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DYNAMIC SYSTEM PERSPECTIVES ON ANXIETY AND DEPRESSION

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Abstract

Anxiety and depression disorders are the biggest mental health hazards of our time and in many ways closely related. The first anxiety disorder episodes emerge during childhood, while the first depression episodes more typically emerge in adolescence. Such early episodes are highly predictive for lifespan developments. This chapter reviews literature on dynamic system perspectives on anxiety and depression across scales of temporal resolution, from affect and highly contextualized emotion episodes to more persistent moods that evaluate the world as a whole, and the personality traits anxiety and depression that capture thematic recurrences of feelings, thoughts and behavior along the lifespan and how people talk about themselves. These various processes are intimately connected via their self-organizing and dynamic nature and circular causality, which demonstrates how dynamic system perspectives can help us to understand anxiety and depression across the lifespan.

"Sherrington (…) thought that the brain worked like a telegraph system. Freud often compared the brain to hydraulic and electro-magnetic systems. Leibniz compared it to a mill, and I am told the ancient Greeks thought the brain functions like a catapult. At present, obviously, the metaphor is the digital computer."

Searle (1984, p. 44).

Anxiety and depression disorders are the biggest mental health hazards of our time, and first episodes often emerge during childhood and adolescence (Merikangas et al., 2010; Rutter et al., 2011). Children can respond with anxiety to separation, animals, thunder, social situations, dentists, and dreams, among others, and many adolescents experience spells of depressed mood, as these are common and transient distress experiences in response to the major biological, psychological and social transitions that are outlined throughout this book (*cf*. Rutter et al., 2011; Revonsuo, 2000). At the end of adolescence, about 25% of the population experienced an anxiety or depression disorder, which is defined by significant suffering and functional impairment (APA, 2013; Beesdo et al., 2009; Merikangas et al., 2010; Rutter et al., 2011). Many children and early adolescents suffer in silence because their mood disorders go unnoticed (Zahn-Waxler et al., 2000), and many more suffer from high anxiety and depression symptom levels. Childhood disorder episodes are often indicative of lifespan developments, as 75% recur during adolescence, up to an average of nine separate episodes over their lifespan (Burcusa & Iacono, 2007; Rutter et al., 2011). Some studies suggests that the majority of the youth who have ever been clinically depressed will be in an episode in any given year over the remainder of their lives (Kessler & Wang, 2009), although others paint a less gloomy future (Bos et al., 2018; Rottenberg et al., 2018). Nonetheless, most adolescents with a depression also report current or past anxiety disorders, while about a third of the adolescents with anxiety disorders also experience depression (Brady, 1992; Davis et al., 2015).

A central goal of psychiatric research is to better understand anxiety and depression states (Kendler et al., 2011). This chapter illustrates the use of dynamic system perspectives to understand anxiety and depression as experiences that emerge from a system of constituent affective, emotion, and mood components that synchronize across scales of resolution and function and evolve as one integrated process within each of us. In doing so this chapter illustrates how dynamic system perspectives can provide new insights into anxiety and depression, connect various literatures, and point at new angles for future research.

Nested systems

Anxiety and depression can be defined as emotions that span minutes to days, as mood episodes that can persist over weeks to months, and as part of our personalities, which change along the lifespan, and describe how people navigate the world, define who they are, and talk about themselves. Dynamic system perspectives can increase our understanding of anxiety and depression as multi-component and dynamic processes that continuously change over time and are inherently connected via their self-organizing and dynamic nature and circular causality. Moods and personality traits are thought to emerge from interactions between highly variable "microscopic" emotion components (as outlined below), after which these more integrated macroscopic system levels start to structure and constrain our moment-to-moment component experiences top-down (see Table 7.1), resulting in circular causality and increasingly complex and stable affect systems (e.g., Fajkowska, 2015; Granic, 2005; Kendler et al., 2011; Van der Stel, 2009; Van Geert & Steenbeek, 2005; Wichers et al., 2018; Witherington, 2007).

The functional unity of this multiscale system is often illustrated with the metaphor of emotions as the weather of our lives (e.g., sadness as rain clouds, a cold breeze of fear, and sunshine as joy), and mood and personality as our internal climates (*e.g*., Liljenström & Svedin, 2005; Ochsner et al., 2012; Russell, 2017). It may be difficult to forecast daily weather and emotions over more than ten days, as these trajectories are inherently chaotic (i.e., irregular and extremely sensitive to small baseline deviations), but more climatic or "average weather" such as seasons are rather stable, predictable, orderly, and relatively enduring (*e.g*., Boeing, 2016; Liljenström et al., 2005). The personality traits Anxiety and Depression can be seen as macro-level attractor basins that calibrate our internal dynamics resulting in less environmental input necessary to move toward specific micro real-time emotional states of anxiety and depression (Jeronimus, 2015; Revelle & Condon, 2017; Van der Stel, 2009). Below we zoom into each of these component levels and processes in detail.

Affect and emotions: the micro level

Affect is a continuous hedonic "commentary" on our current state of affairs that naturally infuses our perception as if it were a "sixth sense" that is integrated with other sensory processing and is typically experienced as a property of people or objects in the world (Barrett, 2017, 2018; Panksepp & Biven, 2012) to guide judgment and decision making (Kahneman & Egan, 2011; Schwarz, 2010; Slovic et al., 2007). Affects are internal subjective states that are

only known to those who have them. Anxiety and depression as emotions refer to discrete snapshots of this continuous stream of affective experience, when a specific context becomes imbued with meaning to instigate a specific action.

Emotions can be defined as (a) intense and transient subjective states that last for seconds up to 72 hours at most (Panksepp & Biven, 2012; Sonnemans & Frijda, 1994; Verduyn et al., 2011); which (b) "emerge" in response to *specific* events or stimuli (extrinsic or intrinsic to the organism); and (c) can be categorized according to their affective valence (from unpleasant to pleasant) and emotional arousal or bodily activation (Anderson & Adolphs, 2014; Yik et al., 2011; Kuppens et al., 2010; Panksepp & Biven, 2012). Anxiety and depression are both unpleasant affects, and low positive affect is relatively specific for depression and social anxiety, with anxiety being marked by high physiological arousal and depression by low arousal (Russell, 2003; Watson et al., 2005). Emotions are detectable on the outside in facial expression, skin color, vocal timbre, gestures, and odor, among others (Ekman, 2008; De Waal, 2019; Panksepp et al., 2012).

The ***classical emotion perspective*** postulated that children are born with abilities to distinguish the primary emotions (e.g., anxiety/fear, depression/sadness, happiness, anger, and disgust) that cover most of our transactions with the world (Darwin, 1872; Russell, 1990). Anxiety and depression were understood as hardwired prototypical adaptive scripts that become activated by a particular class of stimuli (e.g., a threat, obstacle, or loss) to orchestrate psychological changes in feelings and thoughts and activate coordinated thought-action repertoires and goal-oriented behavior, which we evolved to respond quickly and adequately to changes in the environment that might affect our well-being (Damasio et al., 2000; Ortony & Turner, 1990; Panksepp et al., 2012; Plutchik, 2001; Roseman et al., 1994; Russell, 2017).

The ***prototypical script*** for anxiety becomes activated when a threat (stimulus) signals the detection of an ongoing source of danger (cognition) and evokes *anxiety* or fear (affect) as an impulse to prepare, flee, hide, counterattack, or scream (action) to protect ourselves and reach safety (goal), which may well save our lives. Similarly, instances of depression start with the loss of a valued object or support (stimulus) which indicates abandonment (cognition) and evokes *sadness* (affect) and an impulse to cry (action) in order to reattach with this lost object (goal), or to save energy and tread carefully until conditions improve, and our needs are met. More complex emotions such as shame or guilt were thought to originate as mixtures of these five basic emotions (Plutchik, 2001; Russell, 1990; 2017; Shaver et al., 1987).

Table 7.1. Hierarchical temporal organization of levels for analysis of distress experiences

	Level of organization	Time scale	Concept	Construct	Severity
	Nano	Moment-to-moment	Seconds	Feeling - thoughts	Affect - cognitions	+
1.	**Micro**	Fluctuations	Minutes	Emotions	Anxiety, Sadness, Fear, Anger	+
	⇕	Daily - diurnal	Hours	Symptoms	Examples provided in Table 7.3	++
2.	**Meso**	States	Weeks	Moods	Anxiety - depression	++
	⇕	Episodic	Months	Disorder states	MDD - GAD	++++
3.	**Macro**	Dispositions	Years	Temperament	Negative affectivity	++
	⇕	Lifespan	Decades	Personality	Trait anxiety - trait depression	+
	Mega	Generations	Centuries	Culture	Cultural scrips and norms of reaction	
		Lineage	Millennia	Evolution	Forces that maintain heritable variation	

Note: MDD = major depressive disorder; GAD = Generalized Anxiety Disorder. The micro and meso level are often covered in cross-sectional perspectives (e.g., a point prevalence or frequency at a specific point in time) whereas the macrolevel covers lifespan perspectives and lifetime prevalences.

A more dynamically oriented ***constructivist perspective*** postulates that anxiety and depression have no single physical form and must be understood as spectra (like colours) or categories of instances (families of functionally related states) that differ in many degrees, qualities, and intensities (see Table 7.2), but share their *template* – like chairs or cookies – and thus cluster near one another in property space (Barrett, 2017, 2018; Kendler et al., 2011; Posner et al., 2005; Russell, 2003; Salzman & Fusi, 2010). Instances of anxiety and depression differ between people and *within* people at different instances and along the lifespan, because each episode is *constructed* from learned assemblies of bits and pieces of previous experience (i.e., statistical regularities) which form prototypical scripts or cognitive tools to communicate about feelings and to anticipate future events and to deal with them (Barrett, 2017, 2018; Russel, 1990, 2001). Recent emotion theories group the thousands semantic emotion terms we use over up to 27 emotion families including anxiety (nervous), fear (afraid, horror), horror (shock, scared), and depression (sadness), see Table 7.2 (e.g., Cowen et al., 2017; Verduyn et al., 2015).

Today most theorists argue that the emotions anxiety and depression *emerge* from the synchronization of various interoceptive, perceptual, cognitive, and motor components that mutually amplify one another until they converge at a dominant emotion state that best fits the specific situational instance in which one finds oneself, and from which a subjective understanding of the situation emerges to potentiate a particular remedy to deal with it (Adolphs, 2003; Anderson & Adolphs, 2014; Barrett, 2018; Damasio et al., 2000; Lewis, 2000; Scherer, 2009; Tooby & Cosmides, 2008). Subsequently, these anxiety and depression states influence the way people screen, categorize, and interpret information, decide what is important and valuable, and stimulate rumination, which are all *feedback loops* that direct the dynamic system towards a stable emotion configuration or *attractor* (see Chapter 1). Such feedback loops enable the emotion state to unfold over time periods far beyond the presence of the stimuli that caused the emotion and the component processes themselves (called "hysteresis"), a non-linearity that is typical for complex systems (e.g., Hollenstein, 2015; Verduyn et al., 2015; Van der Maas & Molenaar, 1992).

This complex emotion system is favored by natural selection because it can reconfigure itself into a multitude of different states while dissimilar representations can give rise to emotion instances of the same category (such as anxiety or depression) in different contexts (Barrett, 2017; Kuppens et al., 2010). Anxiety and depression are thus understood as self-organizing dynamic processes that combine affect, motivation, evaluation, attention, learning, memory,

wanting, and so on, to construct emotional experiences that give meaning to context. Because every instance of anxiety or depression is constructed, variability is the norm, which enables individuals to respond flexibly, and to establish unique individual-environment relationships (Hollenstein, 2015; Scherer, 2009; Tooby & Cosmides, 2008; Kuppens et al., 2009).

Emotions are multifaceted phenomena that can differ markedly across individuals and cultures, which illustrates their developmental malleability, and each individual should therefore be pictured as a dynamic system with an unique architecture and resulting dynamics over time (Barrett, 2018; Fisher et al., 2018; Fogel et al., 1992; Thompson, 1994). Consequently, two people can experience an identical situation quite differently, and converge to different emotion states (e.g., sad versus anxious) as a consequence of their personal history and situational understanding, including whether the event was unexpected, controllable, can be coped with, was one's own fault, and so on (Barrett, 2017, 2018; Jeronimus et al., 2017; Stanton, 2012). Individual differences in *emotional clarity* or the extent into which one can identify, label, and characterize emotions, can explain why some adolescents recognize and experience anxiety and depression as strongly differentiated and discrete emotion states, while others experience either both together or none (Bailen et al., 2019; Erbas et al., 2014; Fisher et al., 2018; Gohm & Clore, 2000; Mathews et al., 2016).

Adolescents learn to construct and differentiate increasingly fine-tuned feelings as specific emotion categories to summarize experiences more efficiently and precisely, thus increasing *emotional granularity* or "emotional intelligence" (see Table 7.2; Barrett, 2018; Erbas et al., 2014; Nook et al., 2018; Russell, 1990). Adolescents with heightened interoception and low emotional clarity (i.e., difficulties in attributing these inner sensations to specific emotions) or low granularity (i.e., little emotion differentiation) more often feel unhappy, report social problems, and develop anxiety and depression disorders (Barrett, 2018; Demiralp et al., 2012; Erbas et al., 2014; Kashdan & Farmer, 2014; Mathews et al., 2016; Palser et al., 2018; Sendzik et al., 2017). Being able to put a feeling into words (such as sad or afraid) can already decrease the subjective intensity of the experience (Lieberman et al., 2011).

An improved understanding of how adolescents construct anxiety and depression and accept these experiences can result in strategies to intervene in this construction process, to buffer adolescents against all kinds of social and mental adversity, as emotions can be deconstructed into their experiential components to be re-categorized, which is thought to influence how adolescents perceive their reality (Barrett, 2018; Brackett et al., 2012; Kashdan

et al., 2015; Sendzik et al., 2017). Now that we have defined anxiety and depression as prototypical emotion categories (i.e., populations of diverse instances) that emerge in response to specific contexts to give the ebb and flow of life meaning, we zoom into their dynamics.

Table 7.2. Anxiety and depression as emotions and personality traits

	Category		Instances / definitions
Emotions	Anxiety	Nervous	Tense, apprehension, worry, distress, dread, unease, distressed, frustrated, nervousness, etc.
	Fear	Afraid	Alarm, fright, terror, panic, hysteria, horror, shock, mortification, scared, etc.
		Horror	Shock, scared
	Depression	Sadness	Gloomy, sorrow, grief, despair, hopeless, misery, melancholy, bored, droopy, tired, sleepy
			Disappointment, displeasure, dismay
			Guilt, shame, embarrassment, regret, remorse
			Neglect, loneliness, isolation, defeat, rejection, humiliation, insecurity, homesickness, etc.
Personality	Neuroticism		Tendency to perceive the world as threatening, to be prone to experience unpleasant and disturbing emotions in reaction to various types of stress (emotional instability), and to select oneself into situations that foster negative affect.
	Anxiety		Characteristic level of free floating anxiety and fear proneness
	Depression		Tendency to experience feelings of sadness, guilt, loneliness, and hopelessness

Note: William James (1890) already emphasized the tremendous variability in the human emotions that people refer to with the same emotion word. Source: The depicted emotion instances were derived from Barrett (2018), Cowen et al. (2017), Russell (1980), and Shaver et al. (1987). The description of neuroticism was derived from Jeronimus (2015) and the definition of the facet traits anxiety and depression from Costa and McCrae (2006).

Dynamic processes

One of the most challenging topics in the study of anxiety and depression is to understand the processes underlying the temporal dynamics of emotion (Hollenstein, 2015; Houben et al., 2015; Kuppens et al., 2010; Lewis, 2005; Reitsema et al., 2019). The duration of emotions can help to distinguish closely related experiences such as shame versus guilt or fear versus anxiety (Panksepp & Biven, 2012). For example, when studying 27 emotions, in most people sadness lasted the longest (median 48 hours), while anxiety and guilt (median 4 hours) and fear (median 1 hour) and shame (median 30 minutes) were among the shortest emotion episodes (Verduyn et al., 2015). The most studied emotion dynamics in adolescents include the *frequency* with

which they experience anxiety or depression over a protracted period of time, the average magnitude of emotion over time (*intensity*), the range of fluctuations (*variability*), the magnitude of these fluctuations from moment to moment (*instability*), the temporal dependency of emotion states (*inertia*), whether anxiety or depression increase (augment) or decrease (blunt) one another over time, and adolescents' differentiation (*granularity*) and clarity of emotions (see Bailen et al., 2019 and Reitsema et al., 2019 for reviews).

Adolescents show substantial individual differences in the dynamics of anxiety and depression, but the average frequencies and intensities peak in late adolescence, especially in girls, followed by a decrease over adulthood (Bailen et al., 2019; Carstensen et al., 2000; Reitsema et al., 2019; see for adults Fisher et al., 2017, 2018; Houben et al., 2015). Adolescents who report more frequent, intense, persistent, and variable negative emotions (especially sadness, nervousness and anger) and decreased positive emotions and energy are most vulnerable for the development of episodes of anxious or depressed mood (Bailen et al., 2019; Kuppens et al., 2012; Neumann et al., 2011; Silk et al., 2003; Morgan et al., 2017).

Today there is a scarcity of studies of real-time (moment-to-moment) dynamics of affect and emotion components and regulation processes in single individuals across and within time under natural conditions in daily life (Hollenstein, 2015; Houben et al., 2015; Wichers et al., 2015, 2018), or how these emotional experiences change over adolescence (see for reviews: Bailen et al., 2019; Reitsema et al., 2019). Momentary assessment studies (EMA) of emotions typically apply non-adjacent sampling intervals and 3 to 10 assessments per day for 7 to 30 days (Houben et al., 2015; Kuppens & Verduyn, 2017; Reitsema et al., 2019; Trull et al., 2015; Van der Krieke et al., 2015); although some studies assessed daily anxiety symptoms over 236 days (Hoenders et al., 2012) or daily depression symptoms over 239 days (Wichers et al., 2016), and there are studies in which a group completed 500 measures per participant over 4 months (Wichers et al., 2018). Researchers suggest that minimal 25 to 30 assessments per subject may be recommended for multilevel models (Bolger et al., 2012; Maas & Hox, 2005; which still mix within- and between-person effects), whereas for subject-specific dynamic models of interacting variables by means of vector autoregressive (VAR) modeling at least 44-50 assessments are required (Box et al., 2015; Fisher et al, 2018; Van der Krieke et al., 2016) up to 100 assessments to model changes in the conventional dynamic processes themselves (Bringmann et al., 2017; Wichers et al., 2018) and switches in state-space models (Hamaker & Grasman, 2012).

Promising future avenues to improve our understanding of states of anxiety and depression are challenging studies that (a) examine various dynamic processes in single adolescents and changes therein over adolescence (Bailen et al., 2019; Reitsema et al., 2019; Koval et al., 2013; Krone et al., 2018) and (b) capture the stream of affective experience in real time to follow their emergence and unfolding via the synchronization of various emotion components (time-shifting contemporaneous relations), which requires high-frequency sampling. Furthermore, dynamic system perspectives can also help to zoom into instances in which emotions fail to function properly, such as disruptions in affective valence or emotional intensity, and problems with emotional clarity and differentiation (APA, 2013; Sendzik et al., 2017). Examples of emotion intensity disturbances include being over- or under-reactive to emotional situations, such as extremely low levels of positive affect in depressed adolescents, or a swing towards extreme high positive affect intensities during manic-depressive episodes (Birmaher, 2013; Rutter et al., 2011). Finally, future studies may use multimethod assessments to capture adolescent experience, and compare and combine different indices for emotion dynamics (Bos et al., 2018; Houben et al., 2015; Koval et al., 2013; Reitsema et al., 2019).

The emotion literature suggests that (a) anxiety and depression are constructions of the world rather than reactions to it, (b) that changes in emotion dynamics can be indicative for the development of a mood disorder, and (c) may serve as an early warning signal, and these ideas shall be explored in more depth below.

Mood episodes (meso level)

Anxious and depressed mood spells describe sustained negative background affects that color as generalized emotions but are much lower in arousal and wider in scope. Whereas emotions are highly contextualized, moods evaluate the world as a whole, and often lack a specific start and stop (Barrett, 2018; Beedie et al., 2005; Horwitz & Wakefield, 2007). Moods can be defined as internal subjective states perpetuated by extended cognitive configurations that narrow attention towards ongoing internal processes (see Table 7.3) and a restricted set of interactions and understandings of the surrounding world (APA, 2013; Gotlib & Joormann, 2010; Isen, 1990). In short, depressed adolescents are characterized by negative views of themselves, the world, and their future, and uncontrollable self-critical cognitions, which impede their ability to generate positive affect (Gotlib & Joorman, 2010; Rutter et al., 2011). Mood states typically last for weeks to months and have a relatively constant quality even though the state itself is dynamic, and this progression from normal affect fluctuations to entrenchment is what

characterizes mood as a developmental process (De Zwart et al., 2018; Lewis, 2000; Rutter et al., 2011).

Mood episodes are characterized by the emergence of a metacognitive or recursive consciousness (a higher-order structure) as individuals can become aware of their internal state as a mode of perception that underlies cognitive decoupling or "head-and-heart splits" (Damasio et al., 2000; Schooler et al., 2011). People disengage their attention from perception (perceptual decoupling), notice the current contents of consciousness (meta-awareness), and realize that their feelings do not match their cognitive evaluation of the situation, thus that something goes awry. Key examples are anhedonia and guilt (see Table 7.3). Anhedonia refers to being unable to feel pleasure in situations or after events that one recognizes as normally pleasurable activities which is typical for childhood depression (see APA, 2013; Russell, 2017). Depressed adolescents often report guilt, a self-conscious emotion characterized by tension, regret, and remorse about a particular (in)action that comprises one's moral or personal standards (not living up to ideal self) while one could have done otherwise (APA, 2013; Roseman et al., 1994; Rutter et al., 2011). Such higher-order structures illustrate the complexity of mood states, which emerge from various nonlinear dynamic interactions between affective and cognitive elements.

Anxious and depressed syndromes refer to flexible and dynamic systems of constitutive heterogeneous elements (co-occurring feelings, thoughts, and actions, see Table 7.3 and APA, 2013), thus moods are formative dimensional constructs similar to the constructivist perspective on emotions (e.g., Borsboom, 2008, 2017; Constantini et al., 2019; Fried & Nesse, 2015; Gotlib & Joorman, 2010; Heeren et al., 2018; Kendler et al., 2011, 2012; Wichers et al., 2018). There may not even be a classification for anxiety or depression etched in the structure of the world and both may be merely concepts (Kendler et al., 2011, 2015). The idea of anxiety and depression as populations of instances and dynamic perspectives on their development can explain how different causes may eventually yield similar symptom clusters while similar causes do not necessarily result in similar outcomes. In a constantly changing world such stable (or inert) anxious or depressed mood states must be maintained with feedback loops that affect the emotional state space by steeping the slopes towards these attractors that previously were passed easily, including cognitive emotion regulation strategies and behaviors (Aldao et al., 2010; Fogel et al., 1992; Granic, 2005; Lewis, 2000; Mathews et al., 2016; Thompson et al., 1994).

The synchronization of mood elements is often studied using networks of symptoms (or "nodes") and their interactions (or "connections," see Borsboom 2017; Fried et al., 2017; Marsman et al., 2018; McNally, 2016; Wichers, 2013). The interactions in these systems are described with node centrality indexes, especially connection strength, closeness, and betweenness (Bringmann et al., 2018; McNally, 2016; Opsahl ea, 2010). *Strength* indicates the direct influence of each symptom or node on the network (via partial correlations), and can be subdivided over instrength (activated by many other symptoms) and outstrength (activates many other symptoms), and node interconnectedness can also be expressed in terms of shared variance with their neighbors (Haslbeck & Fried, 2017). *Closeness* indicates the shortest distance between each node to identify direct and indirect influences. Betweenness indicates the number of times a node traverses the shortest path between two other nodes. Nodes with high betweenness are "gate keepers" that connect less central nodes or "bridge" different substructures within the psychological network (see Table 7.3), and because reciprocal symptom connections within and between anxiety and depression are often equivalent (Cramer et al., 2010; Fisher et al., 2017), these experiences co-occur.

Recovery time is a network metric that quantifies emotion regulation efficiency (Thompson, 1994; Yang et al., 2018), and the networks of people with higher overall depression require longer recovery time after socioemotional processes (Yang et al., 2018), also after adjustment for recent life events. High or increasing connectivity between symptoms of affect and cognition may indicate emotional inflexibility or "inertia," which is typically understood as a more fragile system state in which sudden transitions towards other symptom states becomes more likely (Scheffer et al., 2012; Wichers et al., 2018). Adolescents often report sudden changes in symptom levels of anxiety and depression (Rutter et al., 2011), and such transitions are a hallmark of complex systems in which tension may rise gradually (as resilience levels may diminish slowly or even without notice) after which minor contextual disturbances can push the system over a "tipping point" towards another basin of attraction (Callahan et al., 1990; Scheffer et al., 2012; Van der Maas et al., 1992; Wichers et al., 2018).

The concept of an attractor basin can reconcile the common experience of mood states as emerging out of the blue (Hayes et al., 2007) with studies that indicate developmental trajectories for mood symptoms (although discontinuous and non-stationary; Myin-Germeys et al., 2009; Wichers et al., 2018). This dynamic bimodality of normal versus disorder system states is intuitive to many scholars and clinicians and has derived some empirical support

Table 7.3. Definitions of distress states according to the Diagnostic and Statistical manual of Mental Disorders (DSM-5)

Symptom	MDD	Dysthymia	GAD	PTSD	#	Criteria for MDD
Dysphoria	X				1	Depressed mood, i.e. feeling sad, empty, or hopeless
Anhedonia	X				2	Diminished interest or pleasure in virtually all activities
Appetite disturbance					3	Weight loss or gain or decreased/increased appetite
Sleep disturbance					4	Insomnia or hypersomnia
Restlessness					5	Psychomotor agitation or retardation (lethargy)
Fatigue					6	Loss of energy
Worthlessness					7	Feelings of worthlessness or excessive or inappropriate guilt
Concentration					8	Problems with thinking/concentration or indecisiveness
Irritability						Irritable mood most of the time (childhood specific)
Suicidal ideation					9	Preoccupation with death, suicidal ideation (plans) or attempt
Worry			X			
Withdrawal						Social withdrawal
Anxiety			X			Apprehensive expectation
Muscle tension						
Guilt						
Shame						

Note: X = core symptoms; MDD = major depressive disorder; GAD = generalized anxiety disorder; PTSD = post-traumatic stress disorder. Four major distress disorders can be identified in the DSM-5 (APA, 2013) on the basis of multiple experiences of which many are shared as indicated in gray (example derived from Lahey et al., 2017, table 1; but also see Kotov et al., 2017; Zahn-Waxler et al., 2000). Children can show several anxiety disorders, including separation anxiety, panic disorder, agoraphobia, specific phobia, social phobia, obsessive-compulsive disorder, generalized anxiety disorder (GAD), and post-traumatic stress disorder (PTSD).

(*e.g.*, Cramer et al., 2016; Hosenfeld et al., 2015; Van de Leemput et al., 2013). One double-blind study using intensive self-monitoring of one man over 239 days (1,474 observations) confirms the presence of a sudden shift in the severity of depressive symptoms (Wichers et al., 2016) and a study over 236 days showed a sharp increase in anxiety symptoms (Hoenders et al., 2012), but such longitudinal evidence remains both scarce and essential (Bos & De Jonge, 2014). The possibility of discrete shifts between normal versus anxious or depressed states is supported by brain stimulation studies (Panksepp & Biven, 2012) and rapid shifts from states of anxiety with marked dysphoria to normal after the anxiety-eliciting situation (such as a separation, animal, object, social situation or thunder) is eliminated (Rutter et al., 2011).

Mood symptoms typically develop, activate, and synchronize over time until the system state becomes self-sustaining and unusually intense or persistent (Myin-Germeys et al., 2009; Wichers et al., 2018). For example, insomnia may drive fatigue and concentration problems, while anhedonia may lead to guilt, which may lead to low self-worth, and so on (Borsboom et al., 2017; Kendler et al., 2011; Wichers et al., 2013). Moods themselves are defined in terms of symptoms that persist for weeks (APA, 2013, macro level) while the underlying processes probably reflect everyday hour-to-hour fluctuations (micro level). In a study of 104 depressed patients by Bos et al. (2017; assessed ten times a day for five days) sadness was most sensitive to the other symptoms (highest instrength), whereas anhedonia had the most influence on other symptoms (outstrength). Daily level changes in positive mood, hopelessness, anger, and irritability most often activated other symptoms in anxious and depressed patients (Fisher et al., 2017), and thus not depressed mood, anhedonia, and worry, the putative cardinal symptoms (see Table 7.3). When studied on a weekly resolution, however, all symptoms of depression showed connections over time (either direct or indirectly), with anhedonia as the most central item (Bringmann et al., 2015).

These examples illustrate that dynamic relationships differ across timescales (Dormann & Griffin, 2015; Hamaker & Wichers, 2017; Schiepek et al., 2016), therefore real-time changes in affect and rapidly cycling emotions (which require high-frequency assessments) must be connected with changes in mood symptoms and negative cognitions (about the self and future), which mandate comparatively low-frequency measurements over weeks and months. Therapeutic processes, for example, cover both micro processes such as interactions within each session and more long-term sequential regularities that occur between consecutive sessions (see Chapter 4; Molenaar, 2010). Studies increasingly combine measurements across multiple

"bursts" of intensive experience sampling over one year (Yang et al., 2018) which may help improve our understanding of mood in adolescence (Maciejewski et al., 2015).

A major application of dynamic system perspectives in contemporary mood research is the quest for generic early warning signals that may indicate upcoming transitions into a mood disorder episode, as such signals would enable for preventive strategies. Most attention goes to critical slowing down, enhanced symptom variability, and increasing autocorrelation as signals for transitions between such qualitatively different system states (Nelson et al., 2017; Wichers et al., 2015, 2016, 2018), but also frequency distributions, varying complexity, or other dynamic features are used (Molenaar, 2010; Schiepek et al., 2016). At the group-level there is some evidence for increases in autocorrelation (Van de Leemput et al., 2013) and higher system entropy before people experience a transition into a depressive state (Lanata et al., 2015). One individual-level study provided evidence for rising autocorrelations and variance before the onset of a depressed episode (Wichers et al., 2016). Studies of therapeutic contexts showed that increasing emotional fluctuations can indicate qualitative change (Lichtwarck-Aschoff et al., 2012; Schiepek, 2016).

Definite proof of generic early warning signals for the onset of anxiety or depression episodes requires researchers to monitor many individuals with high-frequency assessments over a long period in advance of the transition under study – and because such data has been collected with compliance rates of 80% and up (see Hoenders et al., 2012; Wichers et al., 2016, 2018; Schiepek et al., 2016), in the near future we expect studies that show whether the idea of warning signals has substance, and result in the implementation of prevention strategies. At the group-level the timing of such discrete transitions in depressive symptom severity is inconsistent (De Zwart et al., 2018) which indicates substantial individual variability and sudden changes; This is illustrated in Figure 7.1, which shows the recovery trajectory of 267 participants over 140 weeks in terms of their depressive symptoms (a 50% symptom reduction after 30 weeks) and demonstrates how uninformative group-level indicators can be for individual patterns. The idea of non-linear shifts in symptom severity combined with large individual variability favors knowledge on how symptoms evolve at the level of the individual in daily life to elucidate mechanisms, because the underlying causes are probably individual-specific (Fisher et al., 2018; Wichers et al., 2013; Yang et al., 2018). People with a psychosis or bipolar disorder often identify their individualized early warning signals for an upcoming

episode, which illustrates how dynamic system applications can lay hidden in routine care practices (see Chapter 4).

Figure 7.1. A group-level trajectory of depressive symptoms over 140 weeks (above) and the associated person-level trajectories (below) in 267 participants.
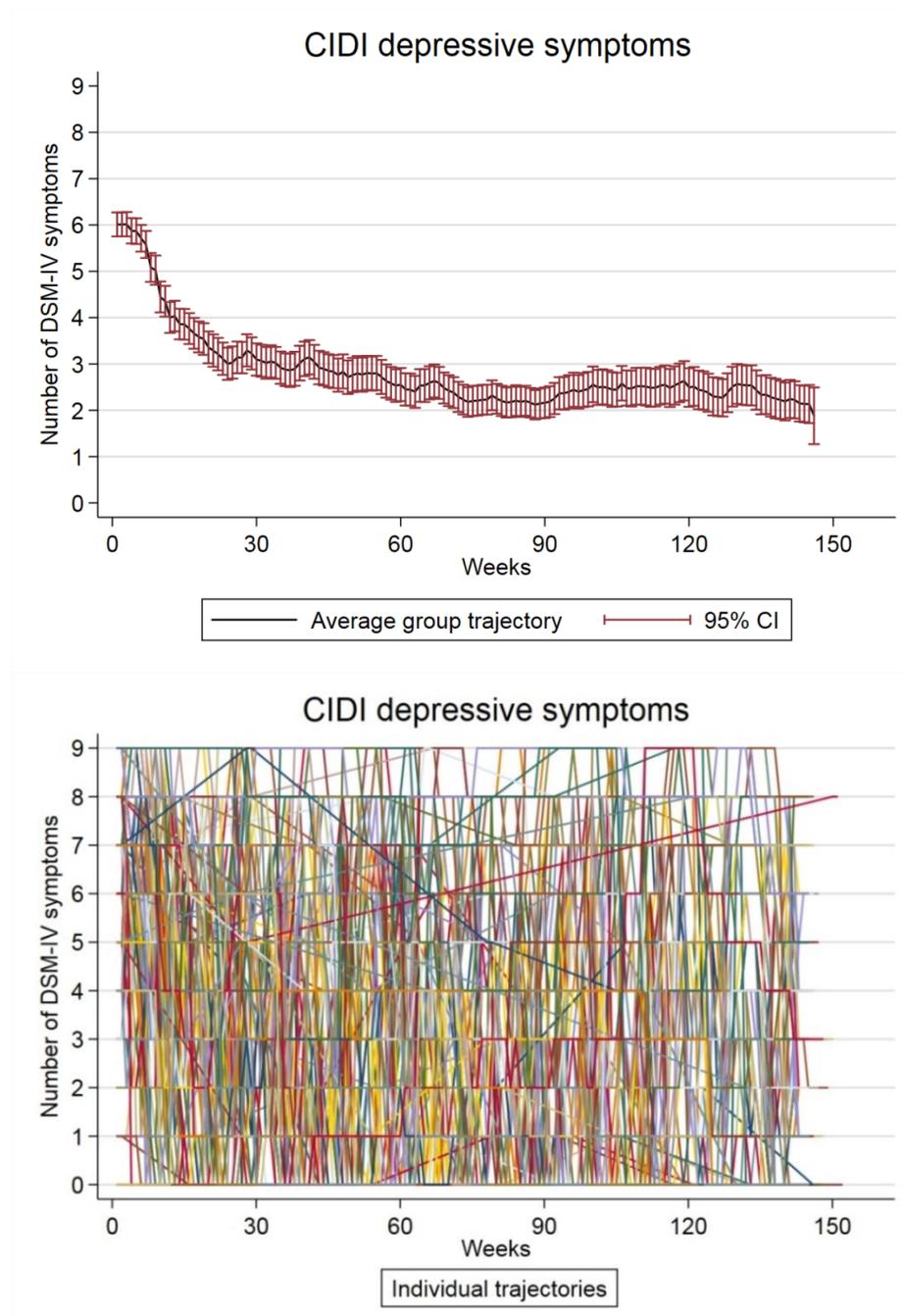
Note. The trajectory of depressive symptoms over 140 weeks as assessed with the composite international diagnostic interview (CIDI) based on the DSM-IV criteria, to study remission rates (≤5 symptoms) and group-level changes over time. Source: Conradi et al. (2007). This figure was generously provided by Peter de Jonge and Elske Bos.

Paradoxically, dynamic system perspectives also predict inherent limitations to the application of warning signals. Mood symptoms are connected via many feedback and multiplicative processes within individuals, which makes our development nonlinear and dynamic, as it depends on our current system state. As previously outlined with the weather metaphor, individual dynamics, emergent processes, thresholds of instability, and sudden transitions limit the predictability of developmental processes, and some futures shall therefore remain unknowable with precision, if only because tiny changes can compound to substantial outcome differences ("the butterfly effect," see Chapter 4; Boeing, 2016; Granic, 2005). Finally, the question remains as to whether mood disorder symptoms (Table 7.3) are defined at the right level of granularity to successfully identify the components of the system (as there may be hundreds of variables) while state transitions (if they exist) are likely to be governed by only a few (Borsboom, 2017; Van der Maas et al., 1992).

Promising future avenues to study anxious and depressed moods include the integration of complex dynamic processes across levels of resolution via simultaneous top-down and bottom-up approaches (Forbes et al., 2016; Witherington, 2007) and models that integrate within and between person estimates (Adolf et al., 2014; Ernst et al., 2019; Fisher et al., 2018). Researchers increasingly estimate person-specific complex dynamic systems, which they subsequently aggregate into group-level clusters with more comparable dynamics and response synchronization processes (Beltz et al., 2016; Ernst et al., 2018; Yang et al., 2018), to inform etiological theories. Studies of mood dynamics often use regression-based methods to unravel autoregressive effects (how symptoms affect themselves) and cross-regressive effects (how symptoms affect each other) over time via VAR models using all lag-1 relations, which can handle unique direct effects, but not shared changes (i.e., shared variance is removed) or stable predictors (see Bulteel et al., 2016 and Molenaar, 2018, for a discussion of limitations, and Bringmann et al., 2013, for multilevel models, e.g. person-mean centering requires the assumption of stationarity). Researchers also questioned the validity of using centrality indices to study mood symptom networks (Bringmann et al., 2018; Forbes et al., 2017; Hallquist et al., 2019), including betweenness and closeness centrality as measures of node importance (Bringmann et al., 2018), and struggled with statistical equivalent network and latent variable models despite their marked conceptual differences (Markman et al., 2018; Molenaar et al., 2007, 2010), which suggests that other and more advanced methodologies are required. Future studies might apply more advanced dynamic system techniques (examples in this book and), dynamic cluster models (Ernst et al., 2019), and more diverse and multimethod measures (e.g,

observers, language analyses, interviews), as the almost exclusive usage of self-report measures of adolescents' anxiety and depression goes along with some threats to validity (Eisenberg et al., 2010), and should be interpreted with caution.

Personality (macro level)

Humans are highly variable and complex, but also show shared patterns in feelings, thoughts, and behaviors that persist over time and across situations. Personality captures the "dynamic organization within the individual of those psychophysical traits that determine his unique adjustments to his environment" (Allport, 1937). A large part of what makes each of us unique is our emotional life and idiographic history (Kuppens et al., 2009; McAdams, 2015). Most individual differences in these patterned characteristics can be summarized in terms of Five Factors or broad "trait families" (John et al., 2008), namely, Neuroticism, Extraversion, Conscientiousness, Agreeableness, and Openness to new experiences (the "Big Five").Nowadays many theorists assume that personality "emerges out of the connectivity structure that exists between the various components of personality" (Cramer et al., 2012, *p.*414, also see Baumert et al., 2017; Constantini et al., 2019; Mõttus & Allerhand, 2017; Ormel et al., 2017), a perspective similar to the constructivist perspectives on emotion and mood, but with different content and over longer time scales (see Table 7.1)[1]. Without such pattern recognition, our observations remain unfocused and random (De Waal, 2019).

The ***neuroticism*** factor taps into the organization and functioning of negative emotion systems (APA, 2013, p.679; Ormel et al., 2013; Shackman et al., 2016), and refers to a dynamic macro-level structure of synchronized preferences, goals, values, concepts, motives, and narratives, which evolves in each of us while we develop along the lifespan (e.g., Back et al., 2011; Cramer et al., 2012; DeYoung, 2015; Fajkowska, 2015; Fleeson et al., 2015; Jayawickreme et al., 2019; Jeronimus, 2015; Lewis, 2000; McAdams, 2015; Mischel & Shoda, 1995; Mõttus et al., 2018; Ormel et al., 2017; Tackett et al, 2012; Wrzus & Roberts, 2017). Prominent members of the neuroticism family are the ***facet traits Anxiety and Depression*** (see Table 7.2 for definitions) and Vulnerability (or general susceptibility to stress), which capture the frequency and intensity with which adolescents experience the emotions anxiety and depression over time and in different situations (Costa & McCrae, 2006), as well as current

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[1] The various dynamic accounts of personality include Whole Trait Theory (Jayawickreme et al., 2019), CB5 theory (DeYoung, 2015), Mixed Model of Personality (Ormel et al., 2017), TESSERA (Wrzus & Roberts, 2017), among others.

mood symptom levels (Kotov et al., 2010; Riese et al., 2015). The neuroticism trait family is a vulnerability for the later development of full-blown anxiety and depression disorders (Jeronimus et al., 2016). A key difference between mood episodes and the facet traits of Anxiety and Depression is that the former are deemed to indicate intra-individual deviations from our particular personal normality, whereas the latter refers to more permanent individual differences in personality dispositions (Jeronimus et al., 2013, 2016; Riese et al., 2015).

Neuroticism can be understood as an umbrella term or macro-level "attractor basin" for negative affect - the rather stable climatic "average weather" over adolescence - but this personality landscape changes over the lifespan, which can help explain why adolescence is marked by high intensity and variable emotion states of anxiety and depression. Most adolescents experience temporary decreases in conscientiousness (self-regulation) and agreeableness (warmth, friendliness and tact) and increase in neuroticism (Anxiety/Depression), a pattern that reverses from early adulthood onwards (see Roberts & Wood, 2006 for a meta-analysis and Soto et al., 2011 for a cross-sectional study of 1 million participants). High neuroticism (or negative emotional reactivity and distress), and low conscientiousness (or poor effortful control and emotion regulation) and low extraversion (or low positive emotionality) underlie individual differences in sensitivity to reward and punishment and predict levels of anxiety and depression over adolescence (Watson et al., 2005; Rutter et al., 2011).

Emotion regulation refers to adolescents' abilities to regulate emotion dynamics back to their "normal" system state and the regulatory processes that are installed to keep their core affect in check ("attractor strength"; see Thompson, 1994; Kuppens et al., 2010), and dysfunctional patterns play a crucial role in the development and persistence of depression and anxiety (Jeronimus et al., 2016; Sendzik et al., 2017; Snyder et al., 2015). Most therapies therefore aim to re-establish cognitive control over emotions, via exposure, re-interpretation (of the way a situation is construed), or suppression (Gross, 2002), and clinicians increasingly focus on neuroticism as a target for therapy (Barlow et al., 2014; Roberts et al., 2017).

High neuroticism is associated with the "***neurotic cascade***" (Suls et al., 2005) which describes a set of processes that can help explain the recurrence of states of anxiety and depression: (a) heightened reactivity, exposure, and negative appraisals to signs of threat and negative emotion in the social world (Ormel et al., 2013; Shackman et al., 2016); (b) being exposed to more negative events (Jeronimus et al., 2013, 2014); (c) the tendency to appraise

objectively neutral or positive events in negative terms (Laceulle et al., 2015; Shackman et al., 2016); (d) mood spill-over, whereby negative feelings in one area of life spill over into others (Jeronimus, 2015); and (e) excessive rumination, worries, and intolerance of uncertainty, which propel feelings of sadness and anxiety and decrease feelings of cheerfulness (Bringmann et al., 2013; Hong & Cheung, 2015; Nolen-Hoeksema, 2000). High neuroticism and Anxiety/Depression are also marked by lower emotional granularity and clarity (Barrett, 2018; Carstensen et al., 2000; Luminet et al., 1999).

Next to the neurotic cascade, high neuroticism scores are also reflected in the way adolescents think and talk about themselves and construct their life narratives, as people vary in their emotional tone, themes, and complexity, which are fundamental aspects of our personality. High-neurotic people report more negatively toned biographical scenes, with more sadness and distress (but not more expressions of fear/anxiety), more negative inferences about themselves or others, more contamination sequences (i.e., good scenes that end poorly for them, which are associated with depression), less agency, and lower recall of specific positive memories (e.g., McAdams, 2015; Singer et al., 2013). Narrative identities subsume tasks, goals, projects, tactics, defences, values, and other developmental, motivational, and/or strategic concerns that contextualize individual lives in time, context, and social roles (McAdams, 2010, 2015). Such meaning-making processes are hallmark of the neuroticism system and treatment strategies (Hong & Cheung, 2015; Roberts et al., 2017) may influence how adolescents experience reality (Laceulle et al., 2015).

Dynamic perspectives

Personality traits like neuroticism are often understood as dynamic equilibria (i.e., "attractor basin" or "set-point") around which micro- and meso-level elements fluctuate in response to life experiences (Fleeson & Jajawickreme, 2015; Fleeson & Law, 2015; Jeronimus et al., 2013; Ormel et al., 2017). Also the attractor landscape itself changes under influence of experiences, as neuroticism and anxiety/depression basins often become less deep after we take on new social roles such as worker or parent (Bleidorn et al., 2013; Roberts et al., 2006; Mund et al., 2018), but deepen in response to stressful life events (especially social stress and conflict) that can be characterized as unpredictable, uncontrollable, unexpected, undesirable, and non-normative from a life history perspective (Jeronimus, 2015). The components of the dynamic system deviate from their balanced configuration (in level or contingencies) until the old or a new homeostatic equilibrium is found.

Rapid increases in the facets anxiety and depression after stressful experiences (in terms of weeks and months) can be followed by slower external adaptation processes in our personal environment (in terms of years and decades) after which the affect landscape gravitates slowly back to the levels to which one was accustomed, due to substitution in resources, identity, habits, social support and social interaction – although these processes can also propel feedback loops that prevent regression towards the previous equilibrium, after which the person stabilizes in a new attractor (Jeronimus, 2015, *p.*260; Ormel et al., 2017). These hypotheses about developmental processes can be tested in detail when both the individual and the changing context are frequently and persistently sampled, but to the best of my knowledge, such high resolution data is currently unavailable.

People are thought to function in a relatively fixed region of a potentially large behavioral space, in balance with their environment, resulting in stable personality states (Cramer et al., 2012, *p.*416; Ormel et al., 2017) based on a Pareto-optimal allocation of one's energy budget, when no additional internal or external change can be made without increasing the costs somewhere else (e.g., Jeronimus, 2015, *p.*256). However, continuous small changes in our environment require adaptations to maintain this Pareto balance, and such fluctuations play out at the micro level. Future studies may unravel the relationship between differences in neuroticism and Anxiety or Depression facets and processes underlying dynamic fluctuations at the individual level. Whether the variation is over days or years, it is important to comprehend what it means for a person to vary from him or herself, and what it means for persons to vary from one another (Adolfs et al., 2014; Breiman, 2011; Fisher et al., 2018; Mroczek et al., 2003; Rose, 2016).

Conclusion

Anxiety and depression emerge from dynamic interactions between various affective, cognitive, and behavioral elements, which synchronize as emotions (micro), moods (macro), and personality traits (meso). In terms of emotions, the dynamic systems perspective supported an understanding of anxiety and depression as constructions of the world (rather than reactions to it), and suggests that changes in emotion dynamics can serve as warning signals for the development of a mood disorder, which could be highly valuable for prevention strategies.

Although multiple studies support the existence of rapid transitions between normal and mood states, there is a dearth of literature that covers such transitions at the individual level.

Dynamic constructivist perspectives and evidence for connections between various anxiety and depression symptoms provided the field with a new explanation for the frequent co-occurrence of anxiety and depression states. Neuroticism was identified as a broad meso-level attractor basin that is stabilized via "the neurotic cascade" and describes our inner climate, which makes some adolescents more prone to experience negative emotions including anxiety and depression, and more vulnerable to develop anxiety and depression disorders. The young age of onset for most anxiety and depression problems suggest that it would be cost-effective to influence these meso-level processes *before* adolescents let symptoms of anxiety and/or depression cascade into other spheres of functioning and the attractor landscape "stabilizes."

Promising future avenues to improve our understanding of states of anxiety and depression include challenging studies that test various dynamic processes in single adolescents and examine changes therein over time. These studies ideally connect processes across multiple time scales, from real-time affective experiences, to the emergence of emotions and of emotion dysfunctions (which requires high-frequency sampling), and the development of symptoms of anxiety and depression and mood problems (which should be assessed in terms of weeks and months) and tendencies and personal narratives (in terms of years and decades). Only studies that capture all three levels (emotion, mood, personality) can illustrate how various emotion components synchronize and enable for the emergence of the macro and meso levels, which in turn influence and constrain the emotions and moods we experience – a circular causality that is the hallmark of the complex dynamic system that evolves within each of us.

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