Consciousness and Cognition 116 (2023) 103600

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

The self and our perception of its synchrony – Beyond internal and external cognition

Andrea Scalabrini [a,*], Michelangelo De Amicis [a], Agostino Brugnera [a], Marco Cavicchioli [b], Yasir Çatal [c,d], Kaan Keskin [e], Javier Gomez Pilar [f,g], Jianfeng Zhang [h], Bella Osipova [i], Angelo Compare [a], Andrea Greco [a], Francesco Benedetti [b,j], Clara Mucci [a], Georg Northoff [c,k,l,b,*]

[a] Department of Human and Social Sciences, University of Bergamo, Bergamo, Italy
[b] University Vita- Salute San Raffaele, Milan, Italy
[c] The Royal's Institute of Mental Health Research & University of Ottawa. Brain and Mind Research Institute, Centre for Neural Dynamics, Faculty of Medicine, University of Ottawa, Ottawa, 145 Carling Avenue, Rm. 6435, Ottawa, Ontario K1Z 7K4, Canada
[d] Department of Cellular and Molecular Medicine University of Ottawa, Ottawa, Canada
[e] Ege University Faculty of Medicine, Department of Psychiatry, 35100 Bornova-İzmir, Turkey
[f] Biomedical Engineering Group, University of Valladolid, Valladolid, Spain
[g] Centro de Investigación Biomédica en Red en Bioingeniería, Biomateriales y Nanomedicina (CIBER-BBN), Valladolid, Spain
[h] Center for Brain Disorders and Cognitive Sciences, Shenzhen University, Shenzhen 518055, Guangdong Province, China
[i] Moscow State University of Psychology and Education (MSUPE)
[j] Psychiatry & Clinical Psychobiology Unit, Division of Neuroscience, IRCCS San Raffaele Scientific Institute, Milan, Italy
[k] Mental Health Centre, Zhejiang University School of Medicine, Tianmu Road 305, Hangzhou, Zhejiang Province 310013, China
[l] Centre for Cognition and Brain Disorders, Hangzhou Normal University, Tianmu Road 305, Hangzhou, Zhejiang Province 310013, China

ARTICLE INFO

Keywords:
Self
Synchrony
Connectedness
Covid-19
Psychological baseline

ABSTRACT

The self is the core of our mental life which connects one's inner mental life with the external perception. Since synchrony is a key feature of the biological world and its various species, what role does it play for humans? We conducted a large-scale psychological study (n = 1072) combining newly developed visual analogue scales (VAS) for the perception of synchrony and internal and external cognition complemented by several psychological questionnaires. Overall, our findings showed close connection of the perception of synchrony of the self with both internal (i.e., body and cognition) and external (i.e., others, environment/nature) synchrony being associated positively with adaptive and negatively with maladaptive traits of self. Moreover, we have demonstrated how external (i.e., life events like the COVID-19 pandemic) variables modulate the perception of the self's internal-external synchrony. These findings suggest how synchrony with self plays a central role during times of uncertainty.

* Corresponding authors at: Department of Human and Social Sciences, University of Bergamo, piazzale Sant'Agostino 2 24129, Bergamo, Italy (A. Scalabrini). The Royal's Institute of Mental Health Research & University of Ottawa. Brain and Mind Research Institute, Centre for Neural Dynamics, Faculty of Medicine, University of Ottawa, Ottawa, 145 Carling Avenue, Rm. 6435, Ottawa, Ontario K1Z 7K4, Canada (G. Northoff).
E-mail addresses: andrea.scalabrini@unibg.it (A. Scalabrini), georg.northoff@theroyal.ca (G. Northoff).

https://doi.org/10.1016/j.concog.2023.103600
Received 17 July 2023; Received in revised form 23 October 2023; Accepted 2 November 2023
Available online 15 November 2023

1. Introduction

When we experience ourselves within the flow of our thoughts or dancing in tune with our body, at the same rhythm with our partner and the music around us we experience as synchronous and connected with ourselves and the environment. This is synchrony as defined as the state of operating in accordance with the same time scale as something/someone else. Synchrony is a key feature of the biological world where different individuals of the same species often synchronize with each other, as for instance in the flight formation of birds (Gunnarsson et al., 2004). Given its biological preponderance including its manifestation in the human brain (Raut et al., 2021), one would assume that synchrony is also present on the psychological level, especially in the human mind in its perception of the self. The self is a key feature of our mental life, which is involved in both internal cognition of one/s inner mental life and external perception of the outer environment. On the one hand, our self allows for internal cognition like mind-wandering (Christoff et al., 2016; Scalabrini, Schimmenti, et al., 2022; Smallwood et al., 2021) and episodic simulation (e.g., mental time travel) (Northoff, 2017; Schacter et al., 2012). At the same time, the self is also related to the perception of the external environment, including its social relationship to others (Atzil et al., 2014; Cirelli, 2018), connectedness (Carhart-Harris et al., 2018), empathy (Koehne et al., 2016; Levy & Feldman, 2019; Yu et al., 2018), and, more generally, nature (Gunnarsson et al., 2004; Motter, 2010; Ravignani, 2017). Given its role in both internal cognition and external perception, the self has been characterized as an integrative function (Sui & Humphreys, 2015) that provides an internal-external relation and thereby serves as "psychological baseline" (Northoff, 2016; Scalabrini, Mucci, et al., 2022; Scalabrini, Schimmenti, et al., 2022; Scalabrini et al., 2021). Is synchrony a key feature in our perception of the self's internal-external relation? Is the perception of the self as an internal-external relation related to its adaptive and maladaptive features as for instance during externally threatening events? Addressing these yet open questions is the goal of our study.

There are various lines of indirect evidence for a key role of synchrony with respect to our self. In the human context, synchronization with the own self and others promotes cooperation and compassion (Valdesolo & DeSteno, 2011; Wiltermuth & Heath, 2009). Intriguingly, the experience of synchrony with the own self and others can dramatically increase during meditation practice (Cooper et al., 2022). Experience of synchrony finds its priors in early internal-external relational experiences with primary caregivers in the context of attachment. Indeed, bio-behavioral synchrony is an important aspect of mother–infant attachment (Feldman, 2007), that contribute to the formation of the sense of self and relatedness (Mucci & Scalabrini, 2021; Scalabrini et al., 2018; Scalabrini, Mucci, et al., 2022). Through synchronization the mother regulates the infant's temperature (Levin, 2006), heart rate (Feldman et al., 2011), sleep and arousal (Feldman et al., 2002). Mothers regulate their infants' immune function by breastfeeding, synchronizing their gut microbiota and antigen-specific antibodies (Arrieta et al., 2014).

All these findings converge with the theory about the origin of human intersubjectivity developed by Colwyn Trevarthen. He gave synchrony a key role in emotional nonverbal communication between caregiver and infant with the function of regulating states of both members of the dyad (Trevarthen, 1993). More specifically, he described the experience of synchrony as the spatiotemporal coordination between the parent's and the child's nonverbal behavior and communicative signals during social interactions in ways that enhance positive reciprocity and mutual engagement (Stern, 1985; Trevarthen & Aitken, 2001). Intriguingly, more recent research found that visuo-tactile synchrony vs. asynchrony can be discriminated by newborns (Filippetti et al., 2013). This process of detecting "*amodal properties*" such as synchrony between different senses has been recently defined as "*mentalization of the body*" (Ciaunica & Fotopoulou, 2017; Fotopoulou & Tsakiris, 2017), indicating the capacity of the individual of organizing sensory input of both subjective and intersubjective origins in a unitary multi-modal schemata that include both internal-interoceptive and external-exteroceptive stimuli.

In this context, we can argue that the mother-infant relationship is a prior for developing the sense of synchrony and connectedness of the self and its relationship with the environment, which can be considered as the capacity to integrate internal and external stimuli. Furthermore, the experience of synchrony as well as the experience of connectedness, otherwise called "*relational alignment*" (Scalabrini et al., 2018; Scalabrini, Mucci, et al., 2022) is the prerequisite that shapes the baseline for the sense of subjectivity and intersubjectivity that, in turn, depend on the degree of attunement and synchronization to the infant's needs by the parents (Atzil & Barrett, 2017; Mucci, 2021; Mucci & Scalabrini, 2021; Schore, 2011). These first synchronic experiences shape the physiological and psychological "baseline" activity (Northoff, 2016; Northoff & Scalabrini, 2021b; Northoff et al., 2022; Scalabrini, Schimmenti, et al., 2022; Scalabrini et al., 2021). The quality and the organization of this psycho-physiological baseline needs to be considered as dependent on the relational experiences, firstly with the attachment figure (e.g., the mother/caregiver) and, secondly, with an extended social world which can impact the self both in a positive or adverse/traumatic way (Ciaunica, Constant, et al., 2021; Di Plinio et al., 2022; Mucci & Scalabrini, 2021; Scalabrini, Mucci, et al., 2022). When lack of attunement and synchrony characterize early relational life experience disorganized attachment, dissociative predisposition, feelings of disconnections and self-dysregulation (Ciaunica, Charlton, et al., 2021; Ciaunica, Roepstorff, et al., 2021; Farina et al., 2019; Liotti, 1992, 2006; Mucci, 2021; Scalabrini et al., 2020; Schimmenti & Caretti, 2016; Schore, 2013) becomes rooted in the self and its "*psychological baseline*". These experiences shape the characteristics of the self in terms of resiliency on one hand or vulnerability on the other. Altogether, these observations about the early mother-infant relation strongly speaks for a key role of synchrony in constituting the self as an internal-external relation in later adulthood.

A multitude of studies investigate the objective neural and psychological-behavioral effects of self-referential vs non-self-referential stimuli (Frewen et al., 2020; Qin et al., 2020). In contrast, the subjective perception or experience of the self, including its role in both internal cognition and external perception, remain to be investigated. Filling in this gap in our knowledge, we conducted a large-scale psychological study ($n = 1072$) where we combine standardized-psychological questionnaires targeting the self in its various domains (e.g., interoceptive awareness, self-concept clarity and connectedness with the natural environment) with newly developed subjective rating scales (visual analogue scales/VAS) on the perception of synchrony with self and its internal-external relation.

We hypothesize a key role (and its centrality using network analysis) of the perception of synchrony with both internal mental-bodily and external social-ecological features. We also expect that the perception of synchrony is positively related with the different psychological questionnaires of different facets of the self, while negatively correlated with maladaptive manifestations (e.g., rumination, emotional dysregulation, fear of covid and general psychopathological symptoms). Finally, we hypothesize the malleability in the perception of our self's internal-external synchrony external features like the COVID pandemic (showing a difference in the perception of synchrony before vs. after COVID).

2. Materials and methods

2.1. Participants

The collection of data started around June 2020 during the first wave of the COVID-19 pandemic and one thousand and seventy-two individuals participated to the study and signed the electronic informed consent. They completed information on sociodemographic variables, the visual analogue scale (VAS) questions section of the survey and a set of psychological self-reports. Overall, the study involved a total of 1072 adults from different nationalities (311 males, 29 %; 761 females, 71 %). More information about participants can be found in Supplementary Information.

2.2. Procedures

All participants were recruited trough an online survey via social networks (e.g., Facebook and web-forums) and provided informed consent prior to participation in the study. This study was consistent with the ethical principles of the American Psychological Association (APA). Privacy of participants was guaranteed in accordance with the European Union General Data Protection Regulation 2016/679. The study is part of the project SYNC (no. 20023).

2.3. Experience/Perception of self and internal-external cognition - visual analogue scale (VAS) assessment

In order to investigate perception or experience, a set of visual analogues scales (VAS) were created *ad hoc* for this investigation. These VAS questions were created to probe different features of the personal experience or perception related to (i) synchrony with self, bodily, social, and environmental features; (ii) internal-external perception of constraints, like the degree of traumatic perception, and (iii) internal cognition like thoughts about the self and mental time travel (Table 1). These questions represent the initial conceptual framework theorized by the authors of a "psychological baseline" featured by the experience of synchrony of the self as different by the mental cognitive level of internal-external representations (Northoff & Huang, 2017; Northoff & Scalabrini, 2021a; Scalabrini, Mucci, et al., 2022; Scalabrini, Schimmenti, et al., 2022). These VAS were applied twice to probe the subjective experience of the individuals related to "during pandemic" (VAS-A) and secondly related to "before the pandemic" (VAS-B) (See Table 1 for questions of VAS "during Covid-19"; See Table S1 for questions of VAS "before Covid-19").

2.4. Psychological questionnaires

In addition to VAS, we also included a set of psychological questionnaires for the assessment of adaptive and maladaptive features related to the self:

Self-Concept Clarity – SCC (Campbell et al., 1996)**.** The SCC is a 12- item measure designed to assess the extent to which a person's

Table 1
Description of VAS scales "during pandemic" used in the study.

		Questions
VAS DURING COVID-19 (VAS-A)	VAS-A Synchrony Body	How much did you feel in synchrony/connected with your BODY during COVID-19 pandemic?
	VAS-A Synchrony Self	How much did you feel in synchrony/connected with your SELF during COVID-19 pandemic?
	VAS-A Synchrony Nature	How much did you feel in synchrony/connected with NATURE during COVID-19 pandemic?
	VAS-A Synchrony Other	How much did you feel in synchrony/connected with OTHERS during COVID-19 pandemic?
	VAS-A Sense Freedom	How much did you feel limited in your SENSE of FREEDOM during COVID-19 pandemic?
	VAS-A Thought Past	How much your personal thoughts were focused on PAST events during COVID-19 pandemic?
	VAS-A Encloseness	How much did you feel ENCLOSED during COVID-19 pandemic?
	VAS-A Traumatic	How much TRAUMATIC do you perceive COVID-19 pandemic?
	VAS-A Thought Present	How much your personal thoughts were focused on PRESENT events during COVID-19 pandemic?
	VAS-A Thought Future	How much your personal thoughts were focused on FUTURE events during COVID-19 pandemic?
	VAS-A Thought focused yourself	How much your thoughts were focused on YOURSELF during COVID-19 pandemic?

self-beliefs are clearly and confidently defined, internally consistent, and stable. Items are rated on a 5-point Likert-type scale ranging from "Strongly disagree" to "Strongly agree." Examples of items include "*my beliefs about myself often conflict with one another*," "*sometimes I feel that I am not really the person that I appear to be*". In our sample the SCC scale has shown high internal consistency (Cronbach's $\alpha = 0.85$).

Multidimensional Assessment of Interoceptive Awareness – MAIA (Mehling et al., 2012)**.** The MAIA is a 32-item instrument that assesses interoceptive and body awareness on 6-point Likert-type scales that range from 0 (Never) to 5 (Always). It comprises eight scales, namely Noticing, Not-Distracting, Not-Worrying, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening, and Trusting. For the aim of the study, we administered only the scales that we thought might be more relevant for our investigation, i.e., Self-Regulation (Cronbach's $\alpha = 0.83$) – ability to regulate psychological distress by attention to body sensations; Body Listening (Cronbach's $\alpha = 0.87$) – active listening to the body for insight; Trusting (Cronbach's $\alpha = 0.89$) – experiences of one's body as safe and trustworthy.

Difficulties in Emotion Regulation Scale – DERS (Gratz & Roemer, 2004)**.** The DERS is a 36-item self-report questionnaire with items rated on a 5-point Likert scale. The DERS consists of six subscales—nonacceptance (e.g. "*when I'm upset, I feel ashamed at myself for feeling that way*"), goals (e.g. "*when I'm upset, I have difficulty focusing on other things*"), impulse (e.g. "*when I'm upset, I lose control over my behaviors*"), awareness (e.g. "*I pay attention to how I feel*"), strategies (e.g. "*when I'm upset, I believe that wallowing in it is all I can do*"), and clarity (e.g. "*I have no idea how I am feeling*"). The higher the total score is, the higher the level of emotional dysregulation. For the purposes of this study, we considered only the DERS total score that in our sample has shown high internal consistency (Cronbach's $\alpha = 0.94$).

Connectedness to nature – CNS (Mayer & Frantz, 2004)**.** The CNS comprises 14 questions, such as "*I often feel a sense of oneness with the natural world around me*" and "*I recognize and appreciate the intelligence of other living organisms*," which assess the sense of oneness with the natural world. These questions are rated using a 5-point response scale, ranging from 1 (strongly disagree) to 5 (strongly agree). An overall score is calculated based on the mean of the responses to all questions, with higher scores reflecting greater connectedness to nature. This scale is widely used to measure the strength of respondents' traits that promote feelings of being emotionally connected to the natural world (Frantz et al., 2005; Howell et al., 2011; Kamitsis & Francis, 2013; Mayer et al., 2009). In our sample the CNS scale has shown high internal consistency (Cronbach's $\alpha = 0.85$).

Identification with All Humanity – IWAH (McFarland et al., 2012)**.** The IWAH consists of nine, 5-point Likert-type items covering different aspects of identification (e.g., "*we*" thinking, helping others, loyalty). For each of these aspects, participants indicated the extent to which this aspect described their relationship to people in their own community, to people from their own nation, and to people from all around the world (e.g., *How much do you identify with [that is, feel a part of, feel love toward, have concern for] each of the following*? (a) People in my community; (b) People of my nationality, (c) All humans everywhere). As a measure of identification with humanity we focused only on the items concerning "*all humans everywhere*". In our sample the scale showed high internal consistency ($\alpha = 0.88$).

Rumination-Reflection Questionnaire – RRQ (Trapnell & Campbell, 1999)**.** The RRQ is a 24-item measure that investigates rumination (RUM) and reflection (REF). Reflection and rumination are considered divergent functional modes or structures of thoughts related to the self: for instance, reflection is related to the item "*My attitudes and feelings about things fascinate me*", while rumination is featured by items like "*My attention is often focused on aspects of myself I wish I'd stop thinking about*". The items are divided equally between the two subscales, evaluated on a five-point Likert scale, from 1 ("completely disagree") to 5 ("completely agree"). In our sample Cronbach's alpha for RUM was 0.87, Cronbach's alpha for REF was 0.86.

Multidimensional Assessment of COVID-19-Related Fears - MAC-RF (Schimmenti et al., 2020)**.** The MAC-RF is an eight-item self-report measure scored on a five-point Likert scale (from 0 to 4) that was developed by the authors of this article to assess the eight facets of fear identified by Schimmenti and colleagues. Scores of the MAC-RF can range from 0 to 32, with higher scores indicating higher COVID-19-related fears. In our study MAC-RF showed good internal consistency (Cronbach's $\alpha = 0.73$).

The DSM-5 Self-Rated Level 1 Cross-Cutting Symptom Measure (Association, 2013), was used to assess psychopathological symptoms. This measure includes 23 items rated on a 4-point Likert-type scale ranging from "very false or often false" to "very true or often true". Each item investigates how often an individual has suffered from specific symptoms in the last 2 weeks. For the purposes of this study, we considered only the total score that in our sample has shown high internal consistency (Cronbach's $\alpha = 0.89$).

2.5. Statistical analysis

Jamovi and JASP were used to analyze the data. Cronbach's α coefficient was used to assess the internal consistency of the psychological questionnaires. Data were initially examined through simple descriptive statistics, while between-group differences were tested by means of independent sample *t*-test and Chi-square test.

The logic of the subsequent statistical analyses comprised different steps:

1) Principal component analysis. To reduce the dimensionality of the data we extracted underlying latent components of the VAS items trough a principal component analysis (PCA). The use of the PCA allows the extraction of relevant latent variables. Keiser-Meyer Olkin criteria (KMO > 0.6) and Bartlett's Test of sphericity (<0.05) were explored. After the administration of the PCA we firstly gave names to the factors, and secondly, we extracted their respective factorial values.

2) Correlation between VAS components and psychological questionnaires

Pearson's *r* coefficient was used to evaluate the association between the factors of the PCA and the psychological questionnaires. Bonferroni correction for multiple comparisons was performed on the obtained correlation coefficients, such that only p values (before correction) were considered significant below $p < 0.05$/number of calculated correlations.

3) Graph-theoretical measure (EBICglasso)

First network analysis was applied to the VAS items that constituted the first component of the PCA (intra-network analysis approach), secondly network analysis was applied to a larger network comprising all variables included in the PCA (inter-network analysis approach). These analyses were administered in order to establish how the different VAS items are related to each other's and which of the single VAS items act as a central node in the intra- and inter-network.

Network analysis allows calculating *closeness* (the inverse of the sum of all shortest paths from the node of interest to all other nodes), *betweenness* (the number of shortest paths that pass through the node of interest), and *degree of centrality* (the sum of the absolute input weights of that node. In general, a higher centrality measure indicates that this node is more central to the network) using EBICglasso technique, i.e. computing a sparse gaussian graphical model with the graphical lasso (Friedman et al., 2008). Tuning parameter is set at 0.5 using the Extended Bayesian Information criterium (EBIC); this 0.5 indicates that more parsimonious models with fewer edges are preferred. This method provides a network of partial correlation coefficients with a limited number of spurious edges (Epskamp et al., 2018; Epskamp et al., 2012). Centrality indices are plotted using standardized z-scores to facilitate interpretation.

4) Difference in the perception of synchrony during the pandemic vs. before the pandemic

As a last step, *a)* by means of paired sample *t*-test we tested the differences between VAS related to before and after pandemic.

Finally, as a further control, G*Power 3.1 (Faul et al., 2009) was used to conduct post-hoc power analysis on the total sample of 1072 subjects for an expected correlation ($r = 0.20$; $\alpha = 0.05$). The analysis revealed a Power (1 – β err prob) of 0.99 suggesting an optimal sample size.

3. Results

3.1. Descriptive statistic

Table S2 (supplementary material) shows descriptive statistics for VAS and Table S3 (supplementary material) shows descriptive statistic for the psychological questionnaire. Table S2bis and S3bis (in supplementary material) also show gender differences for VAS and psychological questionnaires respectively.

3.2. Perception of self and cognition – VAS and principal component analysis

In order to reduce the dimensionality of the VAS data and increase their interpretability, we conducted a principal component analysis (PCA). Kaiser–Meyer–Olkin measure of sampling adequacy (KMO) and Bartlett's Test of sphericity showed the suitability of data for the PCA (KMO = 0.73 l6; Bartlett's Test = $p < 0.001$). Results of Kaiser–Meyer–Olkin test suggested the presence of an adequate sample size relative to the number of items in the scale (Mulaik, 2009). Bartlett's Test evidenced that the correlation matrix was not an identity matrix, or a matrix whose diagonal entries are all 1, and all off diagonal elements are 0 (Mulaik, 2009). The PCA yielded three main components which together explained 51.4 % of the cumulative variance.

Specifically, the first component explained 20.8 % of the variance and included all items related to synchrony like with self, body, other and environment. We named the first component "Synchrony". Notably, none of the synchrony items was included in the other two factors (Table 2). Instead, the other two PCA components concerned perception of external constraints and internal cognition. VAS items for the second components explained 17.3 % of variance and included items focusing on perception of trauma, encloseness, freedom, and past thoughts. We named the second component as "Perception of Constraints". Finally, the third component explained 13.3 % of the variance and included VAS items like thought about present, future and thought about the self (see Table 3). We named the third component "Internal Cognition". Together, our findings clearly support the importance of our perception of synchrony with self, body, others and environment/nature as key component that is distinct from internal cognition and perception of external

Table 2
Principal Component Analysis of VAS during covid-19.

VAS during Covid-19	Components			Uniqueness
	1	*2*	*3*	
VASA Synchrony Body	0.780			0.366
VASA Synchrony Self	0.768			0.365
VASA Synchrony Nature	0.725			0.496
VASA Synchrony Other	0.709			0.503
VASA Sense Freedom		0.722		0.437
VASA Thought Past		0.697		0.522
VASA Encloseness		0.664		0.528
VASA Traumatic		0.623		0.546
VASA Thought Present			0.726	0.455
VASA Thought Future			0.717	0.453
VASA Thought focused Yourself			0.496	0.674

VASA = Visual Analogue Scale during pandemic
Only values > 0.3 are reported in the table

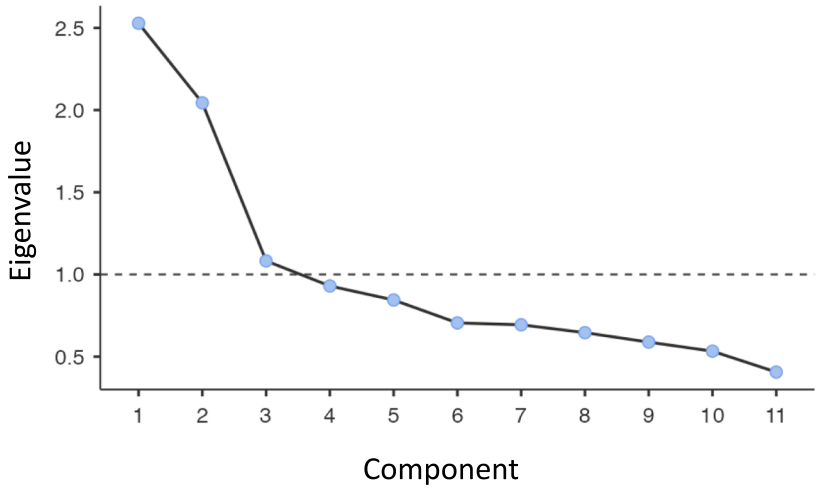

Fig. 1. Scree-test analysis plot of the PCA.

constraints.

Since, the correlation between the three components resulting from the oblimin rotation was very low ($r < 0.2$; Synchrony – Perception of Constraints r = -0.155; Synchrony - Internal Cognition p = 0.126; Perception of Constraints – Internal Cognition p = 0.146) we reported data using the varimax rotation for the PCA.

Table 3
Correlation analysis between psychological scales and PCA components with a 95% confidence interval (CI) based on 1000 bootstrap samples for the bivariate associations.

		Synchrony (1st Component)	Perception of Constraints (2nd Component)	Internal Cognition (3rd Component)
Self Concept Clarity	**Pearson's r**	0.230*	− 0.173*	0.039
	p	< 0.001	< 0.001	0.273
	95 % CI	[0.162 0.295]	[-0.104—0.240]	[-0.031 0.109]
Connectedness with Nature	**Pearson's r**	0.236*	0.044	0.089
	p	< 0.001	0.219	0.014
	95 % CI	[0.168 0.301]	[-0.026 0.109]	[0.018 0.158]
Identification with Humanity	**Pearson's r**	0.170*	0.084	0.080
	p	< 0.001	0.021	0.030
	95 % CI	[0.098 0.238]	[0.013 0.155]	[0.008 0.151]
MAIA Self-regulation	**Pearson's r**	0.302*	− 0.005	0.032
	p	< 0.001	0.893	0.399
	95 % CI	[0.232 0.368]	[-0.080 0.070]	[-0.043 0.107]
MAIA Body Listening	**Pearson's r**	0.224*	0.019	0.013
	p	< 0.001	0.612	0.736
	95 % CI	[0.151 0.294]	[-0.056 0.094]	[-0.062 0.088]
MAIA Trusting	**Pearson's r**	0.274*	−0.023	0.079
	p	< 0.001	0.543	0.273
	95 % CI	[0.203 0.342]	[-0.098 0.052]	[0.004 0.153]
Rumination	**Pearson's r**	− 0.266*	0.243*	−0.038
	p	< 0.001	< 0.001	0.543
	95 % CI	[-0.328—0.202]	[0.179 0.306]	[-0.105 0.030]
Reflection	**Pearson's r**	0.095	0.060	0.090
	p	0.006	0.082	0.009
	95 % CI	[-0.202—0.328]	[-0.008 0.127]	[0.022 0.156]
SVST Tot	**Pearson's r**	−0.339*	0.320*	0.055
	p	< 0.001	< 0.001	0.087
	95 % CI	[-0.394—0.282]	[0.267—0.376]	[-0.008—0.119]
MAC RF Tot	**Pearson's r**	− 0.195*	0.342*	0.140
	p	< 0.001	< 0.001	<0.001
	95 % CI	[-0.253—0.137]	[0.288 0.395]	[0.080 0.199]
DERS Tot	**Pearson's r**	− 0.271*	0.202*	− 0.005
	p	< 0.001	< 0.001	0.897
	95 % CI	[-0.340—0.198]	[0.127 0.274]	[-0. 082 0.072]

* p-value still significant after Bonferroni correction for multiple comparisons.

To further confirm the component structure of our VAS items we also performed PCA on VAS related to before covid (VASB) and we also controlled for gender differences. Intriguingly PCA analysis on VASB scales showed a highly similar structure (See Supplementary material, Table S4). To further confirm our results Table S6 and S7 in supplementary material show a highly similar structure for males and females in relation to VASA (Fig. 1).

3.3. Validation of VAS synchrony component - psychological rating scales relate to VAS

In a next step we extracted the factorial scores of each component, which we correlated with several psychological questionnaires. Intriguingly, this yielded major relationship of the scales with specifically the first PCA component, i.e., Synchrony, whereas there were only sparse correlations with the second component "Perception of constraints" (Table 3).

We observed significant positive correlations of the first PCA component, that is Synchrony, with various MAIA subscales (self-regulation, body-listening and trusting), with Self-concept clarity, with Connectedness with Nature scale, and with Identification with humanity (See Table 3 Correlations). These correlations suggest that higher degrees of synchrony in the VAS relate to higher degrees of interoceptive awareness, clarity of self, and connectedness with both nature and humanity/world. These data suggest that the perception of synchrony relates the self to both internal (body, cognition) and external (nature, humanity, environment) adaptive features – one can thus speak of internal-external synchrony of self. In contrast, we obtained negative correlations of the Synchrony component, with the scales for emotion dysregulation, rumination, fear of covid and symptoms: the weaker the synchrony, the higher the dysregulation of emotions, the higher levels of rumination, and the more general symptomatology and covid-related fear. These data suggest that high synchrony of self provides some kind of prevention against subclinical cognitive-emotional and behavioral malfunction. (See Table 3Correlations).

Unlike the first PCA component, the second PCA component of the VAS, Perception of Constraints showed positive correlations with more or less those variables with which the first component, Synchrony, correlated negatively. Specifically, higher degrees in Perception of Constraints were positively related to higher degrees in symptoms, rumination, more dysregulation of emotions and COVID-related fear. Moreover, we observed a weaker but still significantly negative correlation of Perception of Constraints with Self-concept clarity. Together, these data suggest that high levels of Perception of Constraints can be considered a risk factor for subclinical malfunction. Similar results were also found between components resulting from PCA on VAS before covid-19 and psychological questionnaires (Table S8 in supplementary material).

Last, intriguingly we did not observe any correlation between the third component "Internal Cognition" with other psychological scales.

3.4. Network structure of synchrony – Graph-theoretic analysis

The first PCA component included synchrony with Self, body, others and environment. What is the network relation among these different synchrony items? For that purpose, we applied a graph-theoretical measure that allows calculating the relationship among the distinct VAS items included in the first PCA factor, the synchrony of self (See Fig. 2).

The network analysis yielded high degrees of centrality, betweenness and closeness for specifically *synchrony with self* and *synchrony*

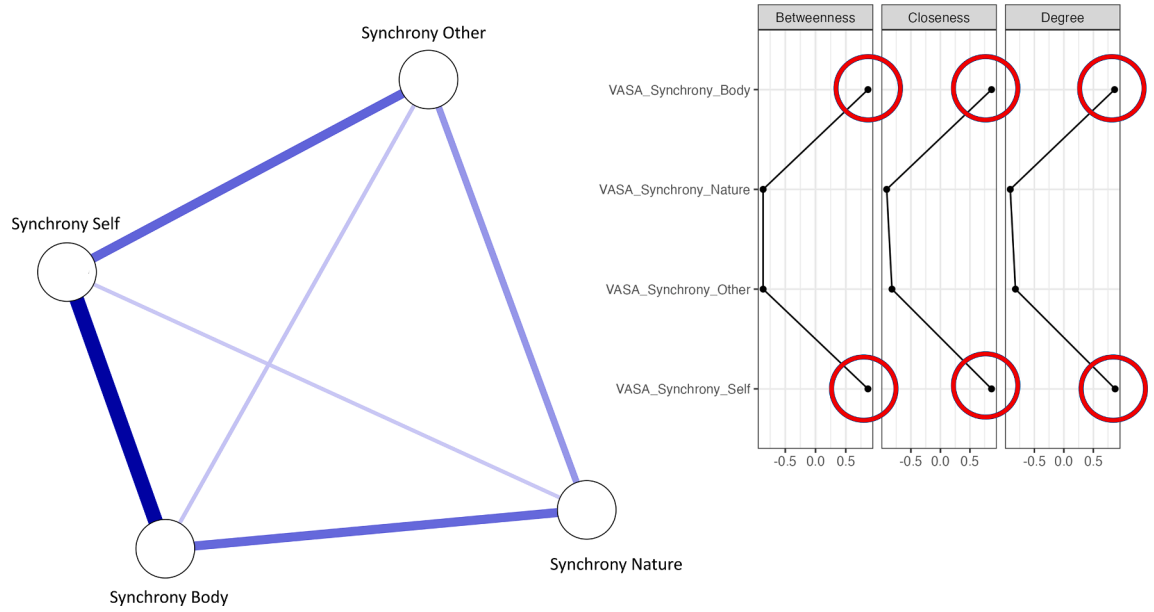

Fig. 2. Network analysis of the first PCA – Synchrony - VASA items (Intra-network).

with body whereas the other synchrony items showed lower values in these measures (Fig. 2). This suggests a key role of the internal synchrony of the self (e.g., mental self) (Qin et al., 2020) and its own body (synchrony with body) in constituting synchrony with external environment and the others.

Extending beyond the first PCA component (i.e., Synchrony), we next included all VAS items of all three PCA components in our network analysis. This again yielded high centrality for two synchrony items, namely *synchrony self* and *synchrony with the body* showing higher degree of centrality and betweenness (Fig. 3). Intriguingly, also the VAS *thought of the self*, belonging to the more cognitive component showed higher betweenness and closeness scores. This suggests that the mental/cognitive self plays a key role in connecting the perception of synchrony and the more cognitive layers of our subjective internal and external perception.

3.5. *Synchrony of self – Malleability by internal and external factors*

Our data show that synchrony consists in the perception of synchrony with both internal (mental self and bodily self) and external (others, environment) features. Do extreme changes in these internal and external features lead to changes in the perception of synchrony? This was probed by investigating the impact of the COVID pandemic on VAS items in subjects that underwent two times testing, before and during COVID (See Table 4).

We observed significant differences in almost all synchrony VAS items after the COVID compared to before COVID. Synchrony with self, body, and environment was significantly lower after the COVID pandemic than before (Fig. 4). In contrast, no significant differences were observed in the VAS items for internal cognition (while the ones for perception of constraints, such as the feeling of encloseness and the reduction of the sense of freedom, increased as expected) (Fig. 4). Together, these findings demonstrate the malleability of the perception of synchrony to xternal environmental events like the COVID pandemic. This suggests environmental sensitivity of perception of synchrony and further supports its internal-external relational character.

4. Discussion

Conducting a large-scale psychological study, we demonstrate the key role of synchrony in our perception of self with respect to both internal cognition and perception of constraints. Our data on subjective visual analogue scales and psychological self-reports, identify the perception of synchrony with both internal self/body and external others/environment as most basic feature as distinct from internal cognition itself and perception of constraints. Using graph-theoretic measures for network analysis, synchrony of self, together with synchrony with the body, takes on the role as node with high centrality and betweenness within the psychological network of internal-external perception. Finally, the perception of synchrony is malleable to both internal (related to adaptive and maladaptive features of the self) and external (life events like COVID pandemic) factors. Together, we demonstrate the importance of synchrony in the perception of our self on the psychological level which, given recent findings, may be met by corresponding synchronization on the neural level (Raut et al., 2021). Synchrony would then be considered as a shared feature in neural and

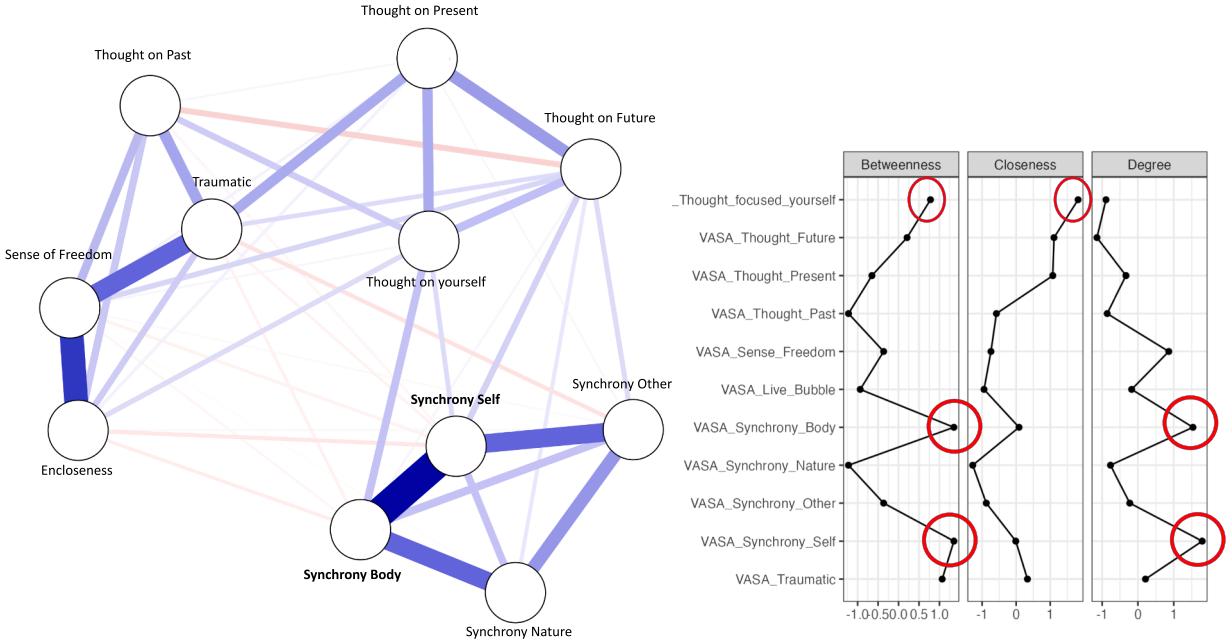

Fig. 3. Network analysis of all VASA items (Inter-network).

Table 4
Paired sample *t* test before vs. after the threat.

	Before		After		Before vs after t	*df*	*p*	95 % CI		Cohen's *d*
	M	*SD*	*M*	*SD*				*LL*	*UL*	
Synchrony Self	59.540	23.768	54.282	26.888	**5.244**	1071	**< 0.001**	3.291	7.226	0.160
Synchrony Other	58.609	24.417	44.631	26.109	**14.518**	1071	**< 0.001**	12.089	15.867	0.443
Synchrony Nature	59.064	25.500	53.367	31.886	**5.188**	1071	**< 0.001**	3.542	7.852	0.158
Synchrony Body	56.710	23.761	53.137	28.332	**3.763**	1071	**< 0.001**	1.710	5.436	0.115
Traumatic	50.038	30.455	49.172	26.939	0.819	1071	0.413	−1.207	2.938	0.025
Enclosed	35.337	27.608	58.152	30.580	**−19.508**	1071	**< 0.001**	−25.110	−20.520	−0.596
Limitation of Freedom	37.723	30.353	63.923	29.714	**−21.932**	1071	**< 0.001**	−28.543	−23.855	−0.670
Thought Past	43.947	25.890	43.914	28.347	0.032	1071	0.033	−1.954	2.020	−0.001
Thought Present	59.848	23.488	59.192	25.841	0.714	1071	0.475	−1.146	2.458	0.022
Thought Future	63.873	25.282	63.712	27.245	0.177	1071	0.860	−1.617	1.938	0.005
Thought focused Yourself	61.657	22.052	62.682	23.439	−1.275	1071	0.202	−2.602	0.552	−0.039

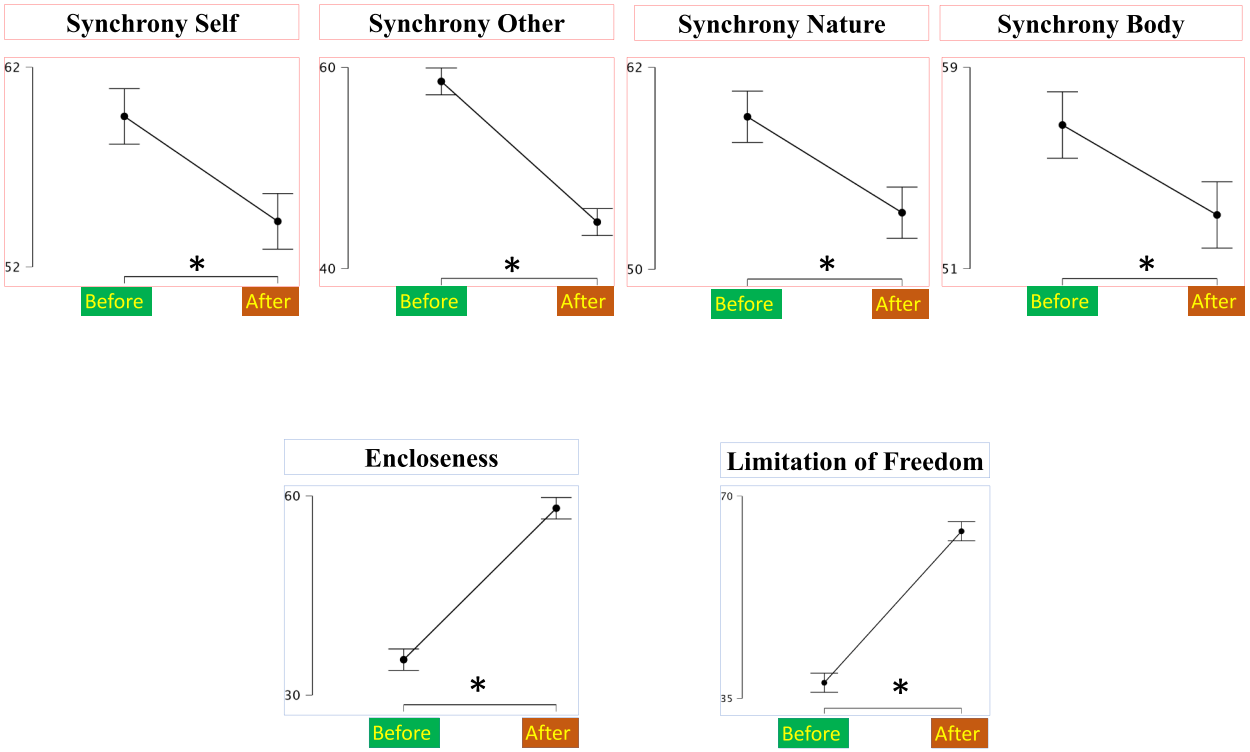

Fig. 4. Graphical plot of VAS significant *t*-test differences for before vs after covid pandemic.

psychological levels as their 'common currency' (Northoff et al., 2020a, 2020b; Scalabrini, Mucci, et al., 2022).

Our main focus was on the subjective perception of synchrony as different from internal cognition and external perception of constraints. We accordingly developed different VAS items subjecting them to principal component analysis. As hypothesized, that yielded a high loading of all VAS synchrony items as distinct from both internal cognition and perception of constraints. Most notably, this included perception of synchrony with self, body, others and environment – this suggests that the perception of synchrony is not restricted to the own inner mental space of the self but extends beyond to the bodily boundaries to the environmental space. Being based on the perception of synchrony, the self can be considered relational as it crosses the gap of the internal mind and the external world. Such internal-external relational conception of self is well in accordance with models proposed in the recent literature (Craig, 2010; Di Plinio et al., 2022; Kim & Johnson, 2012, 2015; Northoff, 2016; Northoff & Panksepp, 2008; Scalabrini, Schimmenti, et al., 2022; Yeshurun et al., 2021).

The key role of synchrony is further supported by our correlation data with the psychological scales. Synchrony measures largely constituted the first PCA component which showed significant positive correlation with various rating scales related to the sense of self (e.g., interoceptive awareness and self-concept clarity), and relation with the natural environment, identification with nature and humanity. This does not only validate our VAS synchrony scales but also underscores the key role of synchrony in establishing relation

with the sense of self, the body, others, and the external environment or nature. Albeit tentatively, we suppose that such relational nature of self can developmentally be traced to mother-infant relationships (Feldman, 2007; Feldman et al., 2011; Feldman et al., 2002) and its impact on self-other relationships in adulthood (Ulmer Yaniv et al., 2021) as described in the introduction. On the other side, synchrony also correlated negatively with rumination, total symptomatology, fear of covid-19 and emotional dysregulation, suggesting how lack of synchrony might represent an internal vulnerability of the self.

The network analysis shows some differentiation even within the first PCA component (i.e., the synchrony component). Synchrony with both self and body showed high degree of centrality and betweenness suggesting that they take on the role as node for the other synchrony items including the synchrony to other and the environment. That is well in line with the robust correlation of synchrony especially with the scale for Self-concept clarity and interoceptive awareness (MAIA), which concern mainly the perception of the own body and the own self. The enlarged network analysis shows that synchrony of self, including again synchrony to body, take on a central role for all the VAS items related to the experience of internal cognition and perception of constraints. We consequently assume that the perception of internal-external synchrony of self may constitute a key component for what recently has been described as

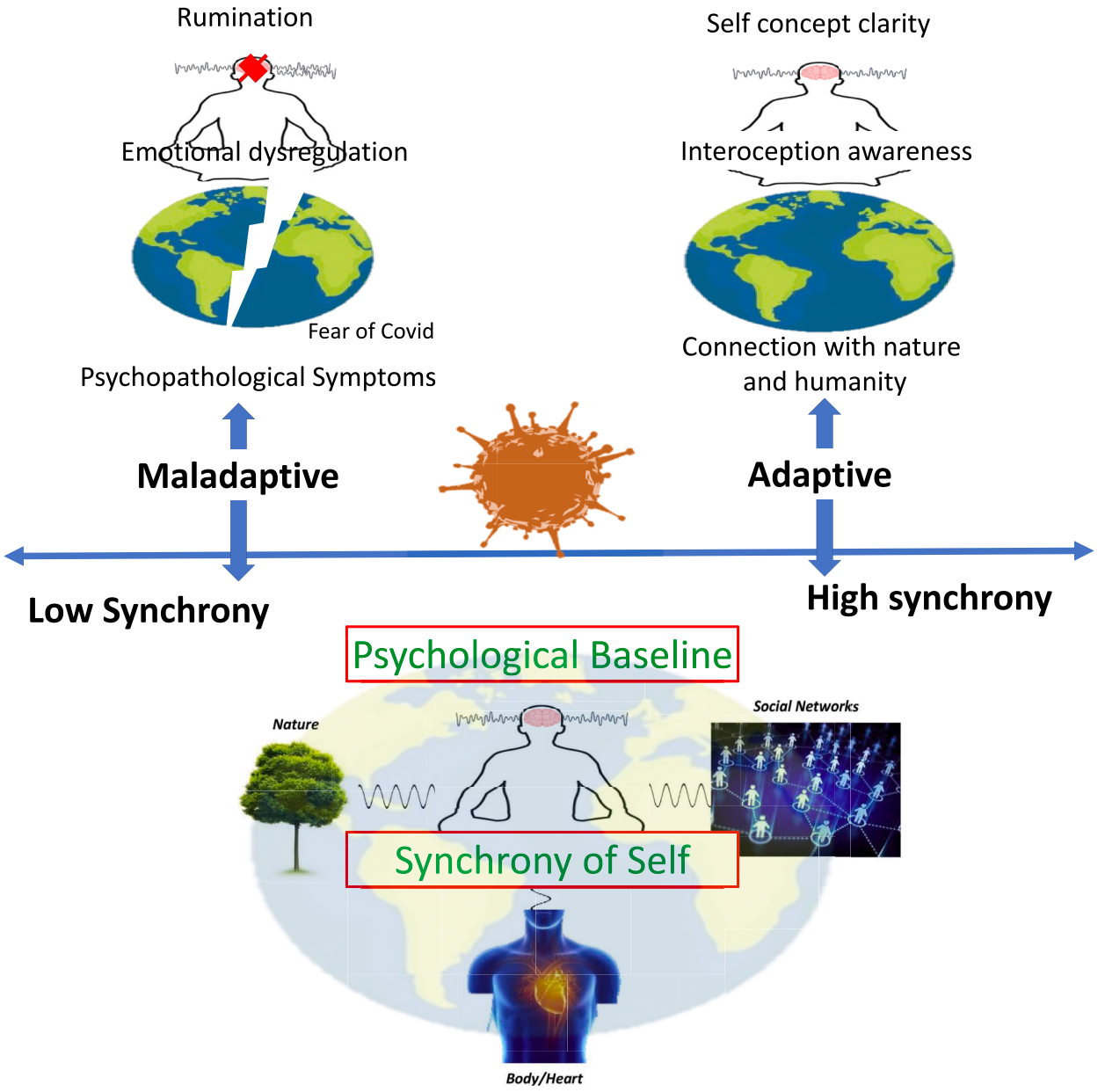

Fig. 5. Graphical representation of main findings of the study. Synchrony can be conceptualized like one of the core features of the "psychological baseline model", that is related with adaptive and maladaptive features of the self and is malleable to the internal vulnerabilities and external events.

"psychological baseline" or "default functionality" for internal and external cognition as well as for perception of constraints (Northoff, 2016; Northoff & Bermpohl, 2004; Northoff & Scalabrini, 2021a; Northoff et al., 2022; Scalabrini, Schimmenti, et al., 2022; Scalabrini et al., 2021).

Finally, we demonstrate that perception of synchrony is malleable by external features. Our data show that an external environmental life event like the COVID pandemic induces significant change in the perception of synchrony with self, body, others and environment. After the pandemic, subjects reported to perceive significantly lower degrees of synchronization of their self (e.g., desynchronization) – its role as "psychological baseline" may thus be destabilized by the external threatening events.

Such perception of a desynchronization of self, body, others and environment, in turn, seems to be associated with subclinical behavioral and psychological symptoms comprising Covid-related fear experience (Schimmenti et al., 2020), higher degree of emotion dysregulation (Siegel et al., 2021) and rumination (Satici et al., 2022). Moreover, we also found some gender differences, indeed after the onset of covid pandemic men reported higher scores then women on the experience of synchrony with self, other and body while, on the contrary, women reported higher scores on the experience of trauma, limitation of freedom, feeling of encloseness (Table S2bis). Regarding the psychological questionnaires women reported higher scores then men in connection with nature, identification with humanity, rumination, and fear of covid (Table S3bis). These data are in line with previous findings related to psychopathological manifestations in covid-19 patients showing that females report higher scores in several psychopathological domains over the time (Mazza et al., 2020; Mazza, Palladini, De Lorenzo, et al., 2022; Mazza et al., 2021; Mazza, Palladini, Poletti, et al., 2022; Scalabrini et al., 2023).

In sum, our data suggest how of the degree of perceived synchrony or connectedness seem to constitute characteristic of resiliency vs. vulnerability in dealing with stressful and uncertain moments of life. Thus, the construct of self and psychological baseline, needs to be considered as an adaptive factor that also suggest how promoting psychological and social well-being should target the experience of connectedness/attunement/synchrony as a key factor to better develop coping and resiliency features.

Together, our findings highlight the key relevance of the perception of an internal-external synchrony of our self with body and environment. This is distinguished from the perception of constraints and internal cognition. Albeit tentatively, we might assume that the perception of an internal-external synchrony of self constitutes a psychological baseline or default for both internally- and externally-oriented (Northoff et al., 2022; Scalabrini, Schimmenti, et al., 2022). The key role of synchrony on the psychological level puts the self in line with both neural and biological levels (e.g., brain and biological world). Various findings show that high neural synchronization is related to higher sense of self (Kolvoort et al., 2020; Scalabrini et al., 2019; Scalabrini et al., 2017; Smith et al., 2022; Wolff et al., 2019; Wolman et al., 2023) – synchrony may then be shared by neural and psychological levels of self as their "common currency" (Northoff et al., 2020a). Synchrony in this sense is neither special to the self nor the brain though. Synchronization processes are abundant in the biological world where they can be observed in different species like aunts, birds, monkeys and others. Hence, rather than being a special higher-order cognitive process, the self may be mediated by synchrony as a most fundamental and completely non-special biological process that is abundant in the biological world (Fig. 5).

5. Limitations

Some limitations shall be mentioned. We are aware that VAS questions are subjective and therefore lack the kind of objectivity one would wish for on methodological grounds. However, we showed their correlation with the objective psychological instruments providing some validity. Moreover, another limitation concern that the VAS scales referring to the period defined as "before covid" were administered retrospectively introducing a subjective bias. However, the key target and focus of our study was exactly on the subjective nature of self, that is, the perception of its synchrony and internal cognition by the subjects themselves. For that VAS are ideally suited. We aimed to validate our VAS by psychological rating scales by correlating both. This showed especially correlation of synchrony with those scales that focus on relationship with self-concept clarity, with the body (MAIA), connectedness with nature scale (CNS), and others/humanity (IWAH). Although requiring future more substantial validation, this provided some evidence for the validity of our VAS items.

Our subjects were from a wide range of different countries which introduces cultural differences. While this may be considered a weak factor, we regard it as strength as it really shows the universality of the perception/experience of synchrony of self across various cultures if not the whole world. That further supports the idea of the synchrony as a most basic and therefore universal feature which, as we speculate, puts the human self on a pair with the biological world and its various species.

Finally, we did not include any neuronal measure. Is the perception or experience of synchrony of self on the psychological level accompanied by corresponding synchronization processes on the neuronal level of the brain? Synchronization in neural activity can be measured in both spatial and temporal domains like in network structure and phase-related processes. Are these neuronal measures of synchrony related to the psychological measures of synchrony, that is, perception of synchrony of self as probed in VAS items? In that case, synchrony would be shared by both neural and psychological levels providing their "common currency" (Northoff et al., 2020a). Being potentially common to both, synchrony may then be central in providing transition or transformation of neuronal into psychological or mental activity.

6. Conclusion

Synchrony is a most fundamental and basic feature in the biological world and thus in nature holding across different species. Does it also apply to our perception of self? Using both subjective VAS and self-report psychological questionnaires, we demonstrate that the perception of an internal-external synchrony of our self with body, others and environment is a most basic fundamental feature of our

mental life that according to its degree of can be related do adaptive or maladaptive manifestations. The perception of the internal-external synchrony of self is highly malleable by either internal psychological difficulties or external life events like the Covid pandemic; such malleability of the synchrony of self leads to psychopathological symptoms like depression with rumination, anxiety/fear, and others. Thus, we suggest that that our self and our degree of synchrony with the body, others and the environment is the psychological component more threatened by an adverse external event (like the COVID-19 pandemic) and, at the same time, the factor more associated with resiliency and coping during such times. Together, we demonstrate the key role of an internal-external synchrony in our perception of self – this aligns the self with the biological world and nature where synchrony is a most basic fundamental feature holding across different species.

7. Funding sources

This research was supported by "Search for Excellence – UdA" to A.S. for the project SYNC (The Self and its psYchological and Neuronal Correlates, European Union's Horizon 2020 Framework Program for Research and Innovation under the Specific Grant Agreement No. 785,907 (Human Brain Project SGA2). G.N. is grateful for funding provided by UMRF, uOBMRI, CIHR and PSI.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.concog.2023.103600.

References

Arrieta, M.-C., Stiemsma, L. T., Amenyogbe, N., Brown, E. M., & Finlay, B. (2014). The intestinal microbiome in early life: Health and disease. *Frontiers in immunology, 5*, 427.

Association, A. A. P. (2013). Diagnostic and statistical manual of mental disorders (5th ed.). https://doi.org/http://dx.doi.10.1176/appi.books.9780890425596.

Atzil, S., & Barrett, L. F. (2017). Social regulation of allostasis: Commentary on "Mentalizing homeostasis: The social origins of interoceptive inference" by Fotopoulou and Tsakiris. *Neuropsychoanalysis, 19*(1), 29–33.

Atzil, S., Hendler, T., & Feldman, R. (2014). The brain basis of social synchrony. *Social cognitive and affective neuroscience, 9*(8), 1193–1202.

Campbell, J. D., Trapnell, P. D., Heine, S. J., Katz, I. M., Lavallee, L. F., & Lehman, D. R. (1996). Self-concept clarity: Measurement, personality correlates, and cultural boundaries. *Journal of personality and social psychology, 70*(1), 141.

Carhart-Harris, R. L., Erritzoe, D., Haijen, E., Kaelen, M., & Watts, R. (2018). Psychedelics and connectedness. *Psychopharmacology, 235*(2), 547–550.

Christoff, K., Irving, Z. C., Fox, K. C., Spreng, R. N., & Andrews-Hanna, J. R. (2016). Mind-wandering as spontaneous thought: A dynamic framework. *Nature reviews neuroscience, 17*(11), 718–731.

Ciaunica, A., Charlton, J., & Farmer, H. (2021). When the window cracks: Transparency and the fractured self in depersonalisation. *Phenomenology and the Cognitive Sciences, 20*, 1–19.

Ciaunica, A., Constant, A., Preissl, H., & Fotopoulou, K. (2021). The first prior: From co-embodiment to co-homeostasis in early life. *Consciousness and cognition, 91*, Article 103117.

Ciaunica, A., & Fotopoulou, A. (2017). The touched self: Psychological and philosophical perspectives on proximal intersubjectivity and the self. *In*. MIT Press.

Ciaunica, A., Roepstorff, A., Fotopoulou, A. K., & Petreca, B. (2021). Whatever next and close to my self—The transparent senses and the "second skin": Implications for the case of depersonalization. *Frontiers in Psychology*, 1219.

Cirelli, L. K. (2018). How interpersonal synchrony facilitates early prosocial behavior. *Current opinion in psychology, 20*, 35–39.

Cooper, A. C., Ventura, B., & Northoff, G. (2022). Beyond the veil of duality—topographic reorganization model of meditation. *Neuroscience of Consciousness, 2022(1), niac013*.

Craig, A. (2010). The sentient self. *Brain structure and function, 214*, 563–577.

Di Plinio, S., Scalabrini, A., & Ebisch, S. J. (2022). An integrative perspective on the role of touch in the development of intersubjectivity. *Brain and Cognition, 163*, Article 105915.

Epskamp, S., Borsboom, D., & Fried, E. I. (2018). Estimating psychological networks and their accuracy: A tutorial paper. *Behavior research methods, 50*, 195–212.

Epskamp, S., Cramer, A. O., Waldorp, L. J., Schmittmann, V. D., & Borsboom, D. (2012). qgraph: Network visualizations of relationships in psychometric data. *Journal of statistical software, 48*, 1–18.

Farina, B., Liotti, M., & Imperatori, C. (2019). The role of attachment trauma and disintegrative pathogenic processes in the traumatic-dissociative dimension. *Frontiers in Psychology, 933*.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. *Behavior research methods, 41*(4), 1149–1160.

Feldman, R. (2007). Parent–infant synchrony: Biological foundations and developmental outcomes. *Current directions in psychological science, 16*(6), 340–345.

Feldman, R., Magori-Cohen, R., Galili, G., Singer, M., & Louzoun, Y. (2011). Mother and infant coordinate heart rhythms through episodes of interaction synchrony. *Infant Behavior and Development, 34*(4), 569–577.

Feldman, R., Weller, A., Sirota, L., & Eidelman, A. I. (2002). Skin-to-Skin contact (Kangaroo care) promotes self-regulation in premature infants: Sleep-wake cyclicity, arousal modulation, and sustained exploration. *Developmental psychology, 38*(2), 194.

Filippetti, M. L., Johnson, M. H., Lloyd-Fox, S., Dragovic, D., & Farroni, T. (2013). Body perception in newborns. *Current Biology, 23*(23), 2413–2416.

Fotopoulou, A., & Tsakiris, M. (2017). Mentalizing homeostasis: The social origins of interoceptive inference. *Neuropsychoanalysis, 19*(1), 3–28.
Frantz, C., Mayer, F. S., Norton, C., & Rock, M. (2005). There is no "I" in nature: The influence of self-awareness on connectedness to nature. *Journal of environmental psychology, 25*(4), 427–436.
Frewen, P., Schroeter, M. L., Riva, G., Cipresso, P., Fairfield, B., Padulo, C., … Kusi-Mensah, K. (2020). Neuroimaging the consciousness of self: Review, and conceptual-methodological framework. *Neuroscience & Biobehavioral Reviews, 112*, 164–212.
Friedman, J., Hastie, T., & Tibshirani, R. (2008). Sparse inverse covariance estimation with the graphical lasso. *Biostatistics, 9*(3), 432–441.
Gratz, K. L., & Roemer, L. (2004). Multidimensional assessment of emotion regulation and dysregulation: Development, factor structure, and initial validation of the difficulties in emotion regulation scale. *Journal of psychopathology and behavioral assessment, 26*(1), 41–54.
Gunnarsson, T. G., Gill, J., Sigurbjörnsson, T., & Sutherland, W. (2004). Arrival synchrony in migratory birds. *Nature, 431*(7009), 646-646.
Howell, A. J., Dopko, R. L., Passmore, H.-A., & Buro, K. (2011). Nature connectedness: Associations with well-being and mindfulness. *Personality and individual differences, 51*(2), 166–171.
Kamitsis, I., & Francis, A. J. (2013). Spirituality mediates the relationship between engagement with nature and psychological wellbeing. *Journal of environmental psychology, 36*, 136–143.
Kim, K., & Johnson, M. K. (2012). Extended self: Medial prefrontal activity during transient association of self and objects. *Social cognitive and affective neuroscience, 7*(2), 199–207.
Kim, K., & Johnson, M. K. (2015). Activity in ventromedial prefrontal cortex during self-related processing: Positive subjective value or personal significance? *Social cognitive and affective neuroscience, 10*(4), 494–500.
Koehne, S., Hatri, A., Cacioppo, J. T., & Dziobek, I. (2016). Perceived interpersonal synchrony increases empathy: Insights from autism spectrum disorder. *Cognition, 146*, 8–15.
Kolvoort, I. R., Wainio-Theberge, S., Wolff, A., & Northoff, G. (2020). Temporal integration as "common currency" of brain and self-scale-free activity in resting-state EEG correlates with temporal delay effects on self-relatedness. *Human brain mapping, 41*(15), 4355–4374.
Levin, B. E. (2006). Metabolic imprinting: Critical impact of the perinatal environment on the regulation of energy homeostasis. *Philosophical Transactions of the Royal Society B: Biological Sciences, 361*(1471), 1107–1121.
Levy, J., & Feldman, R. (2019). Synchronous interactions foster empathy. *Journal of Experimental Neuroscience, 13*, 1179069519865799.
Liotti, G. (1992). Disorganized/disoriented attachment in the etiology of the dissociative disorders. *Dissociation, 5*(4), 196–204.
Liotti, G. (2006). A model of dissociation based on attachment theory and research. *Journal of Trauma & Dissociation, 7*(4), 55–73.
Mayer, F. S., & Frantz, C. M. (2004). The connectedness to nature scale: A measure of individuals' feeling in community with nature. *Journal of environmental psychology, 24*(4), 503–515.
Mayer, F. S., Frantz, C. M., Bruehlman-Senecal, E., & Dolliver, K. (2009). Why is nature beneficial? The role of connectedness to nature. *Environment and behavior, 41*(5), 607–643.
Mazza, M. G., De Lorenzo, R., Conte, C., Poletti, S., Vai, B., Bollettini, I., … Rovere-Querini, P. (2020). Anxiety and depression in COVID-19 survivors: Role of inflammatory and clinical predictors. *Brain, behavior, and immunity, 89*, 594–600.
Mazza, M. G., Palladini, M., De Lorenzo, R., Bravi, B., Poletti, S., Furlan, R., … Melloni, E. M. T. (2022). One-year mental health outcomes in a cohort of COVID-19 survivors. *Journal of Psychiatric Research, 145*, 118–124.
Mazza, M. G., Palladini, M., De Lorenzo, R., Magnaghi, C., Poletti, S., Furlan, R., … group, C.-B. O. C. S.. (2021). Persistent psychopathology and neurocognitive impairment in COVID-19 survivors: Effect of inflammatory biomarkers at three-month follow-up. *Brain, behavior, and immunity, 94*, 138–147.
Mazza, M. G., Palladini, M., Poletti, S., & Benedetti, F. (2022). Post-COVID-19 depressive symptoms: Epidemiology, pathophysiology, and pharmacological treatment. *CNS drugs, 36*(7), 681–702.
McFarland, S., Webb, M., & Brown, D. (2012). All humanity is my ingroup: A measure and studies of identification with all humanity. *Journal of personality and social psychology, 103*(5), 830.
Mehling, W. E., Price, C., Daubenmier, J. J., Acree, M., Bartmess, E., & Stewart, A. (2012). The multidimensional assessment of interoceptive awareness (MAIA). *PloS one, 7*(11), e48230.
Motter, A. E. (2010). Spontaneous synchrony breaking. *Nature Physics, 6*(3), 164–165.
Mucci, C. (2021). Dissociation vs repression: A new neuropsychoanalytic model for psychopathology. *The American Journal of Psychoanalysis, 81*(1), 82–111.
Mucci, C., & Scalabrini, A. (2021). Traumatic effects beyond diagnosis: The impact of dissociation on the mind–body–brain system. *Psychoanalytic Psychology, 38*(4), 279.
Mulaik, S. A. (2009). *Foundations of factor analysis*. CRC Press.
Northoff, G. (2016). Is the self a higher-order or fundamental function of the brain? The "basis model of self-specificity" and its encoding by the brain's spontaneous activity. *Cognitive neuroscience, 7*(1–4), 203–222.
Northoff, G. (2017). Personal identity and cortical midline structure (CMS): Do temporal features of CMS neural activity transform into "self-continuity"? *Psychological Inquiry, 28*(2–3), 122–131.
Northoff, G., & Bermpohl, F. (2004). Cortical midline structures and the self. *Trends in cognitive sciences, 8*(3), 102–107.
Northoff, G., & Huang, Z. (2017). How do the brain's time and space mediate consciousness and its different dimensions? Temporo-spatial theory of consciousness (TTC). *Neuroscience & Biobehavioral Reviews, 80*, 630–645.
Northoff, G., & Panksepp, J. (2008). The trans-species concept of self and the subcortical–cortical midline system. *Trends in cognitive sciences, 12*(7), 259–264.
Northoff, G., & Scalabrini, A. (2021a). *"Project for a Spatiotemporal Neuroscience"–Brain and Psyche Share Their Topography and Dynamic* (p. 4500). Frontiers in Psychology.
Northoff, G., & Scalabrini, A. (2021b). "Project for a spatiotemporal neuroscience"–brain and psyche share their topography and dynamic. *Frontiers in Psychology, 12*, Article 717402.
Northoff, G., Vatansever, D., Scalabrini, A., & Stamatakis, E. A. (2022). Ongoing Brain Activity and Its Role in Cognition: Dual versus Baseline Models. *The Neuroscientist, 10738584221081752*.
Northoff, G., Wainio-Theberge, S., & Evers, K. (2020a). Is temporo-spatial dynamics the "common currency" of brain and mind? In quest of "spatiotemporal neuroscience". *Physics of Life Reviews, 33*, 34–54.
Northoff, G., Wainio-Theberge, S., & Evers, K. (2020b). Spatiotemporal neuroscience–what is it and why we need it. *Physics of Life Reviews, 33*, 78–87.
Qin, P., Wang, M., & Northoff, G. (2020). Linking bodily, environmental and mental states in the self—A three-level model based on a meta-analysis. *Neuroscience & Biobehavioral Reviews, 115*, 77–95.
Raut, R. V., Snyder, A. Z., Mitra, A., Yellin, D., Fujii, N., Malach, R., & Raichle, M. E. (2021). Global waves synchronize the brain's functional systems with fluctuating arousal. *Science advances, 7*(30), eabf2709.
Ravignani, A. (2017). Interdisciplinary debate: Agree on definitions of synchrony [Correspondence]. *Nature, 545*, 158.
Satici, B., Saricali, M., Satici, S. A., & Griffiths, M. D. (2022). Intolerance of uncertainty and mental wellbeing: Serial mediation by rumination and fear of COVID-19. *International journal of mental health and addiction, 20*(5), 2731–2742.
Scalabrini, A., Ebisch, S. J., Huang, Z., Di Plinio, S., Perrucci, M. G., Romani, G. L., … Northoff, G. (2019). Spontaneous brain activity predicts task-evoked activity during animate versus inanimate touch. *Cerebral Cortex, 29*(11), 4628–4645.
Scalabrini, A., Huang, Z., Mucci, C., Perrucci, M. G., Ferretti, A., Fossati, A., … Ebisch, S. J. (2017). How spontaneous brain activity and narcissistic features shape social interaction. *Scientific reports, 7*(1), 1–12.
Scalabrini, A., Mucci, C., Esposito, R., Damiani, S., & Northoff, G. (2020). Dissociation as a disorder of integration–On the footsteps of Pierre Janet. *Progress in Neuro-Psychopharmacology and Biological Psychiatry, 101*, Article 109928.
Scalabrini, A., Mucci, C., & Northoff, G. (2018). Is our self related to personality? A neuropsychodynamic model. *Frontiers in Human Neuroscience, 12*, 346.

Scalabrini, A., Mucci, C., & Northoff, G. (2022). The nested hierarchy of self and its trauma: In search for a synchronic dynamic and topographical re-organization. *Frontiers in Human Neuroscience, 16*.
Scalabrini, A., Palladini, M., Mazza, M. G., Mucci, C., Northoff, G., & Benedetti, F. (2023). In between the psychological and physiological self–the impact of COVID-19 pandemic on the neuro-socio-ecological and inflammatory mind-body-brain system. *Clinical Neuropsychiatry, 20*(4), 342.
Scalabrini, A., Schimmenti, A., De Amicis, M., Porcelli, P., Benedetti, F., Mucci, C., & Northoff, G. (2022). The self and its internal thought: In search for a psychological baseline. *Consciousness and cognition, 97*, Article 103244.
Scalabrini, A., Xu, J., & Northoff, G. (2021). What COVID-19 tells us about the self: The deep intersubjective and cultural layers of our brain. *Psychiatry and clinical neurosciences, 75*(2), 37–45.
Schacter, D. L., Addis, D. R., Hassabis, D., Martin, V. C., Spreng, R. N., & Szpunar, K. K. (2012). The future of memory: Remembering, imagining, and the brain. *Neuron, 76*(4), 677–694. https://doi.org/10.1016/j.neuron.2012.11.001
Schimmenti, A., & Caretti, V. (2016). Linking the overwhelming with the unbearable: Developmental trauma, dissociation, and the disconnected self. *Psychoanalytic Psychology, 33*(1), 106.
Schimmenti, A., Starcevic, V., Giardina, A., Khazaal, Y., & Billieux, J. (2020). Multidimensional assessment of COVID-19-related fears (MAC-RF): A theory-based instrument for the assessment of clinically relevant fears during pandemics. *Frontiers in Psychiatry, 11*, 748.
Schore, A. N. (2011). The right brain implicit self lies at the core of psychoanalysis. *Psychoanalytic dialogues, 21*(1), 75–100.
Schore, A. N. (2013). Relational trauma, brain development, and dissociation. *Treating complex traumatic stress disorders in children and adolescents: Scientific foundations and therapeutic models*, 3-23.
Siegel, A., Mor, I., & Lahav, Y. (2021). Profiles in COVID-19: Peritraumatic stress symptoms and their relation with death anxiety, anxiety sensitivity, and emotion dysregulation. *European Journal of Psychotraumatology, 12*(1), 1968597.
Smallwood, J., Bernhardt, B. C., Leech, R., Bzdok, D., Jefferies, E., & Margulies, D. S. (2021). The default mode network in cognition: A topographical perspective. *Nature reviews neuroscience, 22*(8), 503–513.
Smith, D., Wolff, A., Wolman, A., Ignaszewski, J., & Northoff, G. (2022). Temporal continuity of self: Long autocorrelation windows mediate self-specificity. *Neuroimage, 257*, Article 119305.
Stern, D. N. (1985). *The interpersonal world of the infant: A view from psychoanalysis and developmental psychology*. Routledge.
Sui, J., & Humphreys, G. W. (2015). The integrative self: How self-reference integrates perception and memory. *Trends in cognitive sciences, 19*(12), 719–728.
Trapnell, P. D., & Campbell, J. D. (1999). Private self-consciousness and the five-factor model of personality: Distinguishing rumination from reflection. *Journal of personality and social psychology, 76*(2), 284.
Trevarthen, C. (1993). The self born in intersubjectivity: The psychology of an infant communicating.
Trevarthen, C., & Aitken, K. J. (2001). Infant intersubjectivity: Research, theory, and clinical applications. *The Journal of Child Psychology and Psychiatry and Allied Disciplines, 42*(1), 3–48.
Ulmer Yaniv, A., Salomon, R., Waidergoren, S., Shimon-Raz, O., Djalovski, A., & Feldman, R. (2021). Synchronous caregiving from birth to adulthood tunes humans' social brain. *Proceedings of the National Academy of Sciences, 118*(14), e2012900118.
Valdesolo, P., & DeSteno, D. (2011). Synchrony and the social tuning of compassion. *Emotion, 11*(2), 262.
Wiltermuth, S. S., & Heath, C. (2009). Synchrony and cooperation. *Psychological science, 20*(1), 1–5.
Wolff, A., Di Giovanni, D. A., Gómez-Pilar, J., Nakao, T., Huang, Z., Longtin, A., & Northoff, G. (2019). The temporal signature of self: Temporal measures of resting-state EEG predict self-consciousness. *Human brain mapping, 40*(3), 789–803.
Wolman, A., Wolff, A., Wainio-Theberge, S., Scalabrini, A., El Ahmadi, A., & Northoff, G. (2023). Intrinsic neural timescales mediate the cognitive bias of self–Temporal Integration as key mechanism. *Neuroimage, 119896*.
Yeshurun, Y., Nguyen, M., & Hasson, U. (2021). The default mode network: Where the idiosyncratic self meets the shared social world. *Nature reviews neuroscience, 22*(3), 181–192.
Yu, L., Hattori, Y., Yamamoto, S., & Tomonaga, M. (2018). *Understanding empathy from interactional synchrony in humans and non-human primates. In Evolution of primate social cognition* (pp. 47–58). Springer.