



The interpersonal computational psychiatry of social coordination in schizophrenia

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Impairments in social coordination form a core dimension of various psychiatric disorders, including schizophrenia. Advances in interpersonal and computational psychiatry support a major change in studying social coordination in schizophrenia. Although these developments provided novel perspectives to study how interpersonal activities shape coordination and to examine computational mechanisms, direct attempts to integrate the two methodologies have been sparse. Here, we propose an interpersonal computational framework that (1) leverages the active inference framework to model aberrant social coordination processes in schizophrenia and (2) incorporates dynamical system models to dissect intrapersonal and interpersonal synchronisation to inform a statistical model based on active inference. We discuss how this interpersonal computational psychiatry framework can elucidate the aberrant processes leading to psychopathology, with schizophrenia as an example, and highlight how it might aid clinical intervention and practice. Finally, we discuss challenges and opportunities for using the framework in studying social coordination impairments.

Introduction

Social functioning deficits are prevalent in people with psychiatric illnesses and are manifested as a core dimension of psychopathology in schizophrenia, one of the most debilitating mental disorders.^{1,2} Previous studies have documented that people with schizophrenia present various forms of social deficits, including emotion recognition, mentalisation, and social coordination, possibly due to abnormalities in social-cognitive processes, such as theory-of-mind and empathy.³ Importantly, impairments in social cognition are associated with poor prognoses.⁴

Social cognition generally pertains to the cognitive processes and skills required for understanding, deciphering, and navigating social contexts.⁵ Social coordination, on the other hand, typically refers to any form of coordinated actions in space and time with another individual or individuals in social settings.⁶ Social coordination mainly consists of two domains, behavioural matching and interactional synchrony.^{7,8} Behavioural matching is associated with unconscious and non-verbal (or explicit copying) behaviours in response to a stimulus, whereas interactional synchrony is a dynamic process by which people coordinate their behaviour with that of others.⁷ For people with schizophrenia, previous studies on behavioural matching have yielded mixed findings, however, reports on interpersonal synchrony have been quite consistent, showing impairments across different paradigms (eg, joint action task and mirror game) and measurement methods (eg, behavioural coding and video-based motion capture).⁷ The convergent findings suggest that deficits in interpersonal synchrony could provide a stable marker for schizophrenia and are especially relevant to negative symptoms.^{7,9} Aberrant interpersonal synchrony presents in various forms of psychopathology that involve social deficits (eg, autism spectrum disorder). Here, we use schizophrenia as an example to illustrate our proposed framework.

There are two critical limitations in existing studies on social coordination in schizophrenia. First, social coordination is intrinsically dynamic, requiring at least two individuals, but most conventional studies have measured behavioural and brain activity in single individuals and have not explored interdependencies between interacting individuals.^{10,11} Second, manifestations of social cognitive deficits in schizophrenia are heterogeneous and patients show mild to severe social functioning deficits, varying across clinical groups. This indicates that multiple cognitive processes could underlie these deficits. Further, this heterogeneity poses challenges in dissecting social coordination impairments in schizophrenia and related symptomatology.^{9,12}

At least two branches of research have attempted to overcome these limitations, in parallel—interpersonal psychiatry and computational psychiatry.¹³ Interpersonal psychiatry highlights the necessity of moving from single-person to multi-person approaches, which have higher ecological validity.¹⁴ This approach directly assesses the dynamic interactions of two or more individuals (behaviourally, neurally, or both).¹⁰ In studies on schizophrenia, impairments in social coordination have been particularly related to negative symptoms (eg, social withdrawal)^{7,15,16} and the use of these interpersonal paradigms can facilitate operationalisation and quantification of negative symptoms in laboratory

Lancet Psychiatry 2023;
10: 801–08

Published Online
July 18, 2023
[https://doi.org/10.1016/S2215-0366\(23\)00146-3](https://doi.org/10.1016/S2215-0366(23)00146-3)

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Search strategy and selection criteria

References for this Personal View were identified through searches of PubMed and Google Scholar for articles published from Jan 1, 1990, to March 31, 2023. We used specific search terms such as interpersonal synchrony, coordination, schizophrenia, Kuramoto model, predictive coding, and active inference to identify relevant articles. We also reviewed references cited in those articles to ensure completeness. Only articles published in English were included.

settings. Computational psychiatry, from another perspective, uses formal mathematical models (eg, models based on Bayes' theorem) to uncover mechanistic processes that underlie abnormal behaviour in mental disorders.^{17–20} Modelling based on cognitive theories has emerged as a powerful tool to dissect the psychological and neurophysiological underpinnings of pathological behaviours that are not directly observable.^{21–23} Together, interpersonal psychiatry emphasises naturalistic contexts for studying the interactive nature of social coordination, while computational psychiatry accesses into complex unobservable states.

An integration of both approaches, interpersonal computational psychiatry, could provide novel insights into the mechanisms of social coordination deficits among people with psychiatric illnesses. We first briefly introduce the current advances in interpersonal psychiatry and the representative computational motif that connects afferent sense to high-level cognitive processes and the ensuing actions prevailingly used in the schizophrenia literature. We then extend the modelling to interactional contexts via active inference at the conceptual level. We provide a computational example fusing dynamical modelling and active inference in studying social coordination deficits and discuss how the findings might inform psychopathology. Finally, we discuss the implications, challenges, and opportunities of the proposed interpersonal computational framework in research and clinical applications.

Interpersonal psychiatry in schizophrenia

There has been an increasing interest in dyadic studies involving real-time interactions between two people with schizophrenia or between a person with schizophrenia and a healthy control. This change has generally been referred to as a development towards interpersonal psychiatry.^{14,15,24} Researchers taking the interpersonal psychiatry approach have investigated correlated behavioural or neural processes within a dyad, such as body-to-body, face-to-face, or brain-to-brain synchronies.^{24,25} The past decade has witnessed brilliant applications of interpersonal psychiatry in research on schizophrenia (and related mental disorders). One such application is the assessment of body-to-body synchrony in dyads of people with schizophrenia during social interactions,¹² showing that a low level of synchrony was associated with negative symptoms, low competence, and impaired social functioning. On the neural level, a recent functional near-infrared spectroscopy hyperscanning study²⁶ observed that dyads including a person with clinical high risk of psychosis and a sex-matched healthy control showed reduced interbrain synchrony (ie, correlated neural activity of brains between interacting individuals^{27,28}) in the right inferior frontal gyrus, compared with healthy control dyads during cooperative (but not competitive) button-pressing. Reduced interbrain synchrony in dyads of a

person with clinical high risk of psychosis and a healthy control has been related to prodromal symptoms in individuals with clinical high risk.²⁶ This pattern also exists in neurodevelopmental conditions with compromised social-brain function, such as autism spectrum disorder. For example, Wang and colleagues²⁹ showed that children with more severe autism symptoms showed lower behavioural and brain synchronisation with their parents than did children with less severe autism symptoms. These findings add to the growing body of evidence indicating that aberrant interpersonal synchrony could be linked to impaired dyadic interactions, including those that occur during psychotherapeutic sessions.^{30,31}

Overall, interpersonal paradigms are promising for providing novel markers of social deficits in psychiatric disorders. Although observable (behavioural or neural) data could be readily calculated under such interpersonal paradigms, the use of such paradigms does not address the hidden cognitive processes. For example, how does the person with schizophrenia take the behaviour of others into account? How does a person with schizophrenia consider their own behaviours during social interactions? For these questions, we turn to computational psychiatry.

Computational psychiatry in schizophrenia: Bayesian approach-based computational motif

Computational modelling can help uncover hidden states to improve understanding of cognitive processes in social coordination. Here, we focused on active (Bayesian) inference and its neural implementation for predictive coding, as the past decade has shown considerable theoretical and empirical support for this approach.^{32–35} Much of the computational psychiatry literature invokes the minimisation of precision-weighted prediction errors and the special importance of precision.^{36–38} Under this framework, predictive coding rests on an internal world or generative model that can generate predictions and ensuing prediction errors that are caused by a mismatch between top-down predictions and bottom-up sensory inputs.

In schizophrenia, impairments in the source allocation of sensory signals and false inference are involved in hallucinations and delusions; these have been extensively discussed using predictive coding.^{39–42} The emerging picture is that people with psychosis have difficulties balancing the precision of their prior beliefs with sensory evidence.^{36,43,44} This is often framed in terms of a failure of sensory attenuation; namely, an inability to attenuate or modulate the precision of sensory prediction errors, particularly self-generated sensory signals, leading to errors in source monitoring. Impairments in sensory evidence modulation possibly lead to a compensatory increase in the precision of prior beliefs.^{43,45} This formulation has been used to explain a range of behaviours related to schizophrenia, including the

attenuation of mismatch negativity and other aspects of false inference and predictive processing.^{43,46–48}

In social coordination, updates to the precision weighting of prediction errors in the internal model of each person can be highly complex because the states and actions of the individual and their partner change dynamically.⁴⁷ Sensory attenuation and its complement, selective attention, play crucial roles in dyadic interactions and synchronisation. For example, Friston and Frith⁴⁹ used Lorenz systems with a separation of temporal scales to simulate two birds singing together. The ensuing generalised synchrony—or synchronisation of chaos—depended on the alternating attenuation and augmentation of sensory precision, enabling the two birds to take turns in listening and singing. The tendency of one agent to follow another agent depended on the prior precision of each bird. Exactly the same predictive processing mechanisms have been used to simulate a kind of social inference using multiple agents.⁵⁰ In schizophrenia, the ability to estimate and modulate the precision of sensory signals, relative to the precision of prior beliefs, is possibly impaired, introducing failures of sensory attenuation in dyadic interactions. It has also been suggested that the internal generative model in people with schizophrenia regarding social contexts contains imprecise priors,⁵¹ yielding impaired estimations about their influence on their partner's behaviours during interactions. Imprecise priors indicate that the agent assigns less precision to their prior beliefs and might, therefore, be influenced by sensory evidence—which is afforded relatively greater precision—with consequent false inference that can manifest in symptoms. For example, individuals could infer that something is not there when it is (eg, neglect syndromes and dissociative symptoms) or, conversely, that something is there when it is not (eg, delusions and hallucinations). In short, assigning the right balance of precision to prior beliefs and sensory evidence can have a profound effect on perception and belief updating.

Whereas positive symptoms (eg, hallucinations and delusions) have been largely conceptualised under the predictive coding framework as aforementioned, how negative symptoms emerge from failure of interpersonal coordination remains elusive. Active (Bayesian) inference modelling may help to provide insights into this process. Active inference conceptualises action selection as an inferential process, and this has been applied to understanding action selection. Hence, active inference modelling is well suited for examining the computational mechanisms behind choice behaviours in dyadic contexts. For example, an individual with significant negative symptoms might show diminished responsiveness in a dynamic social coordination process as a consequence of elevated imprecision (ie, uncertainty) in predicting another person's behaviour, and such inferential processes can putatively be captured by an active inference model as suggested.⁵¹

According to active inference, a sentient agent, such as a human, tries to reduce the uncertainty regarding their interactions with the environment, thereby increasing the chance of obtaining desired outcomes from their actions. This uncertainty reduction is made possible by embodying a generative model about the agent's interaction with the environment.^{52,53} Here, perception and action are the observable outcomes of the hidden states. Hidden states are the causes of perception and action in that they are probabilistically generated by the hidden states. In research on schizophrenia, simulation using active inference has shown that hallucinations can be consequences of increased prior precision over policy (ie, a sequence of actions) coupled with a lower precision between hidden states and outcomes.³⁷ Although empirical research is sparse, a 2022 study using a probabilistic Go or No-go task showed that people with first-episode psychosis presented fewer optimal choices compared with healthy controls and individuals with at-risk mental states.⁵⁴ Active inference modelling suggested that the underlying mechanisms might include a higher rate of forgetting past action outcomes together with lower prior precision in choosing optimal actions given preferences and knowledge. Active inference has also been applied to study emotional states⁵⁵ and the psychopathology of internalising disorders and addiction.^{38,56,57}

Although active inference (or other Bayesian modelling tools) is promising in helping researchers to infer the hidden neurocognitive processes and, thereby, uncover the pathogenesis of social coordination deficits in schizophrenia, to date, the research has a single-subject focus. Next, we propose an integrative framework combining interpersonal paradigms and computational modelling to decode the hidden cognitive processes in the context of social coordination deficits in schizophrenia.

Towards an interpersonal computational psychiatry in schizophrenia: dissecting social coordination deficits

Modelling overestimation and underestimation with active inference

Social coordination deficits in schizophrenia assessed with interpersonal paradigms feature heterogeneities in actions and interaction outcomes. Such heterogeneity is associated with the internal processing of each interacting individual, involving multiple hidden states.

In a standard design, the behavioural measures are (1) whether the agent keeps or changes their rhythm and (2), if they change, whether the rhythm becomes more similar to that of their partner's. Moreover, the rhythm can be either objectively correct or inaccurate. For the active inference model, the behaviours are observable outcomes of hidden states, namely, the agent's belief about their own accuracy in rhythm, their prior preference to keep or to change their rhythm, how much the agent cares about accuracy, and the

interpersonal consistency between their own rhythm and their partner's rhythm.

Using this paradigm, overestimation and underestimation of one's own accuracy in rhythm can yield different behavioural patterns. Next, we specified how active inference can help to understand these two types of cognitive processes. For the purpose of illustration, we assumed that the partner's rhythm was objectively accurate and that the individual's initial rhythm, in contrast, was incorrect.

The first type concerns an overestimation state. Without feedback on the task, an individual holds a strong belief that their own rhythm is correct (ie, high-precision assignment to confidence in self). Then, there are at least two subtypes of processes that can yield

different behavioural patterns: (1) if the person does not care about interpersonal consistency (eg, low-precision assignment to self–other consistency outcomes), they will keep their own rhythm throughout the experiment; their rhythm should be inconsistent with the partner's at all times. The situation is more complex when the person cares about interpersonal consistency; the desire to be correct, albeit objectively wrong, is as strong as (or stronger than) the desire to be consistent with the other person. The individual might stick to their own rhythm for the majority of the time while intermittently changing to follow the other's rhythm. (2) The agent can underestimate their own accuracy (ie, lower precision assignment to confidence in themselves relative to confidence in their partner). (3) If the individual cares about accuracy (eg, higher precision assignment to the perceived accuracy outcome), regardless of whether they care about interpersonal consistency, they will tend to follow their partner's rhythm, starting quite early in the experiment. Hence, the outcome becomes more consistent and more accurate over time. (4) If the individual does not care about accuracy or interpersonal consistency (as seen in social withdrawal and avolition), then the behavioural pattern may oscillate between keeping and following, and the interpersonal consistency will be low throughout the experiment.

These different cognitive processes can be parameterised in an active inference model. For example, in the context of (1), for an individual with overestimation, the matrix denoting the prior of accuracy of rhythm should be higher than their partner's. Then, the transition probability from keep the rhythm to follow the rhythm should be low.

Dynamical systems modelling and its integration with active inference

Given that we aimed to dissect the process of interpersonal coordination in people with schizophrenia, we introduce dynamical systems modelling, as this framework has shown its ability to decode the behavioural volatility patterns of dyadic interactions. There are several specific approaches, such as the two-person version of the Kuramoto model^{58,59} and the Haken–Kelso–Bunz model.⁶⁰ The Kuramoto model estimates the weights of within-agent and between-agent coupling, which represent internal and external action–perception synchronisation patterns, respectively.⁶¹ The effectiveness and usefulness of this approach is seen in its ability to explore significant synchronisation parameters, such as coupling strength,⁶¹ and to capture crucial aspects of interpersonal interactions, including the emergence of leader–follower relationships.⁶² This is applicable to various forms of coordination within complex systems.⁵⁸ Moreover, as active inference relies on Bayesian statistics, it faces a challenge in specifying appropriate parameters for model setup. Dynamical systems modelling is effective for constraining the a priori parameters for

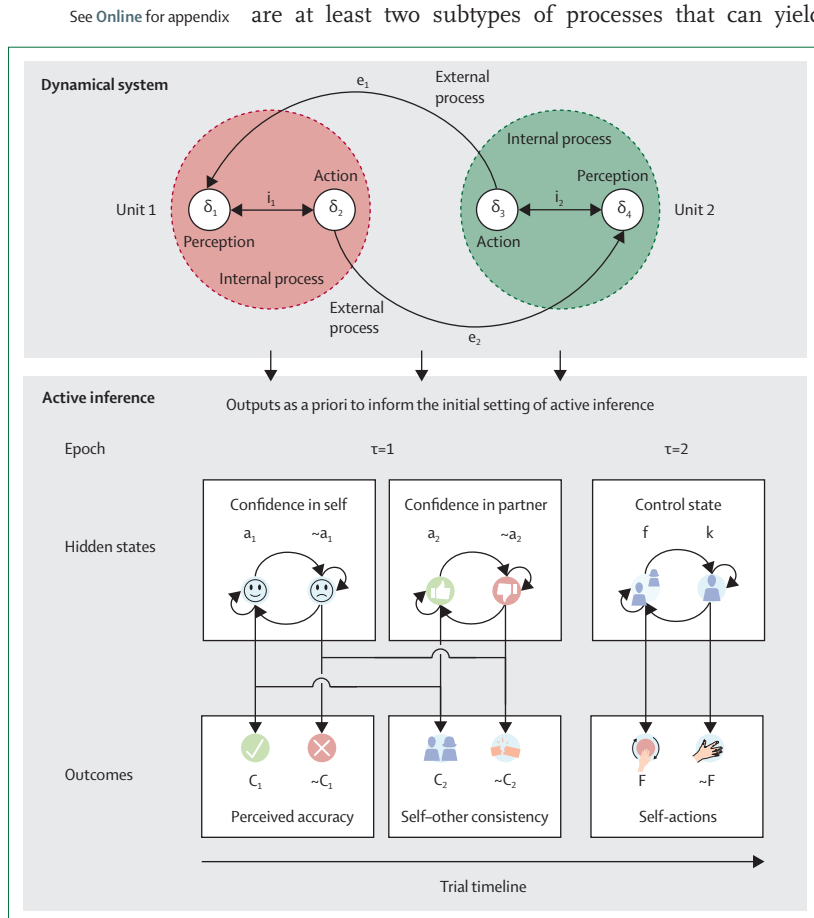


Figure 1: An integrative framework with dynamic systems modelling and active inference

This illustration sketches how dynamic systems and active inference models can be combined to model the behaviours of a dyad consisting of a person with schizophrenia and a healthy partner in a joint finger tapping task (two persons tap isochronously). We show how the specific setting of the active inference model eg, the parameters governing hidden states and the mapping from hidden states to outcomes, can be constrained by outputs from the dynamic systems model (appendix p 2). δ_1 =oscillator 1 (perception) in unit 1. δ_2 =oscillator 2 (action) in unit 1. δ_3 =oscillator 1 (action) in unit 2. δ_4 =oscillator 2 (perception) in unit 2. i_1 =intrinsic processes of perception and action in unit 1. i_2 =intrinsic processes of perception and action in unit 2. e_1 =external process of perception (unit 1) and action (unit 2). e_2 = external process of perception (unit 2) and action (unit 1). τ =epoch (time point). a_1 =accurate rhythm of self. $\sim a_1$ =inaccurate rhythm of self. a_2 =accurate rhythm of the partner. $\sim a_2$ =inaccurate rhythm of the partner. f =to follow the rhythm of the partner. k =to keep the rhythm of the self. C_1 =being consistent with the self-perceived rhythm. $\sim C_1$ =being inconsistent with the self-perceived rhythm. C_2 = being consistent with the partner. $\sim C_2$ =being inconsistent with the partner. F =following the rhythm of the partner. $\sim F$ =not following the rhythm of the partner.

setting up a better informed active inference model. Here, we propose the coupling estimates from the Kuramoto model to provide such an informative integration with active inference. For example, higher within-agent than between-agent coupling implies mostly a low interpersonal consistency outcome, which might relate to the condition that the individual does not care about interpersonal consistency while keeping their own rhythm throughout the experiment. Such a behavioural manifestation would map onto the first subtype of the processes mentioned earlier. In the process of establishing an active inference model for a particular individual, estimates from the Kuramoto modelling, such as higher within-agent than between-agent coupling, could translate into a higher probability of the individual's rhythm being correct than incorrect and a lower probability of following other's rhythm. Such integration can aid in understanding the underlying states responsible for the individual's behavioural patterns, eg, that people with schizophrenia would tend to overestimate.

Hence, these two approaches complement each other and are recommended to be used together (figure 1).

Linking to psychopathology

The state of overestimation or underestimation of causal inference in dynamic social interactions could hold relevance for symptomatology. Although positive symptoms such as paranoid delusions and grandiosity can be linked to overestimation states, as in the predictive coding model, negative symptoms (eg, flat affect and anhedonia) are more difficult to model. However, active inference provides a handy toolkit for the conceptualisation and modelling of these behaviours (figure 2). Specifically, when people underestimate their causal influence in social contexts, this lowered precision in prior beliefs could lead to actions that appear to be random or unresponsive to the environment. When this is coupled with a low-reward state where people care neither about interpersonal consistency nor accuracy, it could result in observable signs associated with the negative symptoms of blunt affect and low spontaneity.

Second, as symptom expression in people with schizophrenia varies over time, predominant positive symptoms might later shift to negative symptoms. As a function of time, these changes might be modelled with overestimation and underestimation with active inference. Imagine an initial overestimation state marked by the expectation that the partner would follow the (objectively inaccurate) agent's rhythm: this expectation would probably be unfulfilled, leading to a diminished predictability of social consequences and thereby reduced precision in priors. With repeated failures, this might even lead to an underestimation state. This pattern could lead to disturbed self–other boundaries^{51,63} to connect with an underestimation state, leading to reduced motivation and refusal of future

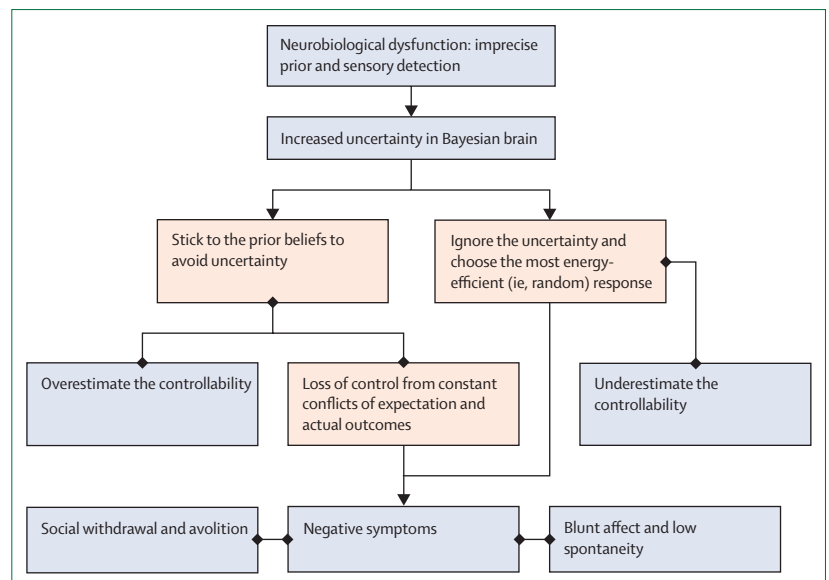


Figure 2: Biased cognitive processes leading to different negative symptoms

The relationships between the overestimation or underestimation of social influence on others and the negative psychopathology in schizophrenia. The orange panels highlight two different action tendencies during social interaction.

interactions, akin to the major negative symptoms such as social withdrawal and avolition.

Together, the integration of dynamical systems models and active inference can help elucidate the exact mechanisms behind aberrant interpersonal synchronisation in different subgroups (eg, overestimation *vs* underestimation in social contexts) of people with schizophrenia.

Implications in research and clinical applications

Here, we discuss the implications of this proposed interpersonal computational framework for future research and clinical applications. First, interpersonal computational psychiatry can facilitate evidence-informed subtyping by examining impairments in social function. This might also help to improve the prediction of the course and outcomes, as social functioning is an important marker for prognosis. Clustering individuals into more homogeneous subgroups could facilitate a better prognosis. In support of this, when interbrain neural properties were assigned as the classification feature, classification performance (discrimination between conditions) improved compared with single-brain measures in studies with functional near-infrared spectroscopy hyperscanning and machine learning algorithms.⁶⁴ Moreover, the mechanistic parameters dissected by theory-based frameworks, such as the active inference model, would serve as a powerful dimensionality reduction process of features to render the machine learning algorithms more efficient and reliable^{18,65} with remarkably improved interpretability.

Second, interpersonal computational psychiatry advances the development and translation of

interventions and treatments. By fitting the active inference model to empirical behavioural data on social coordination (eg, a simple joint finger tapping task⁵⁹), researchers can cast inference at the behavioural level (ie, the observed variables). In our proposed framework, active inference modelling is applied to investigate the computational mechanisms behind aberrant behavioural patterns, with the active inference model constrained by the outcomes of dynamical systems modelling. This can help to unravel the hidden states that yield deficits in interpersonal coordination in individuals with schizophrenia, shedding light on the computational mechanisms of negative symptoms. Findings from this approach can further determine targets for investigating neural processes. One can then reapply dynamical systems modelling to neural data to uncover the neural correlates of active inference-informed hidden states. Then, predictive coding could help to elucidate the precision-weighted flow of information through the neural system. Future studies can specifically delineate such a bridge from behavioural hidden states to brain circuits and instantiate an implementation at the neural level based on predictive coding. When decoding at the neural level, brain imaging data collected simultaneously in coordination tasks can be correlated with the hidden states parameters that are used to measure abnormal cognitive processes. Such mechanistically meaningful targets would fuel the development of more effective therapies on the basis of multi-brain stimulation⁶⁶ and multi-brain neurofeedback.⁶⁷ Beyond psychosocial training and cognitive behavioural therapy, interpersonal computational psychiatry, therefore, enables precise neurobiological treatment design.

Current challenges and future opportunities

There have been constraints in the development of interpersonal computational psychiatry and its translational applications. The first obstacle pertains to the more complex setup for an appropriate computational framework to deal with interpersonal assessments. Compared with standard computational psychiatry methods,⁶⁸ interpersonal computational psychiatry would have to consider interdependencies of data from interacting individuals (*vs* those in isolation) during social encounters. That said, it can analyse the computational processes of social coordination within and across social brains.⁶⁹ This would require further open, transparent efforts toward a unified, adaptive, and interpretable computational pipeline for social coordination in schizophrenia. Of note, a mathematical framework of dyadic active inference, which allows for the modelling of bi-directional processes of communication between the belief states of interlocutors in the form of a joint minimisation of uncertainty, has just been proposed.⁷⁰

A second challenge pertains to clinical translation. Currently, most computational work in social

coordination in schizophrenia was conducted under laboratory or semi-naturalistic conditions. However, psychiatric conditions are often reflected through social-functioning difficulties in everyday life.¹⁵ It remains unknown whether our understanding from laboratory findings could be generalised to the real-world manifestations of schizophrenia, which is key to developing effective personalised assessments and interventions.⁷¹ Therefore, interpersonal computational psychiatry also calls for more ecologically valid research (eg, ecological momentary assessment of rich phenotypes with portable devices).⁷¹ In this regard, the technology of virtual reality holds a high potential to facilitate research, as used in intervention work.⁷²

Although challenges remain, this framework opens new windows into future research and clinical practice: quantitative measurements of social coordination deficits can benefit from data-driven analyses; and functional connectivity derived from meta-analyses can predict diverse social behaviours,⁷³ fostering the establishment of direct brain-behaviour relationships and the detection of key brain networks. Under this data-driven framework, our 2021 study successfully identified social-affective and theory-of-mind networks that reliably predicted disorganised symptoms in people with schizophrenia.³ Future studies should combine similar data-driven derivation with theory-based models, in which the mechanistic features identified from the latter approach would contain complementary information in diagnostic classification, prediction of prognosis, and early detection of risk with improved performance.¹⁹ A second future direction is the development of multi-brain stimulation.⁶⁶ As a new application, in 2021, we stimulated two brains simultaneously, manipulating interbrain synchrony, and measuring the behavioural effects on social learning.⁷⁴ Multi-brain stimulation led to the emergence of spontaneous synchronised body movements between dyads and augmented learning performance. As social coordination in schizophrenia could be reliably captured and characterised by interbrain measurements, future studies on causal manipulation by multi-brain stimulation, with optimised modulation parameters via computational approaches, could lead to a new technological era of transformative applications in schizophrenia and psychiatry. Another future direction is the multimodal collection of interpersonal properties in schizophrenia. Social coordination in schizophrenia relies on multilayer information. First, multi-person neuroimaging such as electroencephalogram functional MRI hyperscanning would provide complementary temporal and spatial information (especially of whole brain and subcortical structures) to disentangle top-down control and bottom-up sensory signals. Further, collecting interaction-based sociometrics (gaze, posture, speech, and brain signals)⁷⁵ holds great promise for the early identification of abnormalities in social functioning. A computational structure based on multimodal

information will help to establish a synthesised framework for understanding social coordination in schizophrenia.

Contributors

JC, YP, and JJ conceptualised this Personal View and wrote the original draft. YP and JJ reviewed and edited the draft. JJ and YW contributed to drafting and revising of the Personal View. JC managed the project.

Declaration of interests

We declare no competing interests.

Acknowledgments

This work was supported by the STI2030-Major Projects (JC; 2022ZD0214000), the National Key R&D Program of China (JC; 2021YFC2502200), the National Natural Science Foundation of China (YP; 62207025 and JC; 82201658), the Humanities and Social Sciences Research Project from the Ministry of Education of China (YP; 22YJC190017), and the Fundamental Research Funds for the Central Universities (YP).

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