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The spatial self in schizophrenia and autism spectrum disorder

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ABSTRACT

Schizophrenia (SZ) and autism spectrum disorder (ASD) have been both described as disorders of the self. However, the manner in which the sense of self is impacted in these disorders is strikingly different. In the current review, we propose that SZ and ASD lay at opposite extremes of a particular component of the representation of self; namely, self-location and the construct of peripersonal space. We evaluate emerging literature suggesting that while SZ individuals possess an extremely weak or variable bodily boundary between self and other, ASD patients possess a sharper self-other boundary. Furthermore, based on recent behavioral and neural network modeling findings, we propose that multisensory training focused on either sharpening (for SZ) or making shallower (for ASD) the self-other boundary may hold promise as an interventional tool in the treatment of these disorders.

1. Schizophrenia and autism spectrum disorder as disturbances in "minimal selfhood"

Schizophrenia (SZ) and autism spectrum disorder (ASD) have long been characterized as disorders of the self (Bleuler, 1911; Kanner, 1943; Nasrallah, 2012). Both disorders are associated with the loss of a coherent sense of self, anomalous self-experience, and the blurring of the distinction between the self and other (Ferri et al., 2012; Parnas et al., 2002; Sass and Parnas, 2003; Hobson and Meyer, 2015). Accordingly, it has been argued that the poor social functioning exhibited by patients with SZ or ASD may be partly a product of a more basic disturbance in the sense of self (Nelson et al., 2009b). Thus, elucidating the neurocognitive mechanisms underlying the altered sense of self in SZ and ASD could lead to a better understanding of the etiologies of these disorders.

Phenomenological descriptions identify three levels of selfhood (Parnas, 2000; Parnas et al., 2003): (1) a pre-reflective selfhood involved in the bottom-up assembly of a sense of self (Legrand, 2007); (2) an explicit awareness of the sense of self that is the invariant subject of experience and action, and (3) a social-narrative self containing personality traits and states, habits, and preferences (Northoff et al., 2006). While the latter conceptualizations of the self are reliant on higher order cognitive constructs and their associated cortical structures (Northoff and Bermpohl, 2004), the pre-reflective sense of self is associated with lower-level sensory and multisensory processes and the responsible brain regions (Tsakiris, 2010). As a consequence of this, recent theoretical models of both SZ and ASD have emphasized that self-disturbances in SZ and ASD may be in part attributable to changes in sensory and multisensory function (Parnas et al., 1998, 2002, 2005; Nelson et al., 2009b).

Although SZ and ASD patients frequently show overlap in their symptomology (e.g., negative symptoms in SZ resemble ASD features), the manner in which ASD and SZ groups interact with their surrounding world is often strikingly different (Crespi and Badcock, 2008). While an over-extended sense of presence (Blanke et al., 2014) and the loss of the self-other boundary (Nelson et al., 2009a; Thakkar et al., 2011; Michael and Park, 2016) are commonplace in SZ, ASD is most frequently associated with difficulties in establishing interpersonal relatedness and problems in adapting a fragile self-concept to changing environments (Asperger, 2008). In the current review we propose that despite these striking different characteristics, abnormalities of basic self-experience in SZ and ASD are closely related, and that self-location (primarily as indexed by the representation of peripersonal space) serves as a fundamental organizational principle placing SZ and ASD at opposite ends of a continuum that relates to the boundary between self and other. Such a model highlights the fact that SZ and ASD patients may interact with

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the world in very distinct manners, yet may share mechanistic similarities in regards to disruptions in the constructs of self and peripersonal space.

Specifically, we propose that the etiological and pathophysiological processes that define SZ and ASD may be founded, respectively, in an extreme shallowness or steepness in the manner in which these two neuropsychiatric conditions represent the boundary between the bodily 'self' and 'other'. As indexed by the representation of peripersonal space (PPS), shallowness and steepness between self and other may be quantified as the spatial extent over which the interactions between touch and the major exteroceptive senses (i.e., vision and audition) transitions from being absent to being complete. In such a conceptualization, a long transition space would equate to a shallow PPS representation, while a short transition space would equate to a steep PPS representation. As indirectly indexed by the ease or difficulty with which patients disembody their own spatial location in order to locate their bodies at another location, a shallow self-other boundary gradient is indexed by the proneness to disembodiment, while a steep self-other boundary gradient is illustrated by an inflexibility in altering one's self-location. This conceptualization allows for a dimensional analysis of shared symptoms, and may represent a powerful framework from which to elucidate the complexity of abnormal social processes in these two disorders. Further, this framework naturally accommodates the observation that SZ and ASD exhibit similarities in their symptomology, while being clearly distinct pathologies.

2. The representation of peripersonal space as a proxy for self-other differentiation

Blanke and Metzinger (2009) put forward that minimal selfhood is composed of a process of self-identification, a first-person perspective, and self-location. The latter component, self-location, is amenable to experimental manipulation, as a number of paradigms have been developed that elicit perceived shifts in the location of a particular limb, or even of the entire body (Blanke et al., 2015). For example, in the Rubber-Hand Illusion (RHI; Botvinick and Cohen, 1998), a visible fake rubber hand is either stroked synchronously or asynchronously with tactile stimulation given on the hidden real hand. After a short period of stimulation, healthy participants report feeling ownership over the fake hand, and demonstrate a bias in the localization of their real hand in the direction of the rubber hand. This so-called proprioceptive drift can be taken as an indirect measure for self- or limb-location, and hence as a proxy measure of the ease or difficulty (and magnitude) with which subjects will alter their bodily representation.

Importantly, proprioceptive drift does not take place if the real and fake hands are placed too far away from one another (Lloyd, 2007), which suggests that localizing one's hands is not only influenced by processing on the limbs themselves, but also by the space occupied by the hands. Indeed, Makin et al., 2008, suggest that alterations in the bottom-up multisensory processing of the PPS surrounding the hand (Rizzolatti et al., 1997; Ferri et al., 2013a, 2013b) are crucial in engendering the RHI. Most recently it has been shown in that the delineation of one's PPS representation around the trunk (Noel et al., 2014; Galli et al., 2015; Serino et al., 2015a, 2015b) shifts toward the location of a synchronously stroked virtual avatar (Noel et al., 2015a, 2015b; Salomon et al., 2016). Collectively, there is a growing body of evidence suggestive that the integration of body-related multisensory signals within PPS is a fundamental component of the ability to localize oneself in space and differentiate self from other.

The close relationship between one's PPS representation and the differentiation between self and other is apparent in that sharing sensory experiences with another blurs self-other distinctions (Tajadura-Jiménez et al., 2012; Sforza et al., 2010) and causes a remapping of one's PPS representation onto the other (Maister et al., 2014). Additionally, the size and placement of one's PPS representation (that is, the location of its boundaries) has been shown to accommodate to the presence of others (Fini et al., 2014) and to do so depending on the quality of the social interaction (Teneggi et al., 2013). It must be noted, however, that prior work has largely focused on the location and absolute size of the PPS, as opposed to the shape of its boundaries, when examining bodily self-other differentiation. This is surprising, as the representation of PPS is undoubtedly one that takes the form of a gradient, with the differentiation between self and non-self blurring as a function of distance from the body (Canzoneri et al., 2013; Longo and Lourenco, 2007). In the next two sections, we review literature pertaining to the examination of bodily illusions and the representation of PPS with an emphasis on differences in the gradient by which SZ and ASD populations encode self-other bodily distinctions.

3. Schizophrenia as a disorder of self due to a shallow self-other gradient

Clinical reports and empirical studies have highlighted the wide array of body-related neurobiological processing abnormalities that characterizes SZ (Chang and Lenzenweger, 2001, 2005; Murakami et al., 2010; Agorastos et al., 2011; Holt et al., 2015). More recently, it has been suggested that a fragile bodily self-representation may be a core component of the pathology, and that the weaknesses in this representation may be caused by inadequate body-related multisensory integration processes (Postmes et al., 2014), which manifests as a loss of implicit self-knowledge and self-other differentiation (Gallese and Ferri, 2014). Indeed, recent theories that frame SZ as a disorder characterized by a disembodiment of the self (Zahavi, 2005; Fuchs, 2005; Stanghellini, 2009; Nasrallah, 2012) echo the original viewpoint expressed by Bleuler (1911).

Thakkar et al. (2011) and Peled et al. (2000) found a stronger RHI in SZ patients than in controls. This increased proneness to the illusion was demonstrated both by self-report questionnaires and by proprioceptive drift. Importantly, the onset of the illusion took place earlier in SZ than in controls (Peled et al., 2000). Further, during the RHI there was also a significant alteration in the latency of evoked somatosensory responses (Peled et al., 2003), as well as a stimulation-dependent change in skin temperature (Thakkar et al., 2011) and most strikingly, an out-of-body experience in a patient with SZ (Thakkar et al., 2011). A weaker and more variable sense of body boundary has also been demonstrated in patients with SZ via the Pinocchio Illusion (PI), which engenders a sensation that one's nose is growing in response to a tactile-proprioceptive manipulation (Michael and Park, 2016). Interestingly, the PI was associated with social isolation regardless of diagnosis, suggesting that reduced self-other social interactions may contribute to disturbances of the bodily self. Collectively, these results suggest a weaker and more variable representation of the body in space in SZ – and hence, a reduced distinction between bodily self and other (shallower gradient from self to other). Ferri et al. (2013a, 2013b) recently corroborated the observation that the RHI can be induced in SZ simply by tactile expectation; however, they also showed that the effect itself was dampened in SZ as compared to controls. Overall the body of evidence appears to indicate an increased proneness to the RHI in the schizophrenia-spectrum (Peled et al., 2000, 2003; Thakkar et al., 2011; Germine et al., 2013), and thus a more flexible PPS representation.

Weakened self-other boundary distinction in SZ is also supported by evidence suggesting a shallower PPS representation in SZ. Delevoye-Turrell et al. (2011) had patients with SZ and healthy controls perform judgments related to the location of the boundary of PPS by asking them to indicate when objects and people entered or exited their reaching space. Results demonstrated that judgments of the extension of PPS (as indexed by the measure of reaching space judgment) were on average, depending on the modality of response, either greater or similar for SZ than for healthy controls. Importantly for the current argument, however, results also revealed that patients with SZ were significantly more variable in their judgments, and this higher variability was selective for PPS judgments. Thus, it appears that the boundary