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What are the neurocognitive correlates of basic self-disturbance in schizophrenia?: Integrating phenomenology and neurocognition Part 2 (Aberrant salience)

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ABSTRACT

Phenomenological research indicates that disturbance of the basic sense of self may be a core phenotypic marker of schizophrenia spectrum disorders. Basic self-disturbance refers to disruption of the sense of ownership of experience and agency of action and is associated with a variety of anomalous subjective experiences. Little is known about the neurocognitive underpinnings of basic self-disturbance. In these two theoretical papers (of which this is Part 2), we review some recent phenomenological and neurocognitive research and point to a convergence of these approaches around the concept of self-disturbance. Specifically, we propose that subjective anomalies associated with basic self-disturbance may be associated with: 1. source monitoring deficits, which may contribute particularly to disturbances of "ownership" and "mineness" (the phenomenological notion of *presence or self-affection*) and 2. aberrant salience, and associated disturbances of memory, prediction and attention processes, which may contribute to hyper-reflexivity, disturbed "grip" or "hold" on perceptual and conceptual fields, and disturbances of intuitive social understanding ("common sense"). In this paper (Part 2) we focus on aberrant salience. Part 1 (this issue) addressed source monitoring deficits. Empirical studies are required in a variety of populations in order to test these proposed associations between phenomenological and neurocognitive aspects of self-disturbance in schizophrenia. An integration of findings across the phenomenological and neurocognitive "levels" would represent a significant advance in the understanding of schizophrenia and possibly enhance early identification and intervention strategies.

1. Introduction

In Part 1 (Nelson et al., 2014-b) we argued for the importance of integration across "levels" of enquiry in schizophrenia research and proposed that there is a convergence in recent phenomenological and neurocognitive research around the concept of disturbance of the basic sense of self as a central feature of schizophrenia. We outlined the phenomenological basic self-disturbance model of schizophrenia and outlined how various aspects of this model, particularly diminished ownership of experience, self-other boundary confusion, and hyper-reflexivity, might correlate with neurocognitive disturbances of source monitoring. In this paper (Part 2) we focus on neurocognitive disturbances of aberrant salience and their possible phenomenological correlates and suggest avenues for empirical enquiry into these proposed associations. Our aim is not to introduce new elements to the existing phenomenological and neurocognitive models but rather to speculate about the possible connections between the two "levels" of enquiry.

2. Aberrant salience: memory–attention disturbances

A considerable amount of research indicates the presence of attention and memory disturbances in schizophrenia. A major theme in this work is the failed suppression of attention to irrelevant or familiar information or stimuli in the environment, leading to aberrant salience of objects and associations (Kapur, 2003; Kapur et al., 2005) — or, to reverse the terminology, excessive attention to information that is irrelevant or highly familiar. The term "salience" is being used broadly in this context to describe the relative attention directed towards a stimulus compared to other stimuli (i.e., how prominent, noticeable, or important a stimulus appears to be) and the resultant affect on goal-directed behaviour (Gray et al., 1991; Hemsley, 1992; Berridge and Robinson, 1998; Kapur, 2003; Kapur et al., 2005). A number of neurocognitive models and experimental paradigms have yielded findings consistent with this view. These include: Keefe and colleagues' memory–prediction model of cortical function (Keefe and Kraus, 2009; Kraus et al., 2009; Keefe et al., 2011); the salience dysregulation model based on dopamine system abnormalities (Gray et al., 1991; Hemsley, 1992; Kapur, 2003); mismatch negativity reduction (Todd et al., 2012); latent inhibition (Gray et al., 1992; Lubow and Gewirtz, 1995;

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Gray, 1998); and Corlett's model of ketamine as a pharmacological model of psychosis (Corlett et al., 2006; Corlett et al., 2007).[1] Both Hemsley (Hemsley, 1987, 1998, 2005a) and Sass (Sass, 1992) have drawn on the notion of malfunction in the hippocampus-based, "comparator" system in schizophrenia, proposing that such dysfunction results in an automatic, hyperreflexive awareness that disrupts the tacit/focal structure essential to normal experience and, in particular, to the normal experience of basic selfhood. In brief, a "comparator" system refers to a comparison between predicted stimuli ("the next expected state of the perceptual world" (Hemsley, 2005a, p.980)) and stimuli actually received. Although space limitations prohibit a full review of these models and relevant findings, below we review what we consider to be the major common themes of these models and how they accord with the phenomenological model of basic self-disturbance.

Keefe and colleagues (Keefe and Kraus, 2009; Kraus et al., 2009; Keefe et al., 2011) have recently attempted to introduce an organising principle in studies of cognition in schizophrenia in the form of a "memory–prediction" model of cortical function, which has substantial affinities with the prediction error models described in Part 1 (this issue), as well as the earlier models of Hemsley (Hemsley, 1987, 1992, 1998) and Gray (Gray et al., 1991). This model will be briefly described and then we will address how it may contribute to aspects of basic self-disturbance. The model is founded on the understanding that perceptual processes do not simply involve the reproduction of stimuli, but that they involve matching fragmented sensory input with "working models" of the world. The brain encodes memories based on the consistent, repeated aspects of our environment, which then constitute a working model of the world. The working model is used to continuously make automatic predictions about what will appear or happen in the flow of experience. This so-called "top-down" process (implying a domination of sensory input by cognitive/sensory schemas) allows us to "fill the gaps" in sensory input and to facilitate efficient interaction with a complex, constantly shifting external world. Keefe and Kraus (2009) provide the example of encountering a partially obscured "STOP" road sign: "…Because of our past experiences with stop signs, we are not confused by deviations from the archetypal stop sign; even if the lower left corner of the sign is bent and the "OP" is obscured by a tree branch, we immediately recognise the symbol and step on the brake" (p.415). In this way, memory–prediction processes infuse familiar forms of meaning into the world, endowing perception and interaction with our environment with a significant amount of ease and automaticity.

It has been argued that the hierarchical structure and column-like architecture of the cortex gives rise to these memory or learning-based predictions (Keefe and Kraus, 2009). If we encounter stimuli that do not neatly fit our predictions based on previous experience (the memory component of the model), as in the 'STOP' signal example, an area of cortex will relay details of these stimuli or patterns of stimuli to higher cortical areas. The signal will keep being passed on to the next higher cortical layer until a match is achieved. If a match is not achieved, a new mental representation of this stimulus will be introduced. When stimuli become more familiar through repetition, their mental representations are shifted to lower cortical areas, allowing higher areas to detect high-level or superordinate patterns. According to this model, familiar stimuli (i.e., input that conforms to expectations/predictions based on previous experience) will be processed at lower cortical levels, allowing for efficient use of cortical resources. As Keefe and Kraus (2009) write, "Thus these memory–prediction processes constitute an elegant and automatic system by which familiar stimuli are efficiently processed by lower level brain regions, unexpected stimuli are flagged for more deliberate analysis by higher cortical areas and the essential elements of experience are encoded into memory" (p. 416).

In schizophrenia, according to this model, the memory–prediction process is compromised. There is disturbance of both "bottom-up" and "top-down" cortical processing, probably due to widespread and early disruption of neuronal circuitry (Keefe and Kraus, 2009). Lower cortical levels do not provide adequate perceptual details for higher levels to establish invariant representations, and higher levels do not provide enough context for lower cortical levels to interpret incoming stimuli. This proposal is consistent with Hemsley's (1998, 2005a, 2005b) earlier suggestion that schizophrenia is characterised by *a loosening of expectations* based on previous experience, an idea anticipated by the Russian psychologist Polyakov who spoke of disturbances of "probability prognosis" (1969, see Sass, 1992, p.127). The consequences of this are 1) slowed, more effortful processing of incoming information and 2) increased probability of arbitrary, internally generated interpretations of stimuli.

One significant feature of the memory-based "context" provided by higher cortical levels is that it will often have or take on an inherently social nature. A given event or situation is likely to be interpreted in a particular way based on its social or public significance (e.g., think of how shaking your head from side to side might be interpreted in one cultural context compared to another). In other words, sociocultural groups "share" representations that are stored in each individual member's memory. When this "shared" context is weakened or disturbed in an individual, as in the case of schizophrenia, then interpretation of events and situations is more likely to be unconventional, arbitrary and idiosyncratic. A brain-based disturbance of memory and attention processes (and associated aberrant salience) could obviously contribute, then, to forms of idiosyncrasy and social disarticulation. The accumulation of inaccurate (but internally meaningful) perceptions may build upon one another into idiosyncratic and incorrect beliefs, distancing the person from common sense and consensual reality (Blankenburg, 2001; Sass, 2001), and even leading, in some instances, to a solipsistic orientation (Sass, 1992, chp 9) and development of delusions and hallucinations.

There is an accumulating body of evidence consistent with this model. Post-mortem studies indicate that brain tissue of people with schizophrenia is characterised by abnormal cerebral cortex architecture, marked by decreased neuropil, decreased synaptic density and disarray of neuronal location, particularly in layers that sit between bottom-up signalling and top-down contextual predictions (layers II and III) (Harrison, 1999). Cortical thinning has also been observed in UHR patients who later develop psychotic disorder (Pantelis et al., 2003). Keefe and Kraus (2009) argue that while such cortical disruption may have a wide-ranging impact on cognition, memory–prediction processes may be particularly affected due to the particular cortical layers most disrupted. Behavioural observations are consistent with this interpretation. Deficits in smooth pursuit eye tracking observed in schizophrenia are largely due to impairments in predictive mechanisms (Thaker et al., 1998, 1999; Hong et al., 2005, 2008). The *improved* performance of schizophrenia patients compared to controls when tracking a target that changes direction unpredictably also suggests a weakening of prediction processes, i.e. that the person is less constrained or directed by automatic predictions. Similarly, reduced mismatch negativity (MMN, see below) and P300 amplitude indicate deficits in physiological responses to unexpected stimuli, consistent with the notion of impairments in memory-based prediction processes. A recent study by Morris et al. (2012) found that attention to irrelevant (i.e., non-predictive) cues, assessed using a causal learning test, was characteristic of schizophrenia and that learning about these cues correlated with intensity of positive symptoms. The authors

[1] However, we note that measures of the constructs that we have proposed are consistent with the notion of aberrant salience, as defined in the current paper, do not consistently display high correlations with each other (e.g., see Gjini et al., 2010; Todd et al., 2012). It could be that measures of these constructs pick up on different processes that all contribute to aberrant salience as an end result. For instance, some measures may pick up on "gating out" processes (habituation to repeated redundant stimuli) and others on "gating in" processes (responding when the incoming stimuli take on new or added significance) (Gjini et al., 2010), both of which may ultimately contribute to aberrant salience. This issue is need of further investigation.