Schizophrenia Bulletin vol. 33 no. 1 pp. 157–165, 2007
doi:10.1093/schbul/sbl056
Advance Access publication on November 14, 2006

Disturbances of Time Consciousness From a Phenomenological and a Neuroscientific Perspective

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The subjective experience of time is a fundamental constituent of human consciousness and can be disturbed under conditions of mental disorders such as schizophrenia or affective disorders. Besides the scientific domain of psychiatry, time consciousness is a topic that has been extensively studied both by theoretical philosophy and cognitive neuroscience. It can be shown that both approaches exemplified by the philosophical analysis of time consciousness (Husserl) and the neuroscientific theory of cross-temporal contingencies (binding of cognitive processes over time) as the neurophysiological basis of human consciousness implemented in the prefrontal cortex (Fuster) converge in 2 respects. Firstly, a tripartite conception of consciousness divides human cognition in 3 different temporal domains comprising *retention*, *presentation*, and *protention* (Husserl) and the *past*, the *present*, and the *future* corresponding to *working memory*, *interference control*, and *preparatory set* (Fuster). Secondly, both concepts refer to the present as an extended duration that integrates information from the recent past and the future. We propose that the integration of phenomenological and neuroscientific approaches can stimulate the development of enriched pathophysiological concepts of mental disorders. This approach appears to be particularly fruitful with respect to schizophrenia that is interpreted as a structural disturbance of time consciousness.

Key words: time experience/schizophrenia/organization of behavior in time/phenomenology/cognitive neuroscience/prefrontal cortex

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Introduction

The experience of time is an essential component of human consciousness and can be understood as "consciousness of temporal objects as temporal," ie, as "a special kind of awareness of temporal objects—an awareness of them as enduring."[1] However, one must be aware that "consciousness does not contain time as a constituted psychological category."[2] Rather, we have to understand time experience as a fundamental underlying constituent of consciousness: "we exist within a transparent web of time."[2] This means, that consciousness depends on its unfolding in time and that this dependency is itself unconscious or transparent. Consciousness itself already employs the temporal domain, even the most simple conscious experiences, such as perceptions, already require "temporal continuity" as a necessary condition.[3] Consciousness thus becomes "fundamentally dynamic"[1] with temporality as an intrinsic feature of consciousness. With respect to psychiatric diseases, time consciousness has been shown to be disturbed both in schizophrenia and affective disorders. Disturbances of time consciousness provide the motivational background to focus on time consciousness in different scientific domains and will be explored here with respect to phenomenology and cognitive neuroscience.

Cognition appears to be closely linked to consciousness as "the subjective experience of cognitive function" that "can emerge from the operation of any cognitive function."[3] Phenomenology focuses on cognitive capacities of humans from a conceptual perspective. Among the different traditions, phenomenology is one of the most influential developments in 20th century philosophy, especially, with respect to the philosophy of time. An essential work in this tradition is Husserl's *Lectures on the Phenomenology of the Consciousness of Internal Time* (Vorlesungen zur Phaenomenologie des inneren Zeitbewusstseins[4]) and its later text-critical editions.[5] Husserl develops a concept of time consciousness that also relies on a tripartite time structure of past, present, and future.[4]

In contrast, cognitive neuroscience focuses on the neural underpinnings of cognitive functions and is based on the strong intuition that "conscious experience results from the operation and interaction of several functions in complex assemblies of cortical networks."[3] Because

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consciousness is "a concomitant phenomenon of cognition"[3] and not an isolated cognitive function itself, the neural correlates of consciousness must be considered as distributed neural processes that recruit different brain regions and/or processes from one instantiation of a conscious experience to another.[3] Fuster proposes that the prefrontal cortex (hereafter: PFC) appears to be crucially involved in the neural constitution of a tripartite concept of time, that comprises the functions of *working memory* (related to the past), *interference control* (related to the present), and *preparatory set* or simply *set* (related to the future) as basic functions of the PFC. "Integration across time is a basic function of the prefrontal cortex and the basis of its cardinal role in the temporal organization of behavior."[3]

Although Husserl himself constantly criticizes psychological explanations of consciousness, we explicitly want to support the view that phenomenological and empirical explanations converge and "should be regarded not only as compatible but as mutually constraining and enriching approaches to the study of the mind."[1] The "subjective," intuitive, phenomenological first-person account and the "objective," operational, cognitive neuroscientific third-person account focus on the same research questions: What are the different components of time consciousness and how do they work together? The aim of this article is two fold. First, we want to demonstrate that phenomenology of time consciousness and cognitive neuroscience converge at least in 2 respects, namely, the concept of a tripartite concept of consciousness and the present as an extended duration. Second, we will apply these concepts on disturbances of time consciousness in schizophrenia.

Phenomenology of Time Consciousness

Theoretical philosophy including phenomenology focuses on cognitive capacities of humans from a conceptual perspective. In this conceptual perspective and with respect to time consciousness, phenomenology principally deals with 2 different series of time: The first series is the *binaristic series* of before-and-after relationships—a model of time (also called "clock time") that relies on the identification of a certain point of time to which other points of time are former or later. And the second series is the *tripartite series* of relationships referring to the past, the present, and the future. This second model is normally underlying biographical and intersubjective understanding but is also recently used with respect to epistemological or empirical concepts (for instance in Fuster's theory, as to be described below).

The differences between both models, first explicitly analyzed by John McTaggart,[6] are manifold, but the main difference is that the relationships of the tripartite series are *dynamic* and *impermanent* (this means that they are subjective), while the relationships of the binaristic series are *static* and *permanent* (this means that they are objective). That an event happened at a certain time means that it objectively happened before and/or after other events. The event as an event happening may be or may have been the experience of an individual subject, but that it happened before or after another event is not a matter of *subjective experience* but a matter of *objective knowledge*.

In the history of philosophy, the objective reduction of time to an abstract, but even measurable continuum of points of time, ie, to a binaristic series, was the predominant model. With respect to epistemological or empirical concepts, it was first questioned at the end of the 19th century when William Stern, Alexius Meinong, and especially, William James recognized that what we call "the present" cannot be a somehow enigmatic "point of time" but must be conceptualized as an extended duration or enduring present: a "saddle-back, with a certain breath of its own on which we sit perched, and from which we look in two directions into time"[7] (for Meinong and Stern, see Bernet[8]).

Although Husserl was a constant critic of psychological explanations,[9] this idea of an extended duration was ultimately important for him[5] and, in fact, was the initial intuition for his own phenomenological thesis that the experience of time relies on a constant *passive synthesis of past and future* or, in other words, is the experience of an *impressional present*, rooted in and constantly modified by the mutual relationship and interaction of a *retentional past* and a *protentional future*—in Fuster's words: a constant act of "bridging" temporal distances.[10]

For Husserl (and, as we will show below, for Fuster too), the intuitive experience of "now," therefore, is always an experience of an "extended" now in a continuing perception. Husserl's most famous example of such an experience is given in his account of perceiving a melody (for a detailed comment see[1,11]). Husserl argues that this perception cannot be explained with reference to an objective time conception. For, although it is true that a melody is a linear progression, a melody or the experience of a melody is not the sum or the summation of single tones: "If we hear a bit of a melody, we do not hear merely single tones, even less moments of single tones or mathematical tone-nows, matching the now-points that could be abstracted in thought. We rather hear enduring tones—specifically, tones combining into a tone-formation; and we grasp this whole tone-formation as a formation that is steadily building up and as that which is heard."[5]

So, phenomenologically speaking, past, present, and future are constituted by 3 intentional acts: *retention* (as the intentional act directed to the past), *protention* (as the intentional act directed to the future), and *presentation* (as the intentional act directed to the present). And any temporal object is only what it is in this referential context of acts or better as this referential context itself: "The immanent temporal object—this immanent tone-content, for example—is what it is only insofar as during its actually present duration [presentation] it points

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ahead to a future [protention] and points back to a past [retention]."[5] There is no point of time that is "now" and another point of time that is "former" or "later," but any temporal object is a "unity of memorial and expectational groups in which a different now-stage corresponds to each group. Or rather, each group *is* a different now-stage. For *now* is something relative. It is relative to stages."[5]

"Now" or the "now" is not a single point of time or not even a *series* of points of time in which other points of time are represented (eg, "now" I remember what happened yesterday or "now" I anticipate what will happen tomorrow). But "now" or the "now" is a "temporal fringe"[5] or a "temporal field," ie, that it is in itself formally structured by the interrelation of protention, retention, and presentation.[5] That means, with respect to Husserl's account of perceiving tones of a melody: The tone "just-past" is not a tone that was perceived before and is now remembered, but is a tone that is perceived, as it is "retained" in its being-past, ie, "Its being-past is something now, something present itself, something perceived."[5] And even the tone "yet-to-come" is not a tone that will be perceived later and is now expected, but a tone that is perceived, as it is "protained" in its being-future, ie, its being-future is something perceived as well.

Therefore, due to a phenomenology of time consciousness, any conscious act, let it be an act of percieving, thinking, moving, or whatever, is a temporally extended, gradually and continously unfolding act with a certain, nonlinear *temporal structure*. And this structure is consisting of the interrelation of 3 intentional acts: of acts directed to the past (retention), directed to the future (protention), and directed to the present (presentation). That is, the unity of these acts (resp. their continuity) depends on *proactive* relationships of retained to protained elements and on *retroactive* relationships of protained to retained elements of the act. In Fuster's terminology: "the two temporal integrative functions of the prefrontal cortex, short-term memory and set, work together in *reconciling the past with the future*."[10]

In Husserl's terminology, this integrating or reconciling function is called a "passive synthesis," a term by which Husserl means a synthesis that is constitutive for consciousness but in itself is not again a *conscious* act. Or, better to say, retention, protention, and presentation are constitutive components of our time consciousness, that are conscious acts, in an objective sense, only in philosophical self-reflections (ie, philosophers are or may be conscious of these acts). Nevertheless, the urgent problem arises what their own temporality is: Are they temporal acts only in a subjective sense? Or are they temporal acts in an objective sense too? The explanational gap between the first-person and the third-person account seems to be persistent even in phenomenology, and it is a justifiable question whether this gap can be closed by cognitive neuroscience.

Cognitive Neuroscience of Time Consciousness

To understand how a brain region such as the PFC can contain a variety of cognitive functions, Fuster[10] integrates the cognitive functions implemented in the PFC into a common framework to develop a "prefrontal theory" that focuses on "the neural mechanisms of prefrontal function."[10] Essentially, Fuster proposes a tripartite concept, that comprises the functions of working memory (related to the past), interference control (related to the present), and preparatory set or set (related to the future) as basic functions.

Working memory constitutes the "temporally retrospective" function of the PFC.[10] Most important is its everchanging content and its "operational character," that is neither necessarily related to the content of a given working memory process nor to the temporal period with which the particular content is kept "online."[10] This is sustained in cortical networks by reverberating activity within those networks, especially, for the purpose of "organizing prospective action."[10] Working memory is essential for our subjective time experience by providing an online access to actual perceptions and contextual memory contents in the present. The impairment of working memory is a well-known neuropsychological feature in schizophrenia. With respect to a more detailed localization within the PFC, it is essentially the dorsolateral portion of the PFC that is crucially involved.[12–15]

Preparatory set or simply set refers to "preparation for action."[10] Set is thus *prospective* in contrast to the *retrospective* capacity of working memory. As a paradigmatic case, Fuster refers to the "readiness potential" as neural indicator of forthcoming actions.[10] The PFC thus "most likely primes the motor apparatus in anticipation of the action."[10] Preparation of actions or action planning is a central function of the PFC, especially, its so-called dorsal parts on the hemispheric convexity both in nonhuman primates[16] and humans.[17,18]

The inhibitory interference control as the third integrative function of the PFC plays an important role in protecting the structure or *gestalt* of behavior from interfering influences, that may conflict with it. It suppresses internal and external influences that might interfere with the sequence currently being enacted. Fuster equals active memory and memory retrieval with a form of selective attention, namely, a form of selective attention to an internal representation.[10] It is well-known from functional imaging studies that attention depends on the integrity of the PFC, predominantly, the anterior medial proportion of the PFC.[19]

With respect to anatomical constraints of the PFC, it is obvious that there are various ways to define it; this is predominantly done on the basis of anatomical characteristics. These anatomical definitions rely on different criteria referring to cytoarchitectural, hodological, and connectivity characteristics. Going back to Brodmann,[20]

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a first approach to define the PFC (as the term is now used) refers to the extension of different cytoarchitectonic regions comprising Brodmann areas 8, 9, 10, 11, 12, 13, 44, 45, and 46. These different regions that have been called ''regio frontalis'' by Brodmann himself are ''nearly coextensive with what is now called the frontal granular cortex or prefrontal cortex.''[10] Most of the functional imaging literature refers to the cytoarchitectonic map and their distribution, which is usually assessed by reference to the standard stereotactic atlas.[21] However, it should be kept in mind that Talairach and Tournoux's version of the Brodmann map does not reflect the complete and up-to-date cytoarchitectonic organization of the human brain. Modern mapping approaches are based on both cyto- and chemoarchitectonic characteristics of the different brain regions.[22,23] Fuster himself prefers a definition of the PFC according to so-called hodological criteria that define cortical regions along the projections of different thalamic nuclei and hence to intrinsic connectivity information of the nervous system. Referring to this hodological criterion, the PFC is defined as the cortical region that receives specific projections from the mediodorsal nucleus of the thalamus.[10] However, a critical aspect here is that this alternative definition is essentially based on data that have been obtained from non-human primates. Recently, the method of diffusion tensor imaging or diffusion-weighted imaging has been employed to address such anatomical connectivity issues. This new magnetic resonance–based imaging method allows to map different fiber systems in humans in vivo.[24,25] According to this methodology, PFC—as defined by cytoarchitectural landmarks—receives connections not only from the mediodorsal but at least also from the ventrolateral thalamic nucleus.[26] So there is considerable debate on how different cortical regions should be delineated, and the given definition of Fuster is a pragmatic definition based on available data among other possible demarcation strategies.

Fusters concept of ''organization of behavior in time'' is essentially based on cross-temporal contingencies that bridge elements such as schemata, goals, or intentions to act that are distant over time. Working memory and preparatory set work together in ''reconciling the past with the future.''[10] These components thus constitute a unitary, holistic result which is a given behavioral act that is generated on the basis of the different functions: ''A structure of action is a temporal gestalt, like a melody.''[10] ''Thus the prefrontal cortex […] manages to bridge for the organism whatever temporal distances there may be between mutually contingent elements in the behavioral sequence, the rational discourse, or the construct of speech.''[10]

Different empirical studies underline this concept and have shown that the PFC plays an essential role for the constitution of time consciousness. Time estimation can be studied employing 4 major paradigms, namely, temporal discrimination, verbal estimation, temporal production, and temporal reproduction. Brain lesion studies[27] suggested that, especially, the cerebellum, the basal ganglia besides the PFC play a considerable role in time estimation.

Employing neuroimaging, increased neural activity was reported that included dorsolateral and medial parts of the PFC besides superior temporal areas and basal ganglia in an auditory estimation task in which participants had to discriminate different durations of tone pairs in the range of 1000–1400 milliseconds (as opposed to a frequency discrimination task as active control task). Comparing time and frequency estimation, activation was restricted to the right putamen suggesting that temporal information is associated with basal ganglia activity.[28] As shown before by Macar,[29] duration estimation recruits the presupplementary motor area (preSMA), as well as prefrontal and parietal cortices and the basal ganglia. The interplay of these different brain regions might constitute a ''clock mechanism'' that serves decision and response-related processes and actives maintenance of temporal information.[30]

Neurophysiologically, an event-related potential (ERP) study explored the neural correlates of a time discrimination task in which subjects had to discriminate between 3 pairs of visual stimuli lasting from 100 milliseconds and 2 seconds by determining whether the second stimulus was longer or shorter than the first. Frontal ERPs obtained after offset of the second stimulus indicated that the accuracy of the performances depended on stimulus duration and presentation order with a higher success rate in the short-long order. A time-related late positive component could be demonstrated supporting the hypothesis that this late positive component may reflect successful decision making or retrieval during time estimation as a result of neuronal activity in the PFC.[31]

However, it seems that other brain regions might be additionally involved. Employing an explicit, prospective time interval production task during which participants were given a time interval and asked to indicate when it elapsed lateral cerebellar and inferior temporal lobe activation were associated with primary time keeping. Behavioral data provided evidence that the procedures for the explicit time judgements did not occur automatically and utilized controlled processes. The data are consistent with prior proposals that the cerebellum is a repository of codes for time processing but also implicate temporal lobe structures for this type of time estimation task.[32]

Biochemically, it is interesting to note that facilitation of dopaminergic transmission increases the velocity of an ''internal clock,'' while inhibition slows it down.[27] Changing the D2 receptor acitivity by D2 antagonists leads to an impairment of time estimation performance suggesting that the D2 receptor activity influences cognitive mechanisms that underly temporal processing of durations in the range of seconds.[33]

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Summarizing these empirical findings, it can be hypothesized that temporal information processing in the brain is constituted by a distributed interaction between modality-dependent sensory cortical functions and the PFC related to attention and memory. The central time mechanism can be assumed to be implemented in the cerebellum, whereas planning abilities are mediated by the PFC that subserve the estimation of longer intervals.

In addition to this tripartite concept of time consciousness related to past, present, and future, it is important to consider another dimension of time that refers to different scales of duration, namely, (1) basic or elementary events, corresponding to perceptual moments, iconic memory, and subjective time quanta, (2) large-scale integration associated with perception-action, memory, motivation, and (3) descriptive-narrative assessments related to linguistic capacities, the ''flow of time related to personal identity,'' or the ''continuity of self.''[2] Varela refers to the concept of transtemporal or diachronic unity here that is considered a necessary constituent of self-consciousness. An empirical indicator of transtemporal unity is autobiographical memory.[34] This consideration refers more explicitly to neurophysiological constraints of cognitive activities that are not only distributed in space but also extended in time and cannot be ''compressed beyond […] the duration of integration of elementary events.''[2] In concrete terms, Varela proposes specific cell assemblies for every particular cognitive act. Cell assemblies are selected through the process of ''precise coincidence of the firing of the cells.''[2] It is important to stress that the experience of nowness is assumed to be the explicit correlate of an assembly of coupled oscillators that attains a transient synchrony that takes a certain time. These ''integration-relaxation processes'' that reflect different states during the oscillation process are assumed to be ''strict correlates of present-time consciousness.''[2] The emergence of time consciousness is thus not a matter of sequentiality but of reciprocal determination and relaxation time.[2] It is thus a consequence that ''now is not a mere temporal location […] it is a space we dwell in rather than a point that an object passes by or through.''[2] The subjective experience, and this is the essence of Varela's intuition presented here, is not a point of time on a physical time scale but a duration that is dynamic and impermanent according to the analysis provided by McTaggart.[6] On a neural level, this corresponds to a certain class of neural processes, namely, the formation of an assembly of coupled oscillators that attains a transient synchrony.

Disturbances of Time Consciousness

Disturbances of time consciousness have been a research topic in the last decades, supporting the hypothesis of a disruption of the ''sense of time'' in schizophrenia.[35] More recent studies have focused in their majority on time estimation tasks. A major finding is the observation of a systematic overestimation of time intervals by schizophrenic patients employing time estimation tasks. Patients tend to show essentially an increased variability of time estimation in a variety of time estimation tasks with some studies demonstrating an overestimation, others showing underestimation. The main finding of a longitudinal study was that patients showed a consistent disturbance either in over- or underestimating time intervals over a long period of time.[36] It is interesting to note that the disturbances of time estimation capacities vary irrespective of the type of schizophrenia, the course of the illness, the presence of positive or negative symptoms or the symptomatic load of schizophrenia.[37,38] Schizotypal personality disorders did not seem to be associated with a tendency to overestimate short time intervals.[37] Exploring differential effects of diagnostic groups on the ability to estimate short time intervals, Tysk[39] showed that patients suffering from depressive states tend to underestimate time, whereas persons in manic states overestimate time.

On the background of these studies, the important question arises whether the presented time estimation disturbances are either specific for different diagnostic groups or, alternatively, reflect a general pattern of disturbance that is independent from diagnostic groups. Two studies are of particular interest in this respect. Timing abilities were studied in schizophrenic patients employing 2 different tasks, first, a temporal generalization task in which participants had to judge whether presented stimuli of various duration had the same or a different length compared with a stimulus with a fixed standard duration presented before and, second, a temporal bisection task in which participants categorized durations as short or long. Under both tasks patients were significantly less accurate without showing a systematic deviation, for instance towards an overestimation as reported before.[40] In another study on healthy subjects and patients with schizophrenia who were studied by means of repeated measurements of time estimation over a period of up to 2 years, patients were often more variable in their estimations and in some cases deviated more from the correct estimation than the healthy subjects.[36] More generally speaking, it must be noted, however, that deficits observed in timing tasks may also well be related to unspecific cognitive and motivational deficits, as they are commonly found in schizophrenic patients. It is not always clear that the effects observed in these tasks specifically refer to alterations in time consciousness. This rather general critical issue should lead to empirical research that explicitly studies attentional and motivational aspects as potentially confounding variables of time estimation studies. In addition, it must be emphasized that the findings do not express a consistent pattern of over- or underestimation over diagnostic groups. Moreover, there seems to be some overlap of disturbances

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(eg, overestimation of time intervals) that occurs both in psychotic states and in nonpsychotic mania. At this stage of empirical research, it must be clearly stated that the different disturbances of time consciousness observed are not specific for a diagnosis. However, we want to stress the observation that there are systematic changes in the sense of overestimation (associated with mania) and underestimation (associated with depression) in nonpsychotic affective diseases, whereas there are no systematic changes in psychosis.

These disturbances of time consciousness in schizophrenia are not restricted to a lower time scale related to elementary events according to Varela[2] but appear to involve on a higher level also "autonoetic awareness" referring to mentally reliving events from one's personal past. Autonoetic awareness is related to an information that binds together separate aspects of events. Comparing schizophrenic patients with control subjects, it was shown that patients exhibited an impaired recognition memory and a reduction in frequency of autonoetic awareness supporting the hypothesis that patients with schizophrenia are unable to link the separate aspects of events into a cohesive, memorable, and distinctive whole as reflected by a quantitative and qualitative impairment of autonoetic awareness.[41]

To extend this disturbance of time consciousness from a purely behavioral level to a more profound pathophysiological level, another line of research is of interest that refers to the well-known phenomenon related to disorders of agency[42] that might be related with an inability to compensate for the sensory consequences of actions,[43] misattribution of external speech,[44] disturbances of verbal self-monitoring and auditory hallucinations,[45] and to the concept of self-monitoring disturbance in general.[46] Here it could be speculated that these disturbances arise from a disturbance of connectivity or communication between different brain regions in certain time frames.

Although the empirical studies on disturbances of time consciousness do not provide conclusive evidence yet, it seems empirically justified to postulate 2 different mechanisms of disturbance of time consciousness. Nonpsychotic affective disorders seem to present a systematic change of velocity: acceleration (mania) or deceleration (depression) of time experience, with the basic temporal structure being preserved. In contrast, an unsystematic disruption of the "web of time" or "structure of time" (as conceptualised by Fuster and Husserl) can be inferred in schizophrenia. This disturbance must be assumed on a more fundamental level that refers to a "structural disturbance" of time consciousness.

On a neural level, there is evidence for the association of PFC dysfunctions and the disturbance of time consciousness. Employing functional magnetic resonance imaging during an auditory time estimation task (timing), and a frequency (ie, pitch) discrimination task, schizophrenic patients revealed less activations in the PFC and the caudate nucleus, when comparing the time estimation task with the rest condition. Timing specific differences (ie, timing vs pitch) between patients and controls were found in the posterior putamen, anterior thalamus, and right medial PFC, with patients showing relative hypoactivity.[47] Additional evidence for the involvement of a cortical-subcortical network including the SMA as part of the PFC in the impairment in a time estimation task associated with schizophrenia was provided by Ortuno and coworkers.[48] This study suggested a particular dysfunctional imbalance of supplementary motor activation during temporal processing.

Related to disturbances of time consciousness is a study on deficits in sustained attention by Ojeda and colleagues.[49] This PET (15)O-water study measuring relative cerebral blood flow demonstrated that patients suffering from schizophrenia showed differential activations in the PFC during continuous counting tasks. Of additional interest are the basal ganglia as a group of brain structures that are controlled by the PFC. Employing positron emission tomography a decrease in the striatal D2 receptor density was shown to be associated with impaired performance on optimal timing tasks and motor processing in patients with schizophrenia.[50]

In the concept of "cognitive dysmetria" as the postulated core disturbance of schizophrenia the PFC, thalamus and cerebellum play a central role. Cognitive dysmetria can be defined as disturbance of coordination of motor and mental activity that relates neurobiologically to a misconnection syndrome in the cortico-cerebellar-thalamic-cortical circuit. The basic idea is that of an "anatomical and functional disruption in neuronal connectivity and communication" that relates to "impairment in a fundamental cognitive process" that is identified with cognitive dysmetria and that leads in turn to disturbances of "second-order cognitive processes" such as attention, memory, language, executive functions, or emotions and to symptoms of schizophrenia such as hallucinations, delusions, negative symptoms, disorganized speech, or behavior.[51] Interestingly, this cognitive core capacity refers to "synchrony" or "fluidly coordinating sequences of motor activity and thought" as a "consequence of very rapid online feedback between the cerebral cortex and the cerebellum, mediated through the thalamus." Cognitive dysmetria is a disturbance thereof and postulated to be the fundamental deficit in schizophrenia. The dysmetria or "poor coordination" results from a defect in the "timing or sequencing component of mental activity."[51,52] Interestingly, this theoretical concept relates to the concept of the time consciousness disturbances named "chronotaraxis" that is related to thalamic pathology.[53] This concept is in concordance with the central hypothesis of this article derived from cognitive neuroscience and phenomenology that the disturbance of time consciousness in schizophrenia is a fundamental "structural disturbance" of time consciousness

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that is related to a dysfunction of the PFC and its related structures.

Conclusions

With respect to the aims of this article, we comment, first, on the convergence of different conceptions of time consciousness and, second, on the relevance for disturbances of time consciousness as occuring in schizophrenia.

Both approaches converge in 2 respects. First, they both develop a tripartite instead of a binaristic conception of time. Whereas the binaristic conception leads to the idea of clock time that is characterized by *before-and-after relationships* (an event happens at a certain point of time and is either former or later to another point of time), the *tripartite* conception corresponds to 3 different temporal domains: to working memory (associated with the past), interference control (associated with the present), and preparatory set (associated with the future). Husserl reconstructs these 3 components as intentional acts that comprise retention (as the intentional act directed to the past), presentation (as the intentional act directed to the present), and protention (as the intentional act directed to the future), respectively. Notably, these 2 concepts converge onto a common concept of the constitution of time from 2 completely different traditions, namely cognitive neuroscience and theoretical philosophy.

Second, both approaches converge with respect to the extendedness of the experience of the present that is not a time point, but an integration of different cognitive subcomponents that takes place in a "temporal fringe"[5] or a formally structured "temporal field."[5] Phenomenologically, the experience of the present is extended. This experience corresponds to the neuroscientific observation that it takes certain time durations (that may vary) to establish a particular cell assembly. Metaphorically speaking, "now" is not a "location," but an "extended space."[2] These are 2 essential aspects that demonstrate a structural homology between cognitive neuroscience and phenomenology in the domain of time consciousness.

As this close relationship allows to propose neuroscientific hypotheses about time consciousness and its disturbances that are based on phenomonological insights, the data related to disturbances of time consciousness may lead to the claim that schizophrenia is possibly a fundamental disturbance of the underlying temporal structure of consciousness in the sense of a "structural disturbance" and therefore is opposed to a more superficial "nonstructural disturbance" associated with nonpsychotic affective disorders (nonpsychotic mania or depression). This pathophysiological hypothesis is supported by empirical data from the field of cognitive neuroscience that relate the postulate of a structural disturbance of time consciousness in schizophrenia to a dysfunction of the PFC.

The empirical studies presented here are of great interest for the topic of time consciousness and its neural correlates, however, it must be kept in mind that these studies are experiments that are performed from a quasiobjective third-person perspective corresponding to the cognitive neuroscience approach. That means, they operate with a *quasiobjective binaristic model* of time and therefore are not—and cannot be—fully compatible with the conceptual presuppositions of the *quasisubjective tripartite model*.

But as this "gap" is not necessarily a detriment to the neuroscientific approach alone, but an inevitable implication of any discussion within the field, let it be phenomenological or neurophilosophical, any empirical test of the above mentioned difference of time experience in schizophrenia (as a structural disturbance) and in nonpsychotic affective disorders (as nonstructural disturbances) must rely on a combination of a quantitative and a qualitative approach. That is, there is no alternative to the *dialogue* of cognitive neuroscience and theoretical philosophy as an inter- and transdisciplinary institutionalization of this combination. And we hope the considerable convergence of both traditions pointed out within this article can stimulate this dialogue.

It must be stressed that this hypothesis, although intuitively plausible, is not fully empirically justified and still needs corroborative studies. For instance, it is important to note that the research field lacks detailed phenomenological analyses of time consciousness in schizophrenia that could considerably enrich the formation of pathophysiological concepts and could support the development of innovative empirical studies. We recommend to develop and follow an integrated interdisciplinary research endeavor that favors a neuroscientific research strategy that is embedded in and enriched by phenomenological approaches. Following Fuster, one would focus on disturbances associated with working memory, interference control, and preparatory set. Systematic studies on these topics are yet missing in the field of schizophrenia research. In our opinion, an important yield of a theoretical article such as this one is that it motivates us to perform empirical studies in this field besides presenting and discussing conceptual insights.

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