Micro-Level Affect Dynamics in Psychopathology Viewed From Complex Dynamical System Theory

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Abstract
This article discusses the role of moment-to-moment affect dynamics in mental disorder and aims to integrate recent literature on this topic in the context of complex dynamical system theory. First, we will review the relevance of temporal and contextual aspects of affect dynamics in relation to psychopathology. Related to this, we will discuss recent insights resulting from a network view on affect dynamics in psychopathology. Next, we explore how we can reconcile literature findings from a perspective of complex dynamical system theory. Finally, future directions with regard to personalized assessment of risk and diagnostic use are discussed.

Keywords
affect, dynamical systems, mental disorder, networks

As mental disorders are an important cause of both societal and individual burden (Eaton et al., 2008), it is crucial to gain more insight into the mechanisms underlying psychopathology. Dysregulation of affect is known to be involved in most, if not all, mental disorders and is therefore attributed a central focus in research. This review focuses on affect dynamics at the micro-level of experience, that is, the moment-to-moment changes in affect, and whether those dynamics can help to understand and predict course of psychopathology. To reliably capture such microlevel dynamics of affect, intensive data-sampling is required. For this, many studies use experience sampling methodology (ESM), in which participants report their current states of affect, behavior, and daily context several times a day for multiple consecutive days (Larson & Csikszentmihalyi, 1983). This yields time-intensive, fine-grained and prospectively collected datasets, enabling a glance into subtle and rapidly changing affect patterns.

The utility of studying small and short-lived affective changes can be questioned. Psychopathology has been linked to larger aspects of life, such as early adversity, traumatic experiences, personality or genes causing long-term and clinically significant alterations in affective states. What is the additional value of a focus on microlevel affect dynamics? First, the impact of such affective patterns may be larger than it seems. For example, people have been shown to respond to minor daily unpleasant situations with a short-lived response of negative affect (NA; Myin-Germeys, van Os, Schwartz, Stone, & Delespauw, 2001; Wichers et al., 2007). However, people differ in the magnitude and duration of this response. Some have tendencies to experience more NA in stressful situations than others, or are slower in returning to their baseline level of NA (Kramer et al., 2013). The cumulative impact of heightened NA reactivity each time something mildly unpleasant happens may put people at increased risk to develop clinically relevant mental health...
problems. Second, moment-to-moment processing of affect is both associated with risk factors and with future course of psychopathology (Geschwind et al., 2010; Kramer et al., 2013; Thewissen, Bentall, Lecomte, van Os, & Myin-Germeys, 2008; Wichers, 2013; Wichers, Geschwind, et al., 2009; Wichers et al., 2007; Wichers, Schrijvers, et al., 2009). This suggests that emotional patterns in everyday life play a key role in the development of psychopathology. If this is true, we may find the smallest essential building blocks that contribute to the development of psychopathology by zooming in to the microlevel of experience.

This article attempts to bring together ideas and findings of previous studies on the possible role of momentary affect processing in shaping mental health. First, literature regarding affect dynamics in relation to psychopathology is reviewed. These include (a) temporal, and (b) contextual aspects of affect dynamics, and (c) a recently formulated network perspective that incorporates the two previous mentioned aspects of affect dynamics. Next, we explore the interpretation of these findings in a context of complex dynamical system theory. Finally, future directions regarding diagnostics and personalized mental health care are discussed.

Temporal Affect Dynamics in Psychopathology: Variability, Inertia, and Instability

In the field of momentary affect research, evidence is accumulating that psychopathology involves alterations in absolute levels of affect, as well as in the way affect fluctuates over time (Koval, Pe, Meers, & Kuppens, 2013). Several aspects of dynamic affect patterns are of interest (see also Trull, Lane, Koval, & Ebner-Priemer, 2015). First, variability in affect over time has been examined extensively. Variability reflects the deviation in momentary affect from the individual’s average affect level, usually measured using the within-person standard deviation. Increased affective variability has been associated with depression (Koval et al., 2013; Peeters, Berkhof, Delespaul, Rottenberg, & Nicolson, 2006), borderline personality disorder (Jahng et al., 2011; Trull et al., 2008), neuroticism (Jacobs et al., 2011), psychosis (Myin-Germeys, Delespaul, & deVries, 2000) and development of future psychopathology (Wichers et al., 2010). Thus, variability in affect patterns seems to signal vulnerability to psychopathology.

Second, resistance to affective change over time has been associated with psychopathology (Koval, Kuppens, Allen, & Sheeber, 2012; Koval et al., 2013; Kuppens et al., 2012; Wigman, Collip, et al., 2013; Wigman, van Os, et al., 2013). Affect changes quickly over time. These subtle affective changes have been suggested to occur as flexible adaptation mechanisms to daily life context (Kuppens et al., 2012). Resistance to affective change, also called inertia, refers to the extent to which affective states persist from one moment to the next (Kuppens, Allen, & Sheeber, 2010). For example, an affective state, for example, anxiety, experienced at time (t) may influence the level of anxiety at time (t+1) and (t+n). Statistically, inertia is measured with the autoregressive coefficient of the variable in question. Typically, higher levels of inertia have been interpreted as signs of increased vulnerability and decreased psychological flexibility (Hollenstein, 2015). Inertia of momentary affective states is associated with current state of depression (Kuppens et al., 2010), general psychological complaints (Wigman, van Os, et al., 2013), the tendency to ruminate on negative thoughts (Koval et al., 2012), and predicts onset of depression (Kuppens et al., 2012).

However, not all studies associate inertia with increased vulnerability. Studies examining the carry-over effect of positive emotions report that an increased tendency for inertia of positive affect (PA) is associated with better current and future recovery from depression (Heller et al., 2009; Hohn et al., 2013). Still, the way in which affect persists over microperiods of time seems relevant in terms of the development of psychopathology.

A third type of temporal pattern is instability of affect. This reflects the moment-to-moment change in affective state and is preferentially calculated as the mean square successive difference (MSSD). Patients with a psychotic disorder, especially those with low levels of negative symptoms, show increased instability of both positive and negative affect compared to healthy controls (Oorschot et al., 2013). Similarly, borderline patients show higher levels of instability of affect compared to depressed patients (Trull et al., 2008). Instability has also been associated with depression (Thompson et al., 2012) and neuroticism (Miller & Pilkonis, 2006).

The paradox of both instability and inertia being associated with psychopathology is addressed by Koval et al. (2013). After controlling for the dependencies between measures, only inertia and variability remained associated with psychopathology while instability did not. Thus, variability and inertia seem to represent separate, and partially independent, characteristics of dynamic patterns of affect relevant to psychopathology (Koval et al., 2013).

Contextual Affect Dynamics in Psychopathology

Besides temporal patterns of affect, differential tendencies in the affective response to current daily context seem important in psychopathological development. Rather than using temporal patterns across measurement moments, the latter is commonly examined using within-measurement information, combining ratings on context and affective states. This allows for a prospective examination of dynamic constructs, for example, sensitivity to stress or reward situations. Compared to healthy controls, people with mental disorders show altered patterns in their affective response to minor daily life stressors (Myin-Germeys et al., 2001; Wichers et al., 2007), as do people at genetic or environmental risk for mental disorders (Lardinois, Lataster, Mengelers, van Os, & Myin-Germeys, 2011; Lataster, Collip, Lardinois, van Os, & Myin-Germeys, 2010; Wichers, Schrijvers, et al., 2009; Wigman, Collip, et al., 2013), or people who will develop symptoms or a mental disorder in the future.
A Network View on Affect Dynamics in Psychopathology

It has been suggested that psychopathology arises over time as the result of a cascade of smaller short-lived changes in affect and behavior that reinforce each other over time (Borsboom & Cramer, 2013; Cramer, Kendler, & Borsboom, 2012; Wichers, 2013). This theoretical perspective on psychopathology encompasses both temporal and contextual aspects of affect dynamics. Specific contexts, for example, daily stressors, may trigger the start of such a cascade by eliciting an affective reaction (see Figure 1). This affective reaction may further impact on affective or behavioral states later in time which, at their turn, propagate the effect forward (Bringmann et al., 2013; Wichers, 2013). Previous studies attempted to visualize such dynamic interrelationships between momentary states using a network approach (see Figure 1; Borsboom & Cramer, 2013; Bringmann et al., 2013; Wichers, 2013).

Theoretically, activation of one or more nodes (representing momentary states) in the network would, depending on the structure of the network, propagate the impact to other neighboring nodes in the network. It can be hypothesized that in a network with more or stronger connections between the nodes, a greater risk exists that activation keeps resonating in the network (see Figure 1). Cramer and colleagues (Cramer, 2013) for example, showed with simulations that networks with low connectivity between its elements proved resilient to external stress, whereas in networks with strong interconnections, a small increase in stress could result in a disproportional response in terms of symptoms. Recent empirical studies, that attempted to model network dynamics by combining multiple time-lagged regression results, confirm this idea, as networks of people with more severe psychopathology appeared more strongly interconnected (i.e., stronger lagged temporal associations between momentary states) than networks of people with less severe psychopathology (Pe et al., 2015; Wigman, van Os, et al., 2013; Wichman et al., 2015). Similarly, the presence of vicious circles within these networks, that is, a group of nodes that keep reinforcing each other, would theoretically be interesting as these may cause individuals to become trapped in the activity of the network (Kendler, Zachar, & Craver, 2010). In support of that idea, a recent study showed that vicious circles between momentary affective states were not found in healthy individuals, but were present in people with mental disorders (Wichman et al., 2015). So far, data support the theory. However, network modeling with affect data is in development and currently still suffers from data analytical constraints.

This recently formulated network perspective may offer a more inclusive view on affective dynamic mechanisms involved in psychopathology. Combined with the ESM approach, it allows for a close observation of momentary affect dynamics (Wichers, 2013). The precise network characteristics, such as the connections present, their strengths, and their relative place in a network are likely to differ individually (Borsboom & Cramer, 2013; Bringmann et al., 2013; Wichers, 2013). Thereby, the network perspective can elegantly deal with the possibility that impact of stress differs per individual. Genetics and gene–environment interactions likely contribute as well in shaping the form of an individual network by influencing connection strengths (Borsboom & Cramer, 2013; Wichers, 2013). Thus, a network view on affect dynamics may accommodate the complexity of psychopathology and may offer new opportunities for personalized medicine in psychiatry.

Affect Dynamics in Psychopathology From the Perspective of Complex Dynamical System Theory

So far, we discussed certain types of affective patterns that reflect risk for psychopathology: increased variance, instability, inertia, and altered dynamics between daily life context and affect. Furthermore, increased dynamic connectivity and negative loops within a network of affective states are associated with psychopathology. The challenge is to integrate all the findings in a theoretical framework that helps us to understand better what psychopathology is, how it emerges and develops. Here, we attempt this by exploring the interpretation of previous findings from a perspective of complex dynamical system theory. We focus on the question whether change in psychopathology follows principles known from transitions in complex dynamical systems.

Complex dynamical systems are systems for which the underlying conditions are influenced by a large variety of factors. This makes it difficult to disentangle the exact mechanisms responsible for changes in the system (Scheffer et al., 2009). Defining features of such systems are that (a) they have multiple stable states and may shift from one state to another in response to changes in underlying conditions and that (b) shifts in the system show a nonlinear relationship with changes in underlying conditions. This means that given certain circumstances, the system is very stable, in that even a strong perturbation may not be enough to enforce a transition of the system to another stable
state. In other circumstances, the state of the system can be unstable and fragile, with only a small stressor being needed to trigger a “critical transition” to another stable state. In that situation, the system is close to a tipping point (Scheffer et al., 2009; Scheffer, Carpenter, Foley, Folke, & Walker, 2001), that is, at an increased risk that the system will transit to an alternative equilibrium. Even if the precise underlying mechanisms of complex systems are unknown, generic warning signals have been shown to exist that indicate the approach of tipping point (Scheffer et al., 2009). Thus, changes in observable indicators can be used as proxies to improve prediction of future developments. Studies examining climate transitions, shifts in ecosystems, and onset of epilepsy showed that rising autocorrelations and variance of the signal are such warning signals that anticipate critical transitions (Dakos et al., 2008; Scheffer et al., 2009; Scheffer et al., 2001).

It may therefore not be a coincidence that previous studies found autocorrelation and variance of affect to be associated with risk for psychopathology (Jahng et al., 2008; Koval et al., 2012; Koval et al., 2013; Kuppens et al., 2012; Peeters et al., 2006). From a dynamic system point of view, these patterns may represent early warning signals that indicate risk for transition (Cramer, 2013; van de Leemput et al., 2014). Affect dynamics may therefore play a key role in identifying closeness to a tipping point and anticipating the shift to an alternative mood state (see Figure 1). However, current empirical support for this idea needs additional evidence from studies that make use of within-subject designs.
This framework may also accommodate the previously mentioned contrasting findings of higher inertia of positive affective states being associated with better future recovery in people with current depression (Hohn et al., 2013), as a rise in warning signals would also be expected to anticipate potential transitions in opposite direction, towards recovery.

Additionally, a complex dynamical system framework fits with findings of increased connectivity between affective states being associated with increased risk for mental illness. Dynamics between affective states (network connectivity) may form the microlevel background conditions, as described before, that can change over time unnoticed, that is, without overt change in psychopathological symptoms. These background conditions can change in such a way that the mood system becomes fragile and vulnerable to transition (see Figure 1; Scheffer et al., 2001). This may happen when connections between the elements in the network increase in strength (Cramer, 2013). In that case, there is an increased chance that activation of a single node (affective state) triggers activation of other nodes. If there is high connectivity, nodes may keep reinforcing each other, thereby causing a cascade of effects (changes in other affective states) that keep resonating in the network. Here, the system would need only little perturbation (activation of a single node) to cause a disproportional change (or critical transition; see Figure 1). This is especially evident if vicious circles ensue in the effects between affective states (Wigman et al., 2015) that prevent the system from returning to its original state. High connectivity between affective states would thus represent a state of increased fragility to shift to an alternative equilibrium. Thus, from the viewpoint of complex dynamical system theory we would hypothesize that high connectivity between (negative) affective states may signal risk for a critical transition towards a higher level of psychopathology, which is in accordance with what has been found in recent studies (Cramer, 2013; van de Leemput et al., 2014; Wigman, van Os, et al., 2013).

Thus, recent findings on affect dynamics in psychopathology fit theoretically in complex dynamical system theory with regards to risk for transitions. If mental disorders indeed behave as complex dynamical systems, affect dynamics may play a major role in determining the fragility and resilience of the system.

Discussion and Future Directions

A complex dynamical system perspective on the nature of mental disorders may inspire novel insights into individual conceptualization of risk and resilience. First, prospective time-series data of affective states can be used to calculate intraindividual changes in variance and autocorrelation—warning signals indicating increased fragility of the system. Future research has to establish to what extent this is helpful in improving personalized prediction of critical transitions in psychiatric disorders. Furthermore, changes in individual moment-to-moment dynamic patterns between affective states can be used to monitor alterations in risk. Theoretically, we would expect that low autocorrelation and low connectivity between affective states indicate a state of resilience as perturbations in such systems will not result in persistence of altered affect states (such as feeling down or insecure; see Figure 1). This may prevent the emergence of a large cascade of effects between affective states in the dynamic network structure. Future research needs to further test these predictions.

Furthermore, the fact that each individual may have a unique underlying dynamic structure determining how affective states propagate their impact over time, may help to explain observed diagnostic individual differences in (a) patterns of symptoms within disorders and in (b) risk for comorbidity with other mental disorders. Furthermore, it may explain that groups of symptoms tend to cluster together and form a variety of stable (ill) mental health states.

The dynamics between affective states at the microlevel of experience seem very relevant in the etiology of mental disorders. This article argued that recent findings in the field of affect dynamics may be understood from a perspective of complex dynamical systems theory. Additional evidence is needed to further establish the relevance of this new perspective on mental disorders (Borsboom & Cramer, 2013; Cramer, 2013; Kendler et al., 2010; van de Leemput et al., 2014; Wichers, 2013) as it may have implications for diagnostic strategies in psychiatry and improvement of personalized mental health care.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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