes et 18 hommes) et 35 personnes témoins en bonne santé (17 femmes et 18 hommes). La gravité des symptômes a été évaluée à l'aide de l'échelle BPRS (Brief Psychiatric Rating Scale) et de l'échelle PANSS (Positive and Negative Symptoms Scale). Ensuite, tous les participant·e·s ont passé une IRMf pendant la tâche suivante : les participant·e·s devaient observer 12 blocs de 10 images provenant de la batterie IAPS au cours de deux sessions, Émotion et Mémoire. Il existe cinq types de contenu d'image en fonction de la saillance et de la valence

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

émotionnelle : forte excitation avec contenu négatif (HA-), faible excitation avec contenu négatif (LA-), neutre (NTR), faible excitation avec contenu positif (LA+) et forte excitation avec contenu positif (HA+). Dans la première phase, tous les participant·e·s ont commencé par la « session émotionnelle ». Les participants devaient observer passivement les images de l'IAPS. Lors de la deuxième session, la « session mémoire », 50 % des images ont été remplacées par d'autres et les participant·e·s devaient appuyer sur un bouton s'ils ou elles pensaient avoir déjà vu l'image devant eux lors de la session précédente ou non.

Résultats : Pendant la tâche, le groupe témoin sain a obtenu un taux de réponses correctes significativement meilleur que les personnes avec une schizophrénie. L'analyse fonctionnelle a permis d'identifier plusieurs circuits présentant une dysconnectivité dans la schizophrénie lors de tâches impliquant à la fois l'émotion et la mémoire. Pendant la phase émotionnelle, une surconnectivité a été principalement observée entre le réseau de saillance et les zones visuelles, tandis que la sous-connectivité affectait principalement les régions frontales et limbiques. Un schéma similaire est apparu pendant la phase mémorielle, avec une surconnectivité entre les zones sensorielles et frontales, tandis que la sous-connectivité était plus prononcée dans le réseau de saillance, le système limbique et les zones sensorielles.

Mots clés : schizophrénie, mémoire émotionnelle, IRMf, réseau de saillance et réseau exécutif, connectivité fonctionnelle

(Traduction réalisée avec l'aide de Deepl, 8 décembre 2025)

Abstract

Context: Schizophrenia is a psychotic disorder which affects 1% of the population (Morera-Fumero & Abreu-Gonzalez, 2013; Schultz et al., 2007). There are two kinds of symptoms from DSM-5-TR: Positive symptoms (hallucination, delusion, thought disorder and abnormal or grossly disorganized motor behaviour) and negative symptoms that are a diminution of normal behavioural functions. The DSM-5-TR say that there are 2 negative symptoms preeminent in schizophrenia, aboulia and decrease of emotional expression. However, schizophrenia is also marked by cognitive symptoms in 98% of the population with this disorder (Keefe et al., 2005). Thus, the aim of this study is to investigate emotional memory in schizophrenia and identify the underlying dysconnectivity patterns.

Method: 70 participants (34 women and 36 men) were recruited, 35 suffer from schizophrenia (17 women and 18 men) and 35 are healthy control people (17 women and 18 men). Severity of symptoms was evaluated with the BPRS (Brief Psychiatric Rating Scale) and PANSS (Positive and

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

Negative Symptoms Scale). Then, all participants passed an fMRI during the following task: Participants had to observe 12 blocks of 10 images from the IAPS battery during two sessions, Emotion and memory. There are five kinds of image content according to the salience and the emotional valence: High Arousal with negative content (HA-), Low Arousal with negative content (LA-), Neutral (NTR), Low arousal with positive content (LA+) and High Arousal with positive content (HA+). In the first phase, all participants started with the “emotional session”. The participants had to passively observe images from the IAPS. In the second session, the “memory session”, 50% of images were changed by others and the participants had to press a button if they think that they had already seen the image in front of him in the previous session or not.

Results: During the task, the healthy control group had a significantly better correct response rate than people with schizophrenia. In functional analysis, several circuits showing dysconnectivity in schizophrenia during tasks involving both emotion and memory were identified. During the emotion phase, overconnectivity was primarily observed between salience network and visual areas, whereas underconnectivity mainly affected frontal and limbic regions. A similar pattern emerged in the memory phase, with overconnectivity between sensory and frontal areas, while underconnectivity was more pronounced in the salience network, limbic system, and sensory areas.

Keywords: schizophrenia, emotional memory, fMRI, salience and executive network, functional connectivity

Introduction

Schizophrenia

There is a partial consensus within the scientific and clinical community regarding the conceptualization of psychosis, including its symptoms, characteristics, development, and risk factors (American Psychiatric Association, 2022). In this work we will approach schizophrenia, a disorder which is part of the psychotic spectrum. Given the heterogeneity of symptoms observed within this spectrum, psychotic disorders have been categorized into eight distinct diagnoses: schizotypal personality disorder (also classified among personality disorders), delusional disorder, brief psychotic disorder, schizophreniform disorder, schizophrenia, schizoaffective disorder, substance- or medication-induced psychotic disorder, and psychotic disorder due to a medical condition (American Psychiatric Association, 2022).

The Diagnostic and Statistical Manual of Mental Disorders, fifth edition Revised (DSM-5-TR) is listing six criteria for schizophrenia diagnosis (American Psychiatric Association, 2022):

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

A, two symptoms like thought disorders, hallucinations, delusion, unorganized behaviour, aboulia, or reduction of emotional expression have to be there for a significant proportion of the time during one month. One of the first three symptoms must be present.

B, since the beginning of the disorder, at least one of the major domains of life like work, social relationship or hygiene is negatively impacted.

C, during a 6-month period, some symptoms of criteria A show continuous signs.

D, there is no depressive or manic episode at the same time as the active symptoms phase. Also, if mood disorder was present during this period, it was during a very short time in comparison with the totality of the phase.

E, there is no link with other physiological effects or substances.

F, there is no link with antecedents of autism spectrum of communication disorder during childhood.

Positive symptoms. Positive symptoms of schizophrenia are characterized by an amplification of perceptual distortions and include hallucinations (visual, auditory, or olfactory), delusions (such as paranoia or beliefs detached from reality), disorganized thinking, and disorganized or abnormal motor behaviour (e.g., agitation, stereotyped movements, or mannerisms (American Psychiatric Association, 2022). Hallucinations are false perceptions that do not correspond to external stimuli, but the patient experiences them as real. These perceptual disturbances can affect any sensory modality, though auditory hallucinations are the most prevalent in schizophrenia, occurring in approximately 60% of cases (Hayward et al., 2017; Suryani et al., 2013). Auditory hallucinations may manifest as echoes or unidentified noises without a discernible source, but they can also take the form of distinct voices articulating clear speech. In most cases, these voices become negative or persecutory over time (Parnas et al., 2024). Visual hallucinations, although less common than auditory ones, can range from vague shapes or shadows to more detailed images such as faces or objects (DSM-5-TR) (American Psychiatric Association, 2022). Delusion is a wrong and irrational belief. The most present in schizophrenia are thus about persecution. In this kind of delusion, the patient has the belief that he or she is spied on, followed or a victim of a conspiracy. Also, there exists other subjects in delusion such as delusion of reference, where the patient has the belief that each aspect of the environment is directed toward him or her, through encrypted messages, for example. Megalomaniacs' delusion, where the patient has the belief that he or she has exceptional fortune, capacity or influence. Erotomanic delusion, where the patient has the belief that a person likes or is in love with him or her. Delusion with a nihilistic theme, where the patient has the belief that a disaster is coming (DSM-5-TR) (American Psychiatric

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

Association, 2022). Although the disorder encompasses multiple speech-related symptoms, patients may exhibit disorganized thinking characterized by abrupt topic shifts, production of new worlds, or incoherent sequences of sentences lacking logical connections (American Psychiatric Association, 2022). Another positive symptom is disorganized behavior, which may manifest as unpredictable or childlike actions, or as markedly reduced responsiveness to environmental stimuli, such as catatonic behavior. For diagnostic purposes, these symptoms must cause significant functional impairment (DSM-5-TR).

Negative symptoms. Negative symptoms of schizophrenia correspond to a reduction in normal functions. According to the DSM-5-TR (American Psychiatric Association, 2022)., two negative symptoms are particularly prominent in this disorder: aboulia and diminished emotional expression. Aboulia refers to a marked loss of motivation and willingness to initiate actions aimed at achieving a goal (American Psychiatric Association, 2022; Marder & Umbricht, 2023). Patients often struggle to start even simple activities, such as household chores, and face even greater challenges with more complex tasks, such as seeking employment (Lutgens et al., 2017; Marder & Umbricht, 2023). Even if they manage to initiate an activity, sustaining effort over time is difficult, leading to frequent giving up. The diminished emotional expression is characterized by reduced facial expressions, decreased eye contact, and a lack of emotional modulation in speech, body language, or prosody (Marder & Umbricht, 2023). However, other symptoms in this category exist like alogia (decrease of speech), anhedonia (loss of pleasure in a positive situation), and associability (loss of social interaction) (Schultz et al., 2007). Negative symptoms significantly impact various aspects of a patient's life, including work, social interactions, and hobbies. Avolition and lack of motivation can lead to social withdrawal and rejection. Moreover, relatives may misinterpret these behaviours as a deliberate withdrawal or loss of interest in their relationships (An et al., 2010; Schultz et al., 2007). Additionally, emotional blunting can contribute to stigmatization. Given the essential role of emotional expression in communication, patients may be perceived as indifferent, unmotivated, or emotionally distant, making social interactions and conversations more challenging. This misinterpretation can further reinforce social isolation and hinder interpersonal relationships.

Cognitive symptoms. Beyond the emotional and motivational disturbances characteristic of negative symptoms, schizophrenia is also associated with cognitive impairments, affecting approximately 98% of individuals diagnosed with the disorder (Keefe et al., 2005). These cognitive deficits are as disabling as positive symptoms and motivation-related disturbances. They are primarily impacting memory, attention, and reasoning and influence directly social functioning, occupational performance, and the individual's ability to adapt to societal demands (Schultz et al., 2007). Cognitive symptoms can emerge early in the course of the disorder and are now considered

Article
Cortica 2025. 4(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

a core dysfunction of schizophrenia (Kruk-Slomka & Biala, 2021; Tamminga et al., 1998). Extensive research has identified key cognitive deficits in schizophrenia, notably impairments in working memory, episodic memory, attention, planning, processing speed, and social cognition (Kruk-Slomka & Biala, 2021; Tripathi et al., 2018).

Development. The development of schizophrenia can be divided into two distinct phases. The first is the prodromal phase, during which the initial cognitive and negative symptoms emerge. This phase typically begins from two to five years before the onset of the first psychotic episode (McCutcheon et al., 2020). However, it is important to note that in some individuals, the disorder progresses more rapidly, with cognitive and negative symptoms appearing only a few months before the first psychotic episode (McCutcheon et al., 2020). In most cases, the early signs of schizophrenia manifest during adolescence. Cognitive symptoms tend to develop gradually, often reflected in declining academic performance and increasing social withdrawal. Identifying these symptoms can be challenging given that adolescence is a period marked by significant personality changes (Fusar-Poli et al., 2012). However, if these symptoms persist for more than a month, early intervention is crucial. Research indicates that the earlier treatment is initiated, the better the prognosis, with a greater likelihood of positive symptom evolution (Aceituno et al., 2019; Williams et al., 2024).

The first psychotic episode typically occurs between the ages of 15 and 25 on average (Solmi et al., 2022). In most cases, a triggering event initiates the episode, often linked to psychoactive substance use (such as cannabis), intense stress, or trauma (Bourque et al., 2013; McCutcheon et al., 2020). At this stage, the patient enters the psychotic spectrum, with diagnosis depending on the duration and severity of symptoms. However, it is important to note that in some cases, the first psychotic episode occurs without any identifiable trigger (Häfner & an der Heiden, 1997). Generally, the first hospitalization occurs during this initial episode for most patients (Yee et al., 2024).

Several factors influence the progression of the disorder, including the onset pattern (gradual or abrupt), the speed of intervention, and the presence or absence of strong social support, particularly from family members (Caqueo-Urízar et al., 2015). Additional lifestyle-related risk factors have also been identified: substance use (drugs and alcohol), social isolation, chronic stress, irregular sleep patterns, diet, and sedentary behaviour all contribute to the prognosis (Stilo & Murray, 2019).

Gender differences also play a role in schizophrenia's onset and progression (Li et al., 2016). On average, women experience symptom onset later, typically between 25 and 35 years old, whereas men develop symptoms earlier, between 18 and 25 years old, with a more abrupt onset (Li et al., 2016). Also, men tend to exhibit more pronounced negative and cognitive symptoms and females tend to present more secondary effects by medication than males. (Galbally et al., 2024).

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

Additionally, women generally have better social reintegration, higher adherence to treatment, and lower relapse rates compared to men (Li et al., 2016).

Schizophrenia is characterized by a low remission rate. In the best-case scenario, 20% of patients achieve partial or total remission within the first month after their initial psychotic episode, with the disappearance of positive symptoms. However, 40% of patients experience alternating periods of stabilization and psychotic relapses, though they still maintain relatively good functional outcomes. Only 13.5% of individuals achieve both social and clinical remission, while for the remaining patients, schizophrenia persists as a long-term condition (Jääskeläinen et al., 2013).

Medical treatment. The treatment of schizophrenia follows a multimodal approach, integrating pharmacological and psychotherapeutic interventions (Stępnicki et al., 2018). The general strategy involves using medication to reduce symptoms, while also engaging the patient in therapy aimed at social rehabilitation and disorder management to maximize their autonomy (Jääskeläinen et al., 2013). The primary objectives of treatment are to attenuate symptoms, manage relapses, prevent recurrences, and improve overall quality of life (Yee et al., 2024). Schizophrenia is primarily treated with antipsychotic medications, which function by modulating dopaminergic neurotransmission. Currently, two main classes of antipsychotics are available:

First-generation antipsychotics, also known as typical antipsychotics, were introduced in 1951. They take action by blocking D2 dopamine receptors, effectively reducing hallucinations and delusions. However, they are associated with significant motor side effects, including tremors and muscular rigidity (Leucht et al., 2024).

Second-generation antipsychotics, also called atypical antipsychotics, were introduced in 2005. In addition to blocking D2 receptors, they also antagonize 5-HT2A serotonin receptors, which helps improve negative and cognitive symptoms (Howes & Kapur, 2009; Leucht et al., 2024). Although they produce fewer extrapyramidal side effects, they are linked to weight gain, metabolic disorders, and an increased risk of diabetes (Carbon et al., 2018).

For this reason, it looks important to optimize the medication and adapt the antipsychotic (e.g. Olanzapine, Risperidone, Clozapine or Aripiprazole) according to symptoms and the patient's needs (Meltzer, 2013). Indeed, there are many antipsychotics with many effects according to affinity with D2 and 5-HT2A receptors. They are all blocking dopamine, however, some of them decrease and others increase serotonin secretion. Those who are 5-HT2A antagonists allow, in blocking serotonin, to increase dopamine secretion in the prefrontal cortex and improve cognitive symptoms (Leucht et al., 2024). Olanzapine, Clozapine, Quetiapine, Risperidone are in this category. However, in addition to weight gain, other side effects can appear. For example, Clozapine can cause agranulocytosis

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

(white blood cell large decrease), or Risperidone can cause hyperprolactinemia (increase of prolactin) (Bostwick et al., 2009; Mijovic & MacCabe, 2020). Those who increase serotonin are partial agonists of 5-HT1A, allowing an improvement of emotional symptoms. Three antipsychotic drugs have this effect: Aripiprazole, Brexpiprazole and Lurasidone. Due to the effect on serotonin, it may cause side effects like sleep disorder, nervousness, and agitation (Orzelska-Górka et al., 2022). In summary, if the patient presents anxiety or depressive symptoms in addition to positive symptoms, a partial agonist of 5-HT1A is better adapted, but if the patient presents high motor side effects, it's better to use 5-HT2A antagonist (Carbon et al., 2018; Meltzer, 2013; Leucht et al., 2024).

Non-medicated treatment. As previously mentioned, in addition to pharmacological treatment, non-medicated interventions are essential to improving quality of life and reducing the risk of relapse. Several therapeutic approaches are available, each with a specific objective (Gregory Jr., 2010; Turkington et al., 2006). Among them, Cognitive Behavioural Therapy (CBT) is the most widely studied and commonly used (Candida et al., 2016). This approach aims to modify dysfunctional thought patterns and develop coping strategies to manage symptoms as they arise. The therapeutic focus depends on the patient's symptoms. For auditory hallucinations, CBT helps normalize the experience and reduce stress-induced overreactions through cognitive remediation. It also assists the patient in recognizing that the voices are internally generated rather than external, using cognitive decentring techniques (Candida et al., 2016). In cases of delusions, therapy encourages patients to critically examine their beliefs, fostering doubt and reducing conviction. Gradual exposure techniques may also be used to help patients confront and cope with delusional thoughts.

Beyond addressing hallucinations and delusions, CBT is also effective in managing anxiety and emotional distress. Techniques such as relaxation training (e.g., controlled breathing), cognitive restructuring (reframing irrational thoughts into rational ones), and problem-solving strategies are commonly employed (Candida et al., 2016). The overarching goal is to reduce the emotional impact of symptoms, reframe their interpretation, and progressively expose the patient to stress-inducing situations, ultimately enhancing resilience and adaptive functioning.

As previously discussed, the social environment plays a crucial role in the development and progression of schizophrenia. In this context, family therapy emerges as a valuable intervention aimed at improving communication, reducing relapse risk, enhancing understanding of the disorder, and supporting treatment adherence (Caqueo-Urízar et al., 2015; Gregory Jr., 2010). This therapeutic approach encompasses various interventions tailored to the needs of both the patient and their family. A key component is psychoeducation, which helps family members, and the patient gain a deeper understanding of schizophrenia. This includes an overview of positive and negative

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

symptoms, the role of medication, and awareness of risk factors and relapse triggers. Beyond education, family therapy focuses on communication strategies, particularly in helping patients to effectively express their emotions (Harvey, 2018). By teaching families how to manage stress and interact positively with the patient, the therapy encourages constructive feedback, reinforcing progress while ensuring that emotions are expressed without hostility (Caqueo-Urízar et al., 2015; Harvey, 2018). This approach fosters realistic expectations, helping caregivers strike a balance between providing support and avoiding overprotection, ultimately promoting the patient's autonomy and emotional well-being.

The final essential component of multimodal care in schizophrenia is social rehabilitation and professional reintegration (Almerie et al., 2015). Social rehabilitation focuses on developing social skills, fostering independence, reducing isolation, and improving the ability to maintain interpersonal relationships despite the impact of negative symptoms (Markiewicz & Dobrowolska, 2020).

One key approach to social skills training involves role-playing exercises, where patients practise everyday interactions such as initiating conversations with strangers, making requests, or interpreting non-verbal cues. Through gradual exposure, these exercises help bridge the gap between therapy and real-life interactions. Additionally, participation in community activities, such as support groups or artistic programs, can facilitate social integration while simultaneously alleviating negative symptoms and enhancing quality of life (Dean et al., 2014; Green et al., 1987).

Professional reintegration represents the final challenge in schizophrenia care and is primarily supported by social workers. A successful reintegration process enables the patient to secure and maintain employment, which is often considered a marker of effective treatment (Oyelade & Nkosi-Mafutha, 2021). Sustaining a job not only fosters financial independence but also demonstrates improved management of the disorder, with reduced impact of negative and cognitive symptoms on daily functioning (Velligan & Gonzalez, 2007).

Explanatory theories. When Kreaplin described *dementia praecox* in 1896, the disorder was considered as a neurodegenerative process (Kraepelin, 1919). Just after, when Bleuleur gave the name of schizophrenia, he proposed a rather psychodynamic and cognitive origin of the disorder. For him, schizophrenia is due to disorganized thinking (American Psychiatric Association, 2022). In 1950, with the aim of improving surgical anaesthesia, the first antipsychotic was created, the Chlorpromazine (Braslow & Marder, 2019). Its initial effect was sedation rather than anaesthesia, then, in 1952, Laborit induced this medication to avoid post-surgery shock. Finally, this year, Deniker tried to induce Chlorpromazine to patients with schizophrenia and observed an hallucination diminution, less aggressiveness and less agitation (Braslow & Marder, 2019).

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

In the 1960's studies on dopamine started and it's in 1976 that Seeman made the link between antipsychotics, dopamine and schizophrenia (Seeman, 2022). From this moment we began to understand the neurological basis of schizophrenia, a dopamine dysregulation. Nowadays, the current state of this theory says that there is a dopamine excess in the mesolimbic pathway, which causes positive symptoms, and at the same time a deficit in mesocortical pathway, which causes negative and cognitive symptoms (Selemon & Zecevic, 2015). The mesolimbic pathway is one of four dopaminergic pathways. It has projections to the acubens, hippocampus, amygdala, cingulate gyrus, and fornix (Cardona-Acosta & Bolaños-Guzmán, 2023). This pathway is implicated in motivation, reward, and emotional processes (Cardona-Acosta & Bolaños-Guzmán, 2023). Then, the overstimulation of D2 receptors in those areas makes a mistaken stimulus interpretation and causes false perception like hallucinations (An et al., 2010). Also, the reward system dysregulation makes an aberrant salience response and causes hypersensibility to neutral stimuli (Kapur, 2003; Sarin & Wallin, 2014 ; Speechley et al., 2010). The mesocortical pathway has projections in the prefrontal area and is implicated in executive function, hence the impact on cognitive and negative symptoms (Kapur, 2003; Veale et al., 2017). More specifically, the dopamine deficit in this area will also affect working memory, attention, and planification for cognitive symptoms and apathy, social withdrawal and anhedonia for negative symptoms (Pedale et al., 2022).

Built on the dopamine hypothesis, the aberrant salience theory was introduced as an alternative explanation for schizophrenia's positive symptoms (Kapur, 2003; Veale et al., 2017). This theory suggests that overstimulation of the mesolimbic pathway leads to biased attribution of salience, causing patients to assign excessive significance to otherwise neutral stimuli. In the case of delusions, this misattribution can manifest as conviction in a conspiracy or other irrational beliefs.

A key observation from this model is that antipsychotic medications, which block D2 receptors, primarily reduce salience rather than perception. This explains why some patients may continue experiencing auditory hallucinations despite treatment, while their delusional convictions diminish (Leucht et al., 2024). By decreasing dopamine activity, these medications make the hallucinations feel less meaningful or intrusive, effectively breaking the cycle of delusional interpretation.

In the 1990s, the glutamatergic hypothesis emerged following observations that certain drugs, such as ketamine and phencyclidine, may induce symptoms resembling both positive and negative symptoms of schizophrenia (Kim et al., 1980; Uno & Coyle, 2019). These substances share a common mechanism: they interfere with NMDA receptors, which play a crucial role in regulating glutamatergic transmission (Howes et al., 2015; Zno & Coyle, 2019).

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

Glutamate is the primary excitatory neurotransmitter in the central nervous system and is essential for synaptic plasticity and cognitive processes. According to this hypothesis, schizophrenia involves NMDA receptor hypoactivity on GABAergic neurons, leading to reduced inhibition and excessive glutamate release in the prefrontal cortex and limbic regions. This dysregulation contributes to cognitive and emotional impairments, further supporting the idea that schizophrenia extends beyond dopaminergic dysfunction alone (Abi-Dargham et al., 2012; Howes et al., 2015).

Later, Javitt and Zukin (Moghaddam & Javitt, 2012; Javitt & Zukin, 1991) proposed that dopamine hyperactivity is induced by glutamate dysregulation due to cortisol excess. This hypothesis marked the beginning of research on the role of hormonal factors in schizophrenia. Subsequent studies provided multiple observations linking endocrine dysfunction to the disorder (Chaumette et al., 2017; Kulkarni et al., 2011; van den Heuvel et al., 2022; Walker & Diforio, 1997). The main findings suggest that patients with schizophrenia exhibit dysregulation of the hypothalamic-pituitary-adrenal (HPA) axis, characterized by chronic hypersecretion of cortisol, which has neurotoxic effects on memory, executive function, and emotional regulation. Additionally, symptom onset of women tends to occur later and with less severity than in men. Notably, symptom severity appears to decrease during pregnancy (Gogos et al., 2015; Kulkarni et al., 2001). These findings have led to the hypothesis that oestrogen exerts a protective effect in schizophrenia by enhancing NMDA receptor activity, thereby reducing excessive dopamine signalling through GABAergic inhibition (Gogos et al., 2015; Lindamer et al., 2004; van den Heuvel et al., 2022).

The last explanatory model discussed is the Neural Correlate Theory, also known as the Dysconnectivity Theory. The first scientist to introduce the concept of "dysconnectivity" in schizophrenia, referring to both structural and functional alterations, was Friston (1995). This model proposes that schizophrenia is characterized by deficits in neural connectivity that either accompany or precede neurotransmitter dysregulation. The hypothesis proposes that positive and negative symptoms results from disorganized neural networks that normally facilitate information integration within sensory and limbic regions (Alderson-Day et al., 2016; Carlsson et al., 2000; Eack et al., 2016; Zheng et al., 2023).

Dysconnectivity can be categorized into four types: (1) Functional dysconnectivity, referring to temporary disruptions in communication between two or more brain regions; (2) Structural dysconnectivity, characterized by abnormal connectivity due to alterations in neural fibre pathways; (3) Efferent dysconnectivity, involving dysfunctional projections from the cortex to the thalamus or cerebellum; and (4) Afferent dysconnectivity, referring to impaired connectivity from the thalamus to the cortex (Horwitz, 2003). In this context, schizophrenia is attributed to functional underconnectivity

Article
Cortica 2025. 4(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

between the dorsolateral prefrontal cortex and the temporal cortex, leading to working memory deficits; underconnectivity between the ventromedial prefrontal cortex and the amygdala, resulting in emotional dysregulation; and overconnectivity between primary sensory areas and the amygdala, contributing to hallucinations and delusions (Braff, 1993; Guo et al., 2019; McCutcheon et al., 2020; Mısır & Akay, 2023; Schimmelpfennig et al., 2023).

Structural dysconnectivity has also been extensively studied using MRI. Findings indicate a reduction in gray matter volume in the frontal and limbic regions (Dickey et al., 2002; Mancini-Marïe et al., 2018; Martinot & Mana, 2011; Rolland, 2014), along with a global decrease in white matter and an enlargement of ventricular volume in individuals with schizophrenia compared to control populations (Mancini-Marïe et al., 2018; Zhang et al., 2021). Additionally, Andreasen introduced the concept of hypofrontality, referring to reduced activity in the prefrontal cortex. This led to his hypothesis of cognitive dysmetria, which describes impaired information integration between the prefrontal cortex, thalamus, and cerebellum, further emphasizing the role of disrupted connectivity in schizophrenia (Andreasen et al., 1992, 1997).

This first part showed that positive and negative symptoms are due to disorganized neural networks normally responsible for information integration in sensorial and limbic areas (LeDoux, 1993, 2000; Menon & Uddin, 2010). Then it seems important to understand how these areas are working. In this way, the focus will be on emotional and memory components.

Emotion and memory

Emotions. Emotions are defined as complex responses involving physiological, behavioural and subjective changes by internal or external stimuli (Papez, 1937; Pessoa, 2017). Current knowledge on emotion says that emotions are a set of neural networks that allow feeling state and process in order to organize cognition and give information on current experience (Izard, 2010). One of the most influential models is that of Paul Ekman (1992) and proposes six main emotions: fear, joy, sadness, disgust, anger and surprise. His theory says that all these emotions are innate and linked with typical facial expressions more or less similar between all humans. Ekman shows this through intercultural studies where people from very different cultures recognize these emotions with facial expressions with very high accuracy.

Russell (1980) proposed a two-dimensional model of emotions, defining them along two axes: valence (pleasant to unpleasant) and arousal (low to high activation). In contrast, Feldman Barrett (2011) challenged Ekman's model, arguing that emotions are not innate but socially constructed. In this model, emotions arise from interoceptive signals interpreted through social and sensory cues, a

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

view supported by MRI studies showing that emotions engage distributed neural networks rather than localized brain regions (Kragel et al., 2021; Zeevi et al., 2022).

A last interesting model is that of Anderson and Adolphs (2014) who propose an internal and external model based on facial expressions like Ekman but also on internal states and neural network of emotions. The main hypothesis is that internal states are an optimal way to answer environmental challenges by adaptive behaviour.

Cerebral bases of emotions. The beginning of explanation based on neuroscience for emotion started in 1937 with James Papez who proposed the first circuit responsible for emotion (Papez, 1937). This circuit is composed of hypothalamus, pituitary glands, posterior cingulate, amygdala and hippocampus. This model was evaluated by MacLean who gave it the name of “Limbic system” and then, through the ages, was expanded by some researchers (Maclean, 1949, 1952) and fragmented by others (Filley, 2002; Heimer & Van Hoesen, 2006; Ursin & Kaada, 1960). Currently, some authors recommend talking about a network linked to an emotion in a specific task rather than talking about a general limbic system. An emotion is the result of several subcortical pathways interactions depending on the situation. However, even if it was proved that there is not one single pathway for all emotions, several of them share some similar area that will be described (Delavari et al., 2023; Malezieux et al., 2023; Imai et al., 2023; Pessoa, 2017).

Amygdala was historically seen as the centre of emotion and is probably the most studied structure in this domain, playing a key role in many emotional states (Amunts et al., 2005; Anticevic et al., 2012; Guo et al., 2023; Pessoa, 2017). It is located in the antero-medial part of the temporal lobe and is segmented in many nuclei. The amygdala is subdivided into 3 mains parts: Basolateral complex, Centromedial complex and cortical nuclei (Delavari et al., 2023). It is activated during detection of emotional valence, in particular in detection and response of danger and fear conditioning. This function was notably demonstrated in patient S.M., who, due to bilateral amygdala damage, was unable to recognize or experience fear despite intact perception of other emotional valence (Amaral & Adolphs, 2016). While fear conditioning is the most extensively studied function of the amygdala, it is also involved in processing anger and positive attraction (Pessoa, 2023).

Next, the prefrontal cortex is divided into two segments. The dorsolateral part is directly linked with emotion for its role in inhibition of emotional responses and cognitive regulation (Gangopadhyay et al., 2021; Zotev et al., 2013). The second part is the ventromedial that allows the evaluation between risk and reward and has projections in amygdala and hippocampus in order to regulate emotion arousal feeling (Eack et al., 2016; Guo et al., 2019).

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

Also linked with emotion, the cingulate gyrus is also divided into two parts. The posterior part is involved in autobiographical memory linked with emotion while the anterior part is involved in empathy and emotional regulation, mainly during negative emotion and is a part of salience network (González et al., 2023; Menon & Uddin, 2010; Veale et al., 2017).

To understand emotional disorder in schizophrenia, salience network must be explained. It's composed of anterior insula, anterior cingulate, and striatum (Molnar-Szakacs & Uddin, 2022; González et al., 2023; Itti & Koch, 2000; Veale et al., 2017). Salience is defined as the distinctiveness of a stimulus (Itti & Koch, 2000; Tholl et al., 2024), in this way this network has two roles: First, it filters and amplifies sensorial information, known as the ascendant treatment, that allows to determine if a stimulus is significant or not (Tholl et al., 2024). The second role is to support cognitive control and behaviour goal-directed, known as the descendant treatment (He et al., 2023). This network is also communicating with mnesic areas and has as effect on the improvement of emotional stimulus encoding in memory according to salience.

Finally, the insula is another key structure involved in emotion processing. It is located between frontal, temporal and parietal lobes, in the Sylvian fissure (Leroy, 2020; Menon & Uddin, 2010; Uddin et al., 2017). It's subdivided into two parts. The posterior part is involved in internal sensorial signals (e.g., anger, pain). The anterior part is involved in integration of affective signals (Molnar-Szakacs & Uddin, 2022). Studies showed that it plays a key role on subjective feeling of emotion arousal following studies of cases of insula lesions (Berntson et al., 2011). In this case with the same type of lesion, Calder et al (2000) showed insula activation during disgust with a patient who had difficulty identifying this emotion in facial expression.

Memory. The memory network is closely interconnected with the emotional network. A stimulus with an emotional valence is better encoded than a neutral stimulus (Lakis et al., 2011; Mancini-Marïe et al., 2018). To illustrate this, the example of psychologist Claparède, who worked with patients suffering from anterograde amnesia, can be taken (Boake, 2000). Although these patients were unable to remember previous encounters, Claparède conducted an experiment where he hid a pin in his hand, pricking the patient when they shook hands. On their next meeting, the patient, despite not recognizing him, hesitated to shake his hand, demonstrating an unconscious memory trace (Boake, 2000). This discovery laid the foundation for research into the distinction between explicit and implicit memory (Hampton et al., 2020; Schacter, 1987).

Explicit memory is the mechanism that allows to consciously remember information. Implicit memory, in the emotional context, is an unconscious association between a stimulus with a positive or negative event (Cohen & Eichenbaum, 1993; Hampton et al., 2020). Among the key figures in the

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

study of emotional memory, LeDoux conceptualized it as a distinct category of memory that relies on implicit learning and the storage of emotionally significant experiences (LeDoux, 1993, 2000). When an individual encounters an emotionally salient event, the salience network is activated to detect its relevance, with the insula and anterior cingulate cortex playing a central role in processing the stimulus. The amygdala then assesses emotional valence, encoding the experience in collaboration with the hippocampus (LeDoux, 1993). This process represents the implicit encoding of emotionally charged stimuli, which can later be integrated into executive memory systems, influencing future decision-making and behaviour.

Working memory is a complex system involving multiple brain regions, each contributing to different aspects of information processing, attention, and decision-making. The prefrontal cortex plays a key role in working memory, allowing the maintenance and retrieval of information while integrating it with emotional signals from the limbic system. It also directs attentional focus based on stimulus salience, ensuring goal-oriented behaviour (Pope et al., 2019; Rottschy et al., 2012). The hippocampus, meanwhile, is responsible for the temporary storage and consolidation of information, ultimately encoding it into long-term memory (Hasselmo et al., 2002; Morris et al., 2006).

The anterior cingulate cortex functions as the brain's error-monitoring system, detecting mistakes and adjusting behaviour accordingly. It also plays a crucial role in attentional control, facilitating communication between the prefrontal cortex and amygdala to regulate emotional responses (Fernandez-Ruiz et al., 2018; Molnar-Szakacs & Uddin, 2022). Lastly, the striatum is central to motivation and reward processing, assessing the effort-reward balance and guiding actions based on the emotional significance of a stimulus (Eack et al., 2016; Eshel et al., 2024; Pessoa, 2017).

Alteration in schizophrenia. Schizophrenia is associated with both emotional dysregulation and memory deficits, impacting the encoding, storage, and retrieval of emotionally significant experiences (Bourque et al., 2013; Lakis et al., 2011; Moore et al., 2013; Zheng et al., 2023). Research on emotional memory in schizophrenia is crucial for understanding the multifaceted nature of this disorder. Schizophrenia, characterized by severe cognitive and emotional disturbances, affects not only emotional perception and expression but also the encoding, storage, and retrieval of emotional memories (Catani et al., 2013; Lakis et al., 2011; LeDoux, 1993; Mancini-Marïe et al., 2018). This deficit is in part due to brain differences. For example, Lakis (2011) and Mancini-Marïe (2018), were interested in the structural differences between patients with schizophrenia and a control group during emotional memory tasks. In this task, researchers showed patients many emotionally charged images during fMRI. Those images come from IAPS battery (International Affective Picture System) (Lang et al., 1997) and was created with the aim to make people feel

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

positive and negative emotions with different types of saliences (very low, low, high and very high). As a result, it was found in structural aspects that people with schizophrenia had a lower gyrification index than control subjects in the frontal, temporal and parietal cortex. In functional aspect, it was found that, compared with healthy subjects, schizophrenic subjects had lower brain activity in the prefrontal and limbic areas during the retrieval of emotional stimuli with a negative valence.

Aim of this thesis

The main goal of this thesis is to understand, at a functional level, what are differences between patients with schizophrenia and a control group in a task that involves emotional memory. To answer this question, a functional analysis of functional Magnetic Resonance Imaging (fMRI) images from Montreal university study will be made. They used the same method as Lakis' study (2011) or Bourques' study (2013). After evaluating the severity of patients' symptoms with the PANSS (Positive and Negative Symptoms Scale) and BPRS **(**Brief Psychiatric Rating Scale), they made an fMRI analysis of brain activation during an emotional memory task. Their experiment was divided in two phases, a first where the patient looked at images passively and a second phase where the patient had to remember images seen in the first phaseThese data will be analysed in order to compare performance in emotional memory between groups and explore whether patients with schizophrenia show dysconnectivity in salience network, executive network and limbic areas in comparison with healthy control groups. This model will provide one independent variable, the group (Patient, Control), and 5 dependent variables: Performance at the emotional memory task, the PANSS score, BPRS score, connectivity involved in emotional condition, and connectivity involved in memory condition.

Hypothesis

First general hypothesis: Healthy control group will have a better emotional memory than patients with schizophrenia

First operational hypothesis: Based on Bourque's (2013) and Lakis' (2011) results, the healthy control group will remember more images from the first phase during the emotional memory task than patients with schizophrenia, reflecting a better emotional memory.

Second general hypothesis: there will be a correlation between symptoms and performance in patient groups.

Second operational hypothesis: Based on Balogh's (2015) and Gooding's (2004) results, it is hypothesized that a negative correlation between all subscales of PANSS and performance in emotional memory tasks, in particular for the negative subscale will be observed.

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

Third general hypothesis: in the same way as the second hypothesis, a significant correlation between symptoms and performance in the patient group but through the BPRS **(**Brief Psychiatric Rating Scale) is expected.

Third operational hypothesis: Based on Balogh's (2015) and Gooding's (2004) results, a negative correlation between all subscale of BPRS and performance in emotional memory tasks will be observed.

Fourth general hypothesis: In the first phase based on emotional circuit, dysconnectivity will mainly be seen in the link with the limbic area.

Fourth operational hypothesis: Based on the literature on emotional deficit in schizophrenia, there is a lot of chance to see underconnectivity in the prefrontal cortex, hippocampus and caudate nuclei and also overconnectivity in amygdala, insula and cingulate (Anticevic et al., 2012; Bourque et al., 2013; Eack et al., 2016; Lakis et al., 2011).

Fifth general hypothesis: In the second phase based on working memory circuits, dysconnectivity mainly in links with mnesic areas will be seen.

Fifth operational hypothesis: Based on the literature on memory deficits in schizophrenia, there is a lot of chance to see underconnectivity in dorsolateral, ventromedial and ventrolateral prefrontal cortex, posterior parietal cortex, and anterior cingulate and also overconnectivity in hippocampus (Kapur, 2003; Speechley et al., 2010).

Method

Participants

Composition. For this experiment, 70 participants (34 women and 36 men) were recruited for a study at the University of Montreal (Lakis et al., 2011). 4 participants were removed from the original study of Lakis et al. (2011) due to problems with the quality of the data. Among them, 35 individuals were diagnosed with schizophrenia (17 women and 18 men), while 35 were healthy controls (17 women and 18 men). The control group was selected through clinical interviews based on the Structured Clinical Interview for DSM-III-R (SCID) (Spitzer et al., 1992). All patients were reassessed by psychiatrists affiliated with the study, according to DSM-IV guidelines to exclude schizoaffective and schizophreniform disorders.

Symptom severity was assessed using the Brief Psychiatric Rating Scale (BPRS) (Overall & Gorham, 1988) and the Positive and Negative Syndrome Scale (PANSS) (Kay et al., 1987). The

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

onset of the disorder was determined based on the first psychiatric consultation. All patients were stabilized with atypical antipsychotics, including clozapine (*n* = 19, mean dosage = 452.63 mg ± 77.23 mg), olanzapine (*n* = 12, mean dosage = 14.58 mg ± 5.4 mg), risperidone (n = 11, mean dosage = 3.73 mg ± 1.67 mg), and quetiapine (*n* = 7, mean dosage = 585.71 mg ± 238.85 mg).

Patients were stabilized for several reasons. Firstly, from an ethical perspective, stabilization ensures greater safety for both patients and staff by preventing potential decompensation during the experiment, thus maintaining a secure environment. Secondly, reduced symptom fluctuation facilitates test performance and minimizes participants drop out due to misunderstanding or non-compliance with the experimental protocol. Finally, patient stabilization enhances ecological validity, as in clinical practice. Individuals experiencing severe episodes of schizophrenia are typically stabilized to support their social reintegration.

A written informed consent was obtained from all participants in accordance with the Declaration of Helsinki prior to their participation. Additionally, the capacity of patients with schizophrenia to provide informed consent was assessed following the recommendations of the Psychiatric Association of Canada. The study was approved by the Research Ethics Committee of the Fernand-Seguin Centre at Louis-H. Lafontaine Hospital and by the Quebec Neuroimaging Research Group.

Healthy controls had no history of psychiatric or neurological disorders and were not taking any medication. Furthermore, fMRI scans did not reveal any structural or functional abnormalities in these groups. Participants' characteristics are presented in Table 1.

Table 1
Descriptive Data of the Sample.

Group	Control (*n* = 35)		Patient (*n* = 35)	
	M	*SD*	*M*	*SD*
Women (*n* = 34)	17	-	17	-
Men (*n* = 36)	18	-	18	-
Women evolution time of disorder in year	-	-	8,65	7,28
Men evolution time of disorder in year	-	-	12,89	7,83
Female means age in years	33,18	7,72	31,63	6,51
Male means age in years	32,11	7,77	32,39	7,69

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

Female PANSS positive	-	-	19,23	8.33
Male PANSS positive	-	-	17,61	5.27
Female PANSS negative	-	-	21,41	8.68
Male PANSS negative	-	-	19,5	5.72
Female PANSS general	-	-	42,58	14.2
Male PANSS general	-	-	38,27	5.52
Female BPRS for schizophrenia	-	-	14.90	8.47
Male BPRS for schizophrenia	-	-	21,77	6.74
Female General BPRS	-	-	25.54	12.7
Male General BPRS	-	-	34.33	7.60

Note. PANSS positive is an average score obtained concerning positive symptoms. PANSS negative represents the average score obtained concerning negative symptoms. PANSS general represents the average score obtained in the entire test. Brief Psychiatric Rating Scale (General BPRS) is an average score obtained concerning psychiatric symptoms. BPRS for schizophrenia is specifically for symptoms that concern schizophrenia.

Exclusion criteria. Exclusion criteria included age outside the 18–45 years range, a neurological disorder or a history of psychiatric illness, alcohol or drug use disorder, uncorrected visual impairment, non-compliance with the experimental protocol, or general contraindications for fMRI studies. Contraindications included the presence of a cardiac pacemaker, aneurysm clips, metal prostheses, artificial heart valves, metal implants in the body or eyes, certain types of dental work, and claustrophobia.

Material

The following tools and materials were required for the execution of this study, organized according to its different stages.

For recruitment. First, the DSM-IV (Diagnostic and Statistical Manual of Mental Disorders, 4th edition) was used to determine the symptoms of which recruitment was based and to confirm the diagnosis of schizophrenia (American Psychiatric Association, 1994).

The Positive and Negative Syndrome Scale (PANSS) (Kay et al., 1987) is a tool used to assess both positive and negative symptoms of schizophrenia, allowing for the quantification of symptom severity. In this study, the PANSS (Kay et al., 1987) was employed to quantify symptom severity and examine the effect of symptoms on emotional memory performance.

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

The Brief Psychiatric Rating Scale (BPRS) (Overall & Gorham, 1988) provides a rapid assessment of psychiatric symptom severity in schizophrenia. It evaluates positive symptoms (hallucinations and delusions), negative symptoms (emotional blunting and poverty of speech), affective symptoms (anxiety and depression), and cognitive symptoms (confusion and disorganized speech).

The Structured Clinical Interview for DSM-IV (SCID) (Spitzer et al., 1992) is a semi-structured clinical interview designed to diagnose mental disorders according to DSM-IV criteria. In this study, it was used to assess healthy control participants and ensure they did not suffer from any psychiatric or neurological disorders.

Additional tests were administered during recruitment to evaluate other participants' characteristics. Although these tests are not directly used in this thesis, they are briefly mentioned here. The Edinburgh Handedness Inventory (Oldfield, 1971) is a questionnaire used to assess laterality. In this study, it was employed to explore whether laterality influences brain structure similarly in both groups. The National Occupational Classification (NOC) (Government of Canada, 2024) is a Canadian classification system for professions. Here, it was used to assess socioeconomic status to control for potential environmental biases. Finally, the Bem Sex Role Inventory (BSRI) (Bem, 1974) was used to evaluate conformity to gender roles based on stereotypical masculine and feminine traits.

For the experiment. For the experiment, researchers used functional magnetic resonance imaging (fMRI), a neuroimaging technique that measures blood oxygen level-dependent (BOLD) signal fluctuations in local brain areas. These variations correlate with brain activation, allowing for the observation of functional differences between healthy controls and individuals with schizophrenia.

In this study, fMRI data were acquired using a Siemens TRIO 3.0 Tesla scanner. The functional acquisition settings were as follows: repetition time (TR) = 3000 ms, echo time (TE) = 30 ms, flip angle = 90°, matrix size = 64 × 64 voxels. Structural acquisition was performed using the following parameters: three-dimensional spoiled gradient echo sequence; 28 slices; slice thickness = 5 mm; TR = 22 ms; TE = 4 ms; flip angle = 30°; matrix size = 256 × 256 voxels.

During fMRI scanning, additional equipment was used to facilitate communication and stimulus presentation. A response button allowed participants to communicate with the researchers, and a display system was used to present International Affective Picture System (IAPS) images during the fMRI session.

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

To incorporate emotional stimuli into this experiment, researchers chose to use the International Affective Picture System (IAPS) (Lang et al., 1997). The IAPS is a standardized collection of more than 1,000 images, designed to elicit specific emotional responses in participants. These images have been evaluated for their valence, which can be positive, negative, or neutral, and they align with the six basic emotions described in Ekman's theory (Ekman, 1992). The use of IAPS images allows for standardized testing of emotional influences on functional brain activation, ensuring international validity (Champagne et al., 2012).

For data analysis. The last tool used for functional analysis was CONN Toolbox 21.a (Whitfield-Gabrieli & Nieto-Castanon, 2012). CONN is an open-source software package based on Statistical Parametric Mapping (SPM), designed for the visualization and analysis of functional connectivity from fMRI sequences, either during a specific task or in a resting-state paradigm. The primary objective of CONN is to facilitate access to this type of analysis and enhance data manipulation capabilities. To achieve this, the software offers a wide range of features across all stages of the analysis process, including:

Data importation: Automatic standardization of data set format, many options for importing raw data.

Pretreatment pipeline: reproducible pipeline which includes susceptibility distortion correction, realignment of movements, slices timing correction, outliers' identification, and segmentation according to the kind of tissue.

Denoising: include artefact cleaning, movement regression, anatomical compcor and bande-pass filtering.

Quality control: Include outlier identification, functional connectivity histogram, Correlation analyses between functional connectivity and quality control measurements.

Connectivity analyses: Many connectivity analyses displayable, it includes Seed-Based Correlations (SBC), ROI-to-ROI Connectivity Matrices (RRC), Theoretical Graph Analysis, Generalized Psycho-Physiological Interaction (gPPI) models, Independent Component Analysis (ICA and masked ICA), Amplitude of Low Frequency Fluctuations (ALFF), Intrinsic and Global Connectivity (ICC & GCOR), Local correlations (LCOR), Inter-Hemispheric Correlations (IHC), Multivariate Analysis of Functional Connectivity Models (fc-MVPA) and Dynamic Connectivity Analyses (dyn-ICA and sliding windows).

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

Group-level analysis: It includes ANOVA, multiple regression, repeated measure and mix level intra- and inter-subjects. The group-level analysis also allows the control of false positives at group level using parametric techniques and nonparametric.

Interface: Conn is based on SPM with its own user-friendly interface but can also be controlled by script in the matlab interface (Nieto-Castanon, 2020; Nieto-Castanon & Whitfield-Gabrieli, 2022.; Whitfield-Gabrieli & Nieto-Castanon, 2012).

For the analysis of these data, Conn Toolbox was configured with 2 sessions and a repetition time of 3 seconds. Data from each participant was uploaded and a corrupted file was filtered.

Although the area of interest was clearly identified, the analysis was set in order to be sure that any important area is not forgotten. Then it was calibrated on grey matter, white matter, networks and atlases. Experiment conditions were defined as two sessions, “emotion” in first and “memory” in second. The temporal aspect was not set because the information provided with these data was not clear. To avoid the risk of creating false results, this part of the experiment was set aside.

Next, the preprocessing and denoising of data was performed. This stage was composed of many steps: Structural image realignment of distortion interactions, slice timing correction, outliers detection, normalization of MNI-space, smoothing. Functional data was realigned with realign & unwarp SPM method. Time misalignment between slices was corrected using SPM's STC algorithm with time interpolation. Aberrant scans were identified by ART, based on the displacement in excess of 0.9 mm or global BOLD signal variations in excess of 5 standard deviations. Data were normalized to MNI space and segmented into gray matter, white matter and CSF, then smoothed with an 8 mm FWHM Gaussian kernel.

Then denoising included regression of confounding effects, the band-pass filtering of BOLD time series between 0.008 Hz and 0.09 Hz and an estimation of CompCor noise components taking into account BOLD averages and orthogonal principal components. The effective degrees of freedom of the BOLD signal after denoising were estimated at between 81.2 and 240.1 (mean 211) for all participants (Nieto-Castanon, 2020; Nieto-Castanon & Whitfield-Gabrieli, 2022; Whitfield-Gabrieli & Nieto-Castanon, 2012).

The next stage was the first level analysis (SBC 01). It started with an estimation of seed-based connectivity map and ROI-to-ROI connectivity matrix to characterize functional connectivity patterns. 164 HPC-ICA networks and ROIs from the Harvard-Oxford atlas were identified. The strength of functional connectivity was represented by Fisher-transformed bivariate correlation coefficients. These coefficients were derived from a weighted generalized linear model (weighted-GLM), defined

Article
Cortica 2025. 4(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

separately for each pair of regions (seed and target). This model was used to model the association between BOLD signal time series from different brain regions. Individual scans were weighted using a boxcar signal characterizing each task or experimental condition, convolved with a canonical SPM hemodynamic response function and then rectified.

For group-level analyses, a GLM (generalized linear model) was used. For each voxel a GLM was estimated with the connectivity measure of the first level analysis as dependent variable, and the group of the participant (control/patient) as independent variable. Statistical hypotheses were evaluated using multivariate parametric statistics with between-participant randomization and a sample covariance estimation from multiple measures. Inferences were made at cluster level (groups of contiguous voxels) and were based on parametric statistics derived from Gaussian random field theory. Results were filtered using a combination of thresholds: $p < 0.001$ for cluster formation at voxel level and $p < 0.05$ for FDR to correct the cluster size threshold and control for false positives at family level (familywise error) (Nieto-Castanon, 2020; Nieto-Castanon & Whitfield-Gabrieli, 2022; Whitfield-Gabrieli & Nieto-Castanon, 2012).

To conclude the second-level analysis, and to identify differences in functional connectivity between the two populations during emotional and memory-related conditions, the “ROI-to-ROI > Individual ROI: Group Analysis” function in CONN Toolbox was employed. This function enables the identification of all brain regions, exhibiting significant differences between the two groups at $p < .05$.

Following this step, filtering process based on the regions of interest was applied. Given that the conditions and tasks involve the executive memory circuit, salience network, and limbic areas, and in accordance with the literature reviewed in the introduction, the analysis were focused on the following regions of interest (ROIs): prefrontal cortex, posterior parietal cortex, hippocampus, amygdala, insula, anterior cingulate, striatum and caudate nuclei. It is possible that others' secondary areas are found and if it presents a link with executive memory, emotion or salience network they will be mentioned in the results.

For behavioural results. All demographic and behavioural results were stocked on Excel files, and a part was analysed with the Statistical Package for the Social Sciences (SPSS) to calculate accuracy rate of image recognition. All following results in this thesis were made from RStudio 2024.04.2 Build 764. For behavioural results, an independent sample T-test and many bivariate correlations were conducted. Several packages were used to allow analysis: car and data.table for T-test, and stats and Hmisc for bivariate correlation.

Article
Cortica 2025. 4(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

Experimental procedure

Task composition. Participants were instructed to observe multiple blocks of 10 images from the International Affective Picture System (IAPS) battery across two sessions. Each image was displayed for 3 seconds, followed by a transitional white screen with a central fixation cross appearing for an average duration of 1.75 seconds (ranging from 1 to 2.5 seconds). The inter-stimulus interval had a mean duration of 4.75 seconds.

The selection of images was based on their normative evaluation in terms of stimulus valence, stimulus salience, and content balance (e.g., whether the image depicted an animal, a person, or a landscape). Images were categorized into five groups according to their emotional valence and salience: High Arousal with negative content (HA-), Low Arousal with negative content (LA-), Neutral (NTR), Low arousal with positive content (LA+) and High Arousal with positive content (HA+). Each block contained only one type of emotional valence and salience. Each emotionally charged block was presented twice, whereas neutral blocks were presented four times. Consequently, each session comprised 12 blocks, all separated by a 16-second inter-block interval. However, the exact order in which the blocks were presented was not recorded.

It is important to note that image salience and valence conditions were not analysed in this thesis. The University of Montreal, which conducted this experiment, treated these factors as independent variables, while participant connectivity as a function of salience was considered the dependent variable. The lack of information regarding block order prevents from analysing these conditions.

Experiment conducting. In the experimental procedure, all participants began with the "emotional session". During this session, they passively observed images from the International Affective Picture System (IAPS) while inside the fMRI scanner. After completing all 12 blocks of the first session, participants waited for 15 minutes to ensure a clear separation between the encoding phase and the subsequent "memory session". To maintain participant attention and engagement during encoding, an attention task was incorporated during the waiting period. Participants were instructed to press a button whenever they saw a face among the presented images. This task was designed to help sustain focus and concentration throughout the waiting period. Importantly, participants were not informed that they would be required to memorize the images, ensuring that the memory assessment in the second session was incidental rather than intentional.

After the 15-minute waiting period, the second session started. As in the first session, 12 blocks of images were presented to participants. However, in this phase, 50% of the images were replaced with new images from the IAPS, which had not been seen by the participants before. Participants were required to press the appropriate button to indicate whether they recognized an image from the

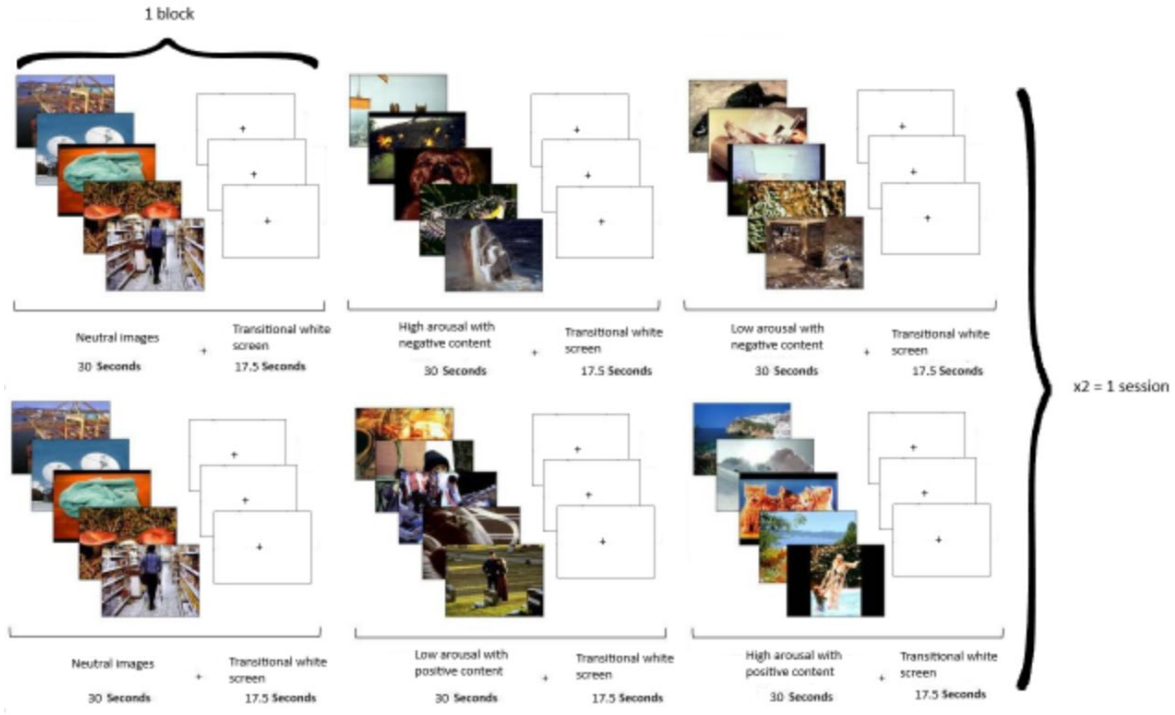
Cortica
www.revue-cortica.net | ISSN : 2813-1940
Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

previous session or believed it was a new one. This constituted the emotional memory task. Immediately after completing the 12 blocks, participants were asked to rate the emotional intensity they experienced, using a scale from 0 (total absence of emotion) to 8 (strongest emotion of their lives).

Below, Figures 1 and 2 provide a graphical representation to facilitate understanding.

Figure 1

Experimental Design of Image Exposure Sessions.

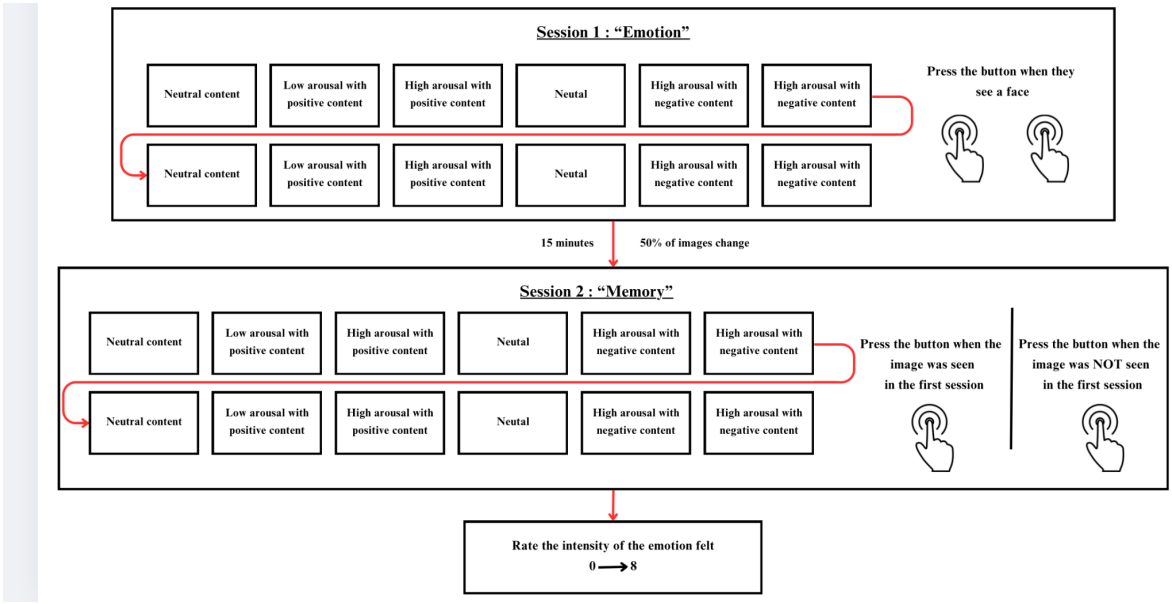


Note. This schematic represents the sequence of image blocks used during the experiment. The order of blocks shown is for illustrative purposes only and does not reflect the actual sequence.

Cortica
www.revue-cortica.net | ISSN : 2813-1940
Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

Figure 2

Schematic View of Experiment.



Note. Here is a schematic view of the experiment. It's important to note that block order is not representative of reality. Neutral refers to images without emotional content; Low or High arousal indicates intensity of emotions; Positive or Negative refers to the valence of emotion targeted.

Results

Behavioural results

Accuracy recognition. With the aim of observing the correct response rate difference between healthy control group and patients, an independent group T-test was conducted with the hypothesis H0 whereby there is no difference between the mean of the two groups and H1 (greater) whereby the control group has a better means than patient groups (Table 2). During the emotional memory task, the healthy control group were significantly better at memorizing images than the patient with a difference of 16.38% in the sample.

Article
Cortica 2025. 4(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

Table 2

T-test of Mean Percentage of Correct Responses for Control and Patient Groups in the Emotional Memory Task.

Group	*M*	*SD*	*p*-value
Control	88.25	14.52	$p < .001$
Patient	71.87	15.74	$p < .001$

Note. The p-value concerns the significance of the difference with the hypothesis (H1) "greater", whereby the control group will have better scores than patients. *M* = Mean; *SD* = Standard Deviation.

PANSS (Kay et al., 1987) correlation. With the aim of observing if schizophrenia symptoms have a significant impact on emotional memory task score, a Pearson correlation test was conducted between each PANSS (Kay et al., 1987) subscale and the percentage of correct responses of participants (Table 3). Table 3 shows that there is no significant correlation between PANSS and correct response rate in the patient sample.

Table 3

Pearson Correlation Between Correct Response Rate and PANSS (Kay et al., 1987) *Score Depending on Subscales.*

Sub Scales	Correlation factor (*r*)	*t*	*p*-value
PANSS Positive	-0.00	-0.01	$p = .99$
PANSS Negative	-0.17	-0.97	$p = .33$
PANSS General	-0.04	-0.04	$p = .78$

Note. PANSS = Positive and Negative Syndrome Scale; *r* = Pearson's correlation coefficient; *t* = *t*-value.

BPRS (Overall & Gorham, 1988) correlation. Also, with the aim of observing if schizophrenia symptoms have a significant impact on emotional memory task score, a Pearson correlation test was conducted between BPRS (Overall & Gorham, 1988), specific items linked with schizophrenia in BPRS and the percentage of correct responses of participants (Table 4). No significant correlation was found between BPRS and correct response rate in the sample.

Table 4

Pearson Correlation Between Correct Response Rate and BPRS (Overall & Gorham, 1988) *Score Depending on Subscales.*

Sub Scales	Correlation factor (*r*)	*t*	*p*-value
BPRS - Schizophrenia items	-0.20	-1.07	$p = .29$
BPRS - General	-0.16	-0.85	$p = .40$

Note. BPRS = Brief Psychiatric Rating Scale; *r* = Pearson's correlation coefficient; *t* = *t*-value.

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

Session 1: Emotion Phase - Functional Connectivity Analysis. It's important to note that not all fMRI data of the 70 participants were analysed. Some of them did not pass the quality control and some files were corrupted. Then, 61 participant's data were included, more detail in table 5.

Table 5

Population Used for Functional Analysis.

Group	Female	Male	Total
Control group	16	16	32
Patient group	16	13	29
Total	32	29	61

Note. Female and Male columns indicate the number of participants per gender in each group. The total column shows the sum of participants for each group.

Underconnectivity in Schizophrenia. The results of brain regions exhibiting underconnectivity in the schizophrenia group compared to the control group during the emotion phase (i.e. participants had to passively observe blocks of images) are reported in Table 6. The results of Table 6 indicate four regions exhibiting underconnectivity in relation to the previously defined regions of interest mentioned in the introduction. It concerns the left and right frontal orbital gyrus, subcallosal cortex, and left part of the insula.

Table 6

Brain Underconnectivity in Schizophrenia During Emotion Phase.

Area	Beta Coefficient	*t*(59)	*p*-FDR corrected
Forb Left			
networks.Salience.AInsula (L)	-0.16	-3.91	$p < .05$
atlas.HG r (Heschl's Gyrus R)	-0.12	-3.70	$p < .05$
Forb Right			
networks.Salience.AInsula (L)	-0.20	-4.38	$p < .05$
atlas.IC l (Insular Cortex L)	-0.14	-3.26	$p < .05$
atlas.HG l (Heschl's Gyrus L)	-0.11	-3.05	$p < .05$
Subcallosal Cortex			
atlas.CO r (Central Opercular Cortex R)	-0.15	-3.84	$p < .05$

Article
Cortica 2025. 4(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

atlas.CO l (Central Opercular Cortex L)	-0.12	-3.70	$p < .05$
atlas.aSMG l (Supramarginal Gyrus, anterior L)	-0.13	-3.70	$p < .05$
atlas.aSMG r (Supramarginal Gyrus, anterior R)	-0.13	-3.67	$p < .05$
networks.Salience.SMG (L)	-0.13	-3.49	$p < .05$
Left Insula (Salience Network)			
atlas.Forb r (Frontal Orbital Cortex R)	-0.20	-4.38	$p < .05$
atlas.Forb l (Frontal Orbital Cortex L)	-0.16	-3.91	$p < .05$

Note. Bold lines are the starting point area and below are areas with which it is linked. Beta = Standardized Coefficient; *t* = *t*-value; *p*-FDR = False Discovery Rate corrected *p*-value.

Frontal Orbital Gyrus (Forb L). Several instances of underconnectivity involving the left frontal orbital gyrus (Forb L) were identified, with beta coefficients ranging from -0.12 to -0.16 and *t*-values between -3.70 and -3.91. These results suggest a small effect size for the beta coefficient, but a moderate significant effect based on *t*-values. The observed underconnectivity of Forb L includes connections with the left insula within the salience network as well as the right Heschl's gyrus.

Frontal Orbital Gyrus (Forb R). Secondly, three instances of underconnectivity involving the right frontal orbital gyrus (Forb R) were identified, with beta coefficients ranging from -0.11 to -0.20 and *t*-values between -3.05 and -4.38. These findings indicate a small effect size for the beta coefficient, but a moderate to strong significant effect for the *t*-values. The underconnectivity of Forb R includes connections with the left insular cortex within the salience network, and the left Heschl's gyrus.

Subcallosal Cortex. Thirdly, five instances of underconnectivity involving the subcallosal cortex were identified, with beta coefficients ranging from -0.12 to -0.15 and *t*-values between -3.49 and -3.84. These findings indicate a small effect size for the beta coefficient and a moderate significant effect for the *t*-values. The observed underconnectivity of the subcallosal cortex includes connections with the left and right central opercular cortex, the left and right anterior supramarginal gyrus, and the left supramarginal salience network.

Left Insula (Salience Network). Finally, two instances of underconnectivity involving the left insula within the salience network were identified, with beta coefficients ranging from -0.16 to -0.20

Article
Cortica 2025. 4(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

and *t*-values between -3.21 and -4.38. These findings suggest a small to moderate effect size based on the beta coefficient and a moderate to strong significant effect based on the *t*-values. The observed underconnectivity of the left insula salience network includes connections with Forb L and Forb R.

Overconnectivity in Schizophrenia. The results of brain regions exhibiting overconnectivity in the schizophrenia group compared to the control group during the emotion phase are reported in Table 7. Table 7 presents five regions of overconnectivity in relation to the previously defined regions of interest mentioned in the introduction. These regions include the Forb R, subcallosal cortex, left supramarginal salience network, right visual lateral network, and right occipital fusiform gyrus.

Table 7

Brain Overconnectivity in Schizophrenia During Emotion Phase.

Area	Beta Coefficient	*t*(59)	*p*-FDR corrected
Forb R			
networks.Visual.Lateral (R)	0.15	4.00	$p < .05$
atlas.iLOC r (Lateral Occipital Cortex, inf R)	0.14	3.61	$p < .05$
atlas.OFusG l (Occipital Fusiform Gyrus L)	0.11	3.39	$p < .05$
atlas.TOFusC r (Temporal Occipital Fusiform R)	0.13	3.31	$p < .05$
networks.Visual.Lateral (L)	0.10	3.19	$p < .05$
atlas.OFusG r (Occipital Fusiform Gyrus R)	0.11	3.01	$p < .05$
Subcallosal Cortex			
atlas.LG r (Lingual Gyrus L)	0.12	4.03	$p < .05$
atlas.LG l (Lingual Gyrus L)	0.13	3.83	$p < .05$
atlas.OFusG l (Occipital Fusiform Gyrus L)	0.14	3.59	$p < .05$
atlas.OFusG r (Occipital Fusiform Gyrus R)	0.14	3.47	$p < .05$
atlas.ICC r (Intra Calcarine Cortex R)	0.10	3.30	$p < .05$
networks.Visual.Medial	0.10	3.29	$p < .05$
SMG L (Salience Network)			

Article
Cortica 2025. 4(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

atlas.OFusG r (Occipital Fusiform Gyrus Right)	0.14	3.93	$p < .05$
Visual Lateral Network R			
atlas.pSMG l (Supramarginal Gyrus, posterior L)	0.18	4.27	$p < .05$
atlas.Forb r (Frontal Orbital Cortex R)	0.15	4.00	$p < .05$
Occipital Fusiform Gyrus R			
networks.Salience.SMG (L)	0.14	3.93	$p < .05$

Note. Bold lines are the starting point area and below are areas with which it is linked. Beta = Standardized Coefficient; *t* = *t*-value; *p*-FDR = False Discovery Rate corrected p-value.

Right Frontal Orbital Gyrus (Forb R). *Six* instances of overconnectivity involving the Forb R were identified, with beta coefficients ranging from 0.10 to 0.15 and *t*-values between 3.01 and 4.00. These results suggest a small effect size for the beta coefficient but a moderate to strong significant effect based on *t*-values. The observed overconnectivity of Forb R includes connections with the left and right visual lateral network, the right inferior lateral occipital cortex, and the left and right occipital fusiform gyrus.

Subcallosal Cortex. Six instances of overconnectivity involving the subcallosal cortex were identified, with beta coefficients ranging from 0.10 to 0.14 and *t*-values between 3.29 and 4.03. These findings indicate a small effect size for the beta coefficient but a moderate to strong significant effect for the *t*-values. The observed overconnectivity of the subcallosal cortex includes connections with the left and right lingual gyrus, the left and right occipital fusiform gyrus, the right intra calcarine cortex, and the medial visual network.

Left Supramarginal (Salience Network). Only one instance of overconnectivity was observed involving the left supramarginal salience network, specifically with the right occipital fusiform gyrus. The beta coefficient was 0.14, with a *t*-value of 3.93. This result suggests a small effect size for the beta coefficient, but a moderate significant effect based on *t*-values.

Right Visual Lateral Network. Two instances of overconnectivity involving the right visual lateral network were identified, with beta coefficients ranging from 0.15 to 0.18 and *t*-values between 4.00 and 4.24. These findings suggest a small effect size for the beta coefficient, but a strong significant effect based on *t*-values. The observed overconnectivity of the right visual lateral network includes connections with the left supramarginal gyrus and the right frontal orbital cortex.

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

Right Occipital Fusiform Gyrus. The final instance of overconnectivity was observed between the right occipital fusiform gyrus and the left supramarginal salience network. This connection showed a small to moderate effect size, with Beta = 0.14, *t*(59) = 3.93.

Session 2: Memory Phase - Functional Connectivity Analysis

Underconnectivity in Schizophrenia.The results of brain regions exhibiting underconnectivity in the schizophrenia group compared to the control group during the memory phase (i.e. participants had to remember if the image in front of them was already seen in the first phase or not) are reported in Table 8. Table 8 presents five regions of underconnectivity in relation to the previously defined regions of interest mentioned in the introduction. These regions include the left superior frontal gyrus, right inferior temporo-occipital gyrus, subcallosal cortex and left temporale and polare planum.

Table 8

Brain Underconnectivity in Schizophrenia During Memory Phase.

Area	Beta Coefficient	*t*(59)	*p*-FDR corrected
(Superior Frontal Gyrus L)			
atlas.HG l (Heschl's Gyrus L)	-0.17	-4.26	$p < .05$
Inferior Temporal Gyrus R temporo-occipital part)			
atlas.FO r (Frontal Operculum Cortex R)	-0.16	-3.97	$p < .05$
atlas.HG r (Heschl's Gyrus R)	-0.21	-4.53	$p < .05$
atlas.SubCalC (Subcallosal Cortex)	-0.14	-3.83	$p < .05$
atlas.MedFC (Frontal Medial Cortex)	-0.15	-3.42	$p < .05$
Subcallosal Cortex			
atlas.PT l (Planum Temporale L)	-0.17	-4.52	$p < .05$
atlas.PO r (Parietal Operculum Cortex R)	-0.15	-4.00	$p < .05$
atlas.PT r (Planum Temporale R)	-0.14	-3.72	$p < .05$
atlas.aSMG l (Supramarginal Gyrus L)	-0.13	-3.53	$p < .05$
atlas.HG l (Heschl's Gyrus L)	-0.11	-3.19	$p < .05$
networks.Salience.SMG R	-0.12	-3.11	$p < .05$

Article
Cortica 2025. 4(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

atlas.PP l (Planum Polare L)	-0.17	-4.31	$p < .05$
atlas.HG r (Heschl's Gyrus R)	-0.13	-3.93	$p < .05$

Area	Beta Coefficient	*t*(59)	*p*-FDR corrected
Planum Polare L			
atlas.AC (Cingulate Gyrus, anterior division)	-0.17	-4.31	$p < .05$
Planum Temporale L			
atlas.SubCalC (Subcallosal Cortex)	-0.17	-4.52	$p < .05$
atlas.PC (Cingulate Gyrus, posterior division)	-0.14	-4.03	$p < .05$

Note. Bold lines are the starting point area and below are areas with which it is linked. Beta = Standardized Coefficient; *t* = *t*-value; *p*-FDR = False Discovery Rate corrected p-value.

Left Superior Frontal Gyrus. The left superior frontal gyrus showed underconnectivity with the left Heschl's gyrus, with a small effect size (β = -0.17) and a significant effect, $t(59) = -4.26$, $p < .05$.

Right Inferior Temporal Gyrus (Temporo-Occipital Part). The right inferior temporal gyrus (temporo-occipital part) exhibited underconnectivity with four regions, with beta coefficients ranging from -0.14 to -0.21 and *t*-values between -3.42 and -4.53. These findings indicate a small to moderate effect size and a moderate to strong significant effect. The observed underconnectivity includes connections with the right Heschl's gyrus, right frontal operculum cortex, and frontal medial cortex.

Subcallosal Cortex. The subcallosal cortex showed eight instances of underconnectivity, with beta coefficients ranging from -0.11 to -0.17 and *t*-values between -3.11 and -4.52. These results suggest a small effect size and a moderate to strong significant effect. The observed underconnectivity includes connections with the left and right temporal planum, left and right Heschl's gyrus, right parietal operculum, left planum polare, left supramarginal gyrus, and the right supramarginal salience network.

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

Left Planum Polare. A single instance of underconnectivity was observed between the left planum polare and the anterior cingulate gyrus, with a beta coefficient of -0.17 and a *t*-value of -4.31. This result suggests a small effect size based on the beta coefficient and a moderate significant effect based on the *t*-value.

Left Temporal Planum. Finally, we identified two instances of underconnectivity involving the left temporal planum, with beta coefficients ranging from -0.14 to -0.17 and *t*-values between -4.03 and -4.52. These results suggest a small effect size based on beta coefficients and a strong significant effect based on *t*-values. The observed underconnectivity includes connections with the subcallosal cortex and the posterior cingulate cortex.

Overconnectivity in Schizophrenia. The results of brain regions exhibiting overconnectivity in the schizophrenia group compared to the control group during the memory phase are reported in Table 9. Table 9 presents three regions of overconnectivity in relation to the previously defined regions of interest mentioned in the introduction. These regions include the left superior frontal gyrus, the medial frontal cortex and the right occipital pole.

Table 9

Brain Overconnectivity in Schizophrenia During Memory Phase.

Area	Beta Coefficient	*t*(59)	*p*-FDR corrected
atlas.SFG l (Superior Frontal Gyrus Left)			
atlas.OP r (Occipital Pole Right)	0.15	4.02	$p < .05$
atlas.MedFC (Frontal Medial Cortex)			
atlas.toITG r (Inferior Temporal Gyrus, Right)	0.13	3.47	$p < .05$
atlas.OP r (Occipital Pole Right)			
atlas.SFG l (Superior Frontal Gyrus Left)	0.15	4.02	$p < .05$

Note. Bold lines are the starting point area and below are areas with which it is linked. Beta = Standardized Coefficient; *t* = *t*-value; *p*-FDR = False Discovery Rate corrected p-value.

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

Left Superior Frontal Gyrus – Right Occipital Pole. *The* first overconnectivity was observed between the left superior frontal gyrus and the right occipital pole, with a small effect size (β = 0.15) and a strong significant effect, *t*(59) = 4.02.

Medial Frontal Cortex – Right Inferior Temporal Gyrus. The second overconnectivity was identified between the medial frontal cortex and the right inferior temporal gyrus, with a small effect size (β = 0.13) and a moderate significant effect, *t*(59) = 3.47.

Right Occipital Pole – Left Superior Frontal Gyrus. Finally, another overconnectivity was detected between the right occipital pole and the left superior frontal gyrus, with a small effect size (β = 0.15) and a strong significant effect, *t*(59) = 4.02.

Discussion

Behavioural results

Results analysis. Three key findings emerged from the behavioural analyses. Firstly, in accordance with previous literature (Bourque et al., 2013; Lakis et al., 2011), healthy controls exhibited significantly better performance on the emotional memory task compared to patients with schizophrenia. Those findings seems to indicate a deficit in memory and/or emotion-related circuits in schizophrenia and supports the first hypothesis (H1), which postulated that healthy controls would demonstrate superior recall performance of emotional images presented during the initial encoding phase.

Secondly, symptom severity, as measured by the PANSS (Kay et al., 1987), was tested for correlation with performance on the emotional memory task (Table 3). Contrary to the second hypothesis (H2), which predicted a correlation between PANSS (Kay et al., 1987) subscale scores and task performance, no significant correlation was found. Thus, H2 was not supported.

Thirdly, potential correlations between emotional memory performance and symptom severity assessed by the BPRS (Overall & Gorham, 1988) (Table 4) were explored as third hypothesis (H3). Similarly, with the PANSS (Kay et al., 1987) results, analyses revealed no significant correlation. Consequently, the third hypothesis, which predicted a negative correlation between BPRS (Overall & Gorham, 1988) subscale scores and memory performance, was not supported.

These findings suggest that symptom severity, as evaluated by clinical scales such as BPRS or PANSS (Kay et al., 1987), may not directly explain emotional memory deficits observed in schizophrenia.

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

Limitations. The relationship between symptom severity, as assessed by PANSS (Kay et al., 1987), BPRS (Overall & Gorham, 1988), and cognitive performance in schizophrenia remains unclear in the literature. While several studies have reported negative correlations between negative symptoms and memory deficits (Cammisuli & Sportiello, 2016; Du et al., 2022), others are aligned with the findings of this study suggesting that clinical symptom severity, as measured by these scales, may not directly predict cognitive performance in emotional memory (Anticevic et al., 2012; Peng et al., 2021),.

Several factors could contribute to the absence of significant correlations in this study. Variability in symptom presentation and the heterogeneity of PANSS (Kay et al., 1987) and BPRS scores (Overall & Gorham, 1988), influenced by factors such as gender or individual differences, may play a role (Gogos et al., 2015; Li et al., 2016; Takahashi, 2013; Tsuang, 1975). Thus, the lack of correlation observed in the results underscores the complexity of cognitive-emotional dysfunction in schizophrenia, suggesting that symptom severity scales alone may not be sufficient to predict deficits in emotional memory.

Emotion phase

Underconnectivity. During the emotion session of the experiment, patients passively observed IAPS images, which primarily engage limbic regions and salience networks. Several instances of underconnectivity were identified in patients compared to the healthy control group (Table 6). The affected areas included the left and right Forb, the subcallosal cortex, and the left anterior insula within the salience network**.**

Frontal Orbital Cortex (Forb) and Emotional Circuit. The frontal orbital cortex (Forb) plays a crucial role in emotional regulation and salience attribution, primarily through its connections with the amygdala and insular cortex (Eack et al., 2016; Fryer et al., 2022; Gangopadhyay et al., 2021; Mancini-Marïe et al., 2018). Results indicate underconnectivity between the Forb and Heschl's gyrus, as well as the Forb and the insular cortex within the salience network. As Heschl's gyrus is a primary auditory processing area, this underconnectivity could lead to difficulty in appropriately attributing emotional significance to auditory stimuli (Anticevic et al., 2012; Crottaz-Herbette & Menon, 2006; Dierks et al., 1999).

Subcallosal Cortex and Emotion Regulation. The subcallosal cortex, located in the ventral part of the anterior cingulate, plays a central role in emotion regulation, stress response, and mood control, particularly in processing negative affect (Fan et al., 2019; Hamani et al., 2011). This region is functioning by inhibiting the amygdala during stressful stimuli, allowing for adaptive responses to emotionally salient information via the salience network (Stoliker et al., 2024). Underconnectivity was

Article
Cortica 2025. 4(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

observed between the subcallosal cortex and three key regions: the insula, opercular cortex, and supramarginal gyrus. The supramarginal gyrus has been implicated in emotional gestures and empathy, playing a key role in social cognition (Imai, 2023; Wada, 2021). The opercular cortex, surrounding the insula, is involved in the integration of emotional signals.

Implications of Underconnectivity. Given the functional roles of these regions, this underconnectivity may contribute to difficulties in managing stressful information, processing emotional cues, and regulating affective responses (Dorland, 1925; Mălîia et al., 2018). Such disruptions could underlie the emotional blunting and social withdrawal frequently observed in schizophrenia (American Psychiatric Association, 2022).

Overconnectivity. During the emotion phase, compared to the healthy control group, the patient group exhibited several instances of overconnectivity, primarily involving the right frontal orbital cortex (Forb R), subcallosal cortex, supramarginal gyrus within the salience network, right visual lateral network, and right fusiform gyrus (Table 7).

Right Forb R and Temporal-Parietal Overconnectivity. The right Forb showed overconnectivity with the temporal and parietal lobes, particularly with visual regions such as the visual network and fusiform area. This dysconnectivity may contribute to overattribution of visual stimuli, potentially leading to sensory misinterpretation (Menon & Uddin, 2010). This finding is consistent with the aberrant salience hypothesis (Kapur, 2003), which suggests that altered salience processing may underlie perceptual distortions in schizophrenia, explaining misinterpretations of sensory cues (Speechley et al., 2010).

Subcallosal Cortex and Visual Overconnectivity. The subcallosal cortex, a key structure in emotional regulation (Fan et al., 2019; Hamani et al., 2011), exhibited overconnectivity primarily with visual regions, including the lingual gyrus, fusiform gyrus, intra-calcarine cortex, and medial visual network. This enhanced connectivity may lead to amplification of visual stimuli, resulting in hypervigilance or misinterpretation of social cues, given the fusiform gyrus' role in facial recognition (Anticevic et al., 2012).

Salience Network and Overconnectivity with the Fusiform Gyrus. Similarly, overconnectivity was observed between the salience network and visual area, particularly the supramarginal gyrus, and the right occipital fusiform gyrus. Since the salience network plays a crucial role in identifying relevant stimuli, this reinforced connectivity with the fusiform gyrus may lead to abnormalities in the processing of visual information (van de Ven et al., 2017; Veale et al., 2017). In the task, participants were viewing IAPS images, some of which contained human faces. This overconnectivity could indicate abnormal responses to facial stimuli, potentially contributing to

Article
Cortica 2025. 4(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

distorted social perceptions. Notably, Table 7 reveals that this overconnectivity is bilateral, suggesting a strong reciprocal influence between the salience network and occipital regions. (Veale et al., 2017)

Visual Network and Salience Network Overconnectivity. The visual network exhibited two significant instances of overconnectivity, one with the right Forb and another with the left supramarginal gyrus, both of which are key components of the salience network (Menon & Uddin, 2010; Molnar-Szakacs & Uddin, 2022; Schimmelpfennig et al., 2023). These findings further support the idea of aberrant sensitivity to visual stimuli, which may contribute to perceptual distortions and reinforce emotional reactivity in schizophrenia (Galdino et al., 2022; Luck & Gold, 2008). Given that the fusiform gyrus is involved in face processing and object recognition, and the supramarginal gyrus is associated with social cognition and empathy (Imai et al., 2023; Menon & Uddin, 2010; Wada et al., 2021), this overconnectivity may contribute to misinterpretations of facial expressions, and potentially leading to paranoia or social withdrawal (Eack et al., 2016; Morris et al., 2009).

Global disconnectivity in emotional processing. The disconnectivity patterns observed during the emotion phase align with well-documented findings in the schizophrenia literature.

Frontal and Limbic Dysconnectivity: Deficits in Emotion Regulation. The results of this study highlight a deficit in connectivity involving frontal regions, particularly the frontal orbital cortex (Forb), as well as several limbic-linked and sensory areas (e.g., subcallosal cortex, insula). These findings suggest impairments in emotion regulation, specifically in relation to salience processing and valence attribution to sensory stimuli. This observation supports previous studies suggesting that fronto-limbic dysconnectivity may be a specific biomarker of schizophrenia, contributing to difficulties in cognitive and emotional processing. The disruption of connectivity between the frontal cortex and limbic regions is well documented in schizophrenia and is associated with altered emotional regulation and impaired cognitive-affective integration.

Overconnectivity in the Salience Network and Visual Processing. The overconnectivity observed between the salience network (insula, supramarginal gyrus) and visual processing areas (lingual gyrus, fusiform gyrus, intra-calcarine cortex) suggests excessive sensitivity to emotional signals linked to visual stimuli. This hyperconnectivity may lead to an exaggerated perception of social cues, contributing to interpretation biases within the salience network (Mancini-Marïe et al., 2018; Menon & Uddin, 2010; Schimmelpfennig et al., 2023; Speechley et al., 2010).

Theoretical Framework: Aberrant Salience and Neural Dysconnectivity in Schizophrenia. Our findings support the aberrant salience theory, which suggests that patients with schizophrenia attribute excessive importance to neutral or non-significant stimuli (Speechley et al.,

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

2010). Furthermore, the results align with the neural dysconnectivity theory, which posits that schizophrenia symptoms arise primarily from disruptions in functional connectivity between brain regions (Heimer & Van Hoesen, 2006; Mancini-Marïe et al., 2018; Marder & Umbricht, 2023; Speechley et al., 2010). The observed dysconnectivity between frontal, limbic, salience, and visual networks reinforce this perspective, highlighting the complex interplay between brain dysconnectivity and cognitive-emotional dysfunction in schizophrenia.

Memory phase

Underconnectivity. During the memory phase, five instances of underconnectivity were identified, involving the following regions: the left superior frontal gyrus, inferior temporo-occipital gyrus, subcallosal cortex, left planum polare, and left temporal planum (Table 8).

Left Superior Frontal Gyrus and Auditory Processing Deficits. The superior frontal gyrus (SFG) is a key region within the prefrontal cortex, playing a crucial role in working memory, executive control, and attention. It is involved in the maintenance and manipulation of temporary information. The observed underconnectivity between the Superior Frontal gyrus (SFG) and Heschl's gyrus (primary auditory cortex) suggests difficulties in integrating auditory information, which may impact memory processes (Crottaz-Herbette & Menon, 2006; Dierks et al., 1999; Stephane et al., 2022). Additionally, since the SFG is responsible for attentional direction, this underconnectivity may contribute to attentional deficits in schizophrenia, leading to an abnormal focus on neutral or non-significant auditory stimuli (Eack et al., 2016; Menon & Uddin, 2010).

Inferior Temporo-Occipital Gyrus and Salience Processing. The inferior temporo-occipital gyrus is located at the junction of the occipital and temporal lobes and is involved in object recognition, complex stimulus identification, and the processing of emotional social signals (Abdel-Ghaffar et al., 2024; Adraoui et al., 2023). The results showed underconnectivity with the salience network, particularly with the subcallosal cortex and frontal operculum. As previously discussed, this disrupted connectivity may affect the processing of salience in complex visual stimuli (Crottaz-Herbette & Menon, 2006; Dierks et al., 1999; Stephane et al., 2022). Additionally, the underconnectivity with the frontal medial cortex, a region involved in working memory and cognitive control, may provide insight into the lower emotional memory scores observed in the patient group (de la Vega et al., 2016).

Bilateral Disconnectivity Between Subcallosal Cortex and Left Planum Temporale. A bilateral underconnectivity was found between the subcallosal cortex and the left planum temporal, regions heavily involved in human voice processing. The planum temporal connects to the insula, where it plays a role in analysing emotional valence in auditory stimuli, including intonation, prosody,

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

and intensity (Esteves et al., 2020; McCarley et al., 1999; Vander Ghinst et al., 2016). However, given that this experiment was based on visual stimuli, the precise impact of this underconnectivity in the current context cannot be speculated.

Subcallosal Cortex and Salience Network Dysconnectivity. The final underconnectivity identified in the memory phase involved the subcallosal cortex and the salience network, particularly through its connections with the parietal operculum and supramarginal gyrus.The subcallosal cortex is strongly linked to emotion and memory, particularly through its connections with the hippocampus via the insula and cingulate cortex, making it a key area in memory retrieval (Fan et al., 2019). The supramarginal gyrus is involved in language processing, working memory, and sensory integration (Imai et al., 2023; Supramarginal Gyrus – an overview | ScienceDirect Topics, n.d.). The parietal opercular cortex is known to contribute to object identification and multisensory integration (Mălîia et al., 2018). In the context of a recall task, this underconnectivity may impair the ability to contextualize memories, distinguish previously seen images from new ones, and associate memories with spatial and temporal cues. Although this dysconnectivity does not directly affect the hippocampus, its disruptive impact on salience and memory retrieval circuits could indirectly impair visual memory performance (Fan et al., 2019; Hamani et al., 2011).

Overconnectivity. The analysis of overconnectivity during the memory phase revealed two primary dysfunctions in schizophrenia compared to the healthy control group (Table 9). These abnormalities involve the left superior frontal gyrus, the frontal medial cortex, and the right occipital pole.

Bilateral Overconnectivity Between the Left Superior Frontal Gyrus and the Right Occipital Pole. A bilateral overconnectivity was observed between the left superior frontal pole and the right occipital pole. The superior frontal pole plays a key role in executive functions, particularly in working memory and attention (Fan et al., 2019; Rottschy et al., 2012). The right occipital pole is a visual processing area, fundamentally involved in the treatment of visual stimuli. This overconnectivity may serve as a compensatory mechanism for other cognitive deficits (Oh & Jagust, 2013; Ulrich & Gaebel, 1987; Yang et al., 2022). Additionally, it could reflect attentional biases commonly observed in schizophrenia, characterized by excessive processing of perceptual details (Yang et al., 2022).

Overconnectivity Between the Frontal Medial Cortex and Inferior Temporal Gyrus. Significant overconnectivity was also found between the frontal medial cortex and the inferior temporal gyrus. The frontal medial cortex is involved in autobiographical memory and decision-making (Klein-Flügge et al., 2022; Maguire, 2001). The inferior temporal gyrus is specialized in visual

Article
Cortica 2025. 4(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

memory and object recognition (She et al., 2024). This abnormal connectivity may indicate dysfunctional visual memory processing, potentially contributing to misinterpretation of stored visual information and distorted recall mechanisms in schizophrenia (An et al., 2010; Li et al., 2019; Speechley et al., 2010).

Global disconnectivity in memory processing. To summarize the dysconnectivity findings during the memory phase, four important underconnectivity and two main overconnectivity were identified.

Underconnectivity: Disruptions in Frontal, Temporal, and Limbic Networks. Underconnectivities involved mainly frontal, temporal and limbic networks. It concerned several superior key regions: the frontal gyrus and Heschl's gyrus; theinferior temporo-occipital in connection with the subcallosal and medial frontal cortex; betweenthe subcallosal cortex and the planum temporale/polare; and finally between the subcallosal cortex and the salience network, notably thesupramarginal gyrus and the parietal opercular cortex. These underconnectivity could have a significant effect on deficit in the integration of auditory stimuli (Dickey et al., 2002 ; Fan et al., 2019 ; Scott & Mishkin, 2016), in the perception of complex stimuli and their integration into emotional memory (Lakis et al., 2011; LeDoux, 1993; Menon & Uddin, 2010), and in the contextualization of visual memory (Itti & Koch, 2000 ; Scott & Mishkin, 2016).

Overconnectivity: Attentional Bias and Memory Retrieval Overload. Theoverconnectivities between the left superior frontal gyrus and the right occipital pole and between the medial frontal cortex and the right inferior temporal gyrus could participate in excessive attentional biases to visual details impairing semantic integration of memory (Rolls et al., 2024) and visual memory retrieval surcharge (Crottaz-Herbette & Menon, 2006; Veale et al., 2017).

Pattern of disconnectivity. These results highlight a pattern of dysconnectivity, in which sensory areas show reduced connectivity with salience and frontal regions, while memory-related areas show excessive connectivity with sensory networks, reflecting difficulties in accessing the information (Fryer et al., 2022; Li et al., 2019).

Clinical implications

Diagnosis. These findings highlight the role of emotional symptoms in schizophrenia and the identification of underconnectivity and overconnectivity within fronto-limbic and salience networks. They suggest that assessing emotional memory deficits could play a greater role in the diagnostic process of schizophrenia. Thus, a future where functional connectivity analyses become a key diagnostic tool for schizophrenia can be envisionned, allowing clinicians to detect specific

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

dysconnectivity patterns that characterize the disorder as a clinical biomarker. This approach could contribute to the development of biomarker-based diagnostic protocols, improving early detection and personalized treatment strategies.

Therapeutic aspect

Cognitive Behavioural Therapy (CBT) and Neuroplasticity-Based Approaches. Specific CBT intervention could target specifically emotional and salience biases and executive function improvement. The goal could be to exploit neuroplasticity to reinforce deficient connections or inhibit overactive circuits. For example active exposition with a direct feedback from the patient would allow him/her to express his/her feeling in order to readapt the salience analyses during a social interaction (Premkumar et al., 2015).

Transcranial Direct Current Stimulation as a Neuromodulation Tool. In addition to therapy, since the 2000s and still in development, TDCS (transcranial direct current stimulation) and TMS (Transcranial Magnetic Stimulation) have been shown to be useful. It is a technique of non-invasive neuromodulation that allows a modification of cerebral activity by low intensity current using the anode and cathode. This technology has insignificant side effects and shows significant results in negative and cognitive symptoms in pharmacoresistant patients (Jiang et al., 2022; Lefaucheur et al., 2017; Palm et al., 2016 ; Wada et al., 2022). In practice, the current protocol is to stimulate for 20 minutes from 1 to 2 mA during 5 to 10 days. Depending on the aim, the position of the anode and cathode can differ. For example, in the treatment of auditory hallucinations, the anode is placed on the left temporo-parietal cortex and the cathode is placed on the right prefrontal cortex (Lefaucheur et al., 2017). For negative symptoms, the focus is on the dorsolateral prefrontal cortex (Tseng et al., 2022). Side effects are in most cases tingling sensation where electrodes were placed and more rarely slight tiredness and slight headaches (Tseng et al., 2022). It is important to notice that there are some patients who show resistance to this technique without any effect on them (Palm et al., 2016). These methods are basically limited by their range due to the non-invasiveness aspect, thus it is complicated to reach deep areas and gyri as salience networks. Indeed, as an example, the TMS cannot stimulate efficiently deeper than 2 mm under the skull (Cao et al., 2021; Vittala et al., 2020). However, nowadays, many methods allow us to bypass this problem. Coupling TMS with a specific task to stimulate a close area well connected with the targeted area (Grossman et al., 2017). As an example, in the aim of improving connectivity between the Forb gyrus and salience network, the dorsolateral prefrontal cortex could be stimulated during an emotional memory task and this could have an impact on the salience network.

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

A method emerging, still in the experimental phase, is Transcranial Focused Ultrasound Stimulation (tFUS). This method allows modification of non-invasive neuronal activity in deep areas. The tFUS uses ultrasound at frequencies ranging from 250kHz to 1 MHz to modify by mechanical effect the excitatory or inhibition of neuronal activity. (Matt et al., 2024; Zhai et al., 2023). This method allows to be no longer restricted to the inconvenient TMS range and to be able to module over and underconnectivities. As an example, Mahdavi (2023) used the tFUS on patients with generalized anxiety disorder with the aim to heal anxiety symptoms through the amygdala stimulation. As a result, symptoms significantly decreased in the 25 participants of the study. In schizophrenia, Zhai et al (2023) used the tFUS on dorsolateral prefrontal cortex in 26 patients with schizophrenia. As a result, all patients saw an improvement of negative and positive symptoms (Matt et al., 2024).

Limitations of the study

This study presents important findings regarding emotional memory deficits in schizophrenia, particularly in relation to functional connectivity patterns. However, several methodological and conceptual limitations must be acknowledged to accurately interpret these results and guide future research.

Methodological Limitations. As a methodological aspect, the absence of temporal aspects can be criticized. The initial study made by the Montreal University (SOURCE) was a functional study butthe results of this study are without time scale. This limitation preventthe conduct of a dynamic functional connectivity analysis, which would have been valuable for examining time-dependent changes in connectivity and how they relate to cognitive processes such as memory encoding and retrieval. Although such an approach would have been highly desirable, it remains infeasible given the available dataset.

As discussed in the introduction, different emotions do not rely on the same neural circuits (Malezieux et al., 2023; Tettamanti et al., 2012). Given that the IAPS stimuli encompass a wide range of emotions with different salience levels, valence, and emotional categories (e.g., joy, sadness, disgust), neglecting the time variable means that distinct emotional circuits are pooled together and an average connectivity measure is computed. Thus, instead of identifying specific connectivity patterns for distinct emotional states, the results reflect an aggregated measure of all circuits activated throughout the emotional sequence, potentially obscuring key neural mechanisms.

Given the salience issues in schizophrenia, it's possible that emotional feeling was not the same as the control group (Mancini-Marïe et al., 2018). If this is the case, it would mean that a comparison between many different circuits is made and it could question the external validity of the results and question the understanding of emotion circuits used in schizophrenia with the task. To counter this

Article
Cortica 2025. 4(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

effect, the emotion felt by the participant in every image and each block should be known, and the comparison of the connectivity per image made. Currently, with the results, it is unsure what the connectivities analysed corresponds to. It reflects another complexity of the study of schizophrenia disorder.

Limitations Related to Sample Heterogeneity. The study of schizophrenia is inherently challenging due to the heterogeneity of the disorder (Takahashi, 2013; Tsuang, 1975). Each participant may exhibit a “unique” combination of symptoms, contributing to variability in neural dysconnectivity patterns. Given this high interindividual variability, studies on schizophrenia should ideally include a large number of participants per group to ensure robust statistical power and greater generalizability of findings (Takahashi, 2013; Tsuang, 1975).

Statistical Considerations: Beta Coefficients and T-Values. It is also important to note that all identified dysconnectivities in this study showed:

Low beta coefficients, indicating that the effect size of these connectivity differences is small.

Moderate to strong t-values, suggesting that the observed differences between groups are statistically significant. This means that although the connectivity alterations are likely due to schizophrenia, their impact remains subtle, with only small deviations from control group values. Future studies should further investigate whether these small connectivity differences accumulate over time, potentially contributing to long-term cognitive and emotional deficits in schizophrenia.

Unclear Causal Relationship. This study doesn't clarify the causal relationships between neural dysconnectivity and cognitive deficits. It remains unclear whether these connectivity alterations are the cause of impaired memory and emotional processing, or rather a consequence of prolonged symptoms. A longitudinal approach that tracks patients at different stages of schizophrenia could help clarify whether network disruptions precede cognitive decline or emerge as a result of chronic symptomatology. Such an approach would provide valuable insights into the temporal evolution of dysconnectivity and its role in cognitive impairments.

Medication Effects. The potential impact of antipsychotic medication on the observed connectivity patterns requires further consideration. As mentioned, all patients in this study were treated with second-generation antipsychotics (SGAs), which have known effects on hormones, behaviour, and brain function (Bostwick et al., 2009; Leucht et al., 2024; Meltzer, 2013). In order to have better control of this variable, it would be interesting to have a third group of non-medicated patients for balancing the medication effect on results. Considering that schizophrenia affects approximately 1% of the population (Morera-Fumero & Abreu-Gonzalez, 2013; Schultz et al., 2007;

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

Stępnicki et al., 2018), it would be inaccurate to assume that all individuals diagnosed and undiagnosed with the disorder are medicated. In reality, a significant proportion of patients remain untreated or do not receive consistent pharmacological care, highlighting the necessity of including a non-medicated group to better isolate the effects of the disorder itself from those induced by antipsychotic treatment.

Further perspectives

While this thesis provides important insights into the neural mechanisms underlying emotional memory impairments in schizophrenia, several clues remain open for further research. One approach would be to refine and expand upon the current methodology. Our findings highlight distinct patterns of underconnectivity and overconnectivity in schizophrenia, particularly in sensorial areas, salience networks, and limbic structures. However, the causal relationships between these alterations and symptomatology remain unclear. Future studies could explore the development of these connectivity patterns through longitudinal research to determine whether these alterations precede symptom onset or emerge alongside disease progression. Longitudinal studies tracking connectivity dysfunctions from the prodromal to chronic phases of schizophrenia would be particularly valuable in addressing this question. Additionally, such studies could investigate the neural changes associated with medication effects (Bostwick et al., 2009; Leucht et al., 2024; Meltzer, 2013).

As schizophrenia is increasingly recognized as a disorder of dynamic network regulation, future research should focus on studying neural activity and connectivity over a temporal axis. This approach could reveal the precise pathways involved in information processing, allowing for the development of an accurate connectivity model and a better understanding of how targeted interventions could be designed.

The findings of this study also raise important clinical implications regarding potential intervention strategies. The dysconnectivity patterns observed are suggesting that neuromodulation approaches, such as transcranial direct current stimulation or transcranial magnetic stimulation, could be tailored to specifically target dysfunctional networks or take advantage of new technology as transcranial focused ultrasound (Grossman et al., 2017; Matt et al., 2024; Zhai et al., 2023). Future studies should investigate whether stimulating or inhibiting key regions identified in this study could help to restore a more balanced connectivity pattern.

In addition, cognitive remediation programs incorporating emotional regulation training may be beneficial for improving memory function in schizophrenia. The integration of these findings into clinical practice could pave the way for more personalized and effective treatment strategies.

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

Conclusion

The aim of this study was to investigate emotional memory in schizophrenia and to identify the underlying dysconnectivity patterns. This thesis is based on their experiment and provides valuable insights into the neural mechanisms underlying emotional memory impairments in schizophrenia.

In summary, this study aimed to investigate emotional memory in schizophrenia and to identify the underlying dysconnectivity patterns. As predicted (H1), behavioural results confirmed that the healthy control group had a higher correct response rate than patients with schizophrenia. However, no significant correlation was found between patients correct response rates and their symptom severity assessed by PANSS and BPRS, leading to the invalidation of hypotheses H2 and H3.

From a functional perspective, several circuits exhibiting dysconnectivity in schizophrenia during tasks involving both emotion and memory sessions were identified. During the emotion phase, overconnectivity was primarily observed between salience and sensory areas, whereas underconnectivity mainly affected frontal and regions of emotional treatment. A similar pattern emerged in the memory phase, with overconnectivity linking sensory and frontal areas, while underconnectivity was more pronounced in the salience network, limbic system, and auditory regions.

The hypotheses H4 and H5 were only partially validated, as no significant dysconnectivity involving the hippocampus or amygdala was detected in the emotion phase, and no hippocampal involvement was found in the memory phase.

This thesis is in line with an actual theoretical current that highlights the importance of dysconnectivities in the disorder and their results on behaviour. Disconnectivities found could provide interesting answers to symptoms caused concerning deficit in emotional memory, emotional blunting, and salience misattribution in schizophrenia.

In a clinical view, these observations emphasize the importance of a therapeutic approach also targeting neural dysfunction in addition to cognitive deficits. New non-invasive methods such as tFUS are promising in this kind of treatment and could be envisaged in the future.

Despite these promising results, the experiment presents some weaknesses. Firstly, with the modest number of participants for enabling a generalization with schizophrenia. Secondly, by the study design, all patients were under treatment without a patient group non-medicated. A lack of information on time variable is also present and and biases linked to basic emotional disorder due to schizophrenia are not counterbalanced.

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

To finish, this thesis raises several questions on the interaction between sensorial treatment, salience attribution and memory retrieval in schizophrenia. Many ways can be approached to continue this study: It could be interesting to verify whether these dysconnectivity patterns are specific to schizophrenia. It is also possible to improve the rigor of design with a better control of medication or the comparability of results in order to improve the accuracy of the study. Schizophrenia is a large domain in psychological disorder, and a lot of thematics remain to be explored.

Notes Article edited by Jeremiah Schenk, Department of psychology, Unit of Clinical and Health Psychology, University of Fribourg, jeremiah.schenk@unifr.ch

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

References

1. Abdel-Ghaffar, S. A., Huth, A. G., Lescroart, M. D., Stansbury, D., Gallant, J. L., & Bishop, S. J. (2024). Occipital-temporal cortical tuning to semantic and affective features of natural images predicts associated behavioral responses. *Nature Communications*, *15*, 5531. https://doi.org/10.1038/s41467-024-49073-8
2. Abi-Dargham, A., Xu, X., Thompson, J. L., Gil, R., Kegeles, L. S., Urban, N., Narendran, R., Hwang, D.-R., Laruelle, M., & Slifstein, M. (2012). Increased prefrontal cortical D1 receptors in drug naïve patients with schizophrenia : A PET study with [11C]NNC112. *Journal of Psychopharmacology*, *26*(6), 794-805. https://doi.org/10.1177/0269881111409265
3. Aceituno, D., Vera, N., Prina, A. M., & McCrone, P. (2019). Cost-effectiveness of early intervention in psychosis : Systematic review. *The British Journal of Psychiatry: The Journal of Mental Science*, *215*(1), 388-394. https://doi.org/10.1192/bjp.2018.298
4. Alderson-Day, B., Weis, S., McCarthy-Jones, S., Moseley, P., Smailes, D., & Fernyhough, C. (2016). The brain's conversation with itself : Neural substrates of dialogic inner speech. *Social Cognitive and Affective Neuroscience*, *11*(1), 110-120. https://doi.org/10.1093/scan/nsv094
5. Almerie, M. Q., Okba Al Marhi, M., Jawoosh, M., Alsabbagh, M., Matar, H. E., Maayan, N., & Bergman, H. (2015). Social skills programmes for schizophrenia. *The Cochrane Database of Systematic Reviews*, *2015*(6), CD009006. https://doi.org/10.1002/14651858.CD009006.pub2
6. Amaral, D. G., & Adolphs, R. (2016). *Living without an Amygdala*. Guilford Publications.
7. American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). https://doi.org/10.1176/appi.books.9780890420614.dsm-iv
8. American Psychiatric Association. (2022). *Diagnostic and statistical manual of mental disorders: DSM-5-TR™* (5th ed., text rev ed.). https://doi.org/10.1176/appi.books.9780890425787
9. Amunts, K., Kedo, O., Kindler, M., Pieperhoff, P., Mohlberg, H., Shah, N. J., Habel, U., Schneider, F., & Zilles, K. (2005). Cytoarchitectonic mapping of the human amygdala, hippocampal region and entorhinal cortex : Intersubject variability and probability maps. *Anatomy and Embryology*, *210*(5-6), 343-352. https://doi.org/10.1007/s00429-005-0025-5
10. An, S. K., Kang, J. I., Park, J. Y., Kim, K. R., Lee, S. Y., & Lee, E. (2010). Attribution bias in ultra-high risk for psychosis and first-episode schizophrenia. *Schizophrenia Research*, *118*(1-3), 54-61. https://doi.org/10.1016/j.schres.2010.01.025
11. Anderson, D. J., & Adolphs, R. (2014). A framework for studying emotions across species. *Cell*, *157*(1), 187-200. https://doi.org/10.1016/j.cell.2014.03.003
12. Andreasen, N. C., O'Leary, D. S., Flaum, M., Nopoulos, P., Watkins, G. L., Boles Ponto, L. L., & Hichwa, R. D. (1997). Hypofrontality in schizophrenia : Distributed dysfunctional circuits in neuroleptic-naïve patients. *Lancet (London, England)*, *349*(9067), 1730-1734. https://doi.org/10.1016/s0140-6736(96)08258-x
13. Andreasen, N. C., Rezai, K., Alliger, R., Swayze, V. W., Flaum, M., Kirchner, P., Cohen, G., & O'Leary, D. S. (1992). Hypofrontality in neuroleptic-naive patients and in patients with chronic schizophrenia. Assessment with xenon 133 single-photon emission computed tomography and the Tower of London. *Archives of General Psychiatry*, *49*(12), 943-958. https://doi.org/10.1001/archpsyc.1992.01820120031006
14. Antal, A., Luber, B., Brem, A.-K., Bikson, M., Brunoni, A. R., Cohen Kadosh, R., Dubljević, V., Fecteau, S., Ferreri, F., Flöel, A., Hallett, M., Hamilton, R. H., Herrmann, C. S., Lavidor,

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

M., Loo, C., Lustenberger, C., Machado, S., Miniussi, C., Moliadze, V., … Paulus, W. (2022). Non-invasive brain stimulation and neuroenhancement. *Clinical Neurophysiology Practice*, *7*, 146-165. https://doi.org/10.1016/j.cnp.2022.05.002

15. Anticevic, A., Van Snellenberg, J. X., Cohen, R. E., Repovs, G., Dowd, E. C., & Barch, D. M. (2012). Amygdala recruitment in schizophrenia in response to aversive emotional material : A meta-analysis of neuroimaging studies. *Schizophrenia Bulletin*, *38*(3), 608-621. https://doi.org/10.1093/schbul/sbq131
16. Balogh, N., Égerházi, A., & Berecz, R. (2015). Neurocognitive changes in patients with schizophrenia during relapse and early remission. *The European Journal of Psychiatry*, *29*(3), 199-209. https://doi.org/10.4321/S0213-61632015000300004
17. Bem, S. L. (1974). The measurement of psychological androgyny. *Journal of Consulting and Clinical Psychology*, *42*(2), 155-162.
18. Berntson, G. G., Norman, G. J., Bechara, A., Tranel, D., Bruss, J., & Cacioppo, J. T. (2011). The insula, the amygdala and evaluative processes. *Psychological Science*, *22*(1), 80-86. https://doi.org/10.1177/0956797610391097
19. Boake, C. (2000). Édouard Claparède and the Auditory Verbal Learning Test. *Journal of Clinical and Experimental Neuropsychology*, *22*(2), 286-292. https://doi.org/10.1076/1380-3395(200004)22:2;1-1;FT286
20. Böge, K., Karadza, A., Fuchs, L. M., Ehlen, F., Ta, T. M. T., Thomas, N., Bajbouj, M., & Hahn, E. (2020). Mindfulness-Based Interventions for In-Patients With Schizophrenia Spectrum Disorders—A Qualitative Approach. *Frontiers in Psychiatry*, *11*, 600. https://doi.org/10.3389/fpsyt.2020.00600
21. Bostwick, J. R., Guthrie, S. K., & Ellingrod, V. L. (2009). Antipsychotic-induced hyperprolactinemia. *Pharmacotherapy*, *29*(1), 64-73. https://doi.org/10.1592/phco.29.1.64
22. Bourque, J., Mendrek, A., Durand, M., Lakis, N., Lipp, O., Stip, E., Lalonde, P., Grignon, S., & Potvin, S. (2013). Cannabis abuse is associated with better emotional memory in schizophrenia : A functional magnetic resonance imaging study. *Psychiatry Research: Neuroimaging*, *214*(1), 24-32. https://doi.org/10.1016/j.pscychresns.2013.05.012
23. Braslow, J. T., & Marder, S. R. (2019). *History of Psychopharmacology*.
24. Calder, A. J., Keane, J., Manes, F., Antoun, N., & Young, A. W. (2000). Impaired recognition and experience of disgust following brain injury. *Nature Neuroscience*, *3*(11), 1077-1078. https://doi.org/10.1038/80586
25. Cammisuli, D. M., & Sportiello, M. T. (2016). Cognitive psychopathology in Schizophrenia : Comparing memory performances with Obsessive-compulsive disorder patients and normal subjects on the Wechsler Memory Scale-IV. *Psychiatria Danubina*, *28*(2), 118-126.
26. Candida, M., Campos, C., Monteiro, B., Rocha, N. B. F., Paes, F., Nardi, A. E., & Machado, S. (2016). Cognitive-behavioral therapy for schizophrenia : An overview on efficacy, recent trends and neurobiological findings. *MedicalExpress*, *3*, M160501. https://doi.org/10.5935/MedicalExpress.2016.05.01
27. Cao, K.-X., Ma, M.-L., Wang, C.-Z., Iqbal, J., Si, J.-J., Xue, Y.-X., & Yang, J.-L. (2021). TMS-EEG : An emerging tool to study the neurophysiologic biomarkers of psychiatric disorders. *Neuropharmacology*, *197*, 108574. https://doi.org/10.1016/j.neuropharm.2021.108574
28. Caqueo-Urízar, A., Rus-Calafell, M., Urzúa, A., Escudero, J., & Gutiérrez-Maldonado, J. (2015). The role of family therapy in the management of schizophrenia : Challenges and solutions. *Neuropsychiatric Disease and Treatment*, *11*, 145-151. https://doi.org/10.2147/NDT.S51331

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

29. Carbon, M., Kane, J. M., Leucht, S., & Correll, C. U. (2018). Tardive dyskinesia risk with first- and second-generation antipsychotics in comparative randomized controlled trials : A meta-analysis. *World Psychiatry: Official Journal of the World Psychiatric Association (WPA)*, *17*(3), 330-340. https://doi.org/10.1002/wps.20579
30. Cardona-Acosta, A. M., & Bolaños-Guzmán, C. A. (2023). Role of the Mesolimbic Dopamine Pathway in the Antidepressant Effects of Ketamine. *Neuropharmacology*, *225*, 109374. https://doi.org/10.1016/j.neuropharm.2022.109374
31. Carhart-Harris, R. L., Bolstridge, M., Day, C. M. J., Rucker, J., Watts, R., Erritzoe, D. E., Kaelen, M., Giribaldi, B., Bloomfield, M., Pilling, S., Rickard, J. A., Forbes, B., Feilding, A., Taylor, D., Curran, H. V., & Nutt, D. J. (2018). Psilocybin with psychological support for treatment-resistant depression : Six-month follow-up. *Psychopharmacology*, *235*(2), 399-408. https://doi.org/10.1007/s00213-017-4771-x
32. Carlsson, A., Waters, N., Waters, S., & Carlsson, M. L. (2000). Network interactions in schizophrenia—Therapeutic implications. *Brain Research Reviews*, *31*(2), 342-349. https://doi.org/10.1016/S0165-0173(99)00050-8
33. Catani, M., Dell'acqua, F., & Thiebaut de Schotten, M. (2013). A revised limbic system model for memory, emotion and behaviour. *Neuroscience and Biobehavioral Reviews*, *37*(8), 1724-1737. https://doi.org/10.1016/j.neubiorev.2013.07.001
34. Chadwick, P., Hughes, S., Russell, D., Russell, I., & Dagnan, D. (2009). Mindfulness Groups for Distressing Voices and Paranoia : A Replication and Randomized Feasibility Trial. *Behavioural and Cognitive Psychotherapy*, *37*(4), 403-412. https://doi.org/10.1017/S1352465809990166
35. Champagne, J., Lakis, N., Bourque, J., Stip, E., Lipp, O., & Mendrek, A. (2012). Progesterone and Cerebral Function during Emotion Processing in Men and Women with Schizophrenia. *Schizophrenia Research and Treatment*, *2012*, 917901. https://doi.org/10.1155/2012/917901
36. Chaumette, B., Kebir, O., & Krebs, M.-O. (2017). Génétique et épigénétique de la schizophrénie et des psychoses. *Biologie Aujourd'hui*, *211*(1), 69-82. https://doi.org/10.1051/jbio/2017015
37. Cohen, N. J., & Eichenbaum, H. (1993). *Memory, Amnesia, and the Hippocampal System*. MIT Press.
38. Crocq, M.-A. (2012). 1. La schizophrénie – histoire du concept et évolution de la nosographie. In *Pathologies schizophréniques* (p. 5-17). Lavoisier. https://doi.org/10.3917/lav.daler.2012.01.0005
39. Crottaz-Herbette, S., & Menon, V. (2006). Where and when the anterior cingulate cortex modulates attentional response : Combined fMRI and ERP evidence. *Journal of Cognitive Neuroscience*, *18*(5), 766-780. https://doi.org/10.1162/jocn.2006.18.5.766
40. Davis, L., Strasburger, A., & Brown, L. (2007). Mindfulness : An Intervention for Anxiety in Schizophrenia. *Journal of psychosocial nursing and mental health services*, *45*, 23-29. https://doi.org/10.3928/02793695-20071101-06
41. de la Vega, A., Chang, L. J., Banich, M. T., Wager, T. D., & Yarkoni, T. (2016). Large-Scale Meta-Analysis of Human Medial Frontal Cortex Reveals Tripartite Functional Organization. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *36*(24), 6553-6562. https://doi.org/10.1523/JNEUROSCI.4402-15.2016
42. Dean, M., Weston, A. R. W., Osborn, D. P., Willis, S., Patterson, S., Killaspy, H., Leurent, B., & Crawford, M. J. (2014). Activity groups for people with schizophrenia : A randomized

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

controlled trial. *Journal of Mental Health*, *23*(4), 171-175. https://doi.org/10.3109/09638237.2014.889285

43. Delavari, F., Rafi, H., Sandini, C., Murray, R. J., Latrèche, C., Van De Ville, D., & Eliez, S. (2023). Amygdala subdivisions exhibit aberrant whole-brain functional connectivity in relation to stress intolerance and psychotic symptoms in 22q11.2DS. *Translational Psychiatry*, *13*(1), 1-12. https://doi.org/10.1038/s41398-023-02458-7
44. Dickey, C. C., McCarley, R. W., Voglmaier, M. M., Frumin, M., Niznikiewicz, M. A., Hirayasu, Y., Fraone, S., Seidman, L. J., & Shenton, M. E. (2002). Smaller left Heschl's gyrus volume in patients with schizotypal personality disorder. *The American Journal of Psychiatry*, *159*(9), 1521-1527. https://doi.org/10.1176/appi.ajp.159.9.1521
45. Dierks, T., Linden, D. E. J., Jandl, M., Formisano, E., Goebel, R., Lanfermann, H., & Singer, W. (1999). Activation of Heschl's Gyrus during Auditory Hallucinations. *Neuron*, *22*(3), 615-621. https://doi.org/10.1016/S0896-6273(00)80715-1
46. Dorland, W. A. N. (1925). *Dorland's illustrated medical dictionary*. Wb Saunders.
47. Du, X.-D., Li, Z., Yuan, N., Yin, M., Zhao, X.-L., Lv, X.-L., Zou, S.-Y., Zhang, J., Zhang, G.-Y., Li, C.-W., Pan, H., Yang, L., Wu, S.-Q., Yue, Y., Wu, Y.-X., & Zhang, X.-Y. (2022). Delayed improvements in visual memory task performance among chronic schizophrenia patients after high-frequency repetitive transcranial magnetic stimulation. *World Journal of Psychiatry*, *12*(9), 1169-1182. https://doi.org/10.5498/wjp.v12.i9.1169
48. Eack, S. M., Wojtalik, J. A., Barb, S. M., Newhill, C. E., Keshavan, M. S., & Phillips, M. L. (2016). Fronto-Limbic Brain Dysfunction during the Regulation of Emotion in Schizophrenia. *PLoS ONE*, *11*(3), e0149297. https://doi.org/10.1371/journal.pone.0149297
49. Ekman, P. (1992). An argument for basic emotions. *Cognition and Emotion*, *6*(3-4), 169-200. https://doi.org/10.1080/02699939208411068
50. Eshel, N., Touponse, G. C., Wang, A. R., Osterman, A. K., Shank, A. N., Groome, A. M., Taniguchi, L., Cardozo Pinto, D. F., Tucciarone, J., Bentzley, B. S., & Malenka, R. C. (2024). Striatal dopamine integrates cost, benefit, and motivation. *Neuron*, *112*(3), 500-514.e5. https://doi.org/10.1016/j.neuron.2023.10.038
51. Esteves, M., Lopes, S. S., Almeida, A., Sousa, N., & Leite-Almeida, H. (2020). Unmasking the relevance of hemispheric asymmetries—Break on through (to the other side). *Progress in Neurobiology*, *192*, 101823. https://doi.org/10.1016/j.pneurobio.2020.101823
52. Fan, F.-M., Xiang, H., Wen, Y., Zhao, Y.-L., Zhu, X.-L., Wang, Y.-H., Yang, F.-D., Tan, Y.-L., & Tan, S.-P. (2019). Brain Abnormalities in Different Phases of Working Memory in Schizophrenia : An Integrative Multi-Modal MRI Study. *The Journal of Nervous and Mental Disease*, *207*(9), 760-767. https://doi.org/10.1097/NMD.0000000000001001
53. Feldman Barrett, L. (2011). *Constructing Emotion*.
54. Fernandez-Ruiz, J., Peltsch, A., Alahyane, N., Brien, D. C., Coe, B. C., Garcia, A., & Munoz, D. P. (2018). Age related prefrontal compensatory mechanisms for inhibitory control in the antisaccade task. *NeuroImage*, *165*, 92-101. https://doi.org/10.1016/j.neuroimage.2017.10.001
55. Filley, C. M. (2002). Neuroanatomy. In V. S. Ramachandran (Éd.), *Encyclopedia of the Human Brain* (p. 403-422). Academic Press. https://doi.org/10.1016/B0-12-227210-2/00237-5
56. Friston, K. J., & Frith, C. D. (1995). Schizophrenia : A disconnection syndrome? *Clinical Neuroscience (New York, N.Y.)*, *3*(2), 89-97.
57. Fryer, S. L., Ferri, J. M., Roach, B. J., Loewy, R. L., Stuart, B. K., Anticevic, A., Ford, J. M., & Mathalon, D. H. (2022). Thalamic dysconnectivity in the psychosis risk syndrome and early

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

illness schizophrenia. *Psychological Medicine*, *52*(13), 2767-2775. https://doi.org/10.1017/S0033291720004882

58. Fusar-Poli, P., McGuire, P., & Borgwardt, S. (2012). Mapping prodromal psychosis : A critical review of neuroimaging studies. *European Psychiatry*, *27*(3), 181-191. https://doi.org/10.1016/j.eurpsy.2011.06.006
59. Galbally, M., Wynter, K., Siskind, D., Correll, C. U., Northwood, K., & Every-Palmer, S. (2024). Sex Differences Between Female and Male Individuals in Antipsychotic Efficacy and Adverse Effects in the Treatment of Schizophrenia. *CNS Drugs*. https://doi.org/10.1007/s40263-024-01089-w
60. Galdino, L. B., Fernandes, T., Schmidt, K. E., & Santos, N. A. (2022). Altered brain connectivity during visual stimulation in schizophrenia. *Experimental Brain Research*, *240*(12), 3327-3337. https://doi.org/10.1007/s00221-022-06495-4
61. Gangopadhyay, P., Chawla, M., Monte, O. D., & Chang, S. W. C. (2021). Prefrontal-Amygdala Circuits in Social Decision-Making. *Nature neuroscience*, *24*(1), 5-18. https://doi.org/10.1038/s41593-020-00738-9
62. Gogos, A., Sbisa, A. M., Sun, J., Gibbons, A., Udawela, M., & Dean, B. (2015). A Role for Estrogen in Schizophrenia : Clinical and Preclinical Findings. *International Journal of Endocrinology*, *2015*, 615356. https://doi.org/10.1155/2015/615356
63. González, H. F. J., Narasimhan, S., Goodale, S. E., Johnson, G. W., Doss, D. J., Paulo, D. L., Morgan, V. L., Chang, C., & Englot, D. J. (2023). Arousal and salience network connectivity alterations in surgical temporal lobe epilepsy. *Journal of neurosurgery*, *138*(3), 810-820. https://doi.org/10.3171/2022.5.JNS22837
64. Gooding, D. C., & Tallent, K. A. (2004). Nonverbal working memory deficits in schizophrenia patients : Evidence of a supramodal executive processing deficit. *Schizophrenia Research*, *68*(2), 189-201. https://doi.org/10.1016/j.schres.2003.07.007
65. Green, B. L., Wehling, C., & Talsky, G. J. (1987). Group art therapy as an adjunct to treatment for chronic outpatients. *Hospital & Community Psychiatry*, *38*(9), 988-991. https://doi.org/10.1176/ps.38.9.988
66. Gregory Jr., V. L. (2010). Cognitive-Behavioral Therapy for Schizophrenia : Applications to Social Work Practice. *Social Work in Mental Health*, *8*(2), 140-159. https://doi.org/10.1080/15332980902791086
67. Grossman, N., Bono, D., Dedic, N., Kodandaramaiah, S. B., Rudenko, A., Suk, H.-J., Cassara, A. M., Neufeld, E., Kuster, N., Tsai, L.-H., Pascual-Leone, A., & Boyden, E. S. (2017). Noninvasive Deep Brain Stimulation via Temporally Interfering Electric Fields. *Cell*, *169*(6), 1029-1041.e16. https://doi.org/10.1016/j.cell.2017.05.024
68. Guo, H., Ye, H., Li, Z., Li, X., Huang, W., Yang, Y., Xie, G., Xu, C., Li, X., Liang, W., Jing, H., Zhang, C., Tang, C., & Liang, J. (2023). Amygdala signal abnormality and cognitive impairment in drug-naïve schizophrenia. *BMC Psychiatry*, *23*, 231. https://doi.org/10.1186/s12888-023-04728-6
69. Häfner, H., & an der Heiden, W. (1997). Epidemiology of schizophrenia. *Canadian Journal of Psychiatry. Revue Canadienne De Psychiatrie*, *42*(2), 139-151. https://doi.org/10.1177/070674379704200204
70. Hamani, C., Mayberg, H., Stone, S., Laxton, A., Haber, S., & Lozano, A. M. (2011). The Subcallosal Cingulate Gyrus in the Context of Major Depression. *Biological Psychiatry*, *69*(4), 301-308. https://doi.org/10.1016/j.biopsych.2010.09.034

71. Hampton, R. R., Engelberg, J. W. M., & Brady, R. J. (2020). Explicit memory and cognition in monkeys. *Neuropsychologia*, *138*, 107326. https://doi.org/10.1016/j.neuropsychologia.2019.107326
72. Harvey, C. (2018). Family psychoeducation for people living with schizophrenia and their families. *BJPsych Advances*, *24*(1), 9-19. https://doi.org/10.1192/bja.2017.4
73. Hasselmo, M. E., Bodelón, C., & Wyble, B. P. (2002). A Proposed Function for Hippocampal Theta Rhythm : Separate Phases of Encoding and Retrieval Enhance Reversal of Prior Learning. *Neural Computation*, *14*(4), 793-817. https://doi.org/10.1162/089976602317318965
74. Hayward, M., Jones, A.-M., Bogen-Johnston, L., Thomas, N., & Strauss, C. (2017). Relating Therapy for distressing auditory hallucinations : A pilot randomized controlled trial. *Schizophrenia Research*, *183*, 137-142. https://doi.org/10.1016/j.schres.2016.11.019
75. He, H., Hong, L., & Sajda, P. (2023). Pupillary response is associated with the reset and switching of functional brain networks during salience processing. *PLOS Computational Biology*, *19*(5), e1011081. https://doi.org/10.1371/journal.pcbi.1011081
76. Heimer, L., & Van Hoesen, G. W. (2006). The limbic lobe and its output channels : Implications for emotional functions and adaptive behavior. *Neuroscience & Biobehavioral Reviews*, *30*(2), 126-147. https://doi.org/10.1016/j.neubiorev.2005.06.006
77. Horwitz, B. (2003). The elusive concept of brain connectivity. *Neuroimage*, *19*(2 Pt 1), 466–470. https://doi.org/10.1016/s1053-8119(03)00112-5
78. Howes, O. D., & Kapur, S. (2009). The dopamine hypothesis of schizophrenia : Version III--the final common pathway. *Schizophrenia Bulletin*, *35*(3), 549-562. https://doi.org/10.1093/schbul/sbp006
79. Howes, O., McCutcheon, R., & Stone, J. (2015). Glutamate and dopamine in schizophrenia : An update for the 21st century. *Journal of psychopharmacology (Oxford, England)*, *29*(2), 97-115. https://doi.org/10.1177/0269881114563634
80. Imai, A., Matsuoka, T., & Narumoto, J. (2023). Emotional Dysregulation in Mild Behavioral Impairment Is Associated with Reduced Cortical Thickness in the Right Supramarginal Gyrus. *Journal of Alzheimer's Disease: JAD*, *93*(2), 521-532. https://doi.org/10.3233/JAD-220948
81. Immigration, R. and C. C. (2024, décembre 13). *Find your National Occupation Classification (NOC)*. https://www.canada.ca/en/immigration-refugees-citizenship/services/immigrate-canada/find-national-occupation-code.html
82. Itti, L., & Koch, C. (2000). A saliency-based search mechanism for overt and covert shifts of visual attention. *Vision Research*, *40*(10-12), 1489-1506. https://doi.org/10.1016/s0042-6989(99)00163-7
83. Izard, C. E. (2010). The many meanings/aspects of emotion : Definitions, functions, activation, and regulation. *Emotion Review*, *2*(4), 363-370. https://doi.org/10.1177/1754073910374661
84. Jääskeläinen, E., Juola, P., Hirvonen, N., McGrath, J. J., Saha, S., Isohanni, M., Veijola, J., & Miettunen, J. (2013). A systematic review and meta-analysis of recovery in schizophrenia. *Schizophrenia Bulletin*, *39*(6), 1296-1306. https://doi.org/10.1093/schbul/sbs130
85. Javitt, D. C., & Zukin, S. R. (1991). Recent advances in the phencyclidine model of schizophrenia. *The American Journal of Psychiatry*, *148*(10), 1301-1308. https://doi.org/10.1176/ajp.148.10.1301
86. Jiang, W.-L., Cai, D.-B., Sun, C.-H., Yin, F., Goerigk, S., Brunoni, A. R., Zhao, X.-W., Mayes, T. L., Zheng, W., & Xiang, Y.-T. (2022). Adjunctive tDCS for treatment-refractory auditory

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

hallucinations in schizophrenia : A meta-analysis of randomized, double-blinded, sham-controlled studies. *Asian Journal of Psychiatry*, *73*, 103100. https://doi.org/10.1016/j.ajp.2022.103100

87. Kapur, S. (2003). Psychosis as a state of aberrant salience : A framework linking biology, phenomenology, and pharmacology in schizophrenia. *The American Journal of Psychiatry*, *160*(1), 13-23. https://doi.org/10.1176/appi.ajp.160.1.13
88. Kay, S. R., Fiszbein, A., & Opler, L. A. (1987). The positive and negative syndrome scale (PANSS) for schizophrenia. *Schizophrenia Bulletin*, *13*(2), 261-276. https://doi.org/10.1093/schbul/13.2.261
89. Keefe, R. S. E., Eesley, C. E., & Poe, M. P. (2005). Defining a cognitive function decrement in schizophrenia. *Biological Psychiatry*, *57*(6), 688-691. https://doi.org/10.1016/j.biopsych.2005.01.003
90. Kim, J. S., Kornhuber, H. H., Schmid-Burgk, W., & Holzmüller, B. (1980). Low cerebrospinal fluid glutamate in schizophrenic patients and a new hypothesis on schizophrenia. *Neuroscience Letters*, *20*(3), 379-382. https://doi.org/10.1016/0304-3940(80)90178-0
91. Klein-Flügge, M. C., Bongioanni, A., & Rushworth, M. F. S. (2022). Medial and orbital frontal cortex in decision-making and flexible behavior. *Neuron*, *110*(17), 2743-2770. https://doi.org/10.1016/j.neuron.2022.05.022
92. Kraepelin, E. (1919). Démence précoce et paraphrénie. *Barclay RM, trad. Édimbourg, Écosse : ES Livingston,*.
93. Kragel, P. A., Čeko, M., Theriault, J., Chen, D., Satpute, A. B., Wald, L. W., Lindquist, M. A., Feldman Barrett, L., & Wager, T. D. (2021). A human colliculus-pulvinar-amygdala pathway encodes negative emotion. *Neuron*, *109*(15), 2404-2412.e5. https://doi.org/10.1016/j.neuron.2021.06.001
94. Kruk-Slomka, M., & Biala, G. (2021). Cannabidiol Attenuates MK-801-Induced Cognitive Symptoms of Schizophrenia in the Passive Avoidance Test in Mice. *Molecules (Basel, Switzerland)*, *26*(19), 5977. https://doi.org/10.3390/molecules26195977
95. Kulkarni, J., de Castella, A., Headey, B., Marston, N., Sinclair, K., Lee, S., Gurvich, C., Fitzgerald, P. B., & Burger, H. (2011). Estrogens and men with schizophrenia : Is there a case for adjunctive therapy? *Schizophrenia Research*, *125*(2-3), 278-283. https://doi.org/10.1016/j.schres.2010.10.009
96. Kulkarni, J., Riedel, A., de Castella, A. R., Fitzgerald, P. B., Rolfe, T. J., Taffe, J., & Burger, H. (2001). Estrogen—A potential treatment for schizophrenia. *Schizophrenia Research*, *48*(1), 137-144. https://doi.org/10.1016/S0920-9964(00)00088-8
97. Lakis, N., Jiménez, J. A., Mancini-Marïe, A., Stip, E., Lavoie, M. E., & Mendrek, A. (2011). Neural correlates of emotional recognition memory in schizophrenia : Effects of valence and arousal. *Psychiatry Research: Neuroimaging*, *194*(3), 245-256. https://doi.org/10.1016/j.pscychresns.2011.05.010
98. Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1997). International Affective Picture System (IAPS) : Technical Manual and Affective Ratings. *1997*. https://www2.unifesp.br/dpsicobio/adap/instructions.pdf
99. LeDoux, J. E. (1993). Emotional memory systems in the brain. *Behavioural Brain Research*, *58*(1), 69-79. https://doi.org/10.1016/0166-4328(93)90091-4
100. LeDoux, J. E. (2000). Emotion circuits in the brain. *Annual Review of Neuroscience*, *23*, 155-184. https://doi.org/10.1146/annurev.neuro.23.1.155
101. Lefaucheur, J.-P., Antal, A., Ayache, S. S., Benninger, D. H., Brunelin, J., Cogiamanian, F., Cotelli, M., De Ridder, D., Ferrucci, R., Langguth, B., Marangolo, P., Mylius,

V., Nitsche, M. A., Padberg, F., Palm, U., Poulet, E., Priori, A., Rossi, S., Schecklmann, M., … Paulus, W. (2017). Evidence-based guidelines on the therapeutic use of transcranial direct current stimulation (tDCS). *Clinical Neurophysiology*, *128*(1), 56-92. https://doi.org/10.1016/j.clinph.2016.10.087

102. Leucht, S., Priller, J., & Davis, J. M. (2024). Antipsychotic Drugs : A Concise Review of History, Classification, Indications, Mechanism, Efficacy, Side Effects, Dosing, and Clinical Application. *American Journal of Psychiatry*, *181*(10), 865-878. https://doi.org/10.1176/appi.ajp.20240738
103. Li, R., Ma, X., Wang, G., Yang, J., & Wang, C. (2016). Why sex differences in schizophrenia? *Journal of translational neuroscience*, *1*(1), 37-42.
104. Li, S., Hu, N., Zhang, W., Tao, B., Dai, J., Gong, Y., Tan, Y., Cai, D., & Lui, S. (2019). Dysconnectivity of Multiple Brain Networks in Schizophrenia : A Meta-Analysis of Resting-State Functional Connectivity. *Frontiers in Psychiatry*, *10*, 482. https://doi.org/10.3389/fpsyt.2019.00482
105. Lindamer, L. A., Lohr, J. B., Harris, J., & Jeste, D. V. (2004). Gender, Estrogen, and Schizophrenia. *Focus*, *2*(1), 138-145. https://doi.org/10.1176/foc.2.1.138
106. Lodge, D. J., & Grace, A. A. (2011). Hippocampal dysregulation of dopamine system function and the pathophysiology of schizophrenia. *Trends in Pharmacological Sciences*, *32*(9), 507-513. https://doi.org/10.1016/j.tips.2011.05.001
107. Luck, S. J., & Gold, J. M. (2008). The construct of attention in schizophrenia. *Biological Psychiatry*, *64*(1), 34-39. https://doi.org/10.1016/j.biopsych.2008.02.014
108. Lutgens, D., Gariepy, G., & Malla, A. (2017). Psychological and psychosocial interventions for negative symptoms in psychosis : Systematic review and meta-analysis. *The British Journal of Psychiatry*, *210*(5), 324-332. https://doi.org/10.1192/bjp.bp.116.197103
109. Maclean, P. D. (1949). Psychosomatic disease and the visceral brain; recent developments bearing on the Papez theory of emotion. *Psychosomatic Medicine*, *11*(6), 338-353. https://doi.org/10.1097/00006842-194911000-00003
110. Maclean, P. D. (1952). Some psychiatric implications of physiological studies on frontotemporal portion of limbic system (visceral brain). *Electroencephalography and Clinical Neurophysiology*, *4*(4), 407-418. https://doi.org/10.1016/0013-4694(52)90073-4
111. Maguire, E. A. (2001). Neuroimaging studies of autobiographical event memory. *Philosophical Transactions of the Royal Society of London. Series B*, *356*(1413), 1441-1451. https://doi.org/10.1098/rstb.2001.0944
112. Mahdavi, K. D., Jordan, S. E., Jordan, K. G., Rindner, E. S., Haroon, J. M., Habelhah, B., Becerra, S. A., Surya, J. R., Venkatraman, V., Zielinski, M. A., Spivak, N. M., Bystritsky, A., & Kuhn, T. P. (2023). A pilot study of low-intensity focused ultrasound for treatment-resistant generalized anxiety disorder. *Journal of Psychiatric Research*, *168*, 125-132. https://doi.org/10.1016/j.jpsychires.2023.10.039
113. Malezieux, M., Klein, A. S., & Gogolla, N. (2023). Neural Circuits for Emotion. *Annual Review of Neuroscience*, *46*, 211-231. https://doi.org/10.1146/annurev-neuro-111020-103314
114. Mălîia, M.-D., Donos, C., Barborica, A., Popa, I., Ciurea, J., Cinatti, S., & Mîndruţă, I. (2018). Functional mapping and effective connectivity of the human operculum. *Cortex*, *109*, 303-321. https://doi.org/10.1016/j.cortex.2018.08.024
115. Mancini-Marïe, A., Yoon, U., Jiminez, J., Fahim, C., Potvin, S., Grant, J. A., Laverdure-Dupont, D., Dubé, A.-A., Betrisey, C., Rainville, P., Evans, A. C., Stip, E., &

Mendrek, A. (2018). Sex, Age, Symptoms and Illness Duration and Their Relation with Gyrification Index in Schizophrenia. *Clinical Schizophrenia & Related Psychoses*, *12*(2), 57-68. https://doi.org/10.3371/CSRP.MAYO.070415

116. Marder, S. R., & Umbricht, D. (2023). Negative symptoms in schizophrenia : Newly emerging measurements, pathways, and treatments. *Schizophrenia Research*, *258*, 71-77. https://doi.org/10.1016/j.schres.2023.07.010
117. Markiewicz, R., & Dobrowolska, B. (2020). Cognitive and Social Rehabilitation in Schizophrenia—From Neurophysiology to Neuromodulation. Pilot Study. *International Journal of Environmental Research and Public Health*, *17*(11), Article 11. https://doi.org/10.3390/ijerph17114034
118. Martinot, J.-L., & Mana, S. (2011). La neuro-imagerie—De la psychiatrie à la pédopsychiatrie—Imagerie et cognition (7). *médecine/sciences*, *27*(6-7), Article 6-7. https://doi.org/10.1051/medsci/2011276017
119. Matt, E., Radjenovic, S., Mitterwallner, M., & Beisteiner, R. (2024). Current state of clinical ultrasound neuromodulation. *Frontiers in Neuroscience*, *18*. https://doi.org/10.3389/fnins.2024.1420255
120. McCarley, R. W., Wible, C. G., Frumin, M., Hirayasu, Y., Levitt, J. J., Fischer, I. A., & Shenton, M. E. (1999). MRI anatomy of schizophrenia. *Biological Psychiatry*, *45*(9), 1099-1119. https://doi.org/10.1016/S0006-3223(99)00018-9
121. McCutcheon, R. A., Reis Marques, T., & Howes, O. D. (2020). Schizophrenia—An Overview. *JAMA Psychiatry*, *77*(2), 201-210. https://doi.org/10.1001/jamapsychiatry.2019.3360
122. Meltzer, H. Y. (2013). Update on Typical and Atypical Antipsychotic Drugs. *Annual Review of Medicine*, *64*(Volume 64, 2013), 393-406. https://doi.org/10.1146/annurev-med-050911-161504
123. Menon, V., Gallardo, G., Pinsk, M. A., Nguyen, V.-D., Li, J.-R., Cai, W., & Wassermann, D. (2020). Microstructural organization of human insula is linked to its macrofunctional circuitry and predicts cognitive control. *eLife*, *9*, e53470. https://doi.org/10.7554/eLife.53470
124. Menon, V., & Uddin, L. Q. (2010). Saliency, switching, attention and control : A network model of insula function. *Brain structure & function*, *214*(5-6), 655-667. https://doi.org/10.1007/s00429-010-0262-0
125. Mijovic, A., & MacCabe, J. H. (2020). Clozapine-induced agranulocytosis. *Annals of Hematology*, *99*(11), 2477-2482. https://doi.org/10.1007/s00277-020-04215-y
126. Moghaddam, B., & Javitt, D. (2012a). From Revolution to Evolution : The Glutamate Hypothesis of Schizophrenia and its Implication for Treatment. *Neuropsychopharmacology*, *37*(1), 4-15. https://doi.org/10.1038/npp.2011.181
127. Moghaddam, B., & Javitt, D. (2012b). From Revolution to Evolution : The Glutamate Hypothesis of Schizophrenia and its Implication for Treatment. *Neuropsychopharmacology*, *37*(1), 4-15. https://doi.org/10.1038/npp.2011.181
128. Molnar-Szakacs, I., & Uddin, L. Q. (2022). Anterior insula as a gatekeeper of executive control. *Neuroscience & Biobehavioral Reviews*, *139*, 104736. https://doi.org/10.1016/j.neubiorev.2022.104736
129. Moore, L., Kyaw, M., Vercammen, A., Lenroot, R., Kulkarni, J., Curtis, J., O'Donnell, M., Carr, V. J., Shannon Weickert, C., & Weickert, T. W. (2013). Serum testosterone levels are related to cognitive function in men with schizophrenia. *Psychoneuroendocrinology*, *38*(9), 1717-1728. https://doi.org/10.1016/j.psyneuen.2013.02.007

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

130. Morera-Fumero, A. L., & Abreu-Gonzalez, P. (2013). Role of Melatonin in Schizophrenia. *International Journal of Molecular Sciences*, *14*(5), 9037-9050. https://doi.org/10.3390/ijms14059037
131. Morris, R. G. M., Inglis, J., Ainge, J. A., Olverman, H. J., Tulloch, J., Dudai, Y., & Kelly, P. A. T. (2006). Memory reconsolidation : Sensitivity of spatial memory to inhibition of protein synthesis in dorsal hippocampus during encoding and retrieval. *Neuron*, *50*(3), 479-489. https://doi.org/10.1016/j.neuron.2006.04.012
132. Morris, R. W., Weickert, C. S., & Loughland, C. M. (2009). Emotional face processing in schizophrenia. *Current Opinion in Psychiatry*, *22*(2), 140-146. https://doi.org/10.1097/YCO.0b013e328324f895
133. Nieto-Castanon, A. (2020). Handbook of functional connectivity Magnetic Resonance Imaging methods in CONN. *MA: Hilbert Press*.
134. Nieto-Castanon, A., & Whitfield-Gabrieli, S. (2022). *CONN functional connectivity toolbox : RRID SCR_009550 release 22*. https://doi.org/10.56441/hilbertpress.2246.5840
135. Oh, H., & Jagust, W. J. (2013). Frontotemporal network connectivity during memory encoding is increased with aging and disrupted by beta-amyloid. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *33*(47), 18425-18437. https://doi.org/10.1523/JNEUROSCI.2775-13.2013
136. Oldfield, R. C. (1971). The assessment and analysis of handedness : The Edinburgh inventory. *Neuropsychologia*, *9*(1), 97-113. https://doi.org/10.1016/0028-3932(71)90067-4
137. Orzelska-Górka, J., Mikulska, J., Wiszniewska, A., & Biała, G. (2022). New Atypical Antipsychotics in the Treatment of Schizophrenia and Depression. *International Journal of Molecular Sciences*, *23*(18), 10624. https://doi.org/10.3390/ijms231810624
138. Overall, J. E., & Gorham, D. R. (1988). The Brief Psychiatric Rating Scale (BPRS) : Recent developments in ascertainment and scaling. *Psychopharmacology Bulletin*, *24*(1), 97-99.
139. Oyelade, O. O., & Nkosi-Mafutha, N. G. (2021). Living beyond the limitation : Rehabilitation, life and productivity of individuals with schizophrenia in South-West Nigeria. *Health Expectations : An International Journal of Public Participation in Health Care and Health Policy*, *24*(2), 198-208. https://doi.org/10.1111/hex.13139
140. Palm, U., Hasan, A., Strube, W., & Padberg, F. (2016). tDCS for the treatment of depression : A comprehensive review. *European Archives of Psychiatry and Clinical Neuroscience*, *266*(8), 681-694. https://doi.org/10.1007/s00406-016-0674-9
141. Papez, J. W. (1937). A PROPOSED MECHANISM OF EMOTION. *Archives of Neurology & Psychiatry*, *38*(4), 725-743. https://doi.org/10.1001/archneurpsyc.1937.02260220069003
142. Parisi, A., Roberts, R. L., Hanley, A. W., & Garland, E. L. (2022). Mindfulness-Oriented Recovery Enhancement for Addictive Behavior, Psychiatric Distress, and Chronic Pain : A Multilevel Meta-Analysis of Randomized Controlled Trials. *Mindfulness*, *13*(10), 2396-2412. https://doi.org/10.1007/s12671-022-01964-x
143. Parnas, J., Yttri, J.-E., & Urfer-Parnas, A. (2024). Phenomenology of auditory verbal hallucination in schizophrenia : An erroneous perception or something else? *Schizophrenia Research*, *265*, 83-88. https://doi.org/10.1016/j.schres.2023.03.045
144. Pedale, T., Mastroberardino, S., Capurso, M., Macrì, S., & Santangelo, V. (2022). Developmental differences in the impact of perceptual salience on short-term memory performance and meta-memory skills. *Scientific Reports*, *12*(1), 8185. https://doi.org/10.1038/s41598-022-11624-8

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

145. Peng, X.-J., Hei, G.-R., Yang, Y., Liu, C.-C., Xiao, J.-M., Long, Y.-J., Huang, J., Zhao, J.-P., & Wu, R.-R. (2021). The Association Between Cognitive Deficits and Clinical Characteristic in First-Episode Drug Naïve Patients With Schizophrenia. *Frontiers in Psychiatry*, *12*. https://doi.org/10.3389/fpsyt.2021.638773
146. Pessoa, L. (2017). A Network Model of the Emotional Brain. *Trends in cognitive sciences*, *21*(5), 357-371. https://doi.org/10.1016/j.tics.2017.03.002
147. Pessoa, L. (2023). How many brain regions are needed to elucidate the neural bases of fear and anxiety? *Neuroscience and Biobehavioral Reviews*, *146*, 105039. https://doi.org/10.1016/j.neubiorev.2023.105039
148. Pope, R. A., Thompson, P. J., Rantell, K., Stretton, J., Wright, M.-A., & Foong, J. (2019). Frontal lobe dysfunction as a predictor of depression and anxiety following temporal lobe epilepsy surgery. *Epilepsy Research*, *152*, 59-66. https://doi.org/10.1016/j.eplepsyres.2019.03.003
149. Premkumar, P., Fannon, D., Sapara, A., Peters, E. R., Anilkumar, A. P., Simmons, A., Kuipers, E., & Kumari, V. (2015). Orbitofrontal cortex, emotional decision-making and response to cognitive behavioural therapy for psychosis. *Psychiatry Research: Neuroimaging*, *231*(3), 298-307. https://doi.org/10.1016/j.pscychresns.2015.01.013
150. Qin, K., Yu, Y., Cai, H., Li, J., Zeng, J., & Liang, H. (2024). Effectiveness of mindfulness-based intervention in schizophrenia : A meta-analysis of randomized controlled trials. *Psychiatry Research*, *334*, 115808. https://doi.org/10.1016/j.psychres.2024.115808
151. Réthelyi, J. (2011). [Diagnosing schizophrenia : From Bleuler to DSM-V]. *Neuropsychopharmacologia Hungarica: A Magyar Pszichofarmakologiai Egyesulet Lapja = Official Journal of the Hungarian Association of Psychopharmacology*, *13*(4), 193-203.
152. Rolland, B. (2014). *Mécanismes dopaminergiques des symptômes schizophréniques et nouvelles perspectives de modulation thérapeutique*.
153. Rolls, E. T., Deco, G., Huang, C.-C., & Feng, J. (2024). The connectivity of the human frontal pole cortex, and a theory of its involvement in exploit versus explore. *Cerebral Cortex (New York, N.Y.: 1991)*, *34*(1), bhad416. https://doi.org/10.1093/cercor/bhad416
154. Rottschy, C., Langner, R., Dogan, I., Reetz, K., Laird, A. R., Schulz, J. B., Fox, P. T., & Eickhoff, S. B. (2012). Modelling neural correlates of working memory : A coordinate-based meta-analysis. *NeuroImage*, *60*(1), 830-846. https://doi.org/10.1016/j.neuroimage.2011.11.050
155. Sarin, F., & Wallin, L. (2014). Cognitive model and cognitive behavior therapy for schizophrenia : An overview. *Nordic Journal of Psychiatry*, *68*(3), 145-153. https://doi.org/10.3109/08039488.2013.789074
156. Schacter, D. (1987). Implicit Memory : History and Current Status. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *13*, 501-518. https://doi.org/10.1037/0278-7393.13.3.501
157. Schimmelpfennig, J., Topczewski, J., Zajkowski, W., & Jankowiak-Siuda, K. (2023). The role of the salience network in cognitive and affective deficits. *Frontiers in Human Neuroscience*, *17*, 1133367. https://doi.org/10.3389/fnhum.2023.1133367
158. Schultz, S. H., North, S. W., & Shields, C. G. (2007). Schizophrenia : A Review. *American Family Physician*, *75*(12), 1821-1829.
159. Scott, B. H., & Mishkin, M. (2016). Auditory short-term memory in the primate auditory cortex. *Brain Research*, *1640*(Pt B), 264-277. https://doi.org/10.1016/j.brainres.2015.10.048
160. Seeman, M. V. (2022). Philip Seeman's contributions to the story of schizophrenia. *Psychological Medicine*, *52*(13), 2401-2403. https://doi.org/10.1017/S0033291721004803

161. Selemon, L. D., & Zecevic, N. (2015). Schizophrenia : A tale of two critical periods for prefrontal cortical development. *Translational Psychiatry*, *5*(8), e623. https://doi.org/10.1038/tp.2015.115
162. She, L., Benna, M. K., Shi, Y., Fusi, S., & Tsao, D. Y. (2024). Temporal multiplexing of perception and memory codes in IT cortex. *Nature*, *629*(8013), 861-868. https://doi.org/10.1038/s41586-024-07349-5
163. Solmi, M., Radua, J., Olivola, M., Croce, E., Soardo, L., Salazar de Pablo, G., Il Shin, J., Kirkbride, J. B., Jones, P., Kim, J. H., Kim, J. Y., Carvalho, A. F., Seeman, M. V., Correll, C. U., & Fusar-Poli, P. (2022). Age at onset of mental disorders worldwide : Large-scale meta-analysis of 192 epidemiological studies. *Molecular Psychiatry*, *27*(1), 281-295. https://doi.org/10.1038/s41380-021-01161-7
164. Speechley, W. J., Whitman, J. C., & Woodward, T. S. (2010). The contribution of hypersalience to the "jumping to conclusions" bias associated with delusions in schizophrenia. *Journal of Psychiatry & Neuroscience : JPN*, *35*(1), 7-17. https://doi.org/10.1503/jpn.090025
165. Spitzer, R. L., Williams, J. B. W., Gibbon, M., & First, M. B. (1992). The Structured Clinical Interview for DSM-III-R (SCID) : I: History, Rationale, and Description. *Archives of General Psychiatry*, *49*(8), 624-629. https://doi.org/10.1001/archpsyc.1992.01820080032005
166. Stephane, M., Dzemidzic, M., & Yoon, G. (2022). Altered corollary discharge in the auditory cortex could reflect louder inner voice experience in patients with verbal hallucinations, a pilot fMRI study. *Schizophrenia Research*, *243*, 475-480. https://doi.org/10.1016/j.schres.2022.02.007
167. Stępnicki, P., Kondej, M., & Kaczor, A. A. (2018). Current Concepts and Treatments of Schizophrenia. *Molecules : A Journal of Synthetic Chemistry and Natural Product Chemistry*, *23*(8), 2087. https://doi.org/10.3390/molecules23082087
168. Stilo, S. A., & Murray, R. M. (2019). Non-Genetic Factors in Schizophrenia. *Current Psychiatry Reports*, *21*(10), 100. https://doi.org/10.1007/s11920-019-1091-3
169. Stoliker, D., Novelli, L., Vollenweider, F. X., Egan, G. F., Preller, K. H., & Razi, A. (2024). Neural Mechanisms of Resting-State Networks and the Amygdala Underlying the Cognitive and Emotional Effects of Psilocybin. *Biological Psychiatry*, *96*(1), 57-66. https://doi.org/10.1016/j.biopsych.2024.01.002
170. *Supramarginal Gyrus—An overview | ScienceDirect Topics*. (s. d.). Consulté 20 mars 2025, à l'adresse https://www.sciencedirect.com/topics/neuroscience/supramarginal-gyrus
171. Suryani, S., Welch, A., & Cox, L. (2013). The Phenomena of Auditory Hallucination as Described by Indonesian People Living With Schizophrenia. *Archives of Psychiatric Nursing*, *27*(6), 312-318. https://doi.org/10.1016/j.apnu.2013.08.001
172. Takahashi, S. (2013). Heterogeneity of schizophrenia : Genetic and symptomatic factors. *American Journal of Medical Genetics. Part B, Neuropsychiatric Genetics: The Official Publication of the International Society of Psychiatric Genetics*, *162B*(7), 648-652. https://doi.org/10.1002/ajmg.b.32161
173. Tamminga, C. A., Buchanan, R. W., & Gold, J. M. (1998). The role of negative symptoms and cognitive dysfunction in schizophrenia outcome. *International Clinical Psychopharmacology*, *13 Suppl 3*, S21-26. https://doi.org/10.1097/00004850-199803003-00004

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

174. Tettamanti, M., Rognoni, E., Cafiero, R., Costa, T., Galati, D., & Perani, D. (2012). Distinct pathways of neural coupling for different basic emotions. *NeuroImage*, *59*(2), 1804-1817. https://doi.org/10.1016/j.neuroimage.2011.08.018
175. Tholl, S., Sojer, C. A., Schmidt, S. N. L., & Mier, D. (2024). How to elicit a negative bias? Manipulating contrast and saturation with the facial emotion salience task. *Frontiers in Psychology*, *15*, 1284595. https://doi.org/10.3389/fpsyg.2024.1284595
176. Tseng, P.-T., Zeng, B.-S., Hung, C.-M., Liang, C.-S., Stubbs, B., Carvalho, A. F., Brunoni, A. R., Su, K.-P., Tu, Y.-K., Wu, Y.-C., Chen, T.-Y., Li, D.-J., Lin, P.-Y., Hsu, C.-W., Chen, Y.-W., Suen, M.-W., Satogami, K., Takahashi, S., Wu, C.-K., … Li, C.-T. (2022). Assessment of Noninvasive Brain Stimulation Interventions for Negative Symptoms of Schizophrenia. *JAMA Psychiatry*, *79*(8), 770-779. https://doi.org/10.1001/jamapsychiatry.2022.1513
177. Tsuang, M. T. (1975). Heterogeneity of schizophrenia. *Biological Psychiatry*, *10*(4), 465-474.
178. Turkington, D., Dudley, R., Warman, D. M., & Beck, A. T. (2006). Cognitive-Behavioral Therapy for Schizophrenia : A Review. *Focus*, *4*(2), 223-233. https://doi.org/10.1176/foc.4.2.223
179. Ulrich, G., & Gaebel, W. (1987). [Psychophysiology of schizophrenic disorders of attention—Concepts, findings and working hypotheses]. *Fortschritte Der Neurologie-Psychiatrie*, *55*(9), 279-288. https://doi.org/10.1055/s-2007-1001830
180. Uno, Y., & Coyle, J. T. (2019). Glutamate hypothesis in schizophrenia. *Psychiatry and Clinical Neurosciences*, *73*(5), 204-215. https://doi.org/10.1111/pcn.12823
181. Ursin, H., & Kaada, B. R. (1960). Functional localization within the amygdaloid complex in the cat. *Electroencephalography and Clinical Neurophysiology*, *12*(1), 1-20. https://doi.org/10.1016/0013-4694(60)90058-4
182. van den Heuvel, L. L., Smit, A. M., Stalder, T., Kirschbaum, C., Seedat, S., & Emsley, R. (2022). Hair cortisol levels in schizophrenia and metabolic syndrome. *Early Intervention in Psychiatry*, *16*(8), 902-911. https://doi.org/10.1111/eip.13238
183. van de Ven, V., Rotarska Jagiela, A., Oertel-Knöchel, V., & Linden, D. E. J. (2017). Reduced intrinsic visual cortical connectivity is associated with impaired perceptual closure in schizophrenia. *NeuroImage: Clinical*, *15*, 45-52. https://doi.org/10.1016/j.nicl.2017.04.012
184. Vander Ghinst, M., Bourguignon, M., Op de Beeck, M., Wens, V., Marty, B., Hassid, S., Choufani, G., Jousmäki, V., Hari, R., Van Bogaert, P., Goldman, S., & De Tiège, X. (2016). Left Superior Temporal Gyrus Is Coupled to Attended Speech in a Cocktail-Party Auditory Scene. *The Journal of Neuroscience*, *36*(5), 1596-1606. https://doi.org/10.1523/JNEUROSCI.1730-15.2016
185. Veale, R., Hafed, Z. M., & Yoshida, M. (2017). How is visual salience computed in the brain? Insights from behaviour, neurobiology and modelling. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *372*(1714), 20160113. https://doi.org/10.1098/rstb.2016.0113
186. Velligan, D. I., & Gonzalez, J. M. (2007). Rehabilitation and Recovery in Schizophrenia. *Psychiatric Clinics of North America*, *30*(3), 535-548. https://doi.org/10.1016/j.psc.2007.05.001
187. Vercammen, A., Skilleter, A. J., Lenroot, R., Catts, S. V., Weickert, C. S., & Weickert, T. W. (2013). Testosterone Is Inversely Related to Brain Activity during Emotional Inhibition in Schizophrenia. *PLOS ONE*, *8*(10), e77496. https://doi.org/10.1371/journal.pone.0077496

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

188. Vittala, A., Murphy, N., Maheshwari, A., & Krishnan, V. (2020). Understanding Cortical Dysfunction in Schizophrenia With TMS/EEG. *Frontiers in Neuroscience*, *14*, 554. https://doi.org/10.3389/fnins.2020.00554
189. Wada, M., Noda, Y., Iwata, Y., Tsugawa, S., Yoshida, K., Tani, H., Hirano, Y., Koike, S., Sasabayashi, D., Katayama, H., Plitman, E., Ohi, K., Ueno, F., Caravaggio, F., Koizumi, T., Gerretsen, P., Suzuki, T., Uchida, H., Müller, D. J., … Nakajima, S. (2022). Dopaminergic dysfunction and excitatory/inhibitory imbalance in treatment-resistant schizophrenia and novel neuromodulatory treatment. *Molecular Psychiatry*, *27*(7), 2950-2967. https://doi.org/10.1038/s41380-022-01572-0
190. Wada, S., Honma, M., Masaoka, Y., Yoshida, M., Koiwa, N., Sugiyama, H., Iizuka, N., Kubota, S., Kokudai, Y., Yoshikawa, A., Kamijo, S., Kamimura, S., Ida, M., Ono, K., Onda, H., & Izumizaki, M. (2021). Volume of the right supramarginal gyrus is associated with a maintenance of emotion recognition ability. *PloS One*, *16*(7), e0254623. https://doi.org/10.1371/journal.pone.0254623
191. Walker, E. F., & Diforio, D. (1997). Schizophrenia : A neural diathesis-stress model. *Psychological Review*, *104*(4), 667-685. https://doi.org/10.1037/0033-295x.104.4.667
192. Whitfield-Gabrieli, S., & Nieto-Castanon, A. (2012a). Conn : A Functional Connectivity Toolbox for Correlated and Anticorrelated Brain Networks. *Brain Connectivity*, *2*(3), 125-141. https://doi.org/10.1089/brain.2012.0073
193. Whitfield-Gabrieli, S., & Nieto-Castanon, A. (2012b). *CONN: A functional connectivity toolbox for correlated and anticorrelated brain networks. Brain connectivity*. *23*(8), 125-141.
194. Williams, R., Ostinelli, E. G., Agorinya, J., Minichino, A., De Crescenzo, F., Maughan, D., Puntis, S., Cliffe, C., Kurtulmus, A., Lennox, B. R., & Cipriani, A. (2024). Comparing interventions for early psychosis : A systematic review and component network meta-analysis. *EClinicalMedicine*, *70*, 102537. https://doi.org/10.1016/j.eclinm.2024.102537
195. Yang, W., Xu, X., Wang, C., Cheng, Y., Li, Y., Xu, S., & Li, J. (2022). Alterations of dynamic functional connectivity between visual and executive-control networks in schizophrenia. *Brain Imaging and Behavior*, *16*(3), 1294-1302. https://doi.org/10.1007/s11682-021-00592-8
196. Yarwood, M. (s. d.). *Russell's (1980) Circumplex Models*. Consulté 19 mars 2025, à l'adresse https://psu.pb.unizin.org/psych425/chapter/circumplex-models/
197. Yee, A., Greene, S., Weiss, A., Chaudhry, S., & Steadman, S. (2024). Hospitalization and help-seeking among first episode psychosis patients. *Discover Mental Health*, *4*(1), 10. https://doi.org/10.1007/s44192-024-00064-7
198. Zeevi, L., Irani, M., Catana, C., Feldman Barrett, L., & Atzil, S. (2022). Maternal dopamine encodes affective signals of human infants. *Social Cognitive and Affective Neuroscience*, *17*(5), 503-509. https://doi.org/10.1093/scan/nsab116
199. Zhai, Z., Ren, L., Song, Z., Xiang, Q., Zhuo, K., Zhang, S., Li, X., Zhang, Y., Jiao, X., Tong, S., Sun, J., & Liu, D. (2023). The efficacy of low-intensity transcranial ultrasound stimulation on negative symptoms in schizophrenia : A double-blind, randomized sham-controlled study. *Brain Stimulation: Basic, Translational, and Clinical Research in Neuromodulation*, *16*(3), 790-792. https://doi.org/10.1016/j.brs.2023.04.021
200. Zhang, Y., Yang, Y., Zhu, L., Zhu, Q., Jia, Y., Zhang, L., Peng, Q., Wang, J., Liu, J., Fan, W., & Wang, J. (2021). Volumetric Deficit Within the Fronto-Limbic-Striatal Circuit in First-Episode Drug Naïve Patients With Major Depression Disorder. *Frontiers in Psychiatry*, *11*, 600583. https://doi.org/10.3389/fpsyt.2020.600583

Article
Cortica 2025. *4*(2), 255-316
https://doi.org/10.26034/cortica.2025.8569

201. Zheng, G., Zhou, Y., Zhou, J., Liang, S., Li, X., Xu, C., Xie, G., & Liang, J. (2023). Abnormalities of the Amygdala in schizophrenia : A real world study. *BMC Psychiatry*, *23*(1), 615. https://doi.org/10.1186/s12888-023-05031-0

202. Zotev, V., Phillips, R., Young, K. D., Drevets, W. C., & Bodurka, J. (2013). Prefrontal Control of the Amygdala during Real-Time fMRI Neurofeedback Training of Emotion Regulation. *PLoS ONE*, *8*(11), e79184. https://doi.org/10.1371/journal.pone.0079184