

The triple network and temporal experience: a phenomenologically informed resting-state fMRI study

Trzy uniwersalne sieci funkcjonalne i doświadczenie czasu:
badanie fMRI w stanie spoczynku oparte na fenomenologii

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Abstract

Introduction and objective: This work integrates findings from functional connectivity and phenomenological psychopathology to answer the question: “Is there a relationship between disturbed implicit and explicit temporal experience and impaired interaction within the triple network in schizophrenia patients?”, proposing a hypothesis on schizophrenia in terms of a lack of synchrony disrupting the constitution of selfhood. **Materials and methods:** Five patients with schizophrenia (Positive and Negative Syndrome Scale, PANSS score ≥ 40) and five healthy controls were scanned (resting-state fMRI) during two trials, each lasting 6 minutes and 34 seconds. In the first trial, participants were asked to keep their eyes closed, and no stimulus was presented. In the second, a digital clock was displayed on the screen. **Results:** A two-sample *t*-test was applied to compare the two groups, revealing caudate and pallidum activity associated with explicit temporal experience ($p < 0.01$), confirmed by research on the basal ganglia and their involvement in governing the temporal structure for movement and cognition. The activity associated with implicit temporal experience showed no significant statistical differences ($p < 0.05$, $p < 0.001$). There was a loss of competition between the SAL/DMN and the CEN/Insula; instead, there was an all-time activation of the DMN and coactivation with the SAL (including the Insula), as reported in earlier research. **Conclusions:** The findings support grounding the notion of selfhood in temporal experience. The limitations and implications of the study are also considered.

Keywords: schizophrenia, temporality, triple network, lived time, phenomenological psychopathology

Streszczenie

Wprowadzenie i cel: Niniejsza praca przedstawia wyniki badań dotyczących funkcjonalnej łączności i psychopatologii fenomenologicznej, aby odpowiedzieć na pytanie „Czy istnieje związek między zaburzonym ukrytym i jawnym doświadczeniem czasowym a zaburzoną interakcją w ramach trzech uniwersalnych sieci funkcjonalnych u pacjentów ze schizofrenią?”. Przedstawiono hipotezę na temat schizofrenii w kategoriach braku synchronizacji zakłócającego konstytucję jaźni. **Materiał i metody:** Pięciu pacjentów ze schizofrenią (wynik Positive and Negative Syndrome Scale, PANSS ≥ 40) i pięć zdrowych osób z grupy kontrolnej zostało poddanych skanowaniu (fMRI w stanie spoczynku) podczas dwóch prób trwających po 6 minut i 34 sekundy każda. W pierwszej próbie uczestników poproszono o zamknięcie oczu i nie przedstawiono im żadnego bodźca. W drugiej próbie na ekranie wyświetlano zegar cyfrowy. **Wyniki:** W celu porównania obu grup zastosowano test *t* dla dwóch prób, wykazując aktywność jądra ogoniastego i bladego związaną z jawnym doświadczeniem czasowym ($p < 0,01$), potwierdzoną badaniami jąder podstawy

dotyczącymi ich udziału w zarządzaniu strukturą skroniową dla ruchu i poznania. Aktywność związana z ukrytym doświadczeniem czasowym nie wykazała istotnych statystycznie różnic ($p < 0,05$, $p < 0,001$). Doszło do utraty konkurencji między SAL/DMN a CEN/Insula, zamiast tego nastąpiła stała aktywacja DMN i koaktywacja z SAL (w tym Insula), jak donoszą badania. CEN jest dezaktywowany w obu przypadkach (z wyjątkiem środkowego zakresu skroniowego), zamiast DMN, który dezaktywuje się podczas aktywności CEN u zdrowych osób. **Wnioski:** Niniejsza praca sugeruje ugruntowanie pojęcia jaźni na doświadczeniu czasowym. Rozważono ograniczenia i implikacje badań.

Słowa kluczowe: schizofrenia, doczesność, potrójna sieć, czas przeżyty, psychopatologia fenomenologiczna

INTRODUCTION

The functional connectivity approach conceptualises the healthy human brain as functionally interacting networks (Fox, 2005). For example, the default mode network (DMN) is anti-correlated with the central executive network (CEN) (Bolton et al., 2020; Bressler and Kelso, 2001; Buckner et al., 2009) in healthy adults, but in patients with schizophrenia and subjects-at-risk of psychosis¹ they are co-activated (Wotruba et al., 2014). This anti-correlation and competitive dynamic between the CEN and DMN are regulated by the right anterior insula (rAI) from the Salience Network (SAL) (Bolton et al., 2020; Bonnelle et al., 2012; Menon, 2011; Nekovarova et al., 2014; Uddin, 2015), which balances the dynamic through dopaminergic projections from the midbrain (Menon and Uddin, 2010). An integrative approach to schizophrenia also accounts for experience itself. Phenomenology methodically studies the structuring process of experience, providing an essential framework for psychopathology. For example, disturbed self-awareness is a phenotypic marker of schizophrenia spectrum disorder (Nekovarova et al., 2014; Nelson et al., 2013, 2014). Self-awareness refers to the self-referential knowledge of consciousness, which can be “reflexive” (explicit) or “pre-reflexive” (implicit), resulting in objective or subjective types of knowledge.

A particular proposal from phenomenological psychopathology claims that schizophrenia patients are affected by a severely disturbed pre-reflexive (implicit) temporal experience (Sass and Feyaerts, 2024; Sass and Parnas, 2003). As a compensatory function, they develop a hyper-reflexive (explicit) temporal experience (Fuchs, 2007, p. 5; Minkowski, 1970, p. 286). The aim of this article is to contrast the latter with the former functional connectivity findings, and answer the following question: “Is there a relationship between disturbed implicit and explicit temporal experience and impaired interaction within the triple network in schizophrenia patients?”. The following four sections articulate a provisional answer based on a pilot-study.

¹ In early editions of the American Psychiatric Association’s Diagnostic and Statistical Manual of Mental Disorders (DSM), it was broadly defined as a “loss of contact with reality” or a “loss of ego boundaries”. Currently, it is defined by the presence of delusions or hallucinations, or both. Notwithstanding that each of these terms requires conceptual clarification, the broad notions are presented. Delusions refer to fixed beliefs not open to correction by contradicting evidence, while hallucinations refer to recurrent perceptions that lack external sensory stimuli.

MATERIALS AND METHODS

Sample

Patients were recruited at the Psychiatric Hospital of the Medical University of Plovdiv with approval from the Ethical Committee (3/26.09.2019) in accordance with the Declaration of Helsinki and international regulations (Nuremberg Code, Resolution 008430, 1993). The sample consisted of five patients with schizophrenia (Positive and Negative Syndrome Scale, PANSS score ≥ 40) contrasted with five healthy controls (Tab. 1).

Experimental design

Participants had two trials of rsfMRI (6 mins 34 s each), under two conditions: (i) eyes closed (sampling implicit temporal experience), and (ii) digital clock on the screen (sampling explicit temporal experience).

To sample the implicit temporal experience, participants were asked to close their eyes to induce a relaxed resting-state condition, allowing assessment of the implicit pattern of temporal experience through co-occurring brain dynamics, targeting DMN activity (Agcaoglu et al., 2019).

In contrast, in the explicit condition, participants were asked to look at a digital clock, as this visually induces an explicit experience of time (“counting time”) while registering the co-occurring brain dynamics, thereby serving the purpose of monitoring the neural underpinnings of more explicit temporal experience.

Resting-state fMRI

The protocol was carried out on a 3-T MRI system (GE Discovery 750 w) using three sequences. A high-resolution scan (Sag 3D T1 FSPGR) was acquired with a slice thickness of 1 mm,

| Patients | | | |
|----------|--------|--------------------------|---------------------------------|
| Age | Genre | Illness duration [years] | Pharmacological treatment |
| 33 | Female | 13 | Antipsychotics, benzodiazepines |
| 33 | Male | 10 | Antipsychotics, benzodiazepines |
| 33 | Male | 11 | Antipsychotics, benzodiazepines |
| 34 | Female | 15 | Antipsychotics, benzodiazepines |
| 48 | Female | 20 | Antipsychotics, benzodiazepines |

Tab. 1. Patient information

matrix 256×256 , relaxation time (TR) 7.2 ms, echo time (TE) 2.3 ms, and flip angle 12° . Two additional 2D resting-state functional scans were acquired with echo planar imaging (EPI), with a slice thickness of 3 mm, matrix 64×64 , TR 2000 ms, TE 30 ms, 36 slices and flip angle 90° , a total of 192 volumes.

Data analysis

Data preprocessing was performed using Statistical Parametric Mapping software (SPM 12, <http://www.fil.ion.ucl.ac.uk/spm/>) running on MATLAB (R2022a for Windows). Echo-planar (EP) images were realigned, co-registered, and normalised to the Montreal Neurological Institute (MNI)

space, and smoothed with Gaussian kernel (8-mm full-width-at-half-maximum).

Using the fMRI toolbox software (GIFT), group Independent Component Analysis (ICA) was conducted to identify brain networks activated during the first condition (without stimuli). Individual ICA maps were calculated using the Infomax algorithm. All subjects were simultaneously analysed for the group ICA, and principal component analysis was employed for data compression, with the number of components set to twenty (20). Based on the maximum voxel, the four most relevant components were extracted, and through a GIFT function the list of regions corresponding to the four components' activity in MNI and Talairach coordinates was obtained.

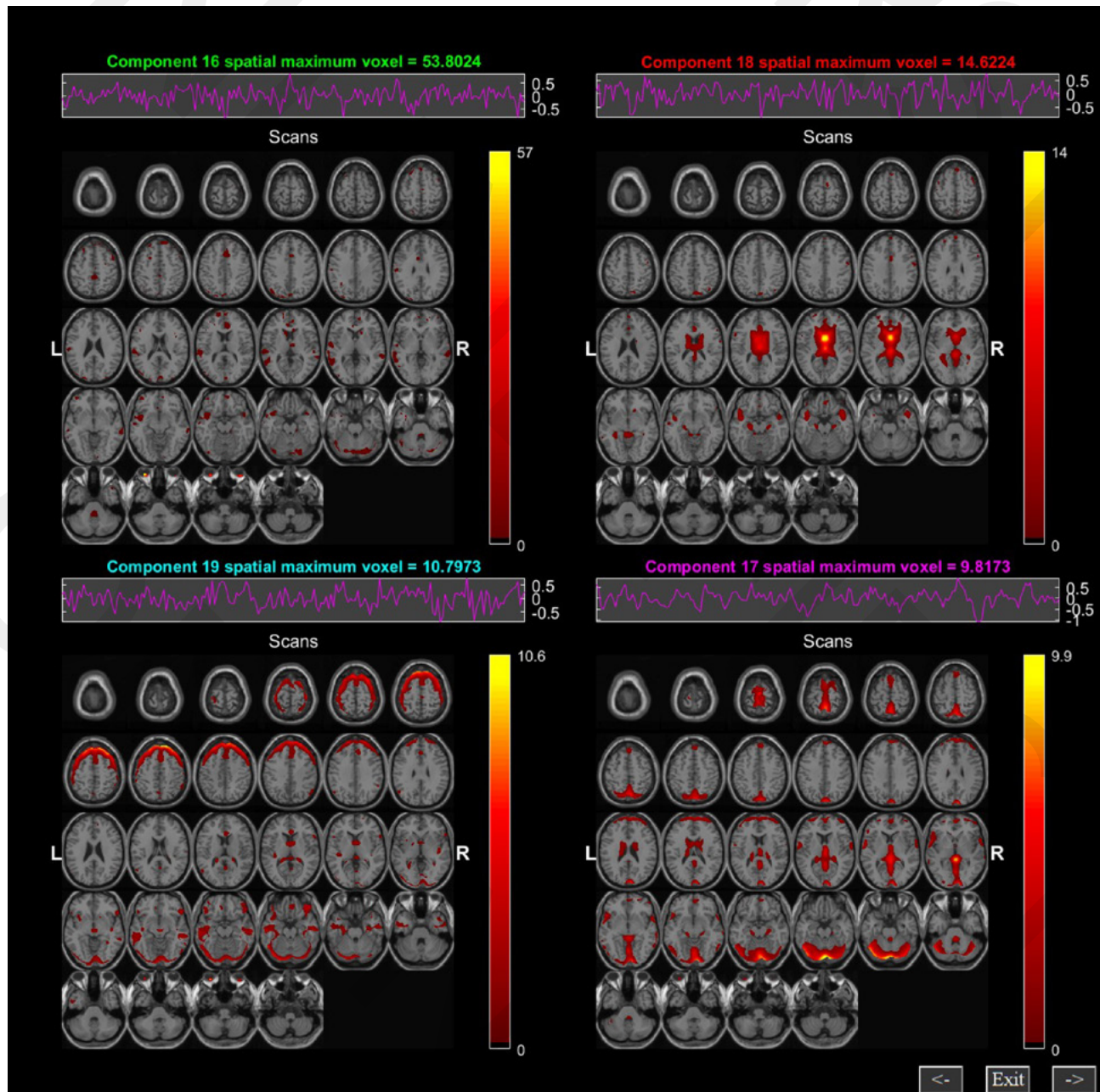


Fig. 1. BOLD signal activity for components 16, 17, 18, 19

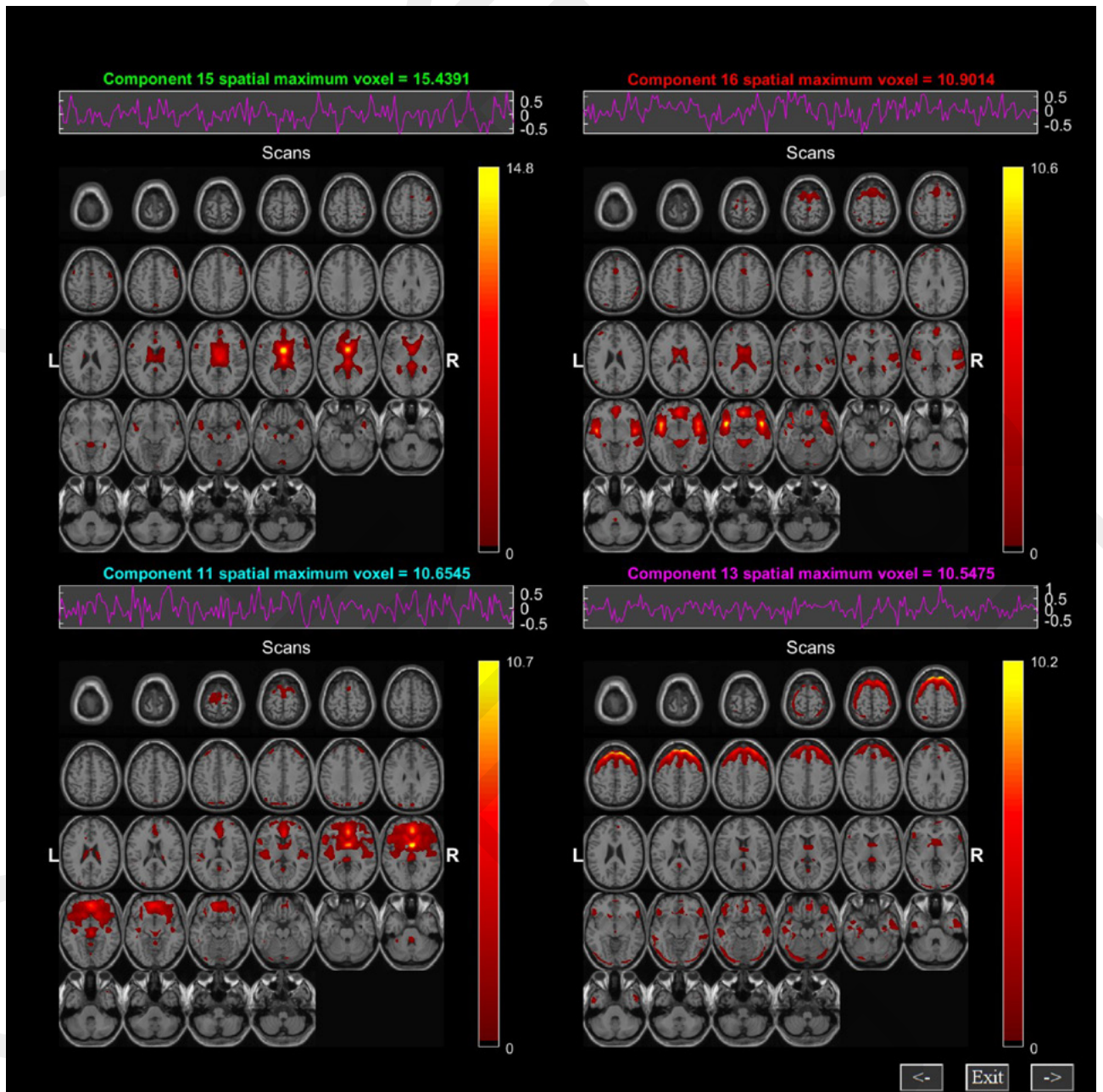


Fig. 2. BOLD signal activity for components 11, 13, 15, 16

The threshold was set to 3.5 mm, and the distance between contiguous voxels to 4 mm, for both conditions.

Statistical analysis

To contrast the two independent samples and determine whether there was a significant difference between them, based on their normal distribution, a two-sample *t*-test was conducted in SPM12 to compare them across the top four components. For the first condition, data analysis was performed at different significance thresholds ($p < 0.05$, $p < 0.001$), and for the second condition, the statistical analysis of component 16 yielded an activity at an uncorrected

significance level of $p < 0.01$; nonetheless, given the small sample size, the results lack statistical robustness.

RESULTS

The analysis of the second condition (component 16) evidenced significant ($p < 0.01$) activity in the caudate nucleus and pallidum. Figs. 1 and 2 represent the BOLD (blood-oxygen-level dependent) signal activity for each component across all subjects, including patients and healthy controls, during both conditions.

For the first condition, results showed meaningful activity in several regions (see Tabs. 2, 3, 4, 5): the superior

| Component 16 | | | | |
|------------------------------|--------------------|-------------|-------------------------------|---------|
| Area | Brodmann area | Volume (cc) | MNI (x, y, z) | Loading |
| Superior temporal gyrus | 13, 22, 38, 39, 41 | 6.7/0.8 | (44, 6, -14)/(68, -26, 0) | + |
| Declive | * | 2.1/2.8 | (-24, -78, -28)/(6, -82, -26) | + |
| Middle temporal gyrus | 19, 21, 22 | 4.2/2.4 | (-66, -34, 2)/(68, -30, -4) | + |
| Inferior frontal gyrus | 9, 44, 45, 46, 47 | 4.5/1.0 | (-52, 20, -2)/(54, 18, -6) | - |
| Superior frontal gyrus | 6, 9, 10 | 3.2/3.8 | (-4, 2, 72)/(22, 54, 34) | - |
| * Unspecified Brodmann area. | | | | |

Tab. 2. Independent component 16 analysis

| Component 17 | | | | |
|------------------------------|----------------|-------------|--------------------------------|---------|
| Area | Brodmann area | Volume (cc) | MNI (x, y, z) | Loading |
| Lingual gyrus | 17, 18 | 3.6/4.0 | (-10, -88, -20)/(12, -88, -18) | + |
| Declive | * | 8.6/7.4 | (-6, -84, -26)/(6, -82, -18) | + |
| Cuneus | 17, 18, 19, 30 | 1.5/3.1 | (0, -94, 18)/(4, -88, 36) | + |
| Fusiform gyrus | 18, 19, 37 | 3.4/1.9 | (-42, -76, -20)/(20, -86, -20) | + |
| Praecuneus | 7, 19 | 2.6/3.6 | (-4, -64, 64)/(4, -86, 40) | + |
| Extra-nuclear | * | 1.2/1.2 | (-4, -40, 4)/(4, -40, 4) | + |
| Middle occipital gyrus | 18, 19, 37 | 1.0/0.4 | (-44, -74, -16)/(8, -96, 12) | + |
| Superior frontal gyrus | 6, 8, 9, 10 | 1.7/3.1 | (-4, 8, 72)/(6, 2, 72) | + |
| Culmen | * | 1.9/1.2 | (-4, -68, -12)/(4, -70, -16) | + |
| Superior temporal gyrus | 22, 38 | 1.9/1.1 | (-62, 2, 2)/(60, 10, -4) | + |
| Caudate | * | 1.4/0.8 | (-4, 8, 8)/(6, 8, 10) | - |
| Superior temporal gyrus | 22, 38 | 1.2/1.0 | (-46, 4, -16)/(42, 14, -20) | - |
| * Unspecified Brodmann area. | | | | |

Tab. 3. Independent component 17 analysis

| Component 18 | | | | |
|------------------------------|---------------|-------------|-----------------------------|---------|
| Area | Brodmann area | Volume (cc) | MNI (x, y, z) | Loading |
| Lateral ventricle | * | 3.3/3.3 | (-4, 2, 10)/(4, 6, 8) | + |
| Caudate | * | 3.5/3.6 | (-4, 6, 8)/(4, 8, 4) | + |
| Extra-nuclear | * | 7.9/8.9 | (-2, -2, 10)/(2, -2, 10) | + |
| Thalamus | * | 5.1/5.2 | (-4, -6, 12)/(4, -16, 12) | + |
| Superior temporal gyrus | 38 | 1.7/1.9 | (-44, 2, -16)/(42, 12, -22) | + |
| Lentiform nucleus | * | 1.0/0.9 | (-14, -2, 10)/(16, -2, 10) | + |
| Insula | 13 | 2.7/1.5 | (-44, -4, 2)/(46, -6, 2) | - |
| Superior temporal gyrus | 22, 39 | 1.7/0.8 | (-48, -4, 0)/(46, -10, 2) | - |
| Inferior frontal gyrus | 46, 47 | 1.5/1.3 | (-42, 14, -6)/(44, 18, -8) | - |
| * Unspecified Brodmann area. | | | | |

Tab. 4. Independent component 18 analysis

frontal gyrus (components 16, 17, 19), associated with (pre-reflexive) self-awareness as an interface between perception and bodily movement, the praecuneus (component 17) associated with reflexive self-awareness, working memory, and high-order visuospatial coordination of bodily movement. Also, the caudate nucleus (components 17, 18) exhibited activity associated with posture, spatially cued anticipatory working memory, and goal-directed movement, while the activity of the insula was associated with homeostasis, interoception, vestibular sensations, and whole-body register of visceral and emotional states. The activity of the post-central gyrus corresponded to the primary somatosensory cortex as the main receptive area of touch.

The second condition (Tabs. 6, 7, 8, 9) showed statistically significant ($p < 0.01$) activity in the caudate nucleus and pallidum, and notable activity in the anterior cingulate cortex. The dorsal pallidum is associated with the pre-reflexive modulation of voluntary movement through sensory feedback i.e. the pallidum's inhibitory function counterbalances the cerebellum's excitatory one, smoothening the movement. The ventral pallidum is associated with the reward system, contributing to a landscape of salience involving the limbic loop. The anterior cingulate cortex is associated with high-order attentional and executive functions, self-awareness, and autonomy.

Fig. 2 represents the BOLD signal activity during the second condition.

| Component 19 | | | | |
|------------------------------|---------------------|--------------------|--------------------------------|----------------|
| Area | Brodman area | Volume (cc) | MNI (x, y, z) | Loading |
| Superior frontal gyrus | 6, 8, 9, 10 | 11.3/11.6 | (-6, 44, 54)/(14, 44, 54) | + |
| Middle frontal gyrus | 6, 8, 9, 11 | 9.0/9.3 | (-28, 34, 52)/(30, 36, 52) | + |
| Inferior occipital gyrus | 18, 19 | 1.3/0.6 | (-26, -88, -22)/(36, -84, -20) | + |
| Fusiform gyrus | 18, 19, 20, 37 | 1.6/1.3 | (-22, -88, -24)/(32, -84, -22) | + |
| Lingual gyrus | 17, 18 | 1.9/2.1 | (-10, -90, -20)/(8, -90, -12) | + |
| Precentral gyrus | 4, 6 | 1.9/2.0 | (-40, -8, 64)/(40, -8, 66) | + |
| Inferior temporal gyrus | 20, 21, 37 | 1.5/0.5 | (-56, -58, -18)/(56, -18, -20) | + |
| Middle occipital gyrus | 18, 37 | 1.1/0.4 | (-44, -80, -16)/(50, -64, -16) | + |
| Middle temporal gyrus | 21, 37 | 2.7/1.5 | (-58, -40, -14)/(52, -20, -18) | + |
| Postcentral gyrus | 1, 2, 3, 5 | 1.2/0.9 | (-44, -34, 66)/(44, -28, 66) | + |
| Superior frontal gyrus | 10 | 1.1/1.2 | (-36, 56, 18)/(12, 66, 20) | - |
| Middle frontal gyrus | 10, 46 | 2.2/2.0 | (-40, 54, 16)/(38, 60, 12) | - |
| Culmen | * | 1.2/0.1 | (-44, -44, -32)/(2, -46, 0) | - |
| Inferior frontal gyrus | 9, 10, 45, 46 | 1.2/1.5 | (-46, 50, 4)/(50, 48, 8) | - |
| Superior temporal gyrus | 21, 22, 38, 42 | 1.3/1.0 | (-62, 2, -2)/(50, 20, -24) | - |
| * Unspecified Brodmann area. | | | | |

Tab. 5. Independent component 19 analysis

| Component 11 | | | | |
|------------------------------|---------------------|--------------------|-----------------------------|----------------|
| Area | Brodman area | Volume (cc) | MNI (x, y, z) | Loading |
| Extra-nuclear | 13, 47 | 4.9/5.6 | (-2, 4, 2)/(2, 4, 2) | + |
| Caudate | * | 1.7/2.0 | (-6, 4, 2)/(6, 4, 2) | + |
| Anterior cingulate | 10, 24, 25, 32 | 5.1/5.9 | (-2, 36, 2)/(2, 36, 2) | + |
| Medial frontal gyrus | 9, 10, 11 | 4.9/4.9 | (-4, 44, -6)/(2, 52, 0) | + |
| Sub-gyral | * | 5.1/4.7 | (-18, 24, -2)/(18, 24, -2) | + |
| Middle frontal gyrus | 10, 11, 47 | 29/3.1 | (-28, 50, -2)/(26, 54, -6) | + |
| Lentiform nucleus | * | 2.4/2.6 | (-18, 16, -2)/(18, 16, -4) | + |
| Superior frontal gyrus | 6, 8, 10 | 1.8/1.6 | (-16, 48, -10)/(30, 58, -4) | + |
| Inferior frontal gyrus | 10, 45, 47 | 5.1/3.6 | (-30, 22, -4)/(36, 20, -2) | + |
| Insula | 13 | 2.9/2.2 | (-30, 18, -4)/(36, 16, -2) | + |
| Lateral ventricle | * | 1.3/1.0 | (-2, 8, 14)/(2, 10, 14) | - |
| Superior temporal gyrus | 22, 38 | 0.9/0.3 | (-46, -2, -8)/(46, 6, -16) | - |
| * Unspecified Brodmann area. | | | | |

Tab. 6. Independent component 11 analysis

| Component 13 | | | | |
|------------------------------|---------------------|--------------------|--------------------------------|----------------|
| Area | Brodman area | Volume (cc) | MNI (x, y, z) | Loading |
| Superior frontal gyrus | 6, 8, 9, 10, 11 | 11.1/13.4 | (-4, 44, 54)/(8, 44, 54) | + |
| Middle frontal gyrus | 6, 8, 9, 11 | 7.9/10.0 | (-26, 24, 60)/(30, 36, 50) | + |
| Fusiform gyrus | 18, 19, 20, 37 | 1.3/1.0 | (-24, -94, -18)/(36, -82, -22) | + |
| Inferior occipital gyrus | 17, 18, 19 | 1.9/0.8 | (-24, -90, -22)/(34, -86, -20) | + |
| Middle occipital gyrus | 18, 19, 37 | 1.2/0.4 | (-48, -74, -16)/(30, -94, -6) | + |
| Inferior temporal gyrus | 20, 21 | 1.2/0.9 | (-52, -2, -36)/(56, -18, -20) | + |
| Middle temporal gyrus | 21 | 2.0/1.5 | (-52, 2, -38)/(54, -14, -22) | + |
| Superior frontal gyrus | 6, 10 | 2.2/0.7 | (-18, -14, 72)/(16, 64, 18) | - |
| Middle frontal gyrus | 10, 46 | 1.6/1.7 | (-34, 58, 16)/(46, 52, 8) | - |
| Lateral ventricle | * | 1.0/1.0 | (-4, 8, 16)/(4, 6, 16) | - |
| * Unspecified Brodmann area. | | | | |

Tab. 7. Independent component 13 analysis

| Component 15 | | | | |
|-------------------------|---------------|-------------|--|---------|
| Area | Brodmann area | Volume (cc) | MNI (x, y, z) | Loading |
| Caudate | * | 3.6/3.8 | (-4, 6, 8)/(4, 8, 4) | + |
| Lateral ventricle | * | 3.6/3.8 | (-4, 2, 10)/(4, 6, 8) | + |
| Extra-nuclear | * | 8.3/8.8 | (-4, -2, 10)/(4, -2, 10) | + |
| Thalamus | * | 4.4/5.1 | (-6, -6, 14)/(4, -18, 12) | + |
| Lentiform nucleus | * | 1.1/1.1 | (-16, 4, 8)/(16, 2, 10) | + |
| Superior temporal gyrus | 38 | 1.5/2.0 | (-44, 4, -16)/(44, 6, -20) | + |
| Insula | 13, 47 | 2.4/1.1 | (-46, -8, 4)/(-46, -8, 4)/(46, -14, 6) | - |

* Unspecified Brodmann area.

Tab. 8. Independent component 15 analysis

| Component 16 | | | | |
|-------------------------|---------------|-------------|------------------------------|---------|
| Area | Brodmann area | Volume (cc) | MNI (x, y, z) | Loading |
| Superior temporal gyrus | 21, 22, 38 | 7.0/9.4 | (-44, 12, -14)/(44, 14, -14) | + |
| Inferior frontal gyrus | 13, 47 | 4.8/5.1 | (-40, 16, -16)/(44, 18, -14) | + |
| Medial frontal gyrus | 6, 10, 11, 25 | 3.0/4.0 | (-2, 42, -14)/(2, 42, -14) | + |
| Extra-nuclear | 13 | 1.9/1.5 | (-40, 12, -10)/(42, 12, -10) | + |
| Sub-gyral | 13, 21 | 2.0/2.8 | (-42, -2, -8)/(42, 2, -12) | + |
| Insula | 13, 22 | 2.4/2.1 | (-42, -6, -6)/(44, -4, -4) | + |
| Middle temporal gyrus | 21, 22, 38 | 1.1/4.0 | (-50, 0, -14)/(50, 2, -14) | + |
| Lateral ventricle | * | 1.7/1.5 | (-6, 4, 16)/(8, 0, 18) | + |
| Caudate | * | 1.5/1.2 | (-10, 0, 18)/(8, 4, 16) | + |
| Thalamus | * | 1.0/0.9 | (-6, -4, 14)/(10, -12, 18) | + |
| Extra-nuclear | * | 2.6/2.4 | (-2, 2, 2)/(2, 2, 2) | - |
| Lateral ventricle | * | 1.0/0.6 | (-2, 6, 4)/(2, 6, 4) | - |
| Caudate | * | 1.0/1.2 | (-6, 2, 4)/(6, 4, 4) | - |
| Lentiform nucleus | * | 1.0/0.6 | (-22, -2, 2)/(14, 6, 2) | - |
| Inferior frontal gyrus | 45, 46 | 1.1/0.3 | (-60, 28, 6)/(62, 30, 12) | - |

* Unspecified Brodmann area.

Tab. 9. Independent component 16 analysis

| | | 1. Implicit temporal experience | 2. Explicit temporal experience |
|----------------|-----|---|---|
| Triple network | DMN | Praecuneus Cuneus Superior frontal gyrus Middle frontal gyrus Inferior temporal gyrus | Anterior cingulate Medial frontal gyrus Superior frontal gyrus Middle frontal gyrus Inferior temporal gyrus |
| | SAL | Superior temporal gyrus Middle temporal gyrus Thalamus Inferior frontal gyrus Insula | Superior temporal gyrus Middle temporal gyrus Thalamus Inferior frontal gyrus Insula Anterior cingulate |
| | CEN | Middle temporal gyrus | Middle temporal gyrus |

Tab. 10. Synthesis of triple network activity during trials

Tab. 10 shows the activity of the triple network across both conditions.

DISCUSSION

Summary of the results in the functional connectivity context

The synthesis of findings revealed caudate and pallidum activity associated with explicit temporal experience,

confirmed by research on the basal ganglia involved in governing the temporal structure for movement and cognition (Kwon et al., 2015). The activity associated with implicit temporal experience showed no significant statistical differences. Nonetheless, relevant activity was observed in both conditions, Tab. 10 shows there was a loss of competition between the SAL/DMN and the CEN/Insula. Instead, there was an all-time activation of the DMN and a coactivation with the SAL (including the insula), as reported in previous research (Bolton et al., 2020; Nekovarova et al., 2014).

The CEN was deactivated in both conditions (except the middle temporal gyrus), instead of the DMN, which deactivates during CEN activity in healthy individuals.

Functional connectivity research in schizophrenia shows dysfunctional modulation of the DMN. Patients are unable to downregulate its activity during goal-directed activities, compromising their cognitive flexibility (Nygård et al., 2012), in contrast to healthy subjects (Yanagi et al., 2020). Williamson and Allman (2012) reported abnormal hyperconnectivity among the DMN regions and hypoconnectivity with other networks; these deficits are proposed to account for the disintegration of self-referential processes. Complementarily, the longer synchronic activation of the rAI and DMN has been proposed (Damaraju et al., 2014; Menon, 2011) to account for the hyper-reflexivity in schizophrenia patients, as the rAI integrates bottom-up interoceptive pathways going through the basal ganglia (Menon and Uddin, 2010), contributing to the development of adapted and efficient behaviours via the CEN.

The DMN has been associated with self-referential cognition (Zabelina and Andrews-Hanna, 2016), to processing of somatosensory and vegetative information through which the subject integrates past, present, and future experiences (Tran The et al., 2022). Confirming the latter, it has been proposed that the DMN contributes to structuring temporal experience (Irving and Thompson, 2018, p. 8; Tran The et al., 2022, p. 5), as its activity has been suggested to be associated with the unfolding of awareness (Leech and Sharp, 2014; Northoff et al., 2006). As one of the resting-state brain networks (Seitzman et al., 2019), is associated with “mind-wandering”² (MW) (Andrews-Hanna et al., 2014).

MW is characterised as a sensory-motor decoupling from the environment (Kam and Handy, 2013), resulting as a trade-off between self-generated thoughts and sensory-motor attenuation³, during which the DMN is upregulated (Christoff et al., 2009; Kirschner et al., 2012; Mason et al., 2007), while, complementarily the motor cortices are downregulated (Weissman et al., 2006). This attenuation isolates the subject from the environment, preserving a train of thought detached from actual bodily movement. This passive bodily engagement reduces the experienced re-afference⁴ (kinaesthetic, proprioceptive, haptic, etc.) to the anticipatory or protentional realm of experience, deprived of actual intercorporeal feedback.

² The notion entails a conceptual issue (Irving and Thompson, 2018). It refers to a spontaneous cognitive activity independent of external stimuli (Schooler et al., 2011) or tasks (Smallwood and Schooler, 2015), or conceived as a form of “unguided thinking” (Irving and Thompson, 2018).

³ The “attenuation effect” refers to the reduction of actual sensory feedback (mostly proprioceptive and tactile (Frith, 2005, p. 7) during self-initiated movement, caused by anticipated or predicted sensory feedback e.g. the difference between self-tickling and being tickled by someone else. This is due to inhibition of the somatosensory cortex.

⁴ Understood as the effect of an organism’s own dynamics, behaviour, and movement on itself, including the experience (Arikan et al., 2021; Jekély et al., 2021; Vallortigara, 2021).

Phenomenological import

These results can be articulated with conceptual proposals from phenomenological psychopathology.

Influenced by Bergson (2001), Bleuler (1911), and Kretschmer (1921), Minkowski distinguished between “schizoidia” and “syntonia”. Syntonia consists in sharing the same rhythm with others and the environment i.e. a form of synchronisation, whereas schizoidia consists in not being able to synchronise (Minkowski, 1970, p. 69–70, 273, 275). This distinction is rooted in the implicit temporal experience, which conveys a sense of “moving forward or becoming”. Minkowski (1927, p. 51) conceived schizophrenia as a spectrum disorder within the schizoidia continuum, mainly consisting in patients not being able to share their temporal experience and synchronise with others. As a further development, this synchronisation may be conceived as follows: social interaction entails a continuous and reciprocal echoing and shaping each other’s sensorimotor habitat (Kyselo and Tschacher, 2014). This reciprocal process modulates each individuals’ structure of affordances and pre-reflective background: social interactions may thus open up or shut down affordances. The reciprocal pre-reflexive background experience entails a coordinated implicit temporality, i.e. reciprocally experiencing intersubjective time (Laroche et al., 2014). Individual temporal experiences are coordinated through affect surging in bodily movement (Sheets-Johnstone, 2014, p. 24, 1999).

CONCLUSION

The Triple Network Hypothesis (Nekovarova et al., 2014; Tran The et al., 2021) proposes that the psychotic loss of the distinction between interoception and the external environment is associated with dysfunction within the triple network. A proposed hypothetical account for the latter is that the functional abnormality of the DMN in mental health issues (Chai et al., 2011) not only preserves the sense of selfhood (threatened by the continuum of psychopathological manifestations) by inducing isolation through MW, but also prompts the subject’s re-synchronisation through the anticipation and evocation of potential scenarios on which the subject exercises potential adaption while preserving a sense of identity.

The study demonstrated an association between schizophrenia and triple network impairment, involving the striatum (caudate nucleus) and the temporal structuring of movement and cognition. It also revealed impaired activation of the DMN and coactivation with the rAI in schizophrenia patients. The latter impairment is hypothetically associated with a lack of temporal synchronisation across a psychopathological continuum, which proportionally accounts for the social isolation every person with mental health issues experiences. The DMN is therefore proposed as a potential indicator of this phenomenon.

The conceptual elaboration of temporal experience impairment in relation to the functional connectivity findings

contributes to grounding a notion of selfhood. Nonetheless, the deep intertwining between temporal and bodily movement experience (Richter and Ostovar, 2016; Sameiro-Barbosa and Geiser, 2016; Sheets-Johnstone, 2014) requires a transdisciplinary work to better ground the notion of selfhood within psychopathology.

LIMITATIONS

The limitations of this study mainly involve the small patient sample size and the technical constraints of fMRI scanning, especially regarding tasks that involve bodily movement. The operationalisation of implicit and explicit experience in the research tasks may also be questioned from a phenomenological perspective. The hypothetical relations proposed between the experimental and conceptual findings remain tentative, as they require further precise evidence, already suggested by some studies (Northoff et al., 2023; Zapata-Fonseca et al., 2021). Nevertheless, these claims call for ongoing transdisciplinary efforts to design experimental protocols that address the subtle and fundamental aspects of a disturbed sense of body. Another limitation is the lack of direct integration of the patient's experience, such as micro-phenomenological interviews, which could explore the temporal aspects of experience and the intentional arcs structuring bodily movement. Finally, the study highlights the ongoing challenge of bridging the gap between theoretical frameworks and practical clinical applications.

Conflict of interest

The authors do not report any financial or personal connections with other persons or organisations which might negatively affect the content of this publication and/or claim authorship rights to this publication.

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Author contribution

Original concept of study; final approval of manuscript: CESS, MM, DS. Collection, recording and/or compilation of data: CESS, DS. Analysis and interpretation of data; writing of manuscript: CESS. Critical review of manuscript: MM, DS.

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