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Brain and Mind in Psychiatry? Presuppositions of Cognitive Ontology

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6.1 INTRODUCTION

Psychiatric disorders have been regarded as disorders of genes, cells, brain regions and networks, experience, emotion, cognition, mind, or/and social environment throughout history. Each of these factors has been investigated extensively in recent years, providing evidence for alterations in basically all levels in disorders like schizophrenia and major depressive disorder (Northoff and Sibille 2014). Moreover, the debate about the nosological classification of psychiatric disorders has flared up intensely in recent years. Clinically, more entity-based classification systems like the *DSM* have been challenged by novel approaches that are more dimension-based. Such dimension-based approaches may apply to the neuronal level of the brain, exemplified by the Research Domain Criteria project (RDoC) (Insel and Cuthbert 2015) and the psychological/cognitive level, exemplified by various cognitive ontology (CO) projects (Bilder et al. 2009, 2013, Poldrack et al. 2011).

Despite the fact that these different classifications operate on different levels – i.e., neuronal, cognitive, personality, etc. – they nevertheless share an allegiance to a dimensionally-based approach. Moreover, they all assume (either implicitly or explicitly) that their respective starting point – i.e., neuronal, cognitive, personality – can be extended to and applied to different levels: this may operate in a bottom-up manner, as in RDoC, from genes and neural circuits to cognitive symptoms and/or personality changes. Or, alternatively, one may proceed, as in CO and the Hierarchical Taxonomy of Psychopathology (HiTOP) in a top-down manner from changes in personality and cognition to the brain and even to the genes.

Crucial to making progress is gaining a better understanding of the link between the brain's neuronal activity changes and the various psychopathological or mental symptoms. Despite extensive research, the exact neural basis and mechanisms underlying psychopathological symptoms (like anhedonia as distinguished from, for instance, major depressive disorder and schizophrenia) remain open. For instance, CO assumes that psychopathological symptoms are cognitive and affective symptoms which can be mapped upon the brain's regions and networks with respective cognitive and affective functions (Bilder et al. 2009, 2013, Poldrack et al. 2011). Apart from such mapping, the underlying mechanisms of how the brain's neuronal activity is transformed into cognitive process remains unclear.

6.2 Cognitive Ontology (CO) – Brain, Mind, and Psychiatric Disorders

CO makes certain presuppositions about brain, mind, and psychiatric disorders which, to a certain degree, remain implicit or tacit. Though we are not able to go into full detail, we here want to shed a brief light on these presuppositions.

CO considers the brain in mainly cognitive terms. The concept of cognitive is here to be understood in a wide sense as referring to all mental processes in a broad sense – including motivation and emotion (Poldrack et al. 2011, footnote 1 on p. 1). The term *cognitive* taken in this wide sense includes various cognitive (as taken in a narrow sense) functions like attention, working memory, central executive functions, etc., as well as affective or emotional functions.

These cognitive and emotional/affective functions are supposed to be mapped onto the brain and even the genes (see, for instance, Figure 4, p. 8 in Poldrack et al. 2011 as well as Poldrack et al. 2011, p. 10). The explicit goal of the cognitive ontology project is to provide a clear conceptual framework for cognitive and emotional/affective functions, a "cognitive atlas," which then can be mapped onto corresponding regions or networks in the brain (Poldrack et al. 2011). For instance, the central executive network in the brain comprises the lateral prefrontal and parietal cortex which are involved in cognitive functions like working memory and goal orientation (Power et al. 2018). Though the focus of CO is not on the level of the brain itself, neural activity in different regions and/or networks is supposed to correspond to the various cognitive constructs included in the cognitive atlas. In other words, for the cognitive ontology project, the brain is a cognitive organ of the mind.

How about the mind? The wide definition of cognitive in terms of all mental processes already makes clear that CO considers the mind in cognitive and affective/emotional terms. The mind is characterized by mental (or cognitive) processes which cannot be directly observed and thus conceived as "latent unobservable constructs" (Poldrack et al. 2011, p. 3) that are defined operationally. This leads us to the distinction between mental processes and mental tasks: mental tasks are experimental tools that can be used to test specific mental processes that operate on or transform mental representations or other, i.e., non-representational forms of mental constructions (Poldrack et al. 2011, p. 3). However, one also needs to consider that one and the same "process" may be operationalized and thus tested in different ways; this makes it necessary to consider both the mental process in question and the experimental measures of said mental process (Poldrack et al. 2011).

The concept of mental representation is thus taken in a loose sense here referring to a "mental entity that stands in some relation to a physical entity or some other mental entity (in that abstract representation)" (Poldrack et al. 2011, p. 3). Note that the concept of mental in both mental processes and representation is ultimately meant in a cognitive or affective/emotional way. Hence, one can speak of cognitive and affective processes and representations.

CO aims to develop a cognitive atlas of the mind's cognitive organization. Different mental processes can be tested experimentally by corresponding mental tasks (i.e., operational definitions/measures). Each mental process supposedly represents a specific mental entity in the atlas. Within the atlas, mental concepts are related to other concepts in a variety of ways. For instance, mental concept A may be identical with another mental concept B, or A could be part of B (mereological relation), or B could result from transformation of A, or A may be the cause of B (Poldrack et al. 2011, p. 5); these are conceptual relations which indicate the logical-conceptual relationships between different mental concepts. How well these conceptual-logical relationships correspond to really existing relations (i.e., empirically confirmable mental or cognitive relationships), remains unclear.

Finally, CO carries major implications for psychiatric disorders. CO aims to provide a "standard ontology for mental function" (Poldrack et al. 2011, p. 10). Such "standard ontology" can, as explicitly stated by the authors, be applied to mental dysfunctions in psychiatric disorders (Bilder et al. 2009, 2013, Hastings et al. 2014, Poldrack et al. 2011). The application of CO to mental dysfunction in psychiatric disorders converges nicely with the development of "cognitive psychopathology" (Halligan and David 2001).

Following traditional psychology and especially cognitive psychology, cognitive psychopathology (CPP) aims to characterize psychopathological symptoms in terms of normal cognitive functions such as working memory and executive function; thereby, CPP will rely on the conceptual framework of cognitive organization developed and provided by CO. Hence, despite their different starting points from either the healthy mind (i.e., CO) or the disordered (i.e., CPP) both CO and CPP consider psychopathological symptoms and psychiatric disorders in general as cognitive (in a wide sense). Finally, CO and CPP also share the ultimate aim of extending beyond the mental or cognitive realm by mapping the mind's cognitive organization (or disorganization) to brain circuits and to lower levels including cellular, molecular, and genetic levels. (See Bilder et al. 2009, 2013, Hastings et al. 2014, Figure 4 in Poldrack et al. 2011.)

6.3 Spatiotemporal Structure – Brain and Mind

How about the recent empirical data about brain, mind, and psychiatric disorders? Do they hold up to the presuppositions of CO? Let us start with the brain.

The brain's neural activity can be characterized by task-evoked activity (Morcom and Fletcher 2007) which is related to extrinsic tasks and stimuli as, for instance, mental (i.e., cognitive or affective) tasks as described in CO. The traditional model is that the tasks or stimuli themselves are sufficient for the amplitude as measured in task-evoked activity. This is also called an extrinsic model of brain activity (Northoff 2012, 2014a, 2014b, 2018, Raichle 2009, 2015). However, in addition to task-evoked activity, the brain's neural activity can also be characterized by spontaneous or intrinsic activity which remains independent of specific stimuli or tasks (Logothetis et al. 2009, Northoff 2014a). The role of the brain's spontaneous activity is not yet fully clear.

Recent data show that the spontaneous activity strongly shapes and determines task-evoked activity. For instance, the functional connectivity between different regions during spontaneous activity strongly predicts the pattern during task-evoked activity (Cole et al. 2014, 2016). Task-evoked activity, featured by its amplitude, may primarily increase relative to the ongoing spontaneous activity and its spatiotemporal pattern. The central role of the brain's spontaneous activity is further supported by various studies showing that spontaneous activity – i.e., resting-state activity – predicts task-related mental and behavioral features. (See, for instance, Huang et al. 2016, Ferri et al. 2017.) Since the data suggest a strong molding and shaping of task-evoked activity and related behavioral effects by the spontaneous or intrinsic activity, one can also speak of an "intrinsic model" of the brain activity (Northoff 2012, 2014a, 2014b, 2018, Raichle 2009, 2015).

The assumption of an intrinsic model of brain activity shifts the focus from the brain's task-evoked activity to its spontaneous activity. Recent data show that the spontaneous activity has elaborate spatiotemporal structure as documented in its functional connectivity and network pattern (Cole et al. 2014, 2016, Power et al. 2018) as well as by its various frequencies and the scale-free organization of its power spectrum (He et al. 2010, He 2014, Northoff and Huang 2017). Moreover, the brain's activity as a whole – that is, across its various regions and networks – seems to be centralized. Such holistic (rather than localized) neural activity can be measured in fMRI by what is called the "global signal" which may not just reflect noise or artifacts in the fMRI signal (Power et al. 2015, 2017), but meaningful neuronal activity (specifically, the infraslow frequency domain (0.01–0.1Hz)) (Liu et al. 2018, Schölvinck et al. 2010).

How about the mind and its mental processes? Consciousness is considered one, if not the hallmark, feature of the mind. Consciousness, put briefly, refers to the subjective experience of oneself, one's own body, and of the environment or world (Northoff 2014b, Northoff and Huang 2017). (See below for more details about the concept of experience.) If CO is right to assume that mental processes are cognitive processes (see above), one would expect consciousness and self, as prototypical features of mind, to be sufficiently accounted for by cognitive functions like attention or working memory.

However, empirical data strongly suggests that this is not the case. Empirical studies demonstrated that consciousness (in the sense of a basic experience) cannot be equated with cognitive functions such as working memory or attention (Northoff 2014a, 2014b, 2018). Moreover, focusing only on cognitive functions might even confound those neural mechanisms and correlates specifically associated with consciousness (as experience). Some authors even suggest research should use "no-report paradigms" rather than "report paradigms" (Tsuchiya et al. 2015). By no-report paradigms they mean using various non-verbal indicators of conscious experience rather than introspective reports of experience.

The characterization of consciousness and self as distinct from cognitive function and processes is further supported by neuronal data. Studies on altered states of consciousness such as loss of consciousness in sleep, anesthesia, or coma have demonstrated changes in spontaneous activity's spatiotemporal structure (i.e., its functional connectivity), its power spectrum, and scale-free activity (Huang et al. 2018, Tagliazucchi et al. 2013, 2016, Zhang et al. 2018), and its global signal (Huang et al. 2016). Moreover, studies using the construct of the self show strong overlap between self-related activity and resting-state activity (D'Argembeau et al. 2005, Davey et al. 2016, Qin and Northoff 2011, Whitfield-Gabrilie et al. 2011). More importantly, the spontaneous activity's spatiotemporal structure predicts the degree of subjectively experienced self-relatedness, i.e., self-consciousness or sense of self (Bai et al. 2016, Huang et al. 2016, Wolff et al. 2019).

6.4 CONCLUSION

Taken together, these neuronal findings strongly suggest that mental features like consciousness and self are rooted in the brain's spontaneous activity and its overall spatiotemporal structure rather than the brain's cognitive functions. Most importantly, they support the assumption that the mind, as featured by consciousness and self, cannot be sufficiently and exhaustingly characterized by cognitive functions or processes even if taken in the broad sense as advocated for in the cognitive ontology project.

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