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Depersonalization Puzzle: A New View from the Neurophenomenological Selfhood Perspective

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Abstract

While there is still a limited understanding of the Selfhood phenomenon, an emerging consensus is that the experiential Selfhood refers to a sense of the undergoing experience in its implicit first-person mode of givenness that is immediately and tacitly given as "mine". It is also evident that there are phenomenological disruptions within self-consciousness ranging from normal everyday short-lived dissociative episodes to pathological, intense and prolonged forms of dissociative experience classified as depersonalization disorder (DD). In the present study we explored the neurophenomenology of Selfhood (using the recently introduced neurophysiological three-dimensional construct model of experiential Selfhood, Fingelkurts et al., 2020) in a newly diagnosed and untreated 29-year-old female who suffers from DD. According to the triad model of Selfhood, three major components of Selfhood (phenomenal first-person agency – "Self", embodiment – "Me", and reflection/narration – "I") are related to three operational modules (OMs) of the self-referential brain network (reliably estimated by electroencephalogram operational synchrony analysis). We have found that subject with DD exhibited a strong enhancement of functional integrity of the brain Self-module, a moderate decrease in the functional integrity of Me-module, and a pronounced decrease in the functional integrity of I-module, – all of which were associated with severity of specific DD symptoms.

Key Words: Self-Referential Brain Network (SRN), Default-Mode Network (DMN), Subjective Sense of Self, First-Person Perspective, Electroencephalogram (EEG), Alpha Rhythm, Operational Synchrony, Functional Connectivity, Depersonalization Disorder (DD), Dissociative Episodes, Triad Model of Selfhood, Self-Me-I

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What has really been changed or diminished with the onset of depersonalization cannot be expressed in speech. Even educated people (as in some cases in the literature) have given no clearer description, they only used metaphors.
Mayer-Gross, 1935 (p. 106)

Introduction

Despite the collective effort of philosophers, scientists, clinicians and religious scholars (James, 1890; Snodgrass and Thompson, 1997;

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Feinberg, 2000; Gallagher, 2000; Travis and Pearson, 2000; Churchland, 2003; Metzinger, 2003; Zahavi, 2005; Damasio, 2010; Fingelkurts and Fingelkurts, 2011; Strawson, 2011; Seth *et al.*, 2012; Velmans, 2014; Musholt, 2015; Klein, 2016; Northoff, 2016; Millière, 2020; just to mention a few), at present, there is still a limited understanding of the Selfhood phenomenon (Fingelkurts *et al.*, 2020). That being said, there is an emerging consensus that experiential Selfhood refers to a sense of the undergoing experience in its implicit first-person mode of givenness that is immediately and tacitly given as mine (Gallagher, 2000; Zahavi, 2005) and it is accompanied by a functionally autonomous experience of subjective confidence or certitude (Metzinger, 2003), making it possible to be engaged in autobiographical thoughts involving semantic and episodic memory events related to self, as well as projecting the self into the future, thus enabling the sense of invariance of a narrative self over time (Damasio, 2010; Gallagher, 2000; Klein, 2016; for a recent evidence and overview see Fingelkurts *et al.*, 2020). Whether this experiential Selfhood (or its minimal phenomenological form) is present in all forms of phenomenal content and functionally underlies all types of conscious experience remains a matter of contention (Zahavi, 2005; Blanke and Metzinger, 2009; Metzinger, 2003; Strawson, 2011; Millière, 2020).

At the same time, there is converging evidence that in the general population (neurotypical people), there are naturally occurring "often-unnoticed"[2] short-term, and reversible phenomenological disruptions within self-consciousness on an everyday basis (Metzinger, 2015). These experiences include such dissociative[3] states as (a) being absorbed in a task or activity (e.g. prayer or sex; Pica and Beere, 1995), when time and immediate conscious awareness of self (and environment) become distorted (Butler, 2006), (b) forms of "highway hypnosis", as commonly experienced when driving a car (Williams, 1963), or (c) daydreaming and mind wandering, which is a spontaneous, task-unrelated thought, characterized by ownership without agency, variable or absent introspective availability of goal-directedness, and frequently by a complete lack of meta-awareness (Metzinger, 2015). Next in this continuum of dissociated states are depersonalisation episodes that are considered to be common (sub-clinical) phenomena, especially in relation to stress, sleep deprivation or fatigue (van Heugten–van der Kloet, 2015; Tibubos *et al.*, 2018), with a lifetime prevalence estimated to be as high as 74% for mild, transient experiences (Hunter *et al.*, 2004). At the extreme end of the continuum lie clinically significant depersonalisation symptoms (more intense and prolonged forms of dissociative experience), that together are classified as Depersonalisation Disorder (DD), an often chronic and distressing condition that causes the sufferers to feel detached

[2] Here, "often-unnoticed" means that the phenomenology in question is introspectively available in principle, but that we almost never direct our attention there (Metzinger, 2015).

[3] Dissociation refers to a state in which one feels as a stranger in one's own body, world and often, a stranger to oneself (Sierra, 2009).

from themselves (Self), their feelings or their reality, in an almost robotic sense (American Psychiatric Association, 2013). Its prevalence varies between 0.5-2%[4] in the general population (Michal *et al.*, 2009). Besides DD being present on its own, DD symptoms are rather common in many other psychiatric conditions, like depression, schizophrenia, post-traumatic stress disorder (PTSD) and personality disorders (Sierra, 2009).

It is plausibly assumed that these different expressions of dissociation experience involve the same underlying psychophysiological mechanisms (Seligman and Kirmayer, 2008). However, since the neurotypical episodes of dissociation as well as depersonalisation episodes related to stress or fatigue are spontaneous, variable and short-lasting, catching and measuring them in laboratory-controlled settings is challenging. In contrast, DD is relatively stable/chronic and can be reliably evaluated in the laboratory. In this context, DD is a highly relevant target for research, because a better understanding of DD may help us to study the phenomenological disruptions within self-consciousness in the form of dissociation from self in a contrasted manner (Sierra, 2009). This is of highest relevance for the neurophenomenological studies of Selfhood, as well as for clinical science and practice (Sierra and Berrios, 2000; Medford *et al.*, 2005). The latter is especially important since DD is the most under-diagnosed psychiatric disorder, and on average it takes 7-12 years for a correct diagnosis[5] (Hunter *et al.*, 2004).

Aim of the study

Therefore, the aim of the present study was to use the DD as a practical and contrasting model to study fracturing of the complex experiential Selfhood, whereas components of Selfhood are dissociated from one another, leading to the peculiar symptoms' phenomenology[6] (Ciaunica *et al.*, 2021, 2022).

DD is an intriguing and paradoxical condition in which individuals report subjective experience of unreality and detachment from their sense of self, as if they were lifeless robots, automata, the outside observers of their bodily sensations, thoughts and feelings (while simultaneously retaining criticality and rational acknowledgement); there is an overall alienation of personality – a depersonalisation (Simeon *et al.*, 2008; Sierra, 2009; American

[4] However, occasionally, some studies report rates up to 23% (Aderibigbe *et al.*, 2001). The reported rate variation between studies is likely to be attributed to differences in the DD symptoms measures, the evaluated symptoms prevalence period, the age of participants, as well as sampling variation.
[5] Diagnosis is hindered by a lack of awareness about DD among medical practitioners (Medford *et al.*, 2005), as well as overlap of DD symptomatology with medical conditions like epilepsy or migraine and psychiatric conditions like depression, schizophrenia, anxiety, PTSD (Sierra, 2009).
[6] The neurophysiological characterisation of the DD was not the aim of this case report. For the potential electrophysiological and neurocomputational mechanisms of DD, the reader is referred to Seth et al (2012).

Psychiatric Association, 2013). Current yet unresolved paradoxes of DD are: (i) the DD patients have a striking lack of affective feelings and emotional numbness but at the same time they have a strong tendency to experience anxiety and fear (Sierra, 2009); (ii) the DD patients feel strangely detached from their body which feels unreal and still rationally acknowledge it as their own (Colombetti and Ratcliffe, 2012); and closely related (iii) even though the DD patients have an overwhelming experience of disembodiment, the interoception[7] is basically still intact in such patients (Michal *et al.*, 2014).

In pursuing the aim of this study, we were exploring the neurophenomenology of Selfhood in a newly diagnosed and untreated (yet)[8] 29-year-old female who suffers from DD. Additionally, in our analysis we applied the recently introduced neurophysiological *three-dimensional construct model of experiential Selfhood* (for an overview and empirical data, see Fingelkurts *et al.*, 2020; for further discussion, see Fingelkurts and Fingelkurts, 2011; Fingelkurts *et al.*, 2022). This triad model of Selfhood has been built to (i) explicitly reflect the multi-faceted and multi-layered nature of self-awareness (Snodgrass and Thompson, 1997; Musholt, 2015; Millière *et al.*, 2020) and (ii) describe the phenomenological distinctions between *three major aspects* of Selfhood, namely first-person agency, embodiment/emotion, and reflection/narration, all of which are commensurate with one another (Gallagher, 2013) and in combination constitute a unified sense of Selfhood (Fingelkurts and Fingelkurts, 2011; Fingelkurts *et al.*, 2020).

The triad model of Selfhood

The triad model of Selfhood is built on *neurophenomenological* evidence[9] (Fingelkurts *et al.*, 2020, 2022). *Neuro*physiologicaly, it considers the three major spatially separate yet functionally interacting *brain* subnets (or operational modules—OMs) that together constitute the self-referential network (SRN) (see Fig. 1 in Fingelkurts *et al.*, 2022), also often referred to as the default mode network (Raichle *et al.*, 2001; Fingelkurts and Fingelkurts, 2011; Northoff, 2016). Each OM is composed by a set of brain regions having tight "functional connectivity" among one another within every given OM (Fingelkurts and Fingelkurts, 2011). The OMs' triad includes the anterior OM and two symmetrical (left and right) occipito-parieto-temporal OMs which can be reliably estimated by means of operational

[7] Interoception is the integrated representation of information about the most basic, "hidden" causes of homeostatic/allostatic bodily fluctuations (that are dynamically controlled) such as visceral signals, blood oxygenation, endocrine and electrolyte balances by binding them into a unified entity – global organismic state (Tsakiris *et al.*, 2011).

[8] This is an important advantage, since there is no history of mediation/suppression of the anomalous subjective experiences by pharmaceutical agents and/or psychotherapy.

[9] Such a neurophenomenological approach (Varela, 1996), which specifies the relationship between specific neuronal processes operating in the brain and specific phenomenal features in the subjective experience, establishes the foundations for a "non-reductive neurophilosophy" (Northoff, 2016).

synchrony analysis of the electroencephalogram (EEG) signal[10] (Fingelkurts and Fingelkurts 2008, 2015).

*Phenomeno*logicaly, the anterior OM is responsible for the *phenomenal* first-person perspective and the *phenomenal* sense of agency (Fingelkurts *et al.*, 2020, 2022). It is labelled the "witnessing observer" or simply the "*Self*" in the narrowest sense (Fingelkurts *et al.*, 2020)—as the phenomenal non-conceptual core in the act of knowing itself (Blanke and Metzinger, 2009); or following Velmans (2014), a sensed "centre of gravity", where one having an experience of directly and immediately present as the focus of a *phenomenal* multimodal perceptual reality (Metzinger, 2003; Revonsuo, 2006; Blanke and Metzinger, 2009). The right posterior OM is associated with the *subjective experience* of self as a normally localized within bodily boundaries entity (i.e. *embodiment* realised through interoceptive and exteroceptive sensory processing integration), as well as related emotional states and autobiographical emotional memories (Fingelkurts *et al.*, 2020, 2022). It is labelled the "representational-emotional agency" or simply "*Me*" (Fingelkurts *et al.*, 2020). Conceptually, this component of Selfhood corresponds to the "minimal self" of Gallagher (2000), the "proto-self" of Panksepp (2005), and the "bodily self" of Damasio (2010). The defining feature of this Me-module is that, in contrast to a phenomenal first-person perspective, here only a purely *geometrical first-person perspective* is present that originates from within the body representation, thus signifying an egocentric spatiotemporal self-model (Blanke and Metzinger, 2009). The left posterior OM is involved in the *experience of thinking about and reflecting* upon oneself, that includes momentary narrative thoughts and inner speech, as well as reinterpretation of episodic and semantic memory events related to self – autobiographical story telling/narration (Fingelkurts *et al.*, 2020, 2022). It is labelled the "reflective agency" or simply "*I*" (Fingelkurts *et al.*, 2020). This component of Selfhood corresponds conceptually to the "narrative self" of Gallagher (2000), the "conceptual self" of Neisser (1988), the "autonoetic self" of Gardiner (2001) and Klein (2016), or the "autobiographical self" of Damasio (2010). It is this narrative self-reflection that provides the basis for the sense of invariance of Selfhood over time (James, 1890; Metzinger, 2015) and relies on the human capability for language (Damasio, 2010; Gallagher, 2000; Craig, 2004).

Notably and as was shown previously (Fingelkurts *et al.*, 2020), these three components of Selfhood are not simply an additive list of

[10] By the same token, every OM is a functional integration of several local brain fields (registered by the correspondent EEG electrodes; see Methods Section), which in their turn are the integration of yet smaller local fields of transient functional neuronal assemblies (Fingelkurts and Fingelkurts, 2008, 2015). Thus, every OM has a clear nested functional hierarchy, where higher levels of the hierarchy are physically composed of lower levels (Feinberg, 2000). Together, the three OMs, form even higher level of a functional nested architecture—the self-referential network (Fingelkurts and Fingelkurts, 2011; Fingelkurts *et al.*, 2020, 2022).

features, but rather a set of components dynamically interrelated in a *pattern* forming a complex emergent gestalt – Selfhood (Gallagher, 2013). The dynamic, functional model of relations between the three SRN OMs and related to them three phenomenal components of experiential Selfhood has been proposed by Fingelkurts and colleagues (2020). According to this conceptualisation, in a healthy neurotypical person a "*full-blown complex Selfhood* emerges as a locus of experience and self-ascription with a strong first-person perspective and bodily agency, accompanied by the attentional and cognitive control at the mental level, coupled with a sense of "knowing that one knows", and revealed through the extended autobiographical self-narrative model equipped with social, emotional and evaluational aspects of self-experience" (Fingelkurts *et al.*, 2020; p. 23). However, because of such inherent complexity, where different components of Selfhood may have different weights and configurations of relations (constant flux and dynamic readjustment), the coherent sense of Selfhood can be altered as, for example, was shown for altered states of Selfhood (Fingelkurts *et al.*, 2022). Such alterations are accompanied by rather particular nuanced "qualitative flavour" (Gallagher, 2013) that effectively distinguishes different altered states of Selfhood among themselves (Fingelkurts *et al.*, 2022). Capitalising on these observations, we expect that such triad model of Selfhood may prove useful in explaining DD and also extending our understanding of the neurotypical dissociated states as they are often observed in the normal population (Williams, 1963; Pica and Beere, 1995; Butler, 2006; Metzinger, 2015).

Methods

Participant

An archived anonymized EEG, demographic and medical dataset was obtained for retrospective analysis from the data-registry of BM-Science (*N* = 1.031 on the day of study onset). Subjects in this registry (initial cases) were either participants from previous studies, or self-selected to receive well-being advice, or were referred by doctors for neurophysiologic evaluations. For inclusion in the present study, subjects had to meet both of the following DD diagnostic criteria: (i) the Cambridge Depersonalization Scale (CDS[11]; Sierra and Berrios, 2000) total score ≥70 on the depersonalization/derealization items, (ii) DD diagnosis according to DSM-5 (American Psychiatric Association,

[11] The CDS is a 29-item questionnaire measuring trait depersonalization and derealization (Sierra and Berrios, 2000). Subjects rate the frequency (range 0–4) and duration (range 0–6) of different experiences over the preceding 6 months, using Likert scale. Frequency and duration scores are summed across all items (range 0–10) with CDS total score ranging from 0 to 290. The cut-off score associated with a clinical diagnosis of DD is 70 (Sierra and Berrios, 2000). Scores were also calculated for four subscales: emotional numbing (CDS-EN), anomalous body experience (CDS-AB), anomalous subjective recall (CDS-ASR), and alienation from surroundings (CDS-AfS) (Sierra, 2009).

2013)[12] confirmed by a qualified psychiatrist. Even though five subjects with dissociative episodes were identified, only *one* subject was eligible according to both inclusion criteria, and thus was included in this study (29-year-old female; CDS = 151). Analysis of medical data records revealed that besides having DD, the subject was in otherwise good physical/neurological health, did not have neither major depressive disorder nor posttraumatic stress disorder, and did not use psychoactive medications.

Additionally, the subject was administered the Beck Anxiety Inventory (BAI)[13] (Beck *et al.*, 1988) and Hamilton Anxiety Rating Scale (HAM-A)[14] (Hamilton, 1959). These instruments were chosen because DD sufferers often experience anxiety and fear (Roth, 1959; Sierra et al., 2002; Sierra, 2009).

All data were initially collected as part of a clinical audit. This study was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) and standards established by the Review Board of BM-Science – Brain and Mind Technologies Research Centre. Prior to EEG recording, the procedure was explained and the participant signed an informed consent form. The use of the data for scientific studies was authorized by written informed consent of the subject and approval by the Review Board of BM-Science – Brain and Mind Technologies Research Centre.

EEG recording and pre-processing

On-going EEG activity was recorded (using a digital Mitsar EEG recording system) late in the morning to minimize drowsiness, in a quiet and dimly lit room for 6 minutes while the subject was seated on a comfortable half reclined armchair with eyes closed. Subject was asked to have a moderate breakfast and refrain from the consumption of nutraceuticals (e.g., vitamins, supplements), drugs and non-pharmaceutical psychostimulants (e.g., coffee, tea, alcohol) at the morning of the EEG-session day. During the EEG recording the subject was requested to remain in a standard resting state

[12] Diagnostic criteria include persistent or recurrent experiences of depersonalization, derealization or both that cause significant distress and are not part of other mental disorder (such as schizophrenia, panic disorder, major depressive disorder, acute stress disorder, or posttraumatic stress disorder), nor attributable to the physiological effects of a substance (e.g., a drug of abuse, medication) (American Psychiatric Association, 2013).

[13] The BAI is a 21-item self-administered anxiety measure (Beck *et al.*, 1988). Subjects rate how much they have been bothered by specific symptoms in the past week using a 4-point Likert scale (0 – "not at all" to 3 – "severely"). Scores range from 0 to 63, with higher scores reflecting more severe anxiety (0–7 = minimal; 8–15 = mild; 16–25 = moderate; 26–63 = severe; Beck *et al.*, 1988).

[14] The HAM-A is a 14-item not self-administered anxiety measure (Hamilton, 1959). The severity of anxiety symptoms is ranked using 5-point Likert scale (0 – "not present" to 4 – "very severe"). Scores range from 0 to 56, with higher values reflecting more severe anxiety (0–5 = no anxiety; 6–14 = minor anxiety; 15 and more = major anxiety; McDowell, 2006).

condition[15]. In this condition, she had to keep muscles relaxed minimizing any movements, avoid talking and stay awake.

The following parameters of the EEG recording were used: (i) 19 scalp locations (i.e. O_1, O_2, P_3, P_4, P_z, C_3, C_4, C_z, T_3, T_4, T_5, T_6, F_z, F_3, F_4, F_7, F_8, Fp_1, Fp_2) according to the International 10–20 System of the EEG electrode placement; (ii) 256 Hz sampling rate; (iii) monopolar montage with linked earlobes as a reference electrode; (iv) 0.5–30 Hz bandpass; (v) 50 Hz notch filter ON; (vi) electrooculogram (0.5–70 Hz bandpass); (vii) impedance below 10 kΩ. Throughout the EEG recording, the experimenter monitored the participant's state and on-going EEG traces to assist the subject in maintaining adequate level of vigilance (i.e., avoiding drowsiness and sleep onset).

Artifact removal was performed by visual inspection of the raw EEG data, augmented by a computerized artifact detection and rejection algorithm (for details, see Fingelkurts *et al.*, 2020, p.7). Artifact-free EEG data were subjected to a further computerized analysis: the EEG signal was fragmented into consecutive 1-min epochs, which were bandpass-filtered (Butterworth filter of sixth order) in the alpha (7–13 Hz) frequency band. Forward and backward filtering were used to eliminate phase shifts. The reasons for the alpha frequency choice are described in detail in Fingelkurts et al (2020).

Additionally, clinical EEG classification developed and validated on a large number of neurological and psychiatric patients that estimates the deviation of resting EEG from the norm (Jirmunskaya and Losev, 1980) was also performed by a researcher with extensive clinical EEG experience (~30 years).

Deriving the triad of SRN OMs and estimating their strength

The following description is largely taken from our previous study (Fingelkurts *et al.*, 2022), as it is a standard procedure. In the current study, a set of brain areas that have been previously established as belonging to the SRN (Fingelkurts and Fingelkurts, 2011) was used. Such areas were not selected arbitrary to be part of the SRN. Nine areas (included in the triad model of Selfhood) naturally emerged as members of three most stable task-independent EEG spatiotemporal patterns (OMs) with extremely high strength of operational synchrony. This finding has been replicated in two independent studies with participation of subjects from two different nationalities and two different sensory modalities (for detail, see Fingelkurts and Fingelkurts, 2011). These nine operationally synchronized cortical areas were used to estimate the operational synchrony strength within the three SRN OMs: *anterior* OM – formed by F_3-F_z-F_4 EEG locations;

[15] Resting-state qEEG reflects intrinsic default brain activity that instantiates the maintenance of information for interpreting, responding to and predicting environmental (internal and external) demands (Rogala *et al.*, 2020).

left posterior OM – formed by T_5-P_3-O_1 EEG locations; and *right posterior* OM – formed by T_6-P_4-O_2 EEG locations (see Fig. 1 in Fingelkurts *et al.*, 2022).

Several hierarchical stages of data processing were required in order to estimate operational synchrony strength within every OM. The details of this multistage procedure can be found elsewhere (Fingelkurts and Fingelkurts, 2008, 2015). Here only a brief overview of the main steps is provided. During the first step, each local EEG signal was reduced to a naturally existing temporal sequence of nearly stationary (quasi-stationary) segments of varying duration. To uncover these quasi-stationary segments from the complex nonstationary structure of local EEG signals, an adaptive segmentation procedure was used (Fingelkurts and Fingelkurts, 2008, 2015). The aim of such segmentation is to divide each local EEG signal into naturally existing quasi-stationary segments by estimating the intrinsic boundaries among segments – *rapid transitional periods* (RTPs). RTP is defined as an abrupt change in the analytical amplitude of the EEG signal above a particular threshold derived from modelling studies and statistical analysis (Fingelkurts and Fingelkurts, 2008, 2015). It has been proposed that each stationary (homogeneous) segment in the local EEG signal corresponds to a temporary stable local microstate—an *operation* executed by a neuronal assembly (Fingelkurts *et al.* 2010). The temporal coupling (synchronization) of such segments among several local EEG recordings then, reflects synchronization of operations (i.e. *operational synchrony*) produced by different neuronal assemblies (located in different cortical regions) into the integrated and unified patterns responsible for complex mental or cognitive operations (Fingelkurts *et al.*, 2010).

During the second step of the analysis estimation of operational synchrony within every OM was performed. Formally, operational synchrony estimates the statistical level of RTP temporal coupling between two or more local EEG recordings (Fingelkurts and Fingelkurts, 2008, 2015). This measure tends toward zero if there is no synchronization between EEG segments derived from every pair of EEG channel, and has positive or negative values where such synchronization exists[16]. Positive values (above upper stochastic threshold) indicate an “active” process of coupling of EEG segments (synchronization of EEG segments is observed significantly more often than expected by chance as a result of random shuffling of segments during a computer simulation), whereas negative values (below lower stochastic threshold) mark an “active” process of decoupling of

[16] The operational synchrony measure used in the current study has been specifically tested through previous modelling experiments to address the issue of volume conduction that may present an obstacle in interpreting EEG data in terms of brain functional connectivity (Fingelkurts and Fingelkurts, 2008, 2015). These tests show that operational synchrony values are sensitive to morpho-functional organization of the cortex as opposed to volume conduction, EEG signal power, and/or choice of the reference electrode (for further details, we refer the reader to Fingelkurts and Fingelkurts, 2008, 2015).

segments (synchronization of EEG segments is observed significantly less than expected by chance as a result of random shuffling of segments during a computer simulation) (Fingelkurts and Fingelkurts, 2008, 2015). The *strength* of EEG operational synchrony is proportional to the actual (absolute) value of the measure: the higher this value, the greater the strength of functional connection and correspondently the *functional integrity* of the OM. Using the described pair-wise analysis, operational synchrony was identified in several (more than two) channels – synchrocomplexes (SC); these define OMs. The criterion for defining an OM is a sequence of the same synchrocomplexes (SC) during every 1-min epoch, whereas a SC is a set of EEG locations in which each location forms a paired combination with valid values of operational synchrony with all other EEG locations within the same SC; meaning that all pairs of EEG locations in an SC have to have statistically significant synchrony linking them together (Fingelkurts and Fingelkurts, 2008, 2015).

Statistical Analyses

The normality of the EEG was assessed by comparing the study subject' EEG with the FDA approved Human Brain Index Reference Database – HBIRD (matched age group: N = 33, 26-30 years old) (Kropotov, 2009). HBIRD served as a healthy age-matched reference and was used in the comparative analysis. The comparison was made using parametric statistical procedures that express the differences between the subject and her appropriate age-matched reference group in the form of Z-scores. A Z-score is the difference between the mean score of a healthy population (normative reference) and the individual subject's score divided by the standard deviation of the population (Sprinthall, 2011). Statistically, Z-scores quantify deviation of an observed value from normative reference data. It expresses how much higher ($Z > 0$: "positive deviation") or lower ($Z < 0$: "negative deviation") the given values of the subject are in comparison with the mean value of the matched normative/healthy data reference, in terms of standard deviation (SD). Deviation from the normative/healthy level is ranged from slight (2 SD; $p < 0.05$), moderate (2.5 SD; $p < 0.01$), high (3 SD; $p < 0.003$) to very high (4 SD; $p < 0.0001$).

The strength of functional connectivity within every OM was assessed using EEG operational synchrony analysis (described in the previous subsection) as an average value for all 1-minute EEGs of the study subject. These values of each OM were compared to the population normative reference values (based on previous study; Fingelkurts and Fingelkurts, 2010). This normative reference (N = 87 – a sample size which is comparable with the required for the normative database comparisons; Congedo and Lubar, 2003) included only healthy persons without current or past neurologic or mental complains. The differences in strength of OMs operational synchrony between study subject and normative reference were presented as a *percent change* from the normative reference and statistical significance of this change was assessed using a One-Sample *t*-Test with a null hypothesis maintaining that the change is “0” (no change).

Results

Case report

A 29-year-old right-handed female, with 17 years of formal education, working in service and being in a married-like relation, who was living a normal and happy life before September 2020, was presented with a sudden onset of a set of symptoms characterised by unreality of herself and her surroundings. The subject reported that several years ago she started to feel stress from doing normal (everyday) things as if they were assignments which she had to finish and that she felt judged for the quality of the work. These feelings lasted a few months and then stopped. In August 2020 she had experienced strong stress at work, with accompanying somatic presentations like hypersalivation that required constant swallowing, which then became persistent even when there was no saliva to swallow; over-reactivity to innocuous stimuli like the phone or door ringing; general oversensitivity and a racing heart. In September 2020, suddenly, she stopped feeling (i) emotions, (ii) tiredness, (iii) need for sleep or food; her body felt numb and the overall feeling was that she is a robot, who is living and doing things mechanically. Such feelings had persisted since then. In February 2021 she was referred to our Centre by her psychiatrist for electrophysiological evaluation of the subject’s brain activity.

Her childhood development was uneventful, with developmental milestones within the normative ranges. There was no clinically significant past or family history; however, the subject did report body-related bullying in early middle school. Physically, the subject appeared normal (no abnormality). On mental status examination, the subject appeared anxious but otherwise conscious, cooperative, well-groomed with adequate eye contact and easy communication during the interview. Her speech was relevant and did not show evidence of formal thought disorder, even though the subject had difficulty forming sequential and coherent narratives of events. Her judgments and insight were intact, though the descriptions were not from the first-person perspective but rather as if she was an outside detached observer. Further, she was preoccupied with her state and rationally distressed with perceptual disturbances in the form of depersonalization and derealization.

Psychometrics

The subject had a total CDS depersonalization/derealization score of 151 (the cut-off is 70; Sierra and Berrios, 2000), thus confirming the DD diagnosis. Additionally, scores for the separate factors representing the DD-related symptoms were also calculated[17] using the same CDS scale: Anomalous Body Experience = 30 %; Emotional Numbing = 70 %; Anomalous Subjective Recall = 62 %; Alienation from Surroundings = 75 %.

Concerning the experience of anxiety, the subject obtained elevated score in both BAI (=17) and also HAM-A (=16) scales, thus indicating a moderate/major increase in anxiety (Beck *et al.*, 1988; McDowell, 2006). Further, in both scales the anxiety was driven by subjective/psychic factor (anxious apprehension)[18] rather than the somatic one (anxious arousal)[19]: score = 13 *vs* 3 for BAI and 11 *vs* 5 for HAM-A.

Neurophysiological findings: Standard EEG assessment for normality

Standard clinical EEG assessment of the study subject revealed marked deviations in resting EEG characteristics from the healthy norm (comparison with matched age group from HBIRD; Kropotov, 2009): alpha frequency decrease (Z score = -1.3 SD); alpha power (especially in right-parietal-occipital-right-temporal areas) increase (Z score = +2 SD); delta power (especially in frontal-central-temporal-parietal areas) increase (Z score = +3 SD); theta power (especially in central-temporal areas) increase (Z score = +2 SD); beta power (especially in frontal-central-temporal areas) increase (Z score = +2 SD).

Neurophysiological findings: Strength of operational synchrony within the triad of SRN OMs

Figure 1 presents the percent change from the matched age normative reference (N = 87; Fingelkurts and Fingelkurts, 2010) in the strength of EEG operational synchrony within every OM belonging to the SRN triad of the study subject. We observed a significant increase from the normative values in the integrity of the self-referential brain network OM related to “Self” (One-Sample t-test: $t = +18.8$; $p = 0.00001$) and reduction in the integrity of the self-referential brain network OMs related to “Me” (One-Sample t-test: $t = -5.9$; $p = 0.0019$), and “I” (One-Sample t-test: $t = -13.8$; $p < 0.00003$).

[17] Since every score is an arithmetic sum of frequency (0-4) and duration (0-6) for a set of items assigned to a given factor, and there are different number of items for different factors, we reported for every factor the percent from the maximum possible total score for every given factor. Such normalisation allows us to compare the factors among each other within the same scale.
[18] Anxious apprehension refers to the mental component of anxiety and consist of negative expectations about self-evaluation, worrying, and disrupted attentional processes (Beck *et al.*, 1988).
[19] Somatic anxiety is a physiological component of anxiety, characterized by autonomic/body arousal, such as heightened blood pressure, sweating, changes in respiratory rate and intensity (Beck et al., 1988).

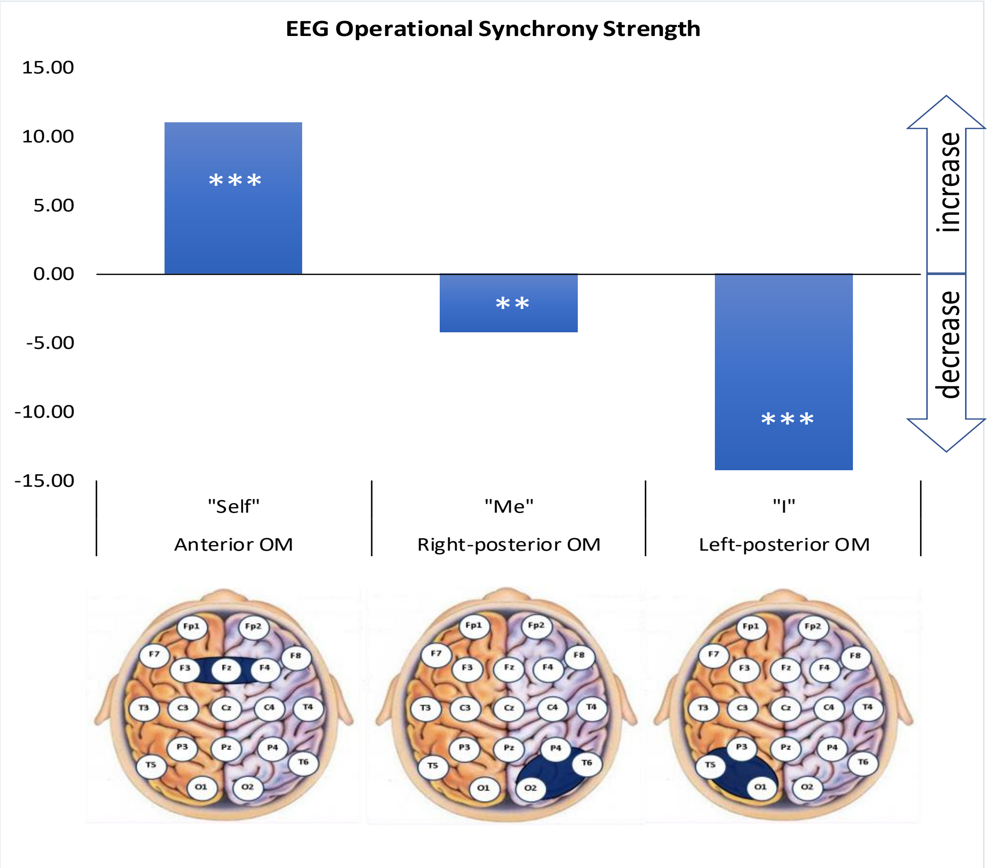

Figure 1. Percent change from the normative reference in the strength of EEG operational synchrony within the three OMs of the brain SRN of the subject suffering from DD. The *Y*-axis presents percent change. The "zero" represents absence of difference from the normative reference. The *X*-axis represents the three OMs corresponding to three phenomenological components of Selfhood: "Self" (witnessing agency), "Me" (body-representational agency) and "I" (reflective/narrative agency). The schematic cortex maps below the graphs indicate the positions of OMs (dark blue shapes). Abbreviations: DD – depersonalisation disorder; OM – operational module. Asterisks denote $p < 0.01$ (**), and $p < 0.001$ (***) (One-Sample *t*-test with a null hypothesis maintaining that the change is "0" – no change).

To estimate how the pattern of percent changes in the operational synchrony strength of triad OMs is associated with the pattern of the accumulated percent of symptoms' expression for different symptom-factors of DD, we transformed the percent change values into mathematical module and also re-arranged the scores of four symptom-factors into three: Alienation from Surroundings (as detached Observer), Anomalous Subjective/Thought Recall, and average of Anomalous Body Experience and Emotional Numbing as a third factor since both are related[20]. Even though the accurate

[20] The rationale behind averaging the scores of "Emotional Numbing" and "Anomalous Body Experience" as a unified factor is that both factors are related whereas emotional states have a bodily dimension as they are expressed and often subjectively experienced though bodily states (for some discussion, see Damasio, 2010; Seth *et al.*, 2012; Gerrans, 2019).

statistical estimation of correlation was not possible due to a very small number of data values (only 3 data-points) for both variables (OMs percent change and accumulated percent of symptoms' expression for different symptom-factors of DD), one can see that both patterns follow similar trend: stronger percent change in the OMs integrity was associated with higher percent of accumulated symptoms in a corresponding symptom-factor.

Discussion

The goal of the present study was to analyse fracturing of the complex experiential Selfhood in a DD subject. It was hypothesised that different components of Selfhood would be dissociated from one another, leading to a peculiar DD symptoms' phenomenology (Simeon, *et al.*, 2008; Sierra, 2009; American Psychiatric Association, 2013; Ciaunica *et al.*, 2021, 2022). As the main result of this study we observed that subject with DD exhibited a profound reorganisation in the integrity of three SRN OMs (indexed by the EEG operational synchrony analysis). Such reorganisation was expressed through a strong enhancement of functional integrity of the *Self*-module of the brain SRN, moderate decrease of the functional integrity of *Me*-module and a considerable decrease of the functional integrity of *I*- module of the brain SRN (Fig. 1). This alteration in the functional integrity of the OMs triad, when approached from the tenets of the triad model of Selfhood and also considering previous findings on the causal links between the functional integrity of the three SRN OMs and correspondent to them the three phenomenological aspects of Selfhood (Fingelkurts *et al.*, 2020), can help to elucidate the DD symptomocomplex.

The anomalous body experience highlighted by a feeling of disembodiment, lack of body ownership and physical agency (as was measured by CDS scale; Sierra and Berrios, 2000) was associated with decreased integrity of the SRN Me-module (measured by the EEG operational synchrony) which (as was documented empirically; Fingelkurts *et al.*, 2020, 2022) brings about diminished automatic and immediate sense of physical agency, accompanied by a decrease in the first-order experiential sense of ownership (that it is me who owns the body; Gallagher, 2000; Tsakiris *et al.*, 2011), as well as body self-location, body orientation, body image and body schema. In a set of experimental studies (Fingelkurts *et al.*, 2020, 2022) we also have shown that these changes were corroborated by an increased sense of involuntariness that marks the lack of deliberate control, feeling that body sensations and thoughts are not caused by oneself thus leading to detachment, where the subject stops experiencing oneself as a fullfledged embodied entity[21]. Further, since embodiment relies heavily on interoception, exteroception, proprioception, and a spatiotemporal reference frame (Metzinger, 2003; Craig, 2004; Blanke and Metzinger, 2009; Tsakiris *et al.*, 2011; Seth *et al.*, 2012), all of which are associated with the perception of emotion-related bodily states[22] (Craig, 2004; Damasio, 2010; Seth *et al.*, 2012; for an overview, see Fingelkurts *et al.*, 2020), one may propose that the very same decreased functional integrity of the SRN *Me*-module was also responsible for the emotional numbness (as measured by CDS scale), as well as lack of integration of affective states with thoughts and perceptions in the study subject. This reinforces the feeling of alienation in the subject, because such a condition elicits a subjective sense that the entity that sustains affect is no longer present (Gerrans, 2019). An independent finding of the increased theta activity in the present study subject confirms these observations; – it has been documented that increased theta activity in DD patients is associated with impairment in processing of the emotional information (Quaedflieg *et al.*, 2013). Narration and self-reflection play a major role here (Gallagher, 2000; Fingelkurts *et al.*, 2020, 2022).

Indeed, it is well documented that patients with DD have problems with the “plot” of their life (Ciaunica *et al.*, 2021, 2022) and difficulties forming sequential and coherent (autobiographical) narratives[23], although their memories are functionally intact (Giesbrech *et al.*, 2010). Furthermore, such memories have a persistent lack of feeling (emotional colors) in such patients (Sierra, 2009). The subject of the present study reported that she constantly feels as if it not she who personally experiences events and that she has an impression as if she is just an outside observer of her life, bodily sensations, feelings and thoughts. These alterations in self-reflection and narrative flow are consistent with the profoundly decreased functional integrity in the brain SRN *I*-module (Fig. 1) that is responsible for the high-level cognitive and narrative aspects, as well as reinterpretation of episodic and semantic memory events related to self – autobiographical story telling (Fingelkurts *et al.*, 2020). Previous studies of altered states of Selfhood (Fingelkurts *et al.*, 2022) and psychedelic effects on self (Girn and Christoff, 2018) have shown that the mentioned alterations in the autobiographical self and personal narrative seem to occur following initial changes in bodily self and altogether are associated with changes in perception of time[24]. This is

[21] This is in line with observations that the more depersonalized the subjects are from their own bodies, the lower their psychophysiological response to a threat delivered to their own body (Sierra and Berrios, 2000).
[22] In other words, emotion comes together with the experience that this is my body (a sense of body ownership), namely, it is me who is living through an event with a particular affective colour (Damasio, 2010).
[23] Having access to a coherent autobiographical knowledge is fundamental for a cognitive Selfhood, because what actions one did and experienced in the past define one’s personal identity in the present and actually shapes how one imagines the self in the future (Morin, 2011).
[24] For example, following the conceptualisation of Wittmann (2013) that continuous visceral and proprioceptive input from the body (embodiment) is the functional anchor of time perception,

consistent with the report of the present study subject, who claimed that her thought process is simple, slow and nonsequential. Distorted sense of time in patients with DD was reported previously (Simeon *et al.*, 2008), mostly indicating time slowing (Freeman and Melges, 1978) or in extreme cases a complete stop of time (Simeon *et al.*, 2008). Interestingly, an independent finding in the present study subject confirms these observations. Indeed, the standard clinical EEG evaluation revealed that alpha frequency decreased. It is well documented that one of the functional roles of alpha rhythm is the sampling of the incoming information into so-called "perceptual moments" (Klimesch *et al.*, 1996; Valera, 1996). This means that a slower alpha rhythm is responsible for longer "perceptual moments" that are phenomenologically experienced as the passage of time slowing, where the perceived world is experienced as an unreal static picture that ceases to move (Colombetti and Ratcliffe, 2012), thus eliciting the feeling of derealization which is yet another symptom of DD (American Psychiatric Association, 2013), characterized by a sense of unfamiliarity with one's own surroundings, including with spaces and objects that are intimately known.

The subject of the present study, similarly to other patients with DD (American Psychiatric Association, 2013), repeatedly reported that she felt as if she is a detached outside observer of her own body, mental process and her life, that she is somehow cut off from it all. This symptomocomplex is consistent with the noticeable upregulation in the integrity of the brain SRN *Self*-module (Fig. 1) which is responsible for the feeling of being a phenomenal spatio-temporal "point", that observes and witnesses itself and the world (Fingelkurts *et al.*, 2020). Broadly speaking, it provides the experience of being a witnessing agent (self in the act of knowing)—an epistemic agent that expands its knowledge by directing its own attention at oneself and the world in the present moment (Velmans, 2014; Metzinger, 2015; see also Gallagher, 2000; Zahavi, 2005; Revonsuo, 2006; Damasio, 2010). Such involuntary hyper-observation and hyper-witnessing (realised by an upregulated Self-module) is likely to be a compensatory mechanism[25] for the feeling of disembodiment and emotional numbness (instantiated by the downregulated Me-module) accompanied by extreme shortage of narration and reflectivity (accomplished by the downregulated I-module). In other words, hyper-observation or hyper-witnessing struggles with a profound lack of intentional reflection due to a loss of narrative flow and thus incapability to make sense ("explain away" Seth *et al.*, 2012) of the experienced disembodiment and lack of "mineness", leading to even stronger feeling of alienation, being an automaton, a robot-like

one may speculate, that decreased sense of body ownership and body image should decrease temporal perception (Fingelkurts *et al.*, 2022). This is so, because subjective time emerges through the bodily self as an enduring embodied entity across time (Wittmann, 2013).

[25] Indeed, it may reflect an attempt to cope with depersonalization–derealization symptoms and hold on to reality (see also, Simeon *et al.*, 2008).

machine (Simeon *et al.*, 2008; Sierra, 2009; Ciaunica *et al.*, 2021, 2022). As a net consequence, depersonalization feelings are prevented from being properly introspected, cognitively reflected and integrated, resulting in subjective feeling of anxiety and fear of losing control that are repeatedly reported by the patients with DD (Roth, 1959; Sierra, 2009), including the present study subject. Indeed, assessment of anxiety in the present study subject, using two separate scales (BAI and HAM-A), revealed the presence of the subjective/psychic anxiety (anxious apprehension) rather than the somatic one (anxious arousal)[26]. This observation was confirmed by an independent line of findings in the present study subject. Indeed, the standard clinical EEG evaluation revealed increased alpha rhythm power (especially in the right hemisphere), as well as increased power in delta and beta rhythms. Such changes have been repeatedly shown to indicate increased anxious apprehension (Andersen *et al.*, 2009).

Can the findings from this case study be generalized? We think that making generalizations shouldn't be done mechanistically. Since the three components of experiential Selfhood are intimately linked to phenomenology, the configuration of Self, Me, and I will vary among patients according to the arrangement (presence, number, and dominance) of their phenomenological symptoms.

Conclusions, significance, limitations and future research

The present study shows a strong indication that the three-dimensional construct model of experiential Selfhood (Fingelkurts *et al.*, 2020, 2022) is a useful explanatory construct for the rather peculiar and paradoxical symtomocomplex of DD (Simeon *et al.*, 2008; Sierra, 2009; American Psychiatric Association, 2013; Ciaunica *et al.*, 2021, 2022). We have shown that all phenomenologically experienced symptoms reported by the study subject and also measured by the standardized scales could be plausibly mapped to alterations in the dynamics of functional integrity of the brain SRN OMs (related to "Self," "Me," and "I"). In this context, some of the seemingly unresolved DD paradoxes are cast in a different light. For example, the simultaneous presence of emotional numbness and a tendency to experience anxiety and fear (Sierra, 2009) could be the result of decreased functional integrity of the SRN *Me*-module (which is responsible for the disembodiment and lack of affective feelings) and increased functional integrity of the *Self*-module (that brings about hyper-observation) coupled with decreased functional integrity of the *I*-module signifying lack of proper introspection, cognitive reflection and integration of the "strange" depersonalization experiences, thus leading to feeling of anxiety and fear of losing control. Another paradox that relates to a parallel presence of the feeling of detachment from

[26] Previous studies have also shown that depersonalisation correlates with anxiety measures (Roth, 1959; Sierra, 2009).

one's own body, which feels unreal coupled with rational acknowledgement of it as one's own (Colombetti and Ratcliffe, 2012) could be understood as the result of decreased functional integrity of the *Me*-module with an increase in functional integrity of the *Self*-module that instantiates an epistemic agent that expands its knowledge by directing its own attention toward oneself and the world in the present moment (Metzinger, 2003; Velmans, 2014). Indeed, persons with DD can perceive and cognise their bodies (Michal *et al.*, 2014). Yet another paradox could be resolved: this one relates to a fact that whilst patients with DD experience disembodiment, their interoception remains essentially intact (Michal *et al.*, 2014). Even though the decreased functional integrity of the *Me*-module results in an overwhelming experience of disembodiment, it does not preclude normal interoception, since the *Me*-module (as well as other modules) is an integration of several brain areas and many neuronal assemblies each of which is responsible for different functions (Fingelkurts *et al.*, 2020). It is the higher-level integration of such different functions that is disrupted in DD, not the separate functions themselves (Michal *et al.*, 2014; Gerrans, 2019).

Further, neurophysiological changes related to the Self-Me-I triad as the function of the DD symptoms may help to extend our understanding of the neurotypical dissociated states in Selfhood as they are observed in the normal population (Williams, 1963; Pica and Beere, 1995; Butler, 2006; Metzinger, 2015). Indeed, as we have observed previously (Fingelkurts *et al.*, 2022), some altered states of Selfhood induced the Self-Me-I triad changes quite similar to the profile of the current study subject with DD, although without the associated distress. This later difference remains to be explored in future studies. However, the following insight could be suggested: An experienced meditator usually intentionally entering a quasi-DD state with some semblance of "ownership" and "control" (as described in Fingelkurts *et al.*, 2022), knowing what to anticipate and how to quickly return to a "normal" state. In contrast, patients usually do not have as much insight/control (if any)… they just "suddenly" and unintentionally plunged into DD state (for further discussion, see Ciaunica *et al.*, 2021).

A limitation of the present study is the single subject that limits the generalizability of the results; hence, the reported findings should be seen as preliminary and have to be validated in a proper sized sample of patients with DD. However, the strength of this study is that the study subject had pure DD which was not confounded by treatment or be a comorbidity of any other mental condition. This is of a high scientific and clinical value, because the majority of DD studies analyze the DD symptoms in other disorders (like schizophrenia, major depression, posttraumatic stress disorder, drug abuse, or borderline personality disorder). Patients with pure DD without concomitant additional diagnoses are both difficult to find and hard to motivate for participation in the scientific studies.

CRediT authorship contribution statement

Andrew A. Fingelkurts: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft, Visualization, Project administration. **Alexander A. Fingelkurts**: Conceptualization, Methodology, Investigation, Resources, Data curation, Writing – review & editing, Visualization.

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Conflict of interest statement

Both co-authors are the scientific co-founders of BM-Science that is involved in fundamental and applied neuroscience research, development of EEG-based brain analyses and well-being applications. Both authors hold senior researcher positions at BM-Science.

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