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OPERATIONALIZING DISEMBODIED INTERACTION: THE PERCEPTUAL CROSSING EXPERIMENT IN SCHIZOPHRENIA RESEARCH[1]

abstract

Embodied and phenomenological approaches to neuropsychiatry have proven to be promising for assessing social cognition and its impairments. Second-person neuroscience has demonstrated that the dynamics of social interaction make a difference when it comes to how people understand each other. This article presents the Perceptual Crossing Experiment (PCE) as a paradigm for studying real-time dyadic embodied interactions in the context of schizophrenia. We draw on the phenomenological concept of interbodily resonance (IR) and show how the PCE can be used to accurately model and assess IR. We then turn to disembodied interaction in schizophrenia and finally propose the PCE as a translational tool for systematically assessing the hindered IR that individuals with schizophrenia suffer from. We offer an experimental approach to phenomenology which could be informative for the development of more embodied interventions aiming to remedy the profoundly disrupted social life that patients with schizophrenia live with.

keywords

social interaction, perceptual crossing, schizophrenia, (inter)bodily resonance, embodied interaction

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1. Introduction

In recent years, the field of neuropsychiatry has pointed out the necessity to adopt tools capable of evaluating the bodily, situated, and interpersonal aspects of psychopathology (Froese *et al.*, 2020; Fuchs & Schlimme, 2009; Schilbach *et al.*, 2013). Some researchers have proposed that many, if not all, mental disorders entail disturbances of the social dimension, shown as difficulties to communicate with others, to make sense of what others do, and to adapt to the dynamics of social interactions present in everyday life (Fuchs, 2010; Schilbach, 2016; Vogeley, 2018).

This shift away from methodological individualism has also incorporated phenomenological evaluations, in which assessments of qualitative aspects of patients' sensorimotor experiences and social surroundings are required to get a better understanding of psychopathology (Fuchs, 2007, 2019; Krueger, 2020; Krueger & Aiken, 2016; Myin-Germeys *et al.*, 2009).

This so-called second-person account of psychopathology takes the interaction between engaged individuals as the main phenomenon of interest (Fuchs, 2015a, 2015b; Ratcliffe, 2015; Schilbach, 2016; Vogeley, 2018). The interpersonal space of patients gains uttermost relevance for the prevention, diagnosis, treatment, and prognosis of mental disorders (Fuchs, 2019; Myin-Germeys *et al.*, 2016). Granted that mental disorders cannot be fully understood without looking at the interactive engagement between people, then an empirical framework also considering the interpersonal level is required.

Embodied approaches to social cognition have developed diverse experimental set-ups to assess the interaction dynamics present in any social encounter. The aim is to study real-time embodied interactions in such a way that the involved individuals feel engaged and take an *interactor* rather than a passive observer role (Auvray & Rohde, 2012; Schilbach *et al.*, 2013). Accordingly, social interaction has been actively researched in real-time dyadic situations such as gaze cueing tasks, structured conversations, psychotherapy sessions, emotional expression workshops, body-oriented psychotherapy, and movement improvisation tasks (Abney *et al.*, 2014; Galbusera *et al.*, 2018; Galbusera *et al.*, 2019; Michael *et al.*, 2015; Ramseyer & Tschacher, 2014; Schilbach *et al.*, 2013).

Although constrained, a dyadic model of interaction is already complex enough to study real-life situations like mother-baby coupling or therapist-client encounters (Montague *et al.*, 2002; Ramseyer & Tschacher, 2011; Trevarthen & Aitken, 2001). A dyadic setup allows quantitative and systematic research of manifold behavioral patterns, elicited by an encounter between two interacting subjects. The dyad becomes the unit of analysis, allowing the assessment of both *intra*- and *inter*-individual aspects brought forth during social interactions.

In this work, we primarily present and refer to the Perceptual Crossing Experiment (PCE),

an empirical paradigm capable of assessing real-time dyadic interactions in a systematic and ecologically valid way (Auvray *et al.*, 2009; Froese *et al.*, 2014; Froese *et al.*, 2020; Hermans *et al.*, 2020; Zapata-Fonseca *et al.*, 2018). After a thorough description of the PCE, we draw on the phenomenological concept of interbodily resonance (IR) (Fuchs & Koch, 2014) and show how it can be captured accurately by the paradigm. Accordingly, we propose an operationalization of IR into observable and testable variables. Afterward, we offer a brief account of schizophrenia as a disorder of embodied interaction, in which the subjective experience of body, time, and environment is altered, and IR therefore profoundly hindered. Finally, we suggest the implementation of the PCE to study disembodied interaction in people with schizophrenia, aiming to build a bridge between the phenomenology of social impairments and the experimental study of embodied social interaction.

2. The Perceptual Crossing Experiment

The Perceptual Crossing Experiment (PCE) is a two-person empirical setup that isolates the interactive aspect of the detection of sensorimotor contingencies (SMC). These can be understood as the sensorimotor affordances and responsive patterns that dynamically change depending on the own active exploration of an environment (Buhrmann *et al.*, 2013; O'Regan & Noe, 2001). Given its dyadic character, the PCE has also been proposed as a tool for assessing self-other SMC, (soSMC), that is, "*the know-how of the regular ways in which changes in others' movements depend on changes in one's movements*" (Froese *et al.*, 2020, p. 1).

Moreover, and despite its minimalist character, the PCE has already been used to investigate various features of dyadic interactions in different groups of people, including adolescents and patients with high-functioning autism (Auvray *et al.*, 2009; Barone *et al.*, 2020; Deschamps *et al.*, 2016; Froese *et al.*, 2014; Froese *et al.*, 2020; Hermans *et al.*, 2020; Zapata-Fonseca *et al.*, 2018). For instance, it has been shown that people suffering from autism were able to solve the task, namely, they could accurately detect the social contingencies. However, when looking at the movement patterns, they showed a significant difference in comparison to the control individuals: they moved rather repetitive and restrictive, likely spending more time on searching than on interacting (Zapata-Fonseca *et al.*, 2019; Zapata-Fonseca *et al.*, 2018).

In the PCE, pairs of physically separated participants can only engage with each other via a haptic human-computer interface (HCI) that reduces their embodied interaction to a minimum of horizontal left to right movement and haptic feedback. Participants are seated at separate desks so that they cannot see each other; the mutual auditory perception is also avoided as they wear noise-canceling headphones (Figure 1A). The task of the game is to move horizontally (left-right) within the unidimensional space and to mark those moments, in which an encounter with the partner has presumably occurred. They are told to help each other to achieve the goal of finding the other and establish an interaction.

Through the technological mediation, both participants are embodied as minimal avatars on an invisible line that wraps around after 600 units of space. Within the space, there are also distracting objects, namely a static and a moving one (see Figure 1B). Participants are to interact as embedded and embodied avatars by using their own HCI:

- They can move a trackball that controls the displacement of their avatar within the shared invisible space.
- And they can feel a vibration in the hand for as long as their avatar overlaps any of the other objects, that is, whenever a *perceptual crossing* occurs.

As shown in Figure 1B, each participant can encounter different kinds of objects within the virtual communal space. In total, three types of objects can be crossed with:

- A static one that is fixed at an arbitrary location.
- The other person's avatar, and
- A moving object that *shadows* the other person's avatar but at a constant distance.

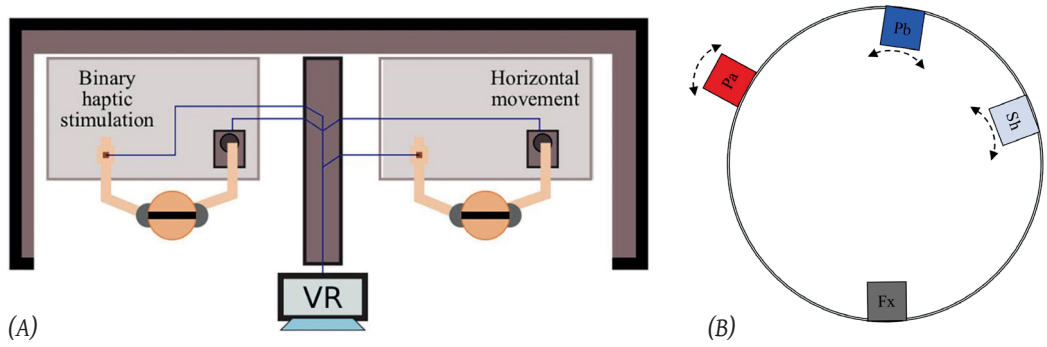

Figure 1. Perceptual Crossing Experiment. *(A) The physical setup: Participants interact exclusively via a Human-Computer Interface consisting of a trackball and a tactile stimulator (modified from Froese & Zapata-Fonseca, 2017). (B) The virtual setup: Participants are embodied as minimal avatars on an invisible one-dimensional circular space. Each participant can encounter three different objects: one located at a fixed position (dark grey square; Fx), another that corresponds to the participant's avatar (red or blue squares; Pa and Pb), and a shadow that moves exactly as the participant's avatar but at a constant distance of it (light gray square, Sh). For the sake of simplicity, (B) shows only the perspective of Pa.*

Only when both participants' avatars are crossing simultaneously, both participants are getting haptic feedback at the very same time.
Crucially, all three objects will elicit an on-off vibration if encountered. Figure 2 shows *perceptual crossings* that are to be distinguished only by the qualities they offer, *i.e.*, by their different possibilities for *(inter)*action, also known as affordances (Gibson, 1979). The static object would be at a certain point in space all the time, so it is inanimate: it does not move. On the contrary, the moving object is animate, but it is not reactive as it merely follows the other person's avatar at a constant distance; that is why this moving object is also called a shadow

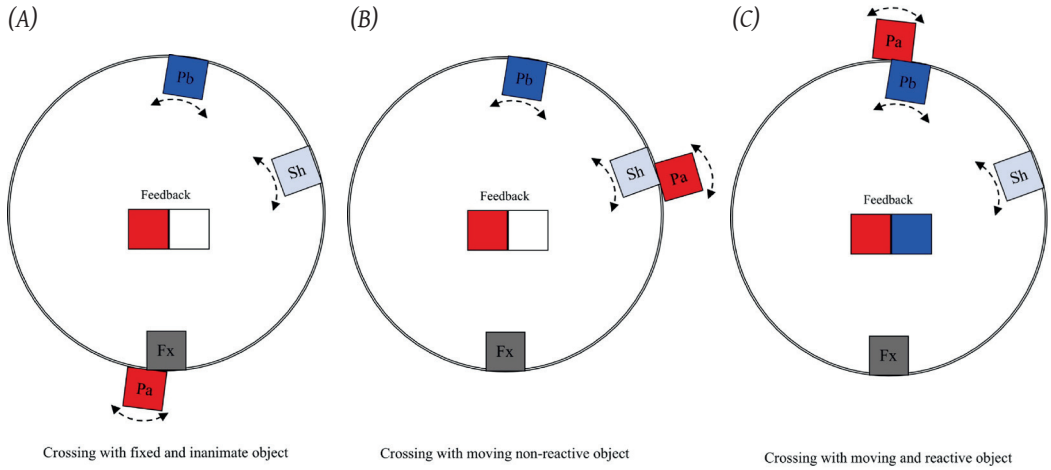

Figure 2. Different types of encounters in the Perceptual Crossing Experiment. *(A) and (B) are situations of one-directional coupling: Pa (red) interacts with two non-reactive objects, either inanimate (Fx) or animate (Sh); in this situations Pa (red) receives stimulation but Pb (blue) remains unaware of that and therefore no responsiveness to the former can be created. (C) shows a mutual encounter, defined as the overlap between participants' avatars (perceptual crossing); consequently, both Pa and Pb receive the tactile feedback simultaneously.*

because even if it is crossed, the *owner* of such shadow will never feel any vibration, making reactivity impossible. So only the avatar of the other person can change its behavior and therefore be both animate and reactive according to the encountered contingencies.
The PCE as an experimental set-up fulfills various requirements needed to establish meaningful embodied interactions. Being affected by *crossings* (haptic sensation) triggers a bodily resonance at physiological and proprioceptive levels, for example, arousal and motor reflexes, as well as back and forth movements to *palpate* the different objects in the environment and finally be able to detect the presence of the other, which in turn influences the perception and evaluation of the affordances that are in the *landscape* (animate, inanimate, reactive and their combinations) and implies a corresponding action readiness at a behavioral level. Like in real life, the different affordances can only be detected through movement and by considering what those movements elicit: there is a need to move and create movements and therefore to establish a sensorimotor coupling between interactants.
Notice that the experience of the body, both as a physical object and as a lived subject, is fundamental for the PCE framework. Because of the immersion in a shared environment, the subject's body is detected by another participant, and at the same time, her body allows her to be embedded and actively present. The embodied subject can *palpate* and *be palpated*, so her actions are perceptions as well. It is only through such embodied duality that the interaction can be realized. Both recognizing one's own creation of movement patterns and detecting reactivity to them become crucial to succeed in the recognition of the presence of the other.
It is also necessary to develop a sensitivity to different sensorimotor patterns resulting from the ongoing interactions not only between participants but also with the distracting objects that are always present in the environment. Therefore, the interaction is co-constructed by the moving and the feeling of the two embodied subjects that are co-present both in time and space.
In sum, the PCE entails an active and bodily based interaction between two subjects, who are simultaneously engaged with the environment through dynamic sensorimotor couplings. Such description is fully compatible with that of IR as we will see in the next section.

3. Inter-bodily Resonance

Inter-bodily resonance (IR) consists of a dynamic intertwinement of *expressions* and *impressions* between two people (Fuchs & Koch, 2014). Both interpersonal and intrapersonal levels are described so that the internal and relational properties can be distinguished. Individuals are regarded as embodied subjects being actively engaged within the environment through dynamic sensorimotor cycles (see Figure 3, adapted from Fuchs & Koch (2014)). In enactive terms, they may be seen as brain-body-environment systems constantly changing their states and situated within a shared environment (Froese *et al.*, 2013).
As shown in Figure 3, each subject experiences a relationship between perception and action, or *affection* and (*e*)*-motion*. If I can be affected, and literally *moved through my body* (intra-bodily resonance), then I am simultaneously capable to be reactive, showing emotional expressions, and making movements considering what the other embodied subject does (bodily feedback). Thus, a circular process unfolds over time, and participants become engaged interactors instead of detached observers (Fuchs & Koch, 2014).
In other words, IR comprises an ever-changing sensorimotor interpersonal system, in which one person's bodily activity (expression) turns into the other person's bodily perception (impression), and vice versa. Such interactive experience comprises the integration of time, the body, and the other:

- *Time* is captured by the fluctuating patterns of interaction within the environment and between embodied subjects. It is only through this dynamic character that cycles of sensorimotor patterns can unfold and become self-sustaining.

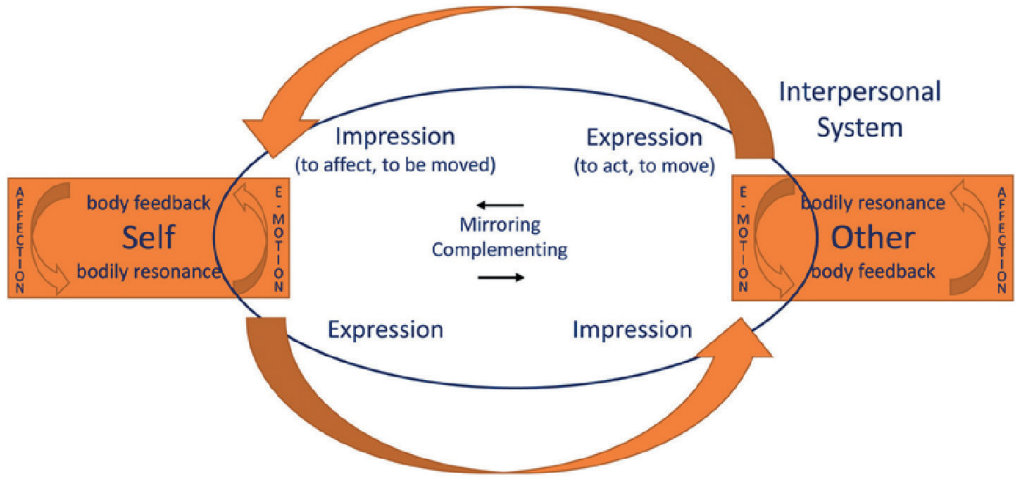

Figure 3. Illustration of the different components and interactive cycle of inter-bodily resonance. *Adapted from Fuchs & Koch (2014). Inter-bodily resonance is a dyadic interaction in real-time between two embodied subjects. Each individual is an intrapersonal system that through sensorimotor cycles is constantly related to itself and the environment.*

- The *Body* is depicted as a sensorimotor resonant system that allows bodily expressions through movements, and bodily impressions leading to being affected and reactive. An action-perception loop is formed, in which to act is to perceive, and vice versa (Froese & Fuchs, 2012).
- The *Other* refers to the embodied subject with whom the interaction is taking place. A reciprocal intertwinement of bodily expressions and impressions allows the feeling of being connected (Fuchs, 2017). Even if the global perceptual field of each subject is a shared environment, a clear demarcation between *Self* and *Other* is always present.

IR thus comprises a fluctuating sensorimotor interpersonal system, in which embodied subjects can move and be moved. They can *express* themselves through *(e-)motions*, and at the same time get *impressions* from the other embodied subject, allowing bodily *affections* to arise (Fuchs & Koch, 2014). This time-dependent and shared situation permits a bidirectional communication, sustained by both intra-individual and dyadic sensorimotor cycles. The unit of analysis is shifted from the isolated individual to the dynamics and properties at the dyadic level.

3.1. Empirical definition of Inter-bodily resonance and its relation to the PCE

From a phenomenological point of view, the task of the PCE experiment includes the recognition of the other's presence within a shared space, in which participants are, through technological mediation, *literally connected* and able to *feel each other*. They can enact meaningful sensorimotor loops, such as staying still after crossing with the other or moving back and forth to convey animacy. These allow them to eventually experience the presence of the other as a sense of embodied intersubjectivity.

Analogous to IR, we now present the integration of time, the body, and the other in the context of the PCE:

- *Time* is implied in the real-time interactions that evolve within and between trials. A flow of sensorimotor patterns that constitute the process of interaction is always present, which will enable the finding and understanding between participants. Both individual and dyadic behaviors unfold over time.

- *The Body* with its movement is the means through which participants interact. The PCE interactions are based on hand movements and the corresponding vibrations such that a sensorimotor cycle enables the interaction. Only through regulation of this sensorimotor engagement, the required communicative and interactive patterns can be achieved.
- *The Other* must be recognized as such to succeed in the game. The technological mediation in the PCE allows participants to intermittently interact with each other and with the other objects. There is a shared world, in which dyadic coupling and mutual communication are possible.

During the PCE, participants have partial control of their perceptual field as they move. In a sense, the participants *are* their movements, and the co-regulation of their movements is the only way of succeeding at the task. The interactants can find each other through *to-and-fro* movements that increase the frequency of the vibrations that are being felt simultaneously by both (see Figure 2C). Eventually, this flexible and adaptive responsiveness indicates the presence of the other. The presence of one participant completes the perception that the other is (co-)creating to actually recognize her partner and therefore establish a complementary social interaction.

Thus, the PCE is a suitable tool for operationalizing IR as it focuses on the interactive process itself and can consider the co-constitution of mutual communication between embodied subjects whose sensorimotor loops are continuously being adapted, both at an intra- and interpersonal level. *Table 1* shows the defined variables measured by the PCE and their corresponding phenomenological terms.

Furthermore, the dynamics taking place during everyday dyadic encounters resemble what happens during interactions in the PCE (Froese & Zapata-Fonseca, 2017). Both in everyday social interactions and during the PCE there is a modulation of the interaction within the dyad. While being constrained by the respective perceptual field, the interaction does not occur between isolated individuals, for the other is always part of the field as well (Fuchs, 2019). Following this second-person methodology, we turn now to the case of schizophrenia as a disorder, in which impaired and disembodied interaction prevails. Schizophrenia can be considered as a social impairment when focusing on the diminished sense of interbodily resonance and on the difficulties that patients have when trying to make sense of the environment and interactions with other people.

4. Disembodied interaction in schizophrenia

According to phenomenological psychopathology, patients with schizophrenia show disturbances in their embodiment, that is, the otherwise fluid oscillation between the modes of the body-as-subject and the body-as-object is disrupted, if not lost (Fuchs, 2010). The related alterations include impaired awareness of oneself or one's own body, a discontinuity of action-perception cycles of everyday performance, and impairment of intercorporeality with other people (Fuchs & Röhricht, 2017; Sass & Parnas, 2003).

The weakened sense of bodily self is manifested as a loss of vital contact with oneself and reality (Minkowski, 1970), sometimes described by patients as being detached from others, "*surrounded by invisible walls"* and feeling foreign to the world (Fuchs & Röhricht, 2017, p. 130). Additionally, there is existential insecurity, in which the own body, the own self, and the environment feel unfamiliar, and *"things can no longer be taken for granted"* (Fuchs & Röhricht, 2017, p. 131).

Patients with schizophrenia also suffer from a loss of sensorimotor coherence. This means a disintegration of automatic, fluid performance: everyday activities such as gait or lacing the shoes may become impaired or fragmented, often requiring deliberate movements and hyperreflective attention like a *"Cartesian action of the mind on the body"*. An example was

Variable	**Definition**	**Phenomenological Correlate**
Movement profile	Quantitative (Zapata-Fonseca *et al.*, 2019): • Mean velocity • Variability of velocity (standard deviation) • Number of changes in direction Qualitative: • Self-report of the employed movements	Sense of bodily agency: Recognition of the own actions as such and acknowledgment of their effects on the environment. Motion flow: Integration of individual movements into meaningful behavior.
Individual performance	Quantitative (Froese *et al.*, 2020): • Number of correctly detected encounters (accuracy of clicks) • Perceptual Awareness Scale (PAS) Qualitative: • Self-report of the experience of the presence of the other	soSMC: Detection of the presence of the other, *i.e.*, the "*know-how of the regular ways in which changes in others' movements depend on changes in one's movements*" (Froese *et al.*, 2020, p. 1).
Learning effect	Quantitative (Froese *et al.*, 2020): • Changes in individual performance across trials (see variables above) Qualitative: • Self-report of the development of strategies	Transparency and degree of incorporation: Acquisition of a skill (dyadic interaction in the PCE) through sensorimotor mastery (Andrada, 2020). The focus of attention changes across trials. Initially, it is on how the device works. Afterwards, it shifts towards the sensorimoto0r patterns and the interaction itself.
Interpersonal sensorimotor matching (dyadic)	Quantitative: (Hermans *et al.*, 2020; Kojima *et al.*, 2017; Zapata-Fonseca *et al.*, 2016) • Amount of seconds spent together • Adaptation of movement profiles • Rapport questionnaire Qualitative: • Self-report of collaborativeness	Embodied (inter)affectivity: *"two cycles of embodied affectivity become intertwined, thus continuously modifying each partner's affective affordances and resonance"*(Fuchs & Koch, 2014, p. 9).

Table 1. Measured variables with the PCE. *The qualitative variables are obtained by implementing a semi-structured interview after participants finish a round of 10 or more trials. soSMC: Self-other sensorimotor contingencies.*

described by a patient as *"I could not perform any movement without having to think about how would I do it"* (Fuchs & Röhricht, 2017, pp. 131,132; Sass & Parnas, 2003). A reduced capability to recognize familiar motor or sensory patterns ensues: single elements of the perceptual field stand out separately (Fuchs, 2019) and the *hypersalient* details become an overwhelming source of information that hinders tacit motor processes. As a result, the perception of the world is no longer transparent but opaque (Froese *et al.*, 2013), and reacting to it becomes increasingly difficult.

Of special relevance for the present work is the dysfunctional intercorporeality that manifests itself as a reduced interbodily resonance and a *"fundamental alienation of intersubjectivity"* (Fuchs & Röhricht, 2017, p. 133). Patients start to feel isolated and detached from the world, and one's own as well as the behavior of others come to be observed from a distant or third person point of view instead of being based on second-person embodied interactions. There is a severely disrupted *"basic sense of being-with-others in a shared life-world"* (Fuchs & Röhricht, 2017, p. 133; Sass & Parnas, 2003).
Such weakened embodied communication and lack of social resonance might be shown as impaired performance in detecting soSMC and difficulties for establishing an interpersonal matching during a real-time interaction (see Table 1 for details on the variables). Therefore, we propose the implementation of the PCE for schizophrenia research.

4.1. Disembodied interaction in the PCE

So far, we have argued that the PCE is an empirical set-up that enables us to quantify parts of the complex process of inter-bodily resonance. The PCE allows the assessment of social interaction including a sense of embodiment grounded in sensorimotor loops, as well as a sense of bodily agency in the form of responsiveness to the different affordances offered within a shared space. Both embodied subjects can initiate and control their own actions, while always remaining in contact with their bodies thanks to the human-computer interface (HCI) (Braun *et al.*, 2018; Tsakiris *et al.*, 2007). Additionally, the technologically mediated environment leads people to rely on the interaction itself from the very beginning of the trials, which corresponds to a second-person approach to psychopathology.
It is worth recalling the crucial role of bidirectional interactions and the adaptation to affordances in the PCE: they become the only way for efficiently distinguishing between the objects presented to the players. Once a trial begins, the environment turns into a dynamic one, in which different sensorimotor contingencies exist so that participants need to develop a perceptual knowledge about the available affordances for interaction and eventually reach an understanding of the sociality that is taking place.
In other words, the PCE relies on sensorimotor interactions that are influenced by adaptive coordination and imply time dependency, both at individual and dyadic levels of description. To be successful in the task, participants must make sense of each other and achieve a co-regulation between their patterns of movement. It is precisely this kind of adaptive behavior during real-time embodied interactions that is compromised in patients with schizophrenia.
To implement the PCE in the context of schizophrenia, it becomes crucial to operationalize disembodied interaction. Accordingly, we consider the following variable categories:
1) the sense of bodily agency (SBA), 2) the accuracy on detecting self-other sensorimotor contingencies (soSMC), and 3) interpersonal sensorimotor matching (ISM).

1) The SBA can be derived from the movement profile (MP) variable shown in Table 1. In the PCE it is possible to look at the active or passive character of the participants' movements (Kojima *et al.*, 2017). If a disturbance of agency is present, rather less and slow movement patterns would prevail (lower mean velocity and diminished variability of it – quantitative aspects of MP). If the individual is capable of initiating purposeful movements and acknowledges them as being created by herself (the qualitative aspect of MP), then it can be said that the agency is preserved.
2) The accuracy of detecting soSMC can be inferred from the amount of correctly assigned clicks and its subjective correlates (shown in Table 1 as individual performance). The animate and reactive object (the partner's avatar) is the only one capable of explicitly signalizing that one's own actions are indeed causing *impressions* and *expressions* on the partner. However, there might be a sense of ambiguity when crossing the static object because it is not the active movement (*expression*) that is causing the *impression*, but

rather a mere location in certain spatial coordinates (Di Paolo *et al.*, 2008). Therefore, accurate detection of soSMC requires not only sensitivity from a passive standpoint but also an active engagement to distinguish between reactive and non-reactive objects.

3) A diminished sensorimotor coupling (a proxy of sensorimotor coherence) might be observable as a predilection either for overstimulation (crossing with as many objects as possible) or for avoiding behavior (minimizing the activation of the haptic feedback). Additionally, a dysfunctional asymmetry between the MP of the dyad could be indicative of a lacking integration of sensorimotor loops measured by the dyadic variable ISM, mentioned in Table 1. The type of movements in terms of exploration or interaction, as well as the adaptive range of such movements (movement profile in Table 1), seem to be appropriate variables to propose potential socio-motor signatures that could resemble the disembodied interaction present in schizophrenia (Zapata-Fonseca *et al.*, 2019).

Importantly, these PCE variables should not be understood as having additive effects. That is, the disembodied interaction in schizophrenia can be manifested in different ways and at different levels. It is only through statistical hierarchical modeling, as suggested in Froese *et al.* (2020), that an integration of the variables and the respective interpretation is possible.

Given that the PCE focuses on the exploration of *prereflective* relational aspects of social interaction, *theorizing* or *mind-reading* are far from being useful for establishing a meaningful and embodied interaction. Given that people with schizophrenia frequently suffer from *hyperreflexivity*, it is expected that they might adopt such an observer's perspective. This detachment might also trigger difficulties for the other embodied subject involved in the interaction. For instance, a patient's behavioral movement might resemble static or animate nonreactive objects (the so-called shadows), which are characterized by absent responsiveness. As rather passive subjects, patients with schizophrenia might project a reduced vitality, hindering the detection of soSMC by the interactive partner. Furthermore, patients with schizophrenia might need more time and rounds to get familiar with the task in comparison with controls. For to successfully solve the task a certain level of intuitive behavior is required and it is precisely this implicit learning that is disrupted, leading to hyperreflexivity.

As a complement to the discussed objective variables, a hybrid assessment of behavioral variables and phenomenological descriptions of the interaction is warranted. The inclusion of qualitative questionnaires about the interactants' experience of *being-with-the-other* has shown to be very useful already. For instance, an integrative analysis of both quantitative and qualitative variables of the PCE was recently conducted, and it was found that "*a clearer perception of the other was not associated with correctness of recognition as such, but with both participants correctly recognizing each other*" (Froese *et al.*, 2020, p. 1).

Finally, given the embodied foundation of the PCE, as well as its engaging and dynamic character, it is possible to research a learning effect through repeated sessions of embodied interactions (Froese *et al.*, 2020; Hermans *et al.*, 2020). Such property could provide insights on how training of minimal embodied dyadic interaction might eventually have a countereffect on or even change the disembodiment suffered by patients with schizophrenia, analogous to well-established body-related interventions (Daly & Gallagher, 2019; Hildebrandt *et al.*, 2016; Martin *et al.*, 2016; Mastrominico *et al.*, 2018). It has been acknowledged that *"intercorporeality may serve as a remedy for the disembodiment in schizophrenia"* (Fuchs & Röhricht, 2017, p. 138). This would be in line with the TESIS study, a randomized controlled trial of embodied group therapy in patients with schizophrenia and autism, which showed that shared body sensitivity training and interaction could improve in particular flat affect, but also other negative symptoms (Martin *et al.*, 2016).

5. Summary

In the present article, we endorsed an embodied and phenomenological approach to psychopathology: mental disorders are understood as different modes of *being-in-the-world*, instead of mere brain disorders (Fuchs, 2007). Thus, we have drawn special attention to the bodily actions and the social dimension of human beings. By considering schizophrenia as a disorder of embodied interaction, we aimed to build a bridge between embodied cognitive sciences and phenomenological psychopathology.

Accordingly, we presented the Perceptual Crossing Experiment (PCE) as a sound paradigm to systematically study dyadic embodied interactions in real-time. We then introduced the theoretical notion of inter-bodily resonance and aimed to operationalize it in terms of the PCE. Based on these theoretical and empirical concepts, we showed how the PCE can capture the subjective experience of one's own body, the temporal context, and the relation to the other. Because of the inherent complexity of sociality, a minimal embodied cognition setup like the PCE yields the opportunity to consider both the individual phenomenology and the multi-scale dynamics that occur between individuals in a manageable experiment.

Consequently, we proposed the implementation of the PCE to study schizophrenia, aiming at a better understanding of the difficulties that schizophrenic patients face every day in the interactions with others. Frequently they experience these interactions as a burden, leading them to withdraw from the social world. Already in 1911 Bleuler introduced the term schizophrenic autism defining it as a detachment from the outer world associated with a predominance of an inner life (Bleuler, 1958). More recently, schizophrenic autism has been defined as a "disturbance of the *prereflective selfworld relation*" (Henriksen *et al.*, 2010, p. 365). Given that the PCE evaluates the *prereflective* relational aspects of social interaction and the fact that it is indeed sensitive to the modes of interaction deployed by patients with autism, it renders then plausible to observe disruptions in the movement trajectories of patients with schizophrenia as well.

The goal of applying the PCE to the study of schizophrenia is to provide a more naturalistic assessment of the disorder in its social context, grounded on the crucial role of embodied interactions. Moreover, the PCE offers a temporal resolution to deal with processes happening at pre-reflective levels, otherwise elusive to quantitative research. This contribution is expected to provide both embodied cognitive sciences and phenomenological psychopathology with a valuable tool for an integrative assessment of schizophrenia as a disorder of intersubjectivity.

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