A conceptual framework for the neurobiological study of resilience

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Abstract: The well-replicated observation that many people maintain mental health despite exposure to severe psychological or physical adversity has ignited interest in the mechanisms that protect against stress-related mental illness. Focusing on resilience rather than pathophysiology in many ways represents a paradigm shift in clinical-psychological and psychiatric research that has great potential for the development of new prevention and treatment strategies. More recently, research into resilience also arrived in the neurobiological community, posing nontrivial questions about ecological validity and translatability. Drawing on concepts and findings from transdiagnostic psychiatry, emotion research, and behavioral and cognitive neuroscience, we propose a unified theoretical framework for the neuroscientific study of general resilience mechanisms. The framework is applicable to both animal and human research and supports the design and interpretation of translational studies. The theory emphasizes the causal role of stimulus appraisal (evaluation) processes in the generation of emotional responses, including responses to potential stressors. On this basis, it posits that a positive (non-negative) appraisal style is the key mechanism that protects against the detrimental effects of stress and mediates the effects of other known resilience factors. Appraisal style is shaped by three classes of cognitive processes – positive situation classification, reappraisal, and interference inhibition – that can be investigated at the neural level. Prospects for the future development of resilience research are discussed.

Keywords: adaptation; allostasis; appraisal; aversion; coping; emotion; emotion regulation; interference; inhibition; mental health; motivation; PASTOR; prevention; reappraisal; recovery; resilience; stress; stressor; trauma

Recent data from epidemiological surveys in Europe show that approximately 30% of the population suffer from a mental disorder, such as anxiety, depression, chronic pain, or addiction, that can at least to some extent be traced back to the influence of exogenous or endogenous stressors such as traumatizing events, challenging life circumstances, or physical illness. Stress-related disorders in the broadest sense, meanwhile, contribute more to the total all-cause morbidity burden than does cardiovascular disease (Wittchen et al. 2011). The direct and indirect economic costs incurred by these conditions in Europe are estimated to be around €300 billion per year (Olesen et al. 2012). These figures are higher than in other regions of the world, yet not atypical for Western industrialized societies (Wittchen et al. 2011). The high incidence of stress-related disorders is puzzling given the historically unprecedented levels of physical health, wealth, and security these societies have achieved – and the accompanying massive reductions in threats to survival and bodily integrity. It is, therefore, fair to say that the promotion of mental health is probably one of the greatest challenges developed countries currently face, and that there is an urgent need to

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advance research on stress-related disorders. Such research must also address the question of why there has been so little progress in the field over recent decades, in particular with respect to the treatment of stress-related disorders.

Among the many obstacles that psychiatric research faces today is a diagnostic classification system that is categorical and based on signs and symptoms that often do not adequately reflect underlying neurobiological and behavioral dysfunctions (Craddock & Owen 2010; Kapur et al. 2012). For example, following *Diagnostic and Statistical Manual of Mental Disorders* (2013) a person is diagnosed with major depression if at least five out of a list of nine symptoms are present nearly every day during a period of two weeks or more. The list of symptoms contains, among others, depressed mood; loss of interest or pleasure; change in weight or appetite; loss of energy or fatigue; feelings of worthlessness or guilt; and suicidal ideation or attempt. Either depressed mood or loss of interest or pleasure must be present.

A consequence of this algorithm is that a person with only four of those nine symptoms will not be classified as depressed, even though his or her functional state may be very similar to that of an individual who meets just one criterion more. Another consequence that is particularly problematic for mechanistic research is that patient samples in studies comparing depressed subjects with healthy controls may be symptomatically highly heterogeneous, comprising, for instance, subjects whose major impairments are related to anhedonia and lethargy (e.g., loss of interest and pleasure, loss of appetite, fatigue or loss of energy) as well as other subjects who suffer mainly from sadness and hopelessness (e.g., showing predominantly depressed mood, feelings of worthlessness or guilt, and feeling pessimistic about the future). Hence, study results may vary extensively as a function of patient sample characteristics. Symptomatic heterogeneity is almost certainly accompanied by pathophysiological heterogeneity; that is, a diagnosis of major depression does not indicate a common underlying pathomechanism. Rather, it groups together patients who are depressed for a range of various reasons. This latter point in particular makes the classical comparison of patient to healthy control largely meaningless. Finally, most symptoms cannot be determined objectively, for example, based on a laboratory test; and cutoffs between normal and pathological symptom levels are arbitrary, introducing much further variability and uncertainty.

On this basis, it has been argued that the current categorical diagnostic system is unsuitable for mechanistic – and in particular, neurobiological – research in psychiatry (Craddock & Owen 2010; Kapur et al. 2012). One proposed solution is to abandon diagnosis-based studies and instead to focus on dimensions of neurobiology and observable behavior that can be investigated across conventional diagnostic boundaries and without the need for a healthy control group (Cuthbert & Insel 2013; Schumann et al. 2013).

We can expect such transdiagnostic studies to greatly improve our understanding of disease mechanisms and make important contributions to the identification of new treatment strategies. In this review, we begin by proposing that an approach that focuses on resilience rather than disease could be another way around the described problem and could have great potential for advancing translational neurobiological research and disease prevention. The transdiagnostic approach and the resilience approach are not mutually exclusive. Rather, we believe resilience research can benefit a lot from the integration of transdiagnostic thinking. The second proposal we would like to state at the beginning of this work, therefore, is that resilience research must be transdiagnostic to achieve its full potential.

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1. Investigating health, not disease: An ongoing paradigm shift

1.1. Resilience research

The term *resilience* refers to a well-described phenomenon: Many people do not become, or only temporarily become, mentally ill despite significant psychological or physical burdens (e.g., Bonanno & Mancini 2011; Feder et al. 2011; Sapienza & Masten 2011). Resilience thus viewed is an outcome, not a static property of the individual or a personality or character trait (Mancini & Bonanno 2009). A current tendency is to go even further and to see resilience as a dynamic process that may have a trajectory of undisturbed, stable mental health during and after a potentially traumatizing event or a prolonged period of adversity, or also consist of temporary disturbances followed by a relatively rapid, successful recovery (American

Psychological Association 2010; Kent et al. 2014; Mancini & Bonanno 2009; Norris et al. 2009; Sapienza & Masten 2011).

Resilience researchers are not interested in pathophysiology; instead of investigating the mechanisms that lead to stress-related illness, they investigate the mechanisms that prevent illness. The topic has become increasingly popular over the last 10 years and, though initially proposed by psychologists and clinicians (Werner 1993), has in the meantime even motivated neurobiological research in animal models (Feder et al. 2011; Franklin et al. 2012; Friedman et al. 2014; Liberzon & Knox 2012; Russo et al. 2012; Scharf & Schmidt 2012; Southwick & Charney 2012). Many resilience researchers make the basic assumption that resilience is not simply the result of an absence of disease processes but also reflects the work of active adaptation mechanisms that have a biological basis (Friedman et al. 2014; Russo et al. 2012). This development effectively constitutes a paradigm shift from disease- to health-oriented research in the fields of clinical psychology and psychiatry. The shift is not yet complete, however.

1.2. Resilience to dysfunctions, not to disorders

Much resilience research has been done in the context of particular diseases, such as post-traumatic stress disorder (PTSD), major depressive disorder, or addiction, focusing on why some people do not develop a particular disorder although they are subject to the same kind of adversities that cause the disorder in other people (for an overview, see Southwick & Charney 2012). Implicitly, this is based on the assumption that there are disorder-specific disease processes that are antagonized by specific protective processes. These types of studies remain rooted in a categorical way of thinking about psychiatric disease. If, however, current disease categories are unsuitable for mechanistic research, then it makes more sense to ask why someone does not develop a certain type of symptom or dysfunction (such as generalized anxiety, hypervigilance, lethargy, anhedonia, or impulsive behavior, for example). This also takes into account that symptoms and dysfunctions overlap between disorders, and that disorders are frequently comorbid. Hence, one element of exploiting the new transdiagnostic approach in resilience research would be to explicitly search for dysfunction-specific resilience mechanisms rather than for disorder-specific resilience mechanisms.

That approach is also more compliant with an evolutionary perspective. Evolution may have equipped us with mechanisms that assure the proper working of organismic functions such as defense, eating, or mating even when they are compromised by stressors. Hence, we may to some extent be protected against exaggerated and indiscriminate fears or against hypo- or hypermotivational states, but it is unlikely that evolution has had an interest in protecting us against PTSD or depression.

1.3. Resilience to many, not to single dysfunctions

The notion of dysfunction-specific resilience mechanisms leads to the interesting question of whether there may also be superordinate resilience mechanisms that protect from more than one dysfunction. The existence of such

general resilience mechanisms is not entirely improbable for two reasons. First, as mentioned, stress-related disorders are frequently comorbid, which implies that the different types of symptoms or dysfunctions that are typical for these disorders are not fully independent. One way to explain the (partly) correlated occurrence of stress symptoms is by the failure or breakdown of general resilience mechanisms, allowing stress to negatively affect various functional systems at the same time. For example, a failure to terminate the stressor-induced activation of the hypothalamus-pituitary-adrenal gland (HPA) axis when the stressor has subsided may lead to unnecessarily prolonged release of the stress hormone cortisol, which can result in long-term dysfunction of many parts of the brain and the body (De Kloet 2008; Holsboer & Ising 2010; McEwen & Stellar 1993; Popoli et al. 2012). Hence, mechanisms that support flexible HPA axis deactivation would be possible general resilience mechanisms.

The example of pathological cortisol effects points to the second reason why the concept of a general resilience mechanism has some theoretical appeal. Any stimulus or situation perceived by the organism as a threat to its integrity will induce an aversive motivational state and evoke a threat or stress response that will engage a wide range of nervous system and body functions in an orchestrated fashion. Observable components of the stress response may include coordinated changes in attention (e.g., vigilance or attentional focusing), cognition (e.g., threat appraisal as well as problem solving, planning, and other forms of cognitive coping efforts), subjective experience (e.g., feelings of nervousness, anxiety, or fear), and sympathetic system and HPA axis activity, with their associated peripheral physiological changes. Finally, stress responses often include overt behavior – that is, primary (defensive) or secondary (compensatory and recuperative) coping responses such as flight or fight, avoidance, impact preparation, support seeking, resource building, and so forth. (Lazarus & Folkman 1984; McEwen & Stellar 1993; Selye 1976; Sterling & Eyer 1988; Weiner 1992).

Hence, the stress response, by its very nature, is a multisystem response that necessarily comes with considerable costs for the involved systems in terms of energy consumption and processing priorities. Therefore, although primarily adaptive, stress responses can become deleterious if they are very intense, prolonged, or chronic – by exhausting internal, but also social or monetary resources and interfering with the pursuit of other important goals, as summarized in the concept of allostatic load (McEwen & Stellar 1993). As a consequence, any mechanism that helps the organism fine-tune stress responses to optimal levels, to terminate them if no longer necessary, and to remain flexible enough to switch to possible alternative coping strategies, thereby facilitating efficient deployment of resources, is likely to protect all or most of the systems involved in the stress response and therefore to prevent a large range of stress-related dysfunctions.

If humans possess general resilience mechanisms, that has important consequences for resilience research. Because strengthening superordinate resilience mechanisms is likely to be a more efficient prevention strategy than strengthening dysfunction-specific resilience mechanisms, resilience research would be well-advised to *focus on the identification and understanding of general resilience mechanisms*.

The distinction between general and dysfunction-specific resilience mechanisms may become clearer when we consider another facet of allostatic load. Every stress response is accompanied by plastic adaptations in the involved systems that serve to facilitate future dealing with identical or similar stressors (McEwen & Stellar 1993). Take the example of an employee suffering from high performance pressure, whose primary (adaptive) stress response involves fear of failure and correspondingly increased efforts at work. In case working harder is eventually met by success, the employee's fear will subside and his behavior will be instrumentally reinforced, increasing the likelihood that he will also respond to future challenges with a similar coping strategy. The employee may also feel more competent than before. In psychological terms, he will enjoy higher perceived "self-efficacy" (Bandura 1977). A different learning experience will occur in case of failure despite repeated efforts. A combination of classical Pavlovian and instrumental mechanisms will lead to dislike for the job, decreased efforts or even avoidance of work, and diminished job-related self-efficacy perceptions. Like the positive reinforcement of working harder in the first case, the negative reinforcement of working and the consequent behavioral adaptations that take place in the second case can be considered helpful because they prevent pointless perseverance and exhaustion (Schwager & Rothermund 2014b). They are, however, helpful only as long as they motivate the employee's search for alternative coping strategies, such as reducing ambitions and redefining work objectives or looking for another job.

Such a flexible, positive approach to a severe social threat, however, requires to not be overwhelmed by it and to not extend aversion and reduced self-efficacy perceptions to work life generally or even to any kind of challenging situation. In other words, the organism needs to limit the aversive state evoked by the stressor to necessary levels; and plastic, allostatic adaptations have to be restricted to generating aversive memories about specific events and actions. Inability to optimally regulate stress responses via general resilience mechanisms might result in feelings of helplessness and a generalized amotivational, lethargic state.

The further disease process might involve secondary dysfunctions such as social withdrawal, despair and suicidal tendencies, aggression, and alcohol abuse. The development of a particular secondary dysfunction may be promoted by situation-dependent risk factors or individual predispositions and prevented by specific protective circumstances or the activation of dysfunction-specific individual resilience mechanisms. For example, alcohol abuse might be prevented by religious beliefs or strong impulse control. None of these secondary dysfunctions will, however, occur if the initial aversion evoked by the experience of failure and the accompanying aversive learning processes have been well tuned in the first place. Hence, people who react to social stressors with optimized aversion are likely to be protected from many types of possible dysfunctions, even if any particular dysfunction-specific protective mechanism may not be very effective in a given person (e.g., if he or she has poor impulse control).

From this analysis it follows that the definition of general resilience mechanisms as protecting from various dysfunctions implies that they work by optimizing stressor-induced aversion. A question addressed further below is whether there may be general resilience mechanisms that deal not only with certain, but with many or all types of stressors (e.g., social as well as physical stressors). We coin these hypothetical mechanisms *global resilience mechanisms*.

To give an overview, we differentiate between

dysfunction-specific resilience mechanisms (protecting against a single stress-induced functional impairment or symptom);

general resilience mechanisms (protecting against several stress-induced functional impairments or symptoms); and

global resilience mechanisms (protecting against several functional impairments or symptoms, induced by exaggerated stress responses to a large range of different stressors).

The example of the stressed employee also shows that the specific pattern of dysfunctions occurring in an individual person when general resilience mechanisms collapse may strongly depend on specific circumstances and personal factors, the latter being shaped by genetic or epigenetic background, learning history, and so forth. One person may show suicidal tendencies, another aggression, another alcohol abuse, and yet another a combination of these. Hence, if resilience research wants to investigate general resilience mechanisms, it should not focus on resilience to any specific dysfunction, as such studies might reveal only dysfunction-specific resilience mechanisms. Rather, outcome measures should test for a wide range of dysfunctions, and they should assess the individual's global or average burden from several dysfunctions, rather than looking at a specific pattern of dysfunctions (i.e., a disorder).

1.4. Resilience to quantitative, not to categorical deterioration

So far, we have incorporated transdiagnostic thinking by proposing that resilience research should focus on dysfunctions rather than on disorders. Pursuing this argument has led us to the further-reaching conclusion that resilience research should focus not on any specific dysfunction or pattern of dysfunctions but on global or average dysfunction. Proponents of the transdiagnostic approach also emphasize that symptoms or dysfunctions do not occur in a binary fashion (Craddock & Owen 2010; Kapur et al. 2012). One is not either lethargic or not. Moreover, as said, the threshold at which the intensity of a dysfunction is considered pathological is essentially arbitrary.

A further element in completing the paradigm shift away from conventional disease-focused and toward health-focused research would then be to measure dysfunctions quantitatively and to use *quantitative – ideally continuous – outcome variables*. Combined with the above suggestions, this leads to a strategy that consists of adding up or averaging quantitative scores on several functional dimensions in order to derive something like an individual *global mental health score*. An example of such an approach can be found in the general health questionnaire (GHQ), which has been used to agglomerate symptoms of somatic irritation, anxiety, social dysfunction, and despair in a single

quantitative outcome variable (Goldberg & Hillier 1979), or also in the adult self report (ASR; Achenbach & Rescorla 2003), which additionally includes externalizing behaviors. One big advantage quantitative outcome variables have over categorical measures is that changes in these variables between measurement time points (e.g., from before to after stressor exposure or treatment) can be quantitatively analyzed, even if a change does not involve passing from one side of an arbitrary cutoff to the other. We only mention here that it would be desirable eventually to replace self- or other-report–based measures such as the GHQ or the ASR with measures based on objective physiological or behavioral parameters.

To conclude this introductory discussion, the currently ongoing paradigm shift from disease to resilience research provides an opportunity to change clinical focus from correcting specific pathophysiological processes to fostering general protective mechanisms. As well as bringing new ideas into therapy research, this would also facilitate the development of new and better prevention strategies. Prevention is of particular interest; intervening before the negative consequences of stress occur is likely to be more effective in reducing human suffering and economic costs than is treating the consequences (Sapienza & Masten 2011). Reaching these goals might be facilitated by integrating new transdiagnostic thinking through the use of quantitative average mental health scores. For neurobiologists, and especially for those using animal models, an important implication of this change in perspective is that it is no longer necessary to model a particular disease or syndrome ("Are my mice depressed?"); rather, researchers can ask the much simpler and more easily objectifiable question of whether their animals survive a stressor without strong and lasting functional impairments in a range of meaningful behavioral assays. Hence, although challenging, the intellectual adventure to rethink how clinical research addresses stress and its consequences from the vantage point of resilience could open up interesting avenues to new insights.

2. Definitions and scope

Before elaborating on these general ideas and exploring whether it is possible to develop a unified conceptual framework for transdiagnostic resilience research that aims at identifying and understanding general resilience mechanisms, it is useful to define the key terms used in this paper, as well as its scope.

Resilience as we understand it is an empirically observable phenomenon, namely that someone does not develop lasting mental health problems although he or she is subject to adversity. *Adversity* is understood in the broadest sense and may include short-term (*acute*) or long-term (*chronic*), social or physical stressors. For the sake of brevity, we take the term *mental health problems* also to embrace stress-related somatic problems. Thus, resilience is an outcome or, if mental health is measured at more than one time point, a series of outcomes – that is, a process. As briefly alluded to before, individuals with certain traits may be more likely to have positive outcomes (e.g., Miller & Harrington 2011), but this relationship is not deterministic (i.e., it is impossible to predict with certainty that someone with a "hardy" or "positive" personality will

not be affected by a stressor). Therefore, resilience-conducive traits are not to be confounded with resilience as an outcome (Mancini & Bonanno 2009).

As also mentioned earlier, several researchers have described various temporal profiles of outcomes, and proposed to give them different labels. So, Bonanno refers to stable functioning throughout the process as "resilience," to temporary dysfunction followed by return to previous levels as "recovery," and to persistent dysfunction as "chronic distress" (for more detailed discussions, see Bonanno et al. 2011; Norris et al. 2009). For reasons we discuss in section 5.2, we do not make this distinction, and here use the term *resilience* for any trajectory that eventually leads to levels of functioning that are comparable to or even better than at the outset.

The definition of resilience as an outcome or process also differentiates resilience from *resilience factors*; that is, empirically derived variables that statistically predict a resilient outcome. Resilience-conducive traits, for instance, would have to be classified in our terminology as resilience factors. Resilience must also be differentiated from any mechanism by which a positive outcome is achieved (*resilience mechanism*). For example, it might be that someone with a resilience-conducive personality (resilience factor) is more likely to have a positive outcome because her personality predisposes her to cope with stressors in a proactive way (e.g., by focusing on effectively removing the stressors). Such a person would ultimately be less exposed to stressors, and therefore would not develop mental problems. Proactive coping would therefore be the resilience mechanism in this example.

The example also illustrates the way we distinguish resilience and *stress coping* in this paper. Although in general language, *coping* is often equated with success in dealing with a challenge (i.e., with a positive outcome), we here exclusively use it for the cognitive and behavioral efforts produced to deal with the challenge, whether successful or not (Lazarus & Folkman 1984). Thus, coping is an inherent aspect of the stress response (see also sect. 1.3).

We have begun this paper by emphasizing the need to act against stress-related mental illness, and therefore limit the scope of our discussion to resilience to dysfunctions as they typically occur in the context of these disorders. We thus exclude resilience to dysfunctions that do not have a clear stress-related etiology, such as age-related memory impairments or the positive symptoms of schizophrenia. This focus of course requires a definition of stress. In section 1.3, we provided a phenomenological definition of *stress* or *stress responses* as orchestrated multisystem reactions to threat. Insofar as *emotions* or *emotional reactions* are phenomenologically defined as orchestrated multisystem reactions to motivationally relevant stimuli or situations (Moors 2009), stress responses are particular types of emotional responses.

Functionally, the role of emotions is to prospectively assure survival and reproduction when there is a significant change in external or internal conditions that cannot be answered by reflexes or habits, that is, by simpler and more rigid types of behavior (Scherer 2001). Globally, emotions can be subdivided into *aversive* (negative) and *appetitive* (positive) reactions, depending on whether their immediate objective is to avoid, remove, or minimize a threat or to obtain a reward, respectively (Dickinson & Pearce 1977;

Gray 1976; Konorski 1967; Mowrer 1960). The aversive-appetitive subdivision is therefore a motivational one; phenomenologically, aversively and appetitively motivated reactions may not always be easily distinguishable. For example, an animal may remain immobile so as not to attract the attention of a predator – or of prey. Also, a similar motivational state may be expressed as different patterns of physiological activation and coping behavior. For example, aversion to a predator may result in the prey's immobility or escape or fight. Nevertheless, certain physiological (e.g., HPA axis activation), behavioral (e.g., facial expression), or, in humans, subjective-experiential criteria (e.g., self-reported valence of feelings, intentions) can be used as relatively good discriminative markers of aversive versus appetitive motivation. On this basis, we classify stress as an "aversive" or "negative" emotional response and will often use these terms as well as *threat response* or *fear response* interchangeably. We will also interchangeably speak of *stressors* or *threats* or of *stimuli* or *situations* that evoke aversive or negative emotional responses.

The root cause of stress, then, is aversive motivation, and the most effective way to prevent stress and stress-related dysfunctions is to limit aversion. This is why in section 1.3 we equated general resilience mechanisms with mechanisms that flexibly adjust aversive motivation to appropriate levels. Emotion regulation mechanisms that act primarily on the behavioral expression of aversion – for example, promoting the suppression of behavioral impulses (cf. expressive suppression [Gross 1998] or impulse control [Bari & Robbins 2013]) – cannot be expected to have comparably generalized protective effects. The same can be assumed for the isolated regulation of any other stress response component, be it the temporary reduction of negative thoughts and feelings through distraction (Gross 1998) or the automatic regulation of physiological (autonomic, hormonal) activation through negative feedback mechanisms (Holsboer & Ising 2010). Successful optimization of aversion, on the other hand, will facilitate behavioral optimization (see the example of the stressed employee in sect. 1.3 whose generalized aversive state makes it impossible for him to look for alternative solutions) and also will result in appropriate adjustments of other response components. The critical question, then, is what determines aversion. We will address this question in section 4, where we attempt to develop a theory of resilience.

Finally, we have briefly mentioned that resilience researchers often emphasize the role of *active processes* or *mechanisms* that support resilience (Russo et al. 2012). *Active* as we understand the term does not necessarily refer to behavioral activity but refers to any resource-demanding process, and may therefore also apply to cognitive processes. The emphasis on active processes is important for resilience research as it further demarcates the discipline from pathophysiological research. Not falling mentally ill is not a passive process, nor the result of not being subject to some stressor or pathological agent or endogenous degenerative process, or of not carrying some molecular abnormality that makes someone else susceptible to a stressor (Russo et al. 2012). Instead, the maintenance or quick recovery of mental health results from processes that shape the organism's stress responses in a way that permits long-term functioning. By describing active resilience mechanisms, resilience research addresses questions that are not in the focus of

pathophysiological research, thus making an original contribution to clinical science.

3. Identifying resilience factors

3.1. Transdiagnostic quantitative study designs in humans

Having explained the key concepts and the most fundamental assumptions on which we base our theory development, we would like to introduce a more practical aspect by asking what a resilience study in humans would look like, and in what way a transdiagnostic quantitative design would differ from the more conventional designs still widely used in resilience studies. (For excellent overviews of the current state of the art, see Kent et al. 2014; Southwick et al. 2011a.) A conventional longitudinal resilience study might involve a mental health characterization at some time point T1 before the likely occurrence of major adversity (e.g., before entering a risky professional career track or beginning a major phase of life transition such as from adolescence to adulthood), focusing on a disorder or a closely related set of disorders that typically develop in such circumstances. Adversity occurring between T1 and the end point T2 is somehow assessed (usually by retrospective self- or other-report), and the T2 mental health characterization usually boils down to an outcome measure of the type *PTSD or not*?

Instead of employing a diagnosis-based binary metric, a transdiagnostic design could base outcome on a quantitative tool such as the GHQ or the ASR (see sect. 1.4) or others to obtain a global sum score of mental burden across various dysfunctions. Mental problems P at T1 and T2 can therefore be expressed in sum scores ΣP_{T1} and ΣP_{T2}, and the outcome would be the change in mental problems from T1 to T2:

$$\Delta \Sigma P = \Sigma P_{T2} - \Sigma P_{T1}$$

where a positive sign of the outcome variable signifies an increase in mental problems. Where T1 data are not available, as is often the case in trauma research, ΣP_{T2} would be the outcome.

Similarly, one could attempt to express an individual's cumulative stressor load between T1 and T2 through a quantitative sum score ΣS. The basic assumption of general resilience mechanisms that are not dysfunction specific (see sect. 1.3) would then permit us to argue that someone is the more resilient at T2 the less that person develops mental problems between T1 and T2 (the smaller $\Delta \Sigma P$), in proportion to the stressor load accumulated between T1 and T2 (ΣS). Normalization of outcome by stressor load is essential, as it pertains to a central question in resilience research, which is why people differ in their long-term responses to stressors. Comparisons of health outcomes between people who have experienced different stressor load would be meaningless without normalization. Especially for illustrative purposes, it might therefore be useful in some cases to express this relationship between mental problems and stressor load in a quantitative outcome quotient[1]:

$$R_{T2} = 1/(\Delta \Sigma P / \Sigma S) = \Sigma S / \Delta \Sigma P$$

See Figure 1 for illustration.

Measures

T1 T2

T2 outcome

ΔΣP (problems) R (resilience)

mental problems

ΣP_{T1} → ΣP_{T2}

ΣP_{T1} → ΣP_{T2}

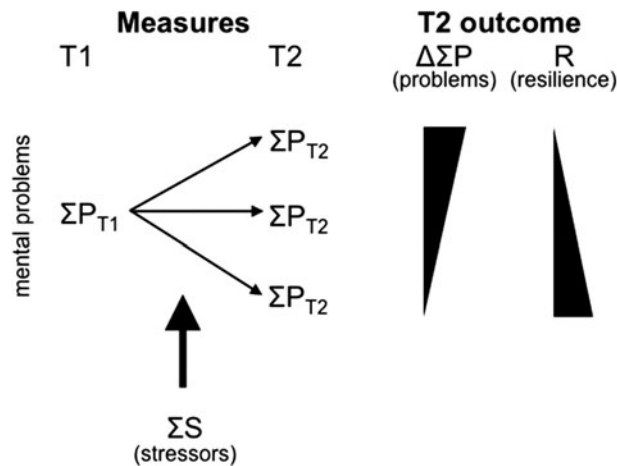ΣP_{T1} → ΣP_{T2}

ΣS (stressors)

Figure 1. Transdiagnostic quantification of resilience. Resilience (R) is calculated as the ratio of changes in summed mental problem burden ΣP between time points T1 and T2 (ΔΣP) and the summed stressor load ΣS accumulated between T1 and T2. Three potential trajectories (of ΣP) are shown.

3.2. Identification of resilience factors

Resilience is thus operationalized as a *quantitative outcome variable* (inverse of ΔΣP, or, if advantageous, R) that is ideally continuous in nature and can be used, for instance, to ask whether independent variables measured at T1 predict resilience at T2. In our terminology, this would be resilience factors (see sect. 2). So, one could calculate the degree to which variance in R_{T2} in the study sample is explained by, for example, a T1 measure of executive functions, a particular genotype combination, or some measure of social integration before or at the time of first adversity.

Provided measures are repeated, one could also correlate changes in some variable of interest taken at both T1 and T2 with R_{T2} (cf. Benight & Cieslak 2011). If, for example, an increase in executive performance co-varied with R_{T2}, this would support a relationship between resilience and executive functions. Several prototypical scenarios are conceivable: (1) T1 executive performance predicts R_{T2} but does not change over time, suggesting executive performance is a relatively stable individual property or resource that protects from stress-related mental illness; (2) T1 executive performance predicts R_{T2} and executive performance increases from T1 to T2 in a way that correlates with R_{T2}, suggesting executive performance is a malleable protective resource that is trained by use; (3) T1 executive performance does not predict R_{T2}, but an increase in executive performance from T1 to T2 correlates with R_{T2}, suggesting that executive functions really improve only during times of adversity.

3.3. Advantages of transdiagnostic quantitative analysis

The practical advantage of using a quantitative outcome variable for the identification of resilience factors is twofold: First, in cases where dichotomization of the outcome variable is difficult and sometimes arbitrary (*PTSD or not?*), a quantitative variable preserves the inherent variance of the data and therefore permits a much more sensitive analysis; second, in samples where only few

subjects fall into the disease category (only few develop PTSD, whereas many others perhaps show subdiagnostic problems that may still significantly affect quality of life, social integration, and professional performance), statistical analysis is still feasible because this subdiagnostic variance is retained. Hence, an operationalization of resilience as a transdiagnostic, quantitative outcome variable not only circumvents the conceptual problems of diagnosis-based research but also provides more power for statistical analysis.

3.4. Quantification of stressor load

The accurate quantification of stressor load in the earlier equation is of clear importance for a successful quantitative analysis of resilience in the way we advocate it, and it therefore deserves some discussion. In particular, it is not self-evident why stressor load should be expressed in a cumulative sum score ΣS and how this can be done practically. For example, in trauma research, the relevant stressor is often a single dramatic event, and one may be inclined to express stressor load in a simple binary variable (0 or 1). Interindividual differences in ΣP_{T2} within the traumatized group would then essentially not be qualified by ΣS, which is 1 in every subject. Stressor exposure will, however, not be identical for all victims in a study. For example, the individual impact of a terror attack, a technological disaster, or a natural disaster may vary with respect to the amount of physical damage caused to the victim, to the extent to which friends or family are involved, to the proximity of the event to one's work or living place, or to whether one witnesses other people being harmed (Galea & Maxwell 2009). That is, there are several stressor dimensions, some being more physical in nature, some social, and on closer inspection, each of them is rather non-binary.

There is another complication. The treatment of a potentially traumatizing event as an isolated, acute stressor is to some extent artificial; any major event will have long-lasting consequences to both the person and the person's environment (Norris & Elrod 2006). Injury during a terror attack may cause chronic physical impairments that constitute stressors in their own right, and the death of a relative may negatively affect social networks or finances. These sequelae of trauma will occur differently in different people, introducing variance that needs to be taken into account when quantifying resilience.

Both complications may be less problematic in life-event research, where subjects usually retrospectively indicate the occurrence of items from a list of potential significant types of events (death of a family member, loss of employment, traffic accident, etc.), and researchers typically sum up the number of adverse events, sometimes weighted by a rating of an event's aversiveness or by the age at which it occurred, to obtain ΣS (Caspi et al. 1996). The underlying assumption here is that interindividual differences in the quality of, or in the exposure to, an event and in the sequelae of events are averaged out when considering a large number of potential event classes, making the sheer number of experienced events a reasonably accurate index of stressor load. This already points to a solution for the problem. It will always be practically impossible to accurately quantify each single stressor or stressor dimension; but by extending stressor monitoring to a wide range of potential stressors that are summed up or averaged, many

smaller interindividual differences in stressor quality, stressor exposure, and stressor consequences, can be ignored.

In addition to major life events, even minor events (the so-called "daily hassles" such as relationship or work conflicts, financial problems, noise, traffic, or housing problems; Hahn & Smith 1999) can have profound effects on mental health when frequent and accumulated over longer intervals (Serido et al. 2004). This implies that stressor monitoring in any longitudinal resilience study should extend beyond the monitoring of major events. Faced with this challenge, many chronic stress researchers have resorted to deliberately assessing broad categories of stress experiences (e.g., social stress from private life or work life; Petrowski et al. 2012), rather than asking about specific stressors or stress situations, thereby, however, giving up the differentiation between stressors and stress. We would therefore favor extended life calendar–like inventories that also include more mundane events as well as chronic stressors. Monitoring less remarkable events requires closely spaced monitoring intervals. Self-report could be complemented by data from other records, where possible (e.g., when studying the effects of physical illness or flight noise or commuting). Stressor reporting will be increasingly facilitated and made more precise by the development of ambulatory methods (ecological momentary assessments; Kubiak & Stone 2012).

A final complication is that one cannot assume that different types of stressors will affect mental health in the same way, and that general resilience mechanisms as defined in section 1.3 will also be global; that is, protect from the effects of any type of stressor. As said, it may well be that the organism regulates aversion to, for instance, minor versus major (e.g., daily hassles vs. trauma) or physical versus social stressors (e.g., pain vs. social exclusion) differently. Even this classification may be too broad, and one may have to make a differentiation between, for instance, different classes of physical stressors (pain, noise, handicap, etc.). This would require choosing study cohorts who are confronted with single classes of stressors only or, where this is unrealistic, such as when looking at the consequences of massive trauma, generating separate scores for single classes of stressors represented in the cohort. These could then be related to outcome $\Delta\Sigma P$ or ΣP_{T2}, and further analyses could be restricted to those scores that show a strong relationship to the outcome. We will come back to this issue in section 4.2.8.

3.5. State of research and current challenges

What resilience factors have been detected to date? Current reviews cite long lists of factors that are presumably causal for resilience. Beyond the extent and quality of the stressors, these include external factors, such as social support or socioeconomic status, as well as internal or personality factors, such as certain character traits, coping style, age, sex, ethnicity, (epi)genetics, spirituality, life history, cognitive abilities, brain function, hormonal factors, and so forth, often complemented by their interactions (e.g., Feder et al. 2011; Mancini & Bonanno 2009; Sapienza & Masten 2011; Stewart & Yuen 2011). These lists are cumbersome, and it has been pointed out that many of these factors overlap conceptually and presumably mediate or otherwise depend on one another (Stewart & Yuen 2011). For instance, it is well conceivable that life

history shapes a character and thereby affects resilience, or that cognitive abilities and brain function are intricately linked and therefore exert nonindependent effects.

4. Identifying resilience mechanisms

4.1. Factor-mechanism distinction

A deeper, conceptual problem in this research, which likely contributes to the plethora of seemingly unrelated findings, becomes apparent when one starts to make a *distinction between resilience factors and resilience mechanisms* (see sect. 2). There may be many different factors that each partly determine whether someone will be resilient, but there are probably fewer paths from determinant to effect than there are determinants. In other words, it is reasonable to assume that there are far fewer distinct psychological or biological resilience mechanisms (M_x in Fig. 2) through which any given determinant (i.e., predictor or resilience factor, F) can act. The challenge is therefore to identify the few general paths or shared mechanisms that make someone more or less resilient (Mancini & Bonanno 2009) (see Fig. 2). The closer a mechanism is to directly affecting the cause of stress-related dysfunctions, the more determinants it will mediate. This is where mechanistic psychobiological research, including in animal models, becomes highly relevant for resilience research.

4.2. A mechanistic theory

Identifying factors requires much exploratory research; identifying a mechanism requires a theory of how a factor leads to an outcome. In the following, we will introduce a
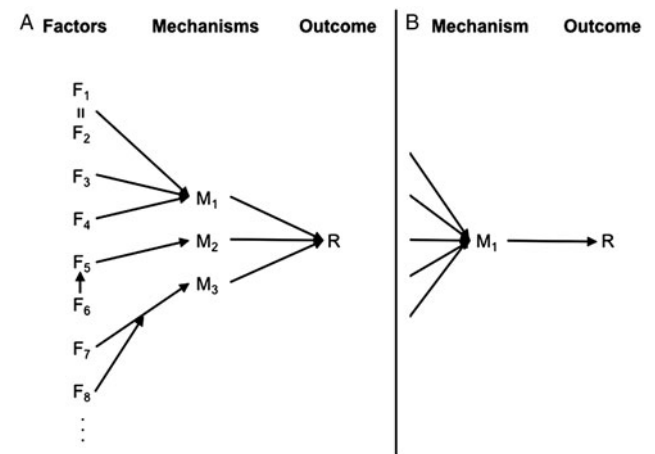

Figure 2. Factor-mechanism distinction. (A) Resilience research has identified many factors (F_x) such as social support, social status, personality, life history, coping style, genetic background, brain function, etc., that partially determine resilient outcome R. But these factors frequently overlap conceptually (F_1 may be similar or identical to F_2, F_1 to F_4 may converge onto a common end-path) and may interact statistically (F_5 may mediate the effects of F_6, F_8 may moderate the effects of F_7). It is postulated that a limited set of shared psychological or biological mechanisms (M_x) ultimately mediate the effects of these factors. (B) A radical possibility that is explored in this paper is that there is a single mediating mechanism M_1 that constitutes the common end-path to resilience.

theoretical framework that is based on the idea of general resilience mechanisms that can protect against a wider range of stress-related dysfunctions rather than being restricted to protecting single systems or functions. We believe this is a good starting point because mechanisms that can prevent many dysfunctions simultaneously are likely to be closer to the cause of stress-related impairment than are mechanisms that can prevent only a specific dysfunction. Strong impulse control in the example of the stressed employee in section 1.3 might protect against habitual drinking, but it cannot abolish the exaggerated stress response to failure and might be useless against social withdrawal or despair. By contrast, successful limitation of the aversion to failure that motivates the stress response in the first place will protect against many dysfunctions at a time.

Our theory is sufficiently broad to be applicable to resilience research in both animals and humans, therefore, we hope, facilitating translational mechanistic investigation. As the theory posits that a positive appraisal style is the key resilience mechanism, we refer to it as *positive appraisal style theory of resilience*, or PASTOR.

4.2.1. Claim 1: Appraisal. We propose that all resilience factors F_x identified so far converge, directly or indirectly, to a *common final path*; that is, there is *a proximal cause for mental health* in the domain of stress-related dysfunction. This common final path (corresponding to a single mechanism M_1, as in the general terminology used in Fig. 2B) is *the way an individual evaluates (appraises, interprets, analyzes) potentially threatening stimuli or situations* in terms of their meaning for the functioning of the organism (PASTOR claim 1).

This claim is rooted in appraisal theory, which holds that the type, quality, and extent of emotional reactions (including stress reactions) are determined not by simple, fixed stimulus-response relationships but by the context-dependent evaluation of the motivational relevance of a stimulus or situation (Arnold 1969; Frijda 1993; Lazarus & Folkman 1984; Roseman & Smith 2001; Scherer 2001) (Fig. 3). The outcome of this evaluation determines both the degree of aversive or appetitive motivation toward a stimulus and the specific behavioral reaction that is chosen to reach the aversive or appetitive goal (Lazarus & Folkman 1984). To achieve the contextually appropriate outcome, the appraisal process integrates different types of internal and external information, or stimulus and situation dimensions. These appraisal dimensions range from basic ones such as stimulus intensity, novelty, or intrinsic (un)pleasantness; to more computationally demanding ones such as outcome probability, (un)predictability, or compatibility with one's goals and needs; up to complex dimensions such as causation (e.g., agency), relation to coping potential (resources, power, control), or norm compatibility (Scherer 2001). As a result, one and the same stimulus may evoke different emotional reactions in different circumstances or individuals (e.g., because goals or coping potential differ).

In this framework, an individual's stress or threat reaction results from the analysis that a significantly unpleasant or goal- or need-incompatible outcome is to be expected with some probability and that he or she may not be able to prepare for or deal with this outcome (Lazarus & Folkman 1984). Stress is therefore mainly determined by estimations of outcome magnitude (unpleasantness, goal or need incompatibility), outcome probability, and coping potential. The employee will feel the more performance pressure, and thus work the harder, the more aversive the consequence of failure would be to him (outcome magnitude; e.g., criticism, salary cut, job loss) and the more he believes he might fail (outcome probability). Both estimates strongly depend on estimated coping potential. For example, outcome magnitude appraisals may be affected by perceived control or resources ("Have I saved enough money?" or "Do I have enough family support to survive a salary cut or temporary unemployment?") or self-efficacy and power ("Am I qualified enough to easily find another job?"). Self-efficacy perceptions may also affect outcome probability appraisals ("Can I manage the job?").

If further considering that outcome magnitude depends on the importance one attributes to a threatened goal or need (e.g., "To what extent do I need the positive affirmation that a job or a high salary provides me with?"), it becomes evident that even a seemingly basic and simple emotion such as stress or fear is the result of a complex interplay of different appraisals along different appraisal dimensions, especially where the stressor is social in nature. The resulting intraindividual (context-dependent) and interindividual (person-dependent) variability in emotional reactions to similar stimuli or situations is further accentuated by the inherent subjectivity of most appraisals. Where the consequences or the probability of an aversive outcome can only be estimated, interindividual differences in how people assign values to appraisal dimensions become important in determining the stress response. An extreme example is the tendency of some people to catastrophize about normal internal perceptions of bodily arousal in a physically challenging situation (a pounding heart, sweaty hands) and to overinterpret them as signifying a potentially lethal threat. This can lead such a person into a vicious cycle of fear and appraisal that eventually results in panic attacks (Beck et al. 1985; Reiss & McNally 1985). Another example is the documented individual differences in the use of positive reappraisal strategies that allow a person to see a negative situation from a different, more benign angle, resulting in less fear (Gross 1998; Lazarus & Folkman 1984).

Hence, appraisal is multidimensional, context-dependent, and subjective. Another important point is that the basic definition of appraisal is a purely functional one: To get from a stimulus or situation to an emotional response takes appraisal; and by taking into account the various stimulus or situation dimensions (by assigning different values to different dimensions), appraisal produces differentiable emotional responses (Moors 2009). This definition does not suggest what cognitive or neural processes could be

Stimulus/Situation → Mental representation → Appraisal → Emotional response

Figure 3. Appraisal theory. Emotional reactions to any stimulus or situation are determined by the appraisal process.

involved in appraisal. In fact, there is considerable debate about the information processing mechanisms (e.g., associative vs. rule based) that underlie appraisal and about what format of representation they work on (e.g., perceptual vs. propositional) (Moors 2009). Neurobiological investigations of appraisal processes are still at relatively initial stages (Kalisch & Gerlicher 2014; Sander et al. 2005).

Nevertheless, most appraisal researchers agree that appraisal involves not only a single process but probably multiple cognitive operations occurring in parallel or serially. Most researchers would also agree that some appraisal processes can be relatively quick, automatic, and unconscious, such as in many conditioned reactions, or also slow, controlled, and conscious, especially where judgments are difficult and complex (Leventhal & Scherer 1987; Robinson 1998). (It is worth pointing out that it is a common misunderstanding that appraisal theory deals only with conscious or higher-order processes or with processes that may only be available to humans; Moors 2010). Finally, appraisal is dynamic and interactive, owing to the need to continuously integrate new incoming information (including about one's own current emotional state) and to continuously adjust appraisal outcomes, leading to online changes in emotional reactions (Scherer 2001). Therefore, in addition to being multidimensional, context-dependent, and subjective, appraisal is procedurally heterogeneous and dynamic. And, of course, appraisal processes are thought to have a biological basis.

4.2.2. Appraisal styles. Why should appraisal theory be relevant to both clinical and animal researchers? In the clinical field, many etiological theories of stress-related disorders have made explicit or implicit reference to appraisal concepts by proposing that the cause of these disorders is intense and prolonged stress reactions, which in turn result as much from a patient's typical ways of appraising potentially aversive situations as they result from the presence of these situations (e.g., Beck & Clark 1988; Clark & Beck 2010; Foa et al. 1996; Gotlib & Joormann 2010; Korn et al. 2014; Mathews & MacLeod 2005; Reiss et al. 1986; Seligman 1972).

The underlying idea is that an individual usually interprets similar situations in a similar fashion, and therefore can be characterized by his or her individual appraisal style or typical appraisal tendencies. These appraisal styles – partly overlapping terms often found in the literature are *beliefs, appraisal habits, cognitive styles, attitudes,* or *interpretive biases* – may be more or less negative. In the case of a patient suffering from a stress-related disorder, the individual appraisal style is overly negative, and thereby frequently produces strong aversive states. For example, the patient might consistently overestimate the aversive consequences of challenging situations (*outcome magnitude* dimension) or the probability of such aversive consequences (*outcome probability* dimension), or both; he may also consistently underestimate his ability to cope (*coping* dimension).

Depending on which type of negative appraisal dominates in the patient, the exact nature of the aversive responses he typically produces may vary. So, a pessimist who mainly overestimates outcome probabilities may act with preemptory aggression in many harmless situations, whereas a person with low perceived self-efficacy (low coping potential) may remain passive even when harm is

likely and could easily be avoided by active coping. Nevertheless, all responses will be fueled by aversive motivation (cf. sect. 2) and will produce undesirable allostatic costs (cf. sect. 1.3), which justifies to subsume different negative appraisal patterns under an umbrella term of "negative" appraisal style.

The counterpart – a non-negative, or (for simplicity) "positive" – appraisal style would be characterized by the absence of such consistently negative evaluations on all three of the described appraisal dimensions, or alternatively, in consistently very positive evaluations on one or two dimensions that outweigh consistently negative evaluations on the other dimension(s). The latter might be the case, for instance, when a person tends to see threats in many places (negative outcome probability estimates) but feels strong enough to deal with whatever happens (positive coping potential estimates). The result of a positive appraisal style is a low frequency of strong aversive states.

An appraisal style does not mean that an individual will produce the same emotional response in every potentially challenging situation. Individuals may also have specific experiences or beliefs associated with specific situations, and those may result in atypical evaluations and responses, including occasional positive appraisals or reactions in otherwise negative appraisers or vice versa. But what counts for mental health, especially if people are confronted with variable and diverse stressors over longer time periods, is the typical way in which they react to challenge. If a person has a tendency to see things negatively, she will more frequently be in a negative emotional state, and therefore more likely to develop stress-related dysfunctions.

Also, our definition of appraisal style does not imply that appraisal styles are invariable and fixed over the course of a lifetime (Benight & Cieslak 2011; Troy & Mauss 2011). Although appraisal styles may well have a hereditary component, it is unquestionable that the appraisal of a specific situation or a whole class of situations can change. An obvious example where appraisals are modified by experience is that of traumatic conditioning, where trauma-associated stimuli and often also perceptually similar stimuli and entire contexts can dramatically change in value. A more positive example is cognitive-therapeutic intervention, where appraisal values are changed deliberately through a combination of experience and instruction in order to improve the patient's emotional behavior. The changes in self-efficacy perceptions that occur in the hypothetical stressed employee in section 1.3 following his more or less successful active coping efforts are another example. Appraisal styles therefore constitute longer-term or character-like processing tendencies that remain, however, malleable to some extent.

On this basis, we introduce a further specification of PASTOR claim 1, positing that a *general tendency for positive appraisal (a positive appraisal style) is protective* and should therefore be considered the *primary pathway (M_1) to resilience* (Table 1). As explained above, positive appraisal style is an umbrella term that applies to any appraisal style that typically produces non-negative, non-aversive (including positive or appetitive) emotional reactions when the individual is challenged.

4.2.3. Appraisal in animals. For animal researchers, the causation of emotional reactions by appraisal processes may at first be less obvious. Conditioned fear reactions,

Table 1. *Positive appraisal style theory of resilience (PASTOR)*

Claim 1: Positive appraisal style
A generalized tendency to appraise potentially aversive stimuli or situations in a non-negative/nonaverse ("positive") fashion is the proximal cause for resilience to stressors (adversity, challenge, trauma). A positive appraisal style is the common resilience mechanism onto which all resilience factors converge and through which they exert their protective effects on mental health.

Claim 2: Positive reappraisal
In mildly aversive situations, positive appraisal is achieved easily by positive situation classification (comparison with earlier, successfully managed situations or activation of positive cultural stereotypes). However, in aversive situations that are strong enough to automatically trigger negative appraisals, protective (less negative) appraisals (see claim 1) result from positively reappraising the situation, either volitionally or nonvolitionally.

Claim 3: Interference inhibition
The positive adjustment of appraisals in strongly aversive situations (reappraisal proper) requires a capacity to inhibit the interference resulting from competing negative appraisals and from the accompanying aversive emotional reactions.

Refer to sections 4.2.1 and 4.2.2. (for claim 1), 4.2.5 (for claim 2), and 4.2.7 (for claim 3) for more details.

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for example, are still often considered to be simple, inflexible stimulus-response phenomena where, through pairing with the unconditioned stimulus (UCS), the conditioned stimulus (CS) such as a tone gains access to the unconditioned response (UCR) that is normally evoked by the UCS (e.g., an electric shock to the feet), and then becomes the conditioned response (CR). An alternative but similarly long-standing view is that CRs result from the activation of a stimulus-stimulus (CS-UCS) association that in turn evokes a species-typical preparatory threat reaction (CR).

The first model is clearly wrong, because a CR such as freezing or the enhanced vigilance and muscle tension assessed with startle probes is different from the UCR to a shock, in which case the animal will jump around. The second model also implies inflexibility of conditioned responding, whereas in fact there are many examples that CRs are expressed in a context-dependent fashion. Perhaps the best example is UCS inflation and deflation, where, after a learning phase, the UCS is presented in either stronger (inflation) or weaker (deflation) magnitude. The result, consistently observed both in animals (Bouton 1984; Rescorla 1974) and in humans (Gottfried & Dolan 2004; Hosoba et al. 2001; White & Davey 1989), is that the CR to a subsequent CS is also inflated or deflated. Hence, the CS must somehow gain access not only to the mere sensory representation of the UCS but also to a representation of its value or meaning, and this is what determines the strength of the CR. In other words, a simple form of appraisal governs conditioned responding.

Formal associative learning models such as the famous Rescorla-Wagner model (Rescorla et al. 1972) and its successors (Dayan & Abbott 2001), though using terminology such as "associative strength" (v) to describe the CS-UCS link, actually formulate predictions of the UCS by the CS, whose strength changes as a function of sampled UCS probability and magnitude. Hence, the CS-UCS association is not a "stupid" stimulus-stimulus link that is fixed once learned. Instead, it has direction (the CS predicts the UCS, not vice versa), meaning (the CS signals potential harm that is defined by UCS magnitude and probability), and a truth value (the prediction may be right or wrong). It is therefore much closer to a proposition than to what is commonly considered an association (Mitchell et al.

2009). Flexible, meaning-dependent emotional responses can also be demonstrated in the context of appetitive stimulation (Hatfield et al. 1996; Nonkes et al. 2010; Pickens et al. 2003), indicating that emotion causation by appraisal is a general principle. This insight makes appraisal theory a framework that can be used to bridge the gap in mechanistic resilience studies between humans and animals.

4.2.4. Appraisal as a mediator.
4.2.4.1. From factor to mechanism. What follows from the PASTOR claim that generalized positive (non-negative) appraisal leads to resilience? One important consequence is that any resilience factor F that has been identified can only be causal for resilience insofar as it promotes positive appraisal. In other words, a *positive appraisal style mediates all other factors*. Or, visually, in Figure 2B, M_1 can be replaced by an index of appraisal style, AS. For instance, a robust and reliable social support network may mentally stabilize an individual (Janicki-Deverts & Cohen 2011) because she knows it will help her cope with many problems. Good executive functions may be an asset (Southwick & Charney 2012) because they allow a person to suppress negative information easily and instead to adopt a more positive perspective when necessary. And if the person is lucky enough to have a protective genetic or epigenetic background (Caspi et al. 2010; Franklin et al. 2012; Hochberg et al. 2010; Lesch 2011; Meaney 2010), that background is protective because it shapes brain function in a way that facilitates positive appraisal.

An immediate criticism might arise from the analysis of the social support example. If the employee in section 1.3 is embedded in a strong social network, does this stabilize him in case of a job loss because it enhances his perceived coping potential or resources, or rather because it actually attenuates the tangible negative consequences unemployment has for him? Does he really react to the new situation less negatively when he has strong ties with family and friends because *he knows* he can count on their help (*perceived social support*) or rather because *he gets* help (say, a loan from a family member) (*received social support*)? The answer that an appraisal theorist would give is that actually getting help acts by improving his appraisal of the situation (unless, of course, the help is disappointing; Norris &

Kaniasty 1996). Hence, the primary cause for mental stability is a less pessimistic appraisal.

This becomes clearer when considering an example where someone has a strong negative appraisal tendency that makes her catastrophize about the situation in spite of good support (perhaps wondering how long a friend's help will last or what she will have to give in return for that help, or perceiving being helped as a loss of control or an attack on her self-esteem). This answer therefore pertains to the inherent subjectivity of appraisal, and it again underscores the basis of appraisal theory: Any given emotional state, whether positive or negative, strong or weak, reflects the underlying appraisal of the stimulus or situation. There is no other way between a situation or stimulus configuration and the emotional state.

There is an even simpler mathematical answer to the question. Received social support (getting help) will change the situation and reduce overall stressor load ΣS. Because resilience is quantified as maintained or reduced mental problem burden $\Delta \Sigma P$ normalized by ΣS (see sect. 3.1), any reduction in $\Delta \Sigma P$ measured in a situation of received social support would constitute a resilient outcome (enhance R) only if it is relatively larger than the reduction in ΣS. Reductions in $\Delta \Sigma P$ that are comparable to reductions in ΣS would simply reflect diminished challenge. They would not require the activation of any psychobiological resilience mechanism. In particular, they would not challenge a person's capacity for positive appraisal.

This highlights an important additional advantage of quantifying resilience as proposed in section 3.1. Received social support would be considered a resilience factor (correlate with R) only if its positive effects on mental health (negative correlation with $\Delta \Sigma P$) are caused by more than a reduction in stressor input (comparable negative correlation with ΣS); for instance, by also changing general appraisal tendencies. In this case, $\Delta \Sigma P$ would drop more than ΣS, and received social support would show a positive correlation with R. Otherwise, received social support could be eliminated from the list of factors that must be investigated.

4.2.4.2. Statistical modeling.
But how can mediation by appraisal style be demonstrated? Let us assume we have only a T1 measure of social integration ("Soc") that does not differentiate between perceived and received social support. Many measures of resilience factors do not differentiate between those aspects of a factor that work by changing appraisals and those aspects that work by changing stressor input ΣS. For instance, executive functions may facilitate positive appraisal, but they may also facilitate adaptive coping behavior and thereby prevent many unfortunate situations. In the causal model in Figure 4A, social integration Soc negatively affects ΣS by providing factual help. ΣS enhances mental health problems $\Delta \Sigma P$. Critically, this happens via appraisal processes. That is, the appraisals are the mediators of the stressors.

It is, however, impossible to measure every appraisal of every stressor and therefore to obtain sum scores of appraisals (in analogy with the sum score of stressors, ΣS). Instead, all produced individual appraisals must be assumed to be well represented by appraisal style. This reflects the specification of PASTOR claim 1 in section 4.2.2. that the way an individual typically appraises the stressors encountered governs how the stressors affect $\Delta \Sigma P$. The
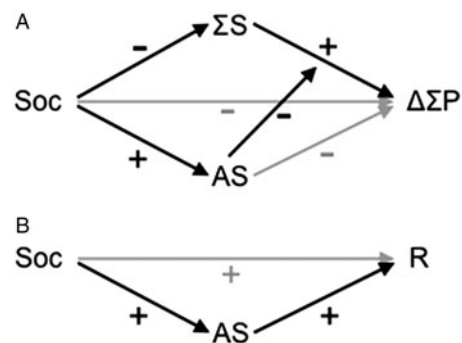

Figure 4. Example of appraisal effects on mental health outcome. (A) The relationship of stressors (ΣS) present between measurement time points T1 and T2 and mental health problems (T2 outcome $\Delta \Sigma P$) (cf. Fig. 1) is moderated by the individual's appraisal style (AS). By taking into account likely causal relationships between an established resilience factor F such as social integration (Soc) and both ΣS and AS, the direct path between the resilience factor and $\Delta \Sigma P$ becomes nonsignificant (grey). There are no remaining effects of the factor on $\Delta \Sigma P$ that are independent of AS. (B) In cases where a resilience factor does not influence stressor exposure, the T2 outcome can also be expressed as the quotient R (inverse of $\Delta \Sigma P$, see Fig. 1) and AS can be introduced as a mediator.

model therefore employs a quantitative appraisal style score AS (for how this could be generated, see sect. 4.3), with higher values signifying a more positive appraisal style. Logically, a style or trait cannot mediate stressor effects, only modulate them. Therefore, AS is introduced as a moderator of the effects of ΣS on $\Delta \Sigma P$. This expresses that stressors have a less deteriorating effect on mental health if the appraisal style is positive. Finally, in addition to affecting ΣS, Soc also affects AS (positively), in particular by enhancing the individual's perceived coping resources (see sect. 4.2.1).

By introducing AS into the model, the direct path from Soc to $\Delta \Sigma P$ (reflecting that Soc is an important resilience factor) should not be significant anymore (grey in Fig. 4A). Instead, Soc is expected to affect $\Delta \Sigma P$ only via its effects on ΣS and AS; moreover, the effect of Soc on $\Delta \Sigma P$ via ΣS is expected to be modulated by its effects on AS. Hence, taking into account these relationships should eliminate direct influences of social integration on resilience and therefore reduce the role of social integration from a potential resilience *mechanism* to a mere "upstream" resilience *factor*. In the model, it may well be that AS turns out to have an additional direct effect on $\Delta \Sigma P$, which, however, would not invalidate the claim that appraisal style is the central resilience mechanism.

Similar mediation models could be built for any other resilience factor. For instance, a protective genetic background might also act via positively shaping appraisal. Additionally, it might determine risk-seeking or avoidance behaviors, thereby also affecting stressor exposure (positively or negatively, respectively). We can also envisage scenarios where no relationship between a resilience factor F and ΣS exists. For example, stressor exposure during a terror attack might not depend on social integration. In such cases, it would be advantageous to eliminate the Soc→ΣS path and instead to lump ΣS and $\Delta \Sigma P$ together in the outcome quotient R, which is greater the less a

person's mental health is affected by stressors (see sect. 3.1). Variance normally attributed to the Soc→R path would then be absorbed by introducing AS as a mediator of the effects of Soc on R (Fig. 4B).

A basic causal model like that in Figure 4 can in theory be extended by including potential confounders, that is, other resilience factors. So, if social integration is the resilience factor of interest and the intention is to show that its effects are mediated by appraisal style, then we might want to consider that both social integration and appraisal style could be influenced by, for instance, life history or genotype. Provided we have performed a sufficient T1 baseline characterization to capture all potential confounders and have a sufficient sample size, we could include such relevant factors in one multifactorial model (after appropriate stepwise or factor-analytic selection procedures).

4.2.4.3. Modeling plasticity. We have earlier described stress responses as involving plastic ("allostatic") adaptations that can change the way the individual deals with future stressors (sect. 1.3). We have also emphasized that appraisal styles are not invariable and may change over time as a result of experience or instruction (sect. 4.2.2). So, in the example of the stressed employee, we have discussed the possibility that self-efficacy perceptions increase when active coping efforts are successful and decrease when they are not (sect. 1.3). Similarly, the employee's social support perceptions might increase when received help is effective and decrease when it is not (sect. 4.2.4.1). Thereby, modifications of appraisal style during or after stressor exposure are cases of allostatic plasticity and are likely consequences of any major stressor exposure.

The inclusion of time-dependent variables has become possible, at least in theory, by the rapid progress in complex causal modeling over the last 15 years (Daniel et al. 2013; Pearl 2009; Rubin 2005), and thus including time-dependent variables constitutes a relevant potential extension of the basic model architecture introduced above. Time-dependent modeling may also be advantageous when stressor load is seen to change over time, which is a likely consequence of using closely spaced stressor monitoring intervals, as proposed in section 3.4. Time-dependent variables raise the problem of time-dependent confounding, where adjustment for some variable might be desired on the one hand to address potential confounding, but adjustment would also remove a mediated effect. For example, a positive appraisal style might lead to reduced stressor exposure (e.g., via reduced aversive motivation, which may permit more-flexible coping behavior; see sect. 1.3); this, in turn, might affect final outcome. That is, stressor exposure becomes a mediator for the effects of appraisal style on outcome. At the same time, stressor exposure needs to be adjusted for in a statistical model to make subjects comparable (see sect. 3.1). To disentangle such effects, multiple measurement time points are required and thus more expensive designs. However, such designs would also allow for looking at the temporal order of changes in the involved variables and may, therefore, actually help in elucidating causal relations.

Such potential future elaborations notwithstanding, the basic claim of PASTOR that a positive appraisal style mediates the effects of all other resilience factors provides a new perspective on the causal relationships between known resilience factors. It also raises the critical question of how appraisal style can be operationalized and measured.

4.2.5. Claim 2: Reappraisal. Before addressing how appraisal styles can be measured, a deeper look into the basic construct of positive appraisal style is necessary. In situations that are only mildly aversive, positive appraisals may be relatively easily generated and stress responses may be prevented from occurring altogether without much cognitive effort. An individual may do this by a simple (often automatic) process of classifying a situation by referring to similar situations that the person has experienced earlier and retrieving the positive values on the relevant appraisal dimensions that she or he has stored in memory for the given class or type of situation. ("This is not the first time I have managed a cut in income!") Classification may also be done with reference to stereotypes that are of cultural origin ("In my family, we don't panic over such things!"), or there may be genetically imprinted appraisal patterns for phylogenetically relevant classes of situations. We could call this memory-based process *positive situation classification*. The more generalized these appraisal patterns are across different types of situations, the more likely a positive appraisal outcome. In more strongly aversive situations (e.g., a job loss), initial stress responses may, however, be essentially unavoidable. A critical question for a person in these less-benign situations is whether she or he can benefit from changes toward the better that may occur over time in a situation or from the emergence of new, more positive information.

It may be helpful to imagine the employee immediately after being sacked. He may initially doubt whether he will receive any support, and thus feel the full blow of the bad news. Later, however, he realizes that friends and family can be counted on. In such a situation, will his initially negative appraisals easily be adjusted to reflect the new, more positive perspective? The answer is probably both yes and no. Neurobiologists have found ample evidence for the existence of evolutionarily old affective circuitry located mainly in brainstem and subcortical areas that is responsible for generating low-threshold defense behavior whenever there is a potential threat and that works in a relatively automatic and uncontrolled fashion (LeDoux 1998). The motto is: Better safe than sorry. The same circuitry is hyperactive in individuals diagnosed with anxiety disorders (Etkin & Wager 2007) and most likely is responsible for the exaggerated negative response beyond their control, even if another part of their mind knows a particular fear or worry is unfounded.

This again highlights an important aspect of appraisal already mentioned (sect. 4.2.1): Appraisal, even within any single appraisal dimension, is not supported by a single, monolithic process, but rather by a collection of processes that are presumably subserved by several brain circuits that often work in parallel to generate behavioral output (Scherer 2001). As a consequence, the brain may produce deviating or even conflicting appraisals of the same stimulus or situation. One part may want to run away from a potential threat, another part may say this is not necessary, and yet another part may see interesting aspects that are worth exploring further. And even if its final decision is to suppress the tendency to run away, and instead to stay and explore, the desire to run away may persist. Coming back to the social support example,

the sacked employee may feel relieved by a friend's help, but at the same time also continue to negatively appraise the situation that made him need help in the first place. Emotional improvement in a changing environment, then, is some kind of sum game.

To summarize, for a less aversive state to develop when an aversive situation improves or when new, positive information arises during or after stressor exposure, appraisals need to change; that is, negative appraisals must become less negative or be complemented by alternative, positive appraisals. This could be referred to as *reappraisal*. Such reappraisal also takes place when new information is produced entirely internally; that is, when an individual remembers past experiences relevant to the current situation, takes a different mental perspective, or detects new aspects in the situation. Reappraisal, in other words, can also happen without any external change.

This is a particularly important point. If we assume that people have a natural motivation to avoid aversive states such as fear, anxiety, or stress, and considering the inherent multidimensionality and subjectivity of appraisal that gives individuals many degrees of freedom in evaluating any situation (sect. 4.2.1), then reappraisal can and will happen in most aversive situations, whether or not it is invited by changes in the external situation. This shifts the emphasis from the external situation (or changes in the situation) to the individual's ability to flexibly adjust a current negative appraisal or to implement new, more positive appraisals and then to maintain those appraisals. Both processes have to occur in the face of interference from automatic and uncontrolled negative appraisals and the accompanying aversive emotional states.

This theoretical insight necessitates an addition to PASTOR claim 1, that positive appraisal style is the single mediating resilience mechanism. We therefore introduce PASTOR claim 2: that in aversive situations that are strong enough to activate the brain's vestigial defense circuitry, *protective, less negative appraisals* (see claim 1) *result from easy positive reappraisal* (see Table 1). Positive reappraisal ability is therefore an inherent aspect of positive appraisal style as the one mediating resilience mechanism, in that it will determine typical appraisal outcomes, especially in strongly aversive situations (i.e., during major stressor exposure).

The term *reappraisal* here is used in the broadest sense of a reinterpretation or reevaluation, not necessarily referring to a volitional or controlled mental act. Of course, an individual can actively try to see a situation in a more positive light (Gross 1998; Lazarus & Folkman 1984), and the ability to do so is important for easy reappraisal. On a lower level of cognitive hierarchy, however, reappraisal can simply consist of an automatic adjustment or replacement of negative appraisals that no longer adequately reflect the situation, such as in the example of the employee above or in a UCS deflation experiment (see sect. 4.2.3). Reappraisal is also not restricted to any particular appraisal dimension. The aversion induced by a potential threat can be attenuated by reducing outcome probability estimations, by downsizing the subjective importance of an incompatible goal, or by reminding oneself of past successful coping experiences, to give just a few examples.

4.2.6. Appraisal contents and appraisal processes.

Up to now, we have discussed appraisal styles solely as a function of the typical appraisal *contents* that characterize them; that is, of the values someone typically assigns to appraisal dimensions such as outcome magnitude, outcome probability, or coping potential. The consideration of reappraisal has introduced a new element, which relates to the neurocognitive *processes* that mediate appraisal. In reappraisal, an individual who is better in detecting new, positive external information or better in internally generating new, more positive appraisals and who can more easily defend them against competing negative appraisals is also more likely to produce an overall positive appraisal outcome in any given aversive situation, whatever the specific situation or his or her prior experiences with similar situations may be. In other words, an appraisal style in severely challenging situations may primarily reflect the effectiveness and efficiency of the cognitive operations that produce and maintain positive (less negative) appraisals in the face of stress.

These operations and their functionality may or may not be the same for different appraisal dimensions; for example, somebody might be good at correcting negative outcome probability but not outcome magnitude estimations. But the important point is that, for strongly aversive situations, an individual's typical appraisal outcomes (the content) are shaped not so much by the positive or negative experiences he has had in life or by the beliefs conveyed by his culture (memory content), but rather by the good or bad workings of his reappraisal processes. By contrast, in less aversive situations, the process or processes permitting positive situation classification can be considered comparatively simple and undemanding, and appraisal content is dominated by memory content; that is, by the appraisal values already stored in the individual's memory for that class of situation. For PASTOR, this analysis implies that, in addition to considering content, we must also consider the processes that produce content.

4.2.7. Claim 3: Interference inhibition.

Positive appraisal adjustment and maintenance in strongly aversive situations (in the further: "reappraisal proper") occur while the brain still generates conflicting negative appraisals and mentally costly negative emotional reactions. How is such interference resolved? Experimental psychology and behavioral neuroscience tell us that, almost certainly, this involves inhibition. Many important insights are derived from counter-conditioning procedures, where a CS first acquires one value (e.g., appetitive, through pairing with a rewarding UCS) and then a conflicting, second value (e.g., aversive, through pairing with a punishing UCS). In the terminology introduced in section 4.2.5, this could be considered a prototypical reappraisal experiment. In such experiments, learning of the aversive value is usually retarded and expression of aversive CRs is usually suppressed relative to a comparison CS that undergoes aversive conditioning without prior appetitive conditioning. These well-replicated observations can be explained within a model of mutually inhibitory appetitive and aversive motivational systems (Dickinson & Pearce 1977; Konorski 1967; Solomon & Corbit 1974), but not with other current learning models (for an in-depth discussion, see Nasser & McNally 2012).

Extinction of conditioned fear is another prototypical example of reappraisal, where a CS first acquires aversive value (again through CS-punishment pairings) and then no longer predicts punishment (because it is repeatedly

presented in the absence of the UCS). It is well known that the conditioning-extinction procedure generates both a fear memory (CS-UCS association) and a safety memory (CS–no UCS association), which, when the CS is presented again later, are both retrieved and give rise to conflicting appraisals of the CS (Bouton 2004). If the safety appraisal wins out (if attenuation of CRs is lasting), this necessarily involves successful neural inhibition of the fear circuitry (Milad & Quirk 2012).[2]

Hence, in many cases, *reappraisal success requires a capacity to inhibit interfering appraisals or other distractors*. This is PASTOR claim 3 (Table 1). Interference inhibition is necessary but not sufficient for successful reappraisal. The primary element of reappraisal is to take the alternative, more positive perspective (reappraisal proper). Inhibition may permit reappraisal proper and protect the new appraisal against interference. Again, we assume that this inhibitory capacity is a character-like trait or style that however remains malleable. It might be interesting to see whether the type of inhibition required during appraisal conflicts is the same as or similar to inhibition in other domains, such as in motor impulse (Aron 2011) or attentional (Corbetta & Shulman 2002) or cognitive (Stahl et al. 2014) control, and might perhaps constitute a general inhibitory trait. We point out, however, that attentional control that is used to (self-) distract from aversive stimuli (Gross 1998) is unlikely to lastingly reduce aversion, because it is improbable that the processing of massive or repeated stressors can be effectively blocked over longer time periods.

4.2.8. Summary of PASTOR. We started this theory section with the radical claim that positive appraisal style is the one general resilience mechanism M_1 that mediates the effect of all other reappraisal factors F_x on resilience R (PASTOR claim 1; cf. Fig. 2B). The following theoretical considerations have then led us to the conclusion that a positive appraisal style (i.e., overall positive appraisal contents in most challenging situations) is determined by at least three elements.

In only mildly aversive situations that do not necessarily and automatically generate a stress response, stress responses are prevented by a process of classifying the situation positively based on its similarity with positively valued prior experiences or cultural stereotypes (*positive situation classification* or *process class 1*, PC_1). The neurocognitive processes underlying classification are considered relatively undemanding, and hence memory content plays a dominant role in determining appraisal content in mildly aversive situations. Any change in memory content as a result of coping experiences can be considered a case of allostatic plasticity that affects future reactivity.

In addition, positive appraisal style is shaped by individual reappraisal ability (PASTOR claim 2). Reappraisal processes are particularly important in strongly aversive situations, where an initial stress response is essentially unavoidable because the situation is automatically classified as negative. Reappraisal attenuates an ongoing stress response by appropriately adjusting negative or generating complementary positive appraisals (*positive reappraisal proper* or *process class 2*, PC_2). Reappraisal proper requires the permissive inhibition of interfering negative appraisals and emotional reactions (PASTOR claim 3; *interference inhibition* or *process class 3*, PC_3). The processes or process

classes of reappraisal proper and interference inhibition constitute mental faculties or skills that determine appraisal outcomes during significant stressor exposure. Their effectiveness and efficiency may have both a heritability and a training component (the latter constituting another form of allostatic plasticity), but they rely less on stored appraisal values (memory content) as a result of experience or culture.

By differentiating the neurocognitive processes that govern the appraisal of mildly versus strongly aversive situations (minor or major stressors), we come back to a theme started in section 3.4 on the quantification of stressor load, where we have discussed that aversion to different types of stressors may be determined differently. General resilience mechanisms working through optimization of aversion may then not be global; that is, they may not help deal with any kind of stressor (see also sect. 1.3). We have therefore anticipated it might be necessary in resilience studies to choose study cohorts that are confronted with single classes of stressors or to generate separate scores for different classes of stressors represented in a cohort. We can now predict that positive situation classification as one class of processes (PC_1) determining positive appraisal style will explain the relationship between exposure to minor stressors and mental health outcome. Such stressors could be daily hassles or minor negative life events. By contrast, positive reappraisal ability based on reappraisal proper and interference inhibition as two additional, separate classes of processes (PC_2, PC_3) determining positive appraisal style will explain the relationship between exposure to major stressors and mental health. Such stressors could be highly aversive chronic stressors or single potentially traumatizing events.

We now formulate this using the terminology of the longitudinal study design proposed in sections 3.1 and 4.2.4. A first, very simple approach to testing PASTOR could be to use some hypothetical global T1 index of appraisal style (AS) that, for instance, uses self-report to measure typical appraisal content or outcome in both mildly and strongly aversive situations. AS should predict R (or $\Delta\Sigma P$) at time point T2 and mediate the effects of upstream resilience factors F_x on R (see Figs. 2B and 4) in any cohort. This concretion of Figure 2B is shown in Figure 5A. If, however, the appraisal of minor and major stressors is determined by different processes, it is not clear whether the respective appraisal outcomes would correspond and whether they could be subsumed in a single score.

A more elaborate approach would therefore be to use separate AS scores for minor and major stressors, respectively (AS_{min}, AS_{maj}). This would equate to dividing the conjectured single mediating resilience mechanism M_1 into two more or less independent variables (Fig. 5B). In cohorts that are exposed to minor stressors only, AS_{maj} would not exert any effect; conversely, in cohorts mainly exposed to major stressors, AS_{min} would be irrelevant. In cohorts exposed to a combination of minor and major stressors, stressor load would also have to be expressed in separate subscores ΣS_{min} (to be moderated by AS_{min}) and ΣS_{maj} (to be moderated by AS_{maj}). One would then have to identify those variance components of R (or $\Delta\Sigma P$) that respond to ΣS_{min} and ΣS_{maj}, respectively, in order to compute the causal model proposed in Figure 4A. (Such decomposition of R is not illustrated in Figure 5B, for simplicity.) This adjustment of the initial model also implies
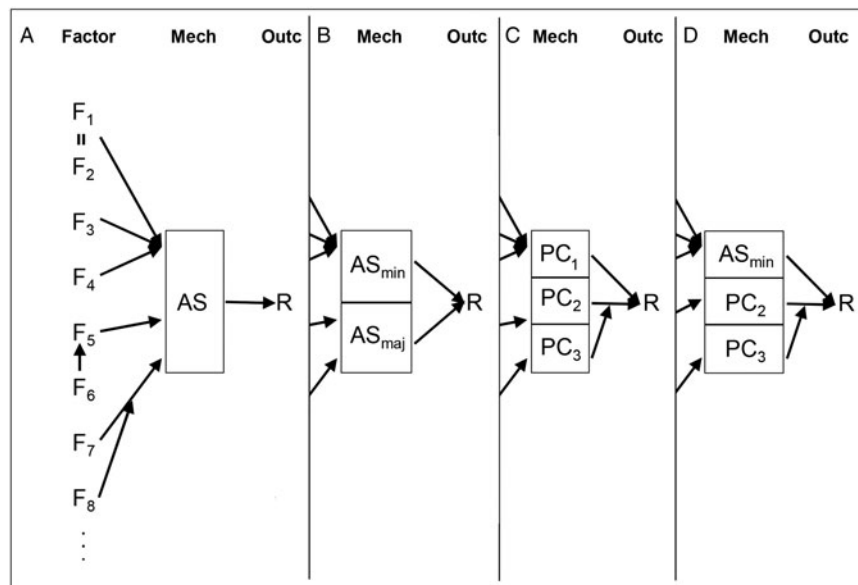
Figure 5. Elaboration of PASTOR: mediation of resilience factors by positive appraisal contents and positive appraisal processes. In the simplest model (A), positive appraisal contents or outcomes (positive appraisal style, AS) determine resilience, R. AS here corresponds to the single resilience mechanism M_1 in Figure 2B. There is no differentiation between mildly versus strongly aversive situations (e.g., daily hassles or minor negative life events vs. highly aversive chronic stressors or single potentially traumatizing events). A more elaborate model (B) takes into account that positive appraisal contents are produced differently in mildly and strongly aversive situations, respectively (appraisal styles AS_{min} and AS_{maj}). A process-based model (C) highlights the role of positive situation classification (PC_1) in mildly aversive situations, and of positive reappraisal proper (PC_2) and interference inhibition (PC_3) in strongly aversive situations. The final model (D) emphasizes the dominant role of stored appraisal contents for appraisal outcomes in mildly aversive situations and the dominance of neurocognitive processes in determining appraisal outcome, and therefore resilience, in strongly aversive situations. F_x denote upstream resilience factors (cf. Fig. 2).

that different upstream resilience factors F_x may exert their effects via separate paths. Both approaches (Fig. 5A, B) focus on appraisal content.

A third approach would be based on the three process classes identified above as determining appraisal style, and therefore use appropriate T1 indices PC_x ($x = 1, 2, 3$) of these three elementary constituents (Fig. 5C). PC_1 (positive situation classification) should independently influence R such that mildly aversive situations do not produce stress and the consequential allostatic load effects. PC_2 (positive reappraisal proper) should independently influence R wherever subjects are exposed to those more aversive situations in which initial negative appraisals are essentially unavoidable. PC_3 (interference inhibition) should moderate the effects of PC_2 (interact with PC_2 in determining R) for these situations, because inhibition is necessary for reappraisal success. In cohorts that are exposed to minor stressors only, PC_2 or PC_3 would not exert any effect; conversely, in cohorts mainly exposed to major stressors, PC_1 would be irrelevant.

Finally, if considering that the situation classification processes (PC_1) producing positive appraisal content (AS_{min}) during minor stressor exposure are undemanding and that appraisal content in these situations is dominated by stored memory contents, then the best graphical representation of PASTOR would be a hybrid model where stored content (AS_{min}) determines R for minor stressor exposure and process classes PC_2 and PC_3 determine R for major stressor exposure (Fig. 5D). The emphasis on content for minor stressor exposure does not exclude that an investigation of processes can be interesting here, as well. The more interesting processes, however, would be related to the

storage of positive appraisal contents during and after successful coping experiences, rather than on their retrieval at the time of exposure. So, the study of the learning and consolidation processes leading to strong, stable, and generalized safety memories could explain why some people benefit more from positive coping experiences than others and are more inclined to classify potentially aversive situations as benign (see also sect. 4.3.3 further below).

4.3. Experimental operationalization in humans

4.3.1. Measuring appraisal contents and processes. There are a number of useful self-report instruments that assess appraisal contents; that is, the values that individuals typically assign to specific relevant appraisal dimensions. These include perceived general coping potential or self-efficacy (Bandura 1977; Benight & Cieslak 2011), or the closely related construct of perceived control (Levenson 1981). Other questionnaires, especially those with a clinical focus, take classes of typical potentially aversive stimuli such as pain, bodily arousal, or negative feelings as a starting point and assess the summed occurrence or strength of (usually negative) appraisals on a range of relevant appraisal dimensions for these stimulus classes (e.g., catastrophizing about the severity and likelihood of negative health outcomes when one is aroused) (Reiss et al. 1986; Sullivan et al. 1995). A different class of instruments tries to assess the habitual use of specific cognitive processes such as reappraisal (Garnefski & Kraaij 2006; Gross & John 2003).

Questionnaire instruments, of course, measure only those appraisal contents or processes of which they

inquire and those that are available to consciousness and can be reported verbally. They are further limited by problems related to the quantification of introspective qualia, semantic ambiguity, and socially desirable reporting. Finally, and crucially for a theory that attempts to promote translational investigation, they cannot be used in animals. If the ambition is to compare findings across species, then instruments for testing PASTOR should rely on observable and objectively quantifiable entities such as behavior, physiology, or brain activity.

The obvious downside of a strategy to assess appraisal based specifically on behavioral or physiological indices is that these indices will reflect appraisal contents only indirectly, via the resulting emotional reaction, and that they are currently not able to determine the specific pattern of appraisal-dimension values that leads to the measured reaction. A stressor-induced aversive behavior or accompanying physiological activation may be primarily driven by a high outcome probability estimate or by perceived low coping potential, but which of these prevail will be hard to decide based on behavioral or physiological measures. Measuring appraisal style (appraisal contents) with these nonsubjective measures, therefore, has to rest on the assumption that the consequences of appraisal-induced aversion for mental health do not depend on which appraisal dimensions contribute most to aversive responding in a given individual and situation. Neural measures in particular may come closer to providing correlates of value (e.g., Levy & Glimcher 2012); but here, too, it needs to be studied to what extent these reflect values on different, separable appraisal dimensions or some resulting summary valuation.

Another downside is that nonsubjective measurements require a relatively controlled experimental environment, which limits ecological validity. This problem is particularly pertinent for brain activation studies in humans that typically use functional magnetic resonance imaging (fMRI) or electroencephalography (EEG). These types of studies, however, are the only ones that have the potential to not only track the outcome or contents of appraisal (via the resulting emotional reaction), but to also observe the emotional reaction "in its making"; that is, to image the neurocognitive processes that underlie appraisal. (For a discussion of how appraisal-related activity can be distinguished from activity related to other processes involved in emotional reactions, namely to downstream response execution, see Kalisch & Gerlicher 2014). Hence, a special contribution that neuroscience can make to resilience research lies in the examination of appraisal processes.

A pragmatic approach to testing PASTOR in humans might therefore be a stepwise one, in which initial studies rely on questionnaire instruments. Scores should ideally be combined somehow into a single AS score (Fig. 5A) or into separate scores AS_{min} and AS_{maj} for exposure to minor and major stressors, respectively (Fig. 5B). A further set of studies could be based on emotional responses (measured via self-report, behavioral observation, and physiological parameters) to a wide range of typical or potential stressors in settings that are as close to real life as possible. Here, as in the quantification of stressor load (sect. 3.4), ambulatory methods (Kubiak & Stone 2012) might be of particular value. The underlying appraisal-theoretic assumption would be that emotional responses reflect appraisal (sect. 4.2.1, Fig. 3). Compared with the

questionnaire studies, a challenge would lie in the combination of multi-modal data into comprehensive AS scores. A third set of studies could employ laboratory measures of emotional responding, including elaborate recordings of physiological or neural activity. At the expense of being performed in a relatively artificial environment, such studies would permit the use of well-studied and controlled experimental paradigms that cannot only be employed to provoke aversive emotional responses (to indirectly assess appraisal style, or content; Fig. 5A, 5B), but can also serve to specifically induce and analyze processes of positive situation classification (or the preceding learning and consolidation processes), positive reappraisal proper, and interference inhibition (Fig. 5C).

The following sections will make some general suggestions for studies in the laboratory. When describing suitable laboratory paradigms, we will also briefly highlight some of the major brain areas or neural processes associated with these paradigms. These examples are mainly meant for illustration, but they may also provide some starting points for a future detailed neurobiological elaboration of PASTOR.

4.3.2. Measuring positive situation classification (PC_1).

Measuring PC_1 or the resulting positive appraisal values attributed to minor stressors (AS_{min}), as said, is based on the assumption that emotional responses are caused by appraisal. It could therefore be done by recording subjective, behavioral, or physiological affective reactions to aversive stimulation in more or less naturalistic situations. Potential neural measures could include activation of the amygdala and the rostral dorsomedial prefrontal cortex (dmPFC). Both structures are involved in attributing relevance and potential threat value to aversive stimuli and also in generating exaggerated negative appraisals, such as during catastrophizing (for review, see Kalisch & Gerlicher 2014; Sander et al. 2003). They might thereby provide inverse measures of positive (non-negative) appraisal.

The circuits specifically supporting positive appraisal during aversive situations have been less studied but are likely to involve reward valuation areas such as the ventral striatum or the ventromedial prefrontal cortex (vmPFC) (Levy & Glimcher 2012), areas that have also been involved in experiencing safety during otherwise threatening situations (Raczka et al. 2011; Schiller et al. 2008). It must be noted, though, that it is not clear at present whether these proposed neural activation measures reflect appraisal contents (values, outcomes) or processes (i.e., positive situation classification).

In the choice of stimuli, it would certainly be advantageous to use a range of different types of stimulations. These could include physical stressors such as pain, CO_2 inhalation, or conditioned or instructed threat of shock, as well as social stressors such as aversive pictures or movies, anticipation of public speaking, or task performance pressure, for example. Next to enhancing validity, the use of various stressors might help average out potential idiosyncratic responses to a specific stimulation (a subject may come with a particular history of pain experiences or expertise in public speaking). It would also permit the extent to which responses to different stressors co-vary to be tested, using factor-analytic methods. If this revealed latent hidden variables that span more than one stressor response or even more than one class of stressor responses

(physical and social), and if such a variable predicted the outcome (resilience R at T2), this would be evidence for general resilience mechanisms that even protect from the effects of more than one stressor or class of stressors – or in other words, evidence for global resilience mechanisms (see sect.1.3).

4.3.3. Measuring positive reappraisal proper (PC₂).

PC_2 could be measured in a laboratory battery that involves externally defined changes in the meaning of stimuli. Examples such as UCS deflation, counter-conditioning, and extinction – where appraisal changes are implicitly invited by a change in outcome values or contingencies – and cognitive reappraisal experiments – where appraisal changes are explicitly instructed – have already been mentioned. There already exists a considerable literature on the neurobiology of these processes (e.g., Buhle et al. 2013; Gottfried & Dolan 2004; Kalisch 2009; Milad & Quirk 2012; Nasser & McNally 2012; Ochsner & Gross 2005; Phelps et al. 2004).

A further possibility that involves implicitly invited reappraisal is discrimination learning (or its counterpart, generalization). For example, one can study responses to neutral cues that are present in many conditioning experiments, as control cues that never get paired with the aversive UCS ("CS−"). Subjects often take some time to learn the safety value of such cues, initially attributing the occurrence of the UCS to any stimulus present, and their ability to finally discriminate between actual UCS predictors (CS+) and safety cues (CS−) may also predict positive health outcomes (Britton et al. 2011; Craske et al. 2012; Gazendam et al. 2013). Similar reappraisal abilities may be needed when learning to distinguish a UCS predictor from physically similar but nonpredictive cues (Lissek et al. 2009; Vervliet et al. 2006) or when learning that the context in which conditioning occurs is not in itself a good UCS predictor (Grillon et al. 2006; Kaouane et al. 2012). Assessing discrimination learning has the desirable quality that it can be done as part of a fear conditioning paradigm used to measure PC_1. Furthermore, the existing neurobiological literature on hippocampal and vmPFC function in discrimination already provides good neuroanatomical hypotheses (e.g., Kaouane et al. 2012; Kheirbek et al. 2012; Lissek et al. 2014; Xu & Südhof 2013).

Finally, the termination of an aversive stimulation per se is of course an event that invites reappraisal. Therefore, the measurement of recovery times from aversive stimulation as performed in a PC_1 test battery might be another cost-effective way to index positive reappraisal proper (e.g., Javaras et al. 2012; Verduyn et al. 2012).

Successful reappraisal is a special case of a positive coping experience, characterized by the experience of relief and safety, that may leave traces in memory. Successful reappraisal may thereby lead to the storage of positive appraisal values for the reappraised situation that can be retrieved at a later confrontation with the same or with comparable situations. The more these positive reappraisal memories generalize to similar situations and the stronger and more stable they are, the more they can facilitate the process of positive situation classification (PC_1) that is responsible according to PASTOR for optimizing aversion to minor stressors (sect. 4.2.8).

Hence, the study of positive reappraisal proper (PC_2) and of the subsequent memory consolidation processes

may also inform the study of positive situation classification. An example is the safety memory that is generated during extinction when subjects find out that a CS is no longer followed by the UCS (the "extinction memory" or "CS–no UCS association"; cf. sect. 4.2.8). If the extinction memory is successfully retrieved during a later confrontation with the CS, it can prevent the generation of aversive CRs (Bouton 2004). Consolidation of this particular type of reappraisal memory appears to involve concerted activity of the dopaminergic midbrain and the vmPFC during the hour following extinction, a neural process that also predicts generalized vmPFC activation at the later CS confrontation (Haaker et al. 2013). Hence, interactions of the mesocortical dopamine system with putative positive situation classification areas such as the vmPFC during reappraisal memory consolidation may be one important aspect of positive situation classification (PC_1).

4.3.4. Measuring interference inhibition (PC₃).

PASTOR claim 3 implies that the inhibition of conflicting negative appraisals and interfering emotional reactions is probably involved in the success of any reappraisal measured in a putative PC_2 test battery. How can the generation and maintenance of more positive appraisals per se (positive reappraisal proper, PC_2) be distinguished from the inhibition of interfering information processing? Time may be part of the answer. In extinction retrieval situations, the function of the retrieved extinction memory is to inhibit CR generation, and as outlined in sect. 4.2.7, in laboratory animals this necessarily involves the recruitment of inhibitory amygdala interneurons by efferents from the vmPFC. Hence, vmPFC activation and amygdala deactivation during an extinction retrieval test could be used as a proxy for fear inhibition (Etkin et al. 2011; Haaker et al. 2013; Kalisch et al. 2006a; Milad et al. 2007). Interestingly, the vmPFC is less consistently active during the preceding extinction learning phase, and in animals, is not necessary for extinction learning to succeed (Milad & Quirk 2002), suggesting that it is not directly involved in the change of appraisals that occurs during extinction. Reappraisal during extinction more likely involves ventral striatal reinforcement learning systems (Abraham et al. 2013; Raczka et al. 2011).

A similar distinction between positive reappraisal proper and the later exertion of inhibition should in theory also be observable in other reappraisal paradigms provided an appropriate task design. This idea, of course, comes close to measuring positive situation classification (PC_1), a potential confound that could be avoided by making the retrieval session itself strongly aversive. "Pure" inhibition of emotional distraction (without a prior reappraisal step, thereby circumventing any PC_1 confound) may be inferred from interference or conflict resolution paradigms where subjects have to perform a cognitive task while being distracted by salient emotional material, a function that again involves the vmPFC (Etkin et al. 2011). Another powerful measure to assess inhibition is conditional discrimination (for details, see Jovanovic & Ressler 2010).

4.3.5. Potential results.

To sum up, an ideal human longitudinal resilience study should include some combined testing battery for PC_1 or AS_{min}, or both, as well as for PC_2 and PC_3 to determine M_1 at time point T1 (and possibly T2, or even at intervening time points). The battery

might, for instance, contain an element of discriminatory fear conditioning (PC_1, PC_2), subsequent extinction (PC_2), and later extinction memory testing (PC_3), plus a range of other stressors (PC_1) with intermittent recovery periods (PC_2), plus maybe some volitional reappraisal task (PC_2). Important measures could be derived from psychophysiology and neuroimaging. Factor-analytic methods might be used to reduce the data and extract latent hidden variables, which should map onto constructs 1 to 3. Those hidden T1 variables that turn out to predict resilience R at T2 (and which perhaps change from T1 to T2 in proportion to R; see sect. 3.2) could then be taken to index likely general resilience mechanisms – or with PASTOR, elementary constituents of a positive appraisal style as the central resilience mechanism M_1. They can be expected to mediate the effects of other, more distal resilience factors (social integration, executive functions, genetics, etc.).

It is important to note that such an approach might well result in a number of predictive hidden variables that exceeds three. As emphasized, appraisal is presumably mediated by a heterogeneous collection of (unconscious and conscious) processes distributed over a wide neural circuitry. It is those processes that PASTOR is ultimately interested in, and the assumption of three classes of processes PC_1 to PC_3 is mainly of heuristic value. It may also be that some of the identified hidden variables span two or three of the classes, which would be unproblematic.

In any case, the elucidated mechanisms would be worthy of further behavioral and neurobiological investigation, including in animal models, and would be rational targets for developing preventive interventions. For example, if a predictive hidden variable should happen to mainly reflect extinction memory performance (or, at the neural level, perhaps vmPFC activity during extinction memory retrieval), this could stimulate research in extinction memory mechanisms (or corresponding vmPFC function) in rodent and human laboratory models. It would also place extinction training in the focus of prevention programs, which, ultimately, might also involve an adjunctive neurobiological-based intervention. Demonstration of improved prevention through improved extinction would also provide the missing causal link between this mechanism and resilience.

4.4. Specific considerations for animal research

The field of extinction research is a particularly good example of how animal research has already informed human research to paint a coherent (yet still incomplete) cross-species picture of a central emotion-regulatory faculty (Milad & Quirk 2012). Translational research in the field of extinction has been so successful because animal and human researchers speak a common language and share a conceptual framework. Our motivation to propose an appraisal-based theory of resilience is to provide such common ground for the broader field of resilience research.

In the remainder of this paper, we will try to show that our logic of examining certain important hypothetical resilience mechanisms (according to PASTOR: neurocognitive mechanisms underlying positive situation classification, PC_1; positive reappraisal proper, PC_2; and interference inhibition, PC_3) in a prospective longitudinal design that involves stressors ΣS and a mental health outcome $\Delta \Sigma P$ or R can and should also be applied to the design and interpretation of animal studies, albeit with some adaptations.

4.4.1. Basic design choices. One could simply continue as usual and use theoretical considerations or the above hypothetical result from a human resilience study to investigate, for instance, extinction or also some neural function identified in that study to relate to extinction performance. (For first evidence suggesting that a role for extinction in resilience is more than hypothetical, see Lommen et al. 2013). This might yield valuable insights into extinction mechanisms, which might in turn be exploited for improving extinction in humans. However, such an approach would not help to understand whether improved extinction or related neural functions actually improve an animal's resilience, thereby missing out on one of the major advantages of animal laboratory models – that causality can be established relatively easily.

Let us therefore consider two more ambitious scenarios. In scenario 1, the hypothesis is that a particular type of adaptive behavior (e.g., good extinction memory) promotes resilience; in scenario 2, the hypothesis is that a particular neural mechanism (e.g., dopamine release in the vmPFC during extinction memory consolidation) promotes resilience. Such a hypothesis could be motivated by findings that suggest this neural mechanism is involved in extinction memory (e.g., Haaker et al. 2013), combined with evidence from retrospective (post-stress) neurophysiological comparisons of resilient versus non-resilient mice for a role of dopamine in the vmPFC in resilience (Chaudhury et al. 2013; Friedman et al. 2014). In scenario 1, it would be desirable to show that individual differences in extinction memory predict resilience, or better, that a manipulation to enhance or decrease extinction memory also enhances or decreases resilience. In scenario 2, it would be desirable to show that individual differences in vmPFC dopamine release or an appropriate manipulation of it affect resilience, ideally complemented by some assessment of how those differences, or the manipulation, affect extinction.

In either scenario, one needs a resilience readout R, which would require two elements: (1) a battery of stressors that tries to appropriately model the life stressors ΣS experienced by an unfortunate human and (2) a "mental health" testing battery that assesses the animal's functioning before and after having being subjected to the stressor battery to model the psychiatric assessments made at T1 and T2 in human participants (ΣP_{T1}, ΣP_{T2}). Determining the effects of the stressor battery on ΣP ideally would require a comparison group of nonstressed animals. The inclusion of such a control group also could make T1 functional testing dispensable, provided appropriate randomization. T2 functional testing should in any case not be performed immediately after the stressor battery, but some time (weeks) following stressor termination, to avoid capturing the acute stress response and to instead provide a long-term outcome. This criterion could be dropped if an immediate measure can be reliably shown to strongly correlate with a delayed measure and thereby serve as a surrogate marker (Krishnan et al. 2007).

4.4.2. Resilience readouts: Combined stressor and functional testing batteries. Some elaborate stressor and functional testing batteries (whose roles in the design should not

in any way be confounded with the testing battery for PC_1, PC_2 and PC_3 suggested above for human studies) have already been proposed (e.g., Franklin et al. 2012; Russo et al. 2012; Scharf & Schmidt 2012), and it is beyond the scope of this paper to discuss them in detail. It suffices here to make three general points. First, for the stressor battery, ecological validity may be higher when choosing chronic rather than acute stressors, and a combination of multiple (physical and social) stressors rather than a single type of stressor. This follows from our discussion in section 3.4 about the diverse nature of stress experiences humans make when confronted with major adversity. Habituation to repeated physical stressors such as restraint, which can be a problem, could be prevented by randomly switching between a social and a physical stressor over days. This would additionally introduce an anxiogenic element of unpredictability. These considerations, of course, do not apply when one is interested in resilience to specific stressors.

Second, in the selection of function tests, it would be a mistake to try to produce human-like disease symptoms (such as when trying to see a depressed, lethargic state in a rat's floating during a Porsolt forced swim test). Rather, one should start from some species-specific normal adaptive behavior and establish whether it is vulnerable to disruption (including exacerbation) by prior stress, making it a sensitive marker for nondisruption – that is, resilience (Russo et al. 2012). Good examples are social interaction, hedonic and reproductive behaviors, aversive behaviors, higher cognitive functions, and sleep.

Third, it has been argued that relying on more than one type of readout is preferable. That is, one needs more than one function test and ideally a combination of behavioral, physiological, and molecular measures (Franklin et al. 2012; Russo et al. 2012; Scharf & Schmidt 2012). One obvious reason is reliability. Another reason is that an identified resilience mechanism (say, extinction memory) can be classified as general only if it protects more than one behavioral function (see sect. 1.3).

Whatever the exact experimental choices, such ambitious longitudinal studies in animals involving a causal manipulation of a hypothesized resilience mechanism and an analysis of its effects on resilience via combined stressor and function batteries would be extremely powerful tools to examine the behavioral and neurobiological pathways to resilience. They would have obvious advantages over designs that only manipulate a hypothesized resilience mechanism without assessing the resilience outcome, but also over designs where behavior in a single task is used to index resilient outcome. An unavoidable limitation of animal studies is that they are restricted to resilience mechanisms that are homologous between humans and animals.

5. Comparison with other perspectives on resilience

In this text, we have argued that the big challenge for resilience research in humans is to proceed from collecting more and more resilience factors to identifying and characterizing general resilience mechanisms. We have advocated four measures to aid this transition: an operationalization of resilience as a transdiagnostic and quantitative outcome; hypothesis generation on the basis of an appraisal-theoretic

framework; an emphasis on neurobiological examination; and closer alignment of animal and human studies on the basis of prospective experimental designs and a common mechanistic theory. We have made suggestions for what mutually informative human and animal neurobiological resilience studies could look like. We recognize that these suggestions involve relatively ambitious designs, but we are nevertheless confident that any attempt to approximate these ideal designs will be instrumental in advancing next-generation resilience research.

We would like to finish by comparing PASTOR with some other existing approaches to the question of resilience, with the intention of further clarifying some of its key aspects.

5.1. Appraisal theories of resilience

Other theorists have stressed the relevance of appraisal mechanisms for resilience. Mancini and Bonanno (2009) have likened appraisal to social support in its importance for resilience, albeit not considering appraisal a mediator of the effects of social support. Benight and Cieslak (2011) have gone further, in arguing that appraisals also can mediate social support effects. These authors have focused on conscious appraisals of self-efficacy or coping potential as can be accessed via self-report instruments. Troy and Mauss (2011) have suggested that the ability to volitionally reappraise negative information is potentially crucial for resilience. Generally speaking, the notion that appraisal processes might be key mediators of resilience appears to be gaining ground and might serve as a unifying framework for resilience research in the next decade. We have tried here to unite these various strands and further promote this research avenue by extending the framework to nonconscious or nonreportable appraisals, by naming potential underlying neurocognitive processes, and by proposing experimental paradigms that allow the limitations of self-report studies to be surpassed and appraisal research to be extended to animal models. We expect that incorporating appraisal concepts into neurobiological investigations, including in animal models, will turn out to be crucial for developing a coherent theory of resilience.

5.2. Temporal profiles of resilience

As mentioned in section 2, life-event research has described various temporal profiles of resilience responses, ranging from maintained mental health to a profile of initial dysfunction followed by recovery (Bonanno & Mancini 2011; Norris et al. 2009). In principle, one could extend the longitudinal study scheme developed in section 3.1 with additional measurement time points T_X to delineate trajectories of ΣS, AS, and ΣP (or R) across time and to thereby more accurately describe resilience as a process rather than a single outcome. This approach might logistically be considerably more demanding. However, as pointed out in the discussion of time-dependent confounders in section 4.2.4.3, repeated measures of factors, stressors, mediators (appraisal style), and outcomes might also be able to shed a brighter light on causal relationships. It is important to note that such more finely grained temporal analysis ultimately would resolve what appear to be distinguishable profile classes (resilience, recovery, chronic distress) into individual cases where the

temporal evolution of the individual's appraisal style and its stressor exposure determine outcome at any given measurement time point.

6. Conclusion: Implications for prevention

PASTOR is in its essence a relatively radical program to focus resilience research on those psychobiological mechanisms that are likely to provide most leverage when trying to improve people's mental health prospects. PASTOR is based on the idea that individual differences in stress and eventual mental health outcome are determined by subjective appraisal processes, provided individual differences in stressor exposure are factored out by normalizing mental health outcome to stressor load (our operational definition of resilience). External or social factors affect resilience indirectly by affecting either appraisal or stressor exposure or both. This has the consequence that we ultimately place resilience in the individual.

We by no means try to deny the well-documented influence of socio-environmental factors on mental health (Janicki-Deverts & Cohen 2011; Zautra 2014), but we consider them as distant influences. We also do not deny the potential that lies in interventions focusing on the building of social relationships, on the strengthening of communities, or on the improvement of the physical environment for promoting mental health (Janicki-Deverts & Cohen 2011; Reissman et al. 2011; Southwick et al. 2011b; Zautra 2014). We also acknowledge the important role that social factors play in determining an individual's belief system (i.e., consciously available appraisal values). All these insights can, and should be, exploited when trying to change stressor exposure and appraisal styles.

Nevertheless, new ideas for prevention that might emerge from the type of research that we propose are likely to target individual factors. Next to changing an individual's *contents* of appraisal, such prevention will focus on training the *cognitive machinery or mental skills* (the neurocognitive processes) that allow an individual to produce positive and to inhibit negative appraisals in the face of stress. Our hope is that our proposals can make an original contribution to the promotion of mental health through the development of new and better methods of prevention.

NOTES
1. To avoid a negative denominator, $\Delta\Sigma P$ could be range corrected ($\Delta\Sigma P_{rc}$). To avoid a denominator of 0, $\Delta\Sigma P_{rc}$ could be replaced by sqrt ($\Delta\Sigma P_{rc}^2 + var(\Delta\Sigma P_{rc})$) such that the denominator mainly expresses the outcome error variance when $\Delta\Sigma P_{rc}$ is 0 or close to 0. A person's change in mental problems between T1 and T2 would then have a greater weighting the more it exceeds the error variance in omental problem changes in the sample, thereby also protecting the quotient against the influence of potential limited test-retest reliability of the $\Delta\Sigma P$ measure.

2. The existence of opponent (mutually inhibitory) appetitive and aversive systems is also supported by findings of an inverse relationship between negative and positive emotions (Zautra 2000). This relationship is specifically observed during aversive but not normal situations (Zautra 2000). The best explanation is that positive (safe or relieving) aspects of an otherwise stressful situation provide a basis for reappraisals (see sect. 4.2.5), leading to positive emotion (Moskowitz et al. 1996). This activation of the appetitive system in turn inhibits the aversive system.

Open Peer Commentary

What do we know about positive appraisals? Low cognitive cost, orbitofrontal-striatal connectivity, and only short-term bolstering of resilience

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Abstract: The PASTOR framework needs to be reconciled with existing research on positive illusions, which finds that positive appraisals of stressors have a short shelf life as a mechanism of resilience, do not draw on costly executive functioning, and rely on neural networks that are distinct from those found in studies of experimentally instructed reappraisal or value.

The PASTOR framework is an exciting development in research on stress because it takes a transdiagnostic view of mechanisms of resilience. The framework would be further strengthened if it were revised to account for its inconsistencies with the existing literature on the behavioral and neural mechanisms of positive illusions. Positive illusions are the human tendency to appraise stressors, situations, personal control, and personal abilities as more positive or "non-negative" than is indicated by objective measures (Taylor & Brown 1988).

It is understandable that the PASTOR framework may not have initially addressed this existing research because of the focus on generating hypotheses that cross human and animal research. Positive illusions have not been a focus of animal research because of measurement challenges. The positive illusions appraisal style is, however, a fundamental aspect of human cognition with important consequences for resilience (e.g., Colvin et al. 1995; Robins & Beer 2001; Taylor & Brown 1988). Therefore, the behavioral and neural research on positive illusions warrants incorporation into any meaningful framework of the association between appraisal style and resilience.

Despite initial hypotheses to the contrary, three decades of research find that this positive appraisal style has only short-term benefits for managing stress (e.g., Colvin et al. 1995; Robins & Beer 2001; Taylor & Brown 1988). For example, students characterized by this positive appraisal style are more resilient in the face of immediate, short-term stressors but show long-term decline when emotional well-being is tracked over the four years of college (Robins & Beer 2001; Thomaes et al. 2009). Furthermore, this positive appraisal style undermines the ability to develop strong social networks of support (i.e., social relationships tend to be poor: Colvin et al. 1995; Paulhus 1998). In contrast to the main hypothesis of the PASTOR framework, this research

suggests that positive appraisals of stressors have a short shelf life as a mechanism of resilience.

Furthermore, the PASTOR framework proposes that positive appraisals draw on costly executive function; yet research finds that cognitive demand increases positive appraisals rather than diminishing them. Time restrictions or distracting tasks tend to exacerbate the positivity of appraisals about one's qualities or future, and that effect persists when stressors challenge positive self-evaluations (e.g., Beer et al. 2013; Paulhus et al. 1989). These findings suggest that positive appraisal either does not rely on executive function or relies on executive function that has become so practiced that it is not undermined when cognitive resources are taxed.

Finally, the target article partially draws candidate neural networks from studies that instructed participants to reappraise situations in a positive manner, yet it ignores the literature on the neural basis of spontaneously occurring positive illusions. This literature suggests that functional connectivity between orbitofrontal cortex (OFC) and the striatum supports the tendency to maintain positive appraisals in stressful circumstances (Flagan & Beer 2013; Hughes & Beer 2012a; 2012b; 2013). For example, increased functional connectivity between OFC and striatum supports the ability to positively appraise the self in the face of contrary information (Hughes & Beer 2013). Therefore, the PASTOR model should be revised to include the neural research on spontaneous positive appraisals of stressors.

The importance of not only individual, but also community and society factors in resilience in later life

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Abstract: Little work has focused on resilience amongst older adults, and few factors have been identified that promote their resilience. Kalisch et al. suggest that socioenvironmental factors are distant influences. We argue, however, that community and societal influences are as important as individual ones. Further, an ecological framework explains why some older adults are resilient whilst others are not.

One of the strengths of the paper by Kalisch et al. on a framework for the neurobiology of resilience is the way in which it focuses on general resilience mechanisms that may be appropriate across different challenges and protect from stress-related mental illness. The authors' suggestion that the influences of diverse resilience factors on good outcomes are mediated through a limited number of resilience mechanisms is intriguing. The model they propose potentially lends itself to testing beyond the neurobiological community, and we would welcome the opportunity to explore the strengths and limitations of broadening the theory.

Kalisch et al. suggest that numerous factors have been identified that influence resilience. In relation to later life, we suggest that relatively few factors have been identified (Windle 2011; Windle & Bennett 2011). This is in part because research on resilience in later life has received far less attention than at the other end of the age spectrum (Windle 2012). We would argue, therefore, that examining whether or not this may offer an advantage to further understanding resilience mechanisms is a worthy extension of the authors' theory.

Kalisch et al. focus on an intraindividual mechanism. They comment that they regard socioenvironmental factors as distant influences, although they acknowledge that these influences are well documented. And in speaking of these as "influences," Kalisch et al. distance them from the resilience *factors* that they discuss, suggesting that the former are not central. The key factor that Kalisch et al. focus on is appraisal, an intraindividual factor. We would strongly argue, however, that these interpersonal and socioenvironmental influences are instead important and proximal factors in resilience (Bennett 2010; Windle 2012).

We propose an ecological model of resilience that explains resilience more fully in older adults. In our formulation, we refer to these factors as *resources*. We identify these resources at three, nonhierarchical, interacting levels, which we call "individual," "community," and "societal" (Windle 2012; Windle & Bennett 2011) (see Fig. 1). At the individual level, we identify the following resources: psychological, material, biological, health behaviours, age, and gender. Appraisal, as outlined by Kalisch et al., can be seen as a psychological resource. At the community level, we believe that social support, social cohesion and participation, and housing are important. Finally, at the societal level, resources such as social, health, and welfare services; social policy; the economy, and neighbourhood all have the potential to contribute to resilience.

Taking one aspect of Kalisch et al.'s argument, we can illustrate how the ecological model can effectively explain resilience in older adults. If one takes Kalisch et al.'s own example of social support, we argue that this is a community-level resource. Although, their theory reduces it to a mediator of appraisal, it remains an important component of resilience. When one looks at the literature both on stress and on resilience, social support remains a significant factor (Bennett 2010; Fuller-Iglesias et al. 2008; Netuveli et al. 2008; Wells 2010). This remains the case when aspects of social support – for example, its availability, quality, and quantity – are examined. We would argue that social support has a greater influence than its mere appraisal. One can extend that argument to other resources such as social participation, social and health service provision, and culture, including religion (Lee et al. 2008; Seddon et al. 2006; Ungar 2011). We do not believe that the majority of people can be resilient without these resources, and indeed, the utilisation of these resources.

Drawing on our own work with older adults in the field of resilience, we recognise the broader antecedents, processes, and outcomes of resilience. Whereas intraindividual factors such as mastery (Windle & Woods 2004), personal control, competence, and self-esteem are important in older adults for what has been described as psychological resilience (Windle et al. 2008), so are community and societal factors, as well (Windle & Bennett 2011). Bennett (2010) found that amongst older widowed men, social support, both formal and informal, was a key factor in determining who became resilient and who did not. Similarly, in work with spousal carers of people with dementia, Donnellan et al. (2014) found that social support from friends (as opposed to family) was a key factor in determining whether a carer became resilient or not. Societal factors such as social policy, culture, and religion also have been identified as important contributors. For example, Donnellan et al. (2014) found the provision of support groups by the third sector and local government was an important factor in resilience, as was the availability of respite services, as well.

Kalisch et al.'s formulation suggests that fundamentally, resilience lies within the individual and that the individual is required to act in achieving resilience by appraising situations in a particular way. We would argue, however, that the acquisition of resilience does not necessarily require the action of the individual; that is, the individual may be at least initially passive. We would argue that in some circumstances, resilience could be facilitated by external agency (Bennett 2010). For example, in the case of some older widowed men, it required external agency and the involvement of neighbours, strangers, and health and welfare
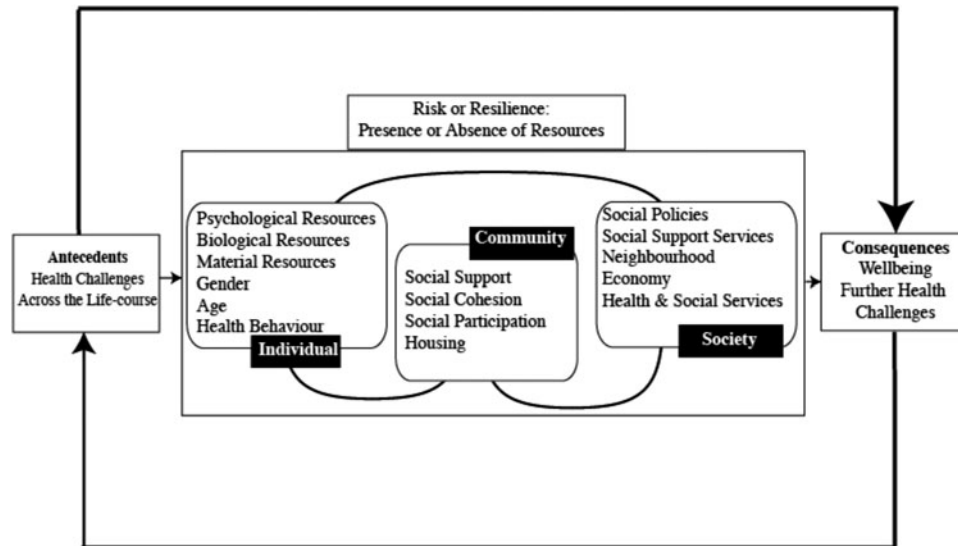
Figure 1 (Bennett & Windle).   The Resilience Framework (adapted from Windle & Bennett 2011). The figure shows the relationships between the antecedents of resilience and the presence (or absence) of resources at the individual, community, and societal levels and their consequences for resilience.

professionals to provide the first steps towards a resilient outcome (Bennett 2010). These widowers would not have been able to achieve resilience alone, and certainly not by appraisal alone (Bennett 2010). Hence, we would argue that the environment/context is an important aspect of positive development and subsequent resilience. It follows, then, that individual-level factors (e.g., traits and characteristics), whilst important, are strongly influenced by the content and function of these environments. Any subsequent appraisal processes are then determined by the interaction between the individual and that individual's environment.

Resilience and psychiatric epidemiology: Implications for a conceptual framework

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Abstract: Kalisch and colleagues present a conceptual framework for the study of resilience, using a neurobiological approach. The present commentary examines issues arising for the study of resilience from epidemiological data, which suggest that resilience is most likely a normative function that may operate as a kind of psychological immune system. The implications of the epidemiological data on the development of a neurobiological theory of resilience are discussed.

The target article by Kalisch and colleagues presents a unified conceptual framework for the study of resilience at the neurobiological level. The authors argue that resilience is best understood as a process. They suggest that resilience can be examined via the study of appraisal style and the extent to which appraisal style protects against stressors and mediates the effects of other factors related to resilience. One key argument made by Kalisch and colleagues is that a better understanding of the processes underlying resilience will contribute to a paradigm shift in psychological and psychiatric research, away from a focus on disorder and psychopathology.

The field of psychiatric epidemiology has a long-standing interest in the concept of resilience, with a range of studies examining the factors that appear to buffer individuals from the effects of exposure to severe stressors (Luthar 2003). Because these studies employ measures of real-world stressors and psychiatric symptomatology, research in psychiatric epidemiology has important implications for the development of a conceptual framework for the study of resilience.

One critical issue, as noted by Kalisch and colleagues, is that effect sizes for the associations between exposure to severe stressors and psychiatric disorders are relatively modest. For example, several studies of exposure to deadly natural disasters, including hurricanes, floods, bushfires, and earthquakes, have shown that the increase in risk of mental health disorders attributable to disaster exposure is surprisingly small (Fergusson et al. 2014a). Fergusson and colleagues, using data from a longitudinal birth cohort, found that individuals with the highest level of exposure to a series of earthquakes had adjusted rates of mental disorder that were only 1.4 times higher than those not exposed, and that exposure to the earthquakes accounted for only 10% to 13% of the total mental disorder in the cohort. Similarly, studies of exposure to severe levels of childhood sexual abuse, which has been shown to be one of the most severe stressors to which individuals may be exposed, also have shown modest adjusted associations between abuse exposure and later psychiatric disorders. For example, Fergusson et al. (2013) found that exposure to sexual abuse in childhood accounted for 5.7% to 16.6% of mental health problems during the period aged 18–30 years, with effect sizes (Cohen's *d*) ranging from 0.24 to 0.48.

The consistent findings of relatively modest mental health effects attributable to severe stress exposure suggest that if resilience processes are protecting individuals from more severe symptoms, these processes almost certainly must be operating in a global manner. Such processes could be described as a kind of psychological immune system (Davydov et al. 2010; Shastri 2013), and it is clear that such functioning is a normative psychological phenomenon in humans. Such a system would fit comfortably into the framework developed by Kalisch and colleagues, who posit both general and symptom-specific resilience processes.

To better understand the operation of such a normative system, however, it is critical to understand factors that compromise the system and cause it to operate less effectively. From the perspective of the psychiatric epidemiology literature, those factors may be identified as covariate factors that exist prior to or contemporaneously with the exposure, and which increase the likelihood of psychiatric symptomatology. Such factors include adverse socioeconomic and family circumstances, parental and childhood maladaptive behavior, genetic factors, and individual characteristics/personality factors (e.g., Fergusson et al. 2013; 2014b). Taking such factors into account in statistical models of the associations between stress exposure and psychiatric symptoms generally reduces the magnitude of the associations, suggesting that exposure to a variety of adverse life circumstances increases the risk of an individual developing psychiatric symptoms following stress exposure.

An important implication arising from this general pattern of associations is that it will prove difficult to develop models of resilience that do not take into account the range of adverse circumstances that individuals may be subject to, and that may compromise the operation of a resilience system or process. In the context of laboratory research on resilience, it will be important for researchers to account for possible mediating effects of adverse life circumstances on appraisal processes. More generally, these considerations imply that in order to understand the processes that protect individuals from psychopathology, it still will be necessary to focus on factors that put individuals at risk. This suggests perhaps not a paradigm shift, but rather a nuanced view of the factors that mediate the associations between stress exposure and psychopathology.

An additional issue arises from the small effect sizes observed in psychiatric epidemiological studies of severe stressors and mental health: It also will be difficult to replicate such stress levels in a laboratory environment when working with human participants. This issue has been observed in the literature on the mechanisms of psychological defense, in which it is both impractical and unethical to induce high levels of stress or expose individuals to strong negative emotional material (Draguns 2004; Hentschel et al. 2004). One way of addressing this issue is to study individuals who tend to display exaggerated responses following exposure to laboratory stressors, such as trait repressors (Boden & Baumeister 1997; Weinberger 1990). Although it is certainly within the scope of laboratory research to expose individuals to stress at the level of "daily hassles," it is not at all clear that such stress levels would cause an effect of sufficient magnitude for individuals who respond in a normative manner to engage resilience processes (Del Giudice et al. 2011).

In summary, the study of resilience has been a feature of the psychiatric epidemiology literature for some time. Data from the literature suggest that the consistent relatively small effect sizes for the associations between severe stress exposure and mental health symptomatology raise key considerations for neurobiological studies of resilience. The conceptual framework developed by Kalisch and colleagues represents a promising advance in our understanding of resilience processes, but the development of this model should take into account these and related issues.

"If you want to understand something, try to change it": Social-psychological interventions to cultivate resilience

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Abstract: We argue that social psychology has unique potential for advancing understanding of resilience. An exciting development that illustrates this is the emergence of *social-psychological interventions* – brief, stealthy, and psychologically precise interventions – that can yield broad and lasting benefits by targeting key resilience mechanisms. Such interventions provide a causal test of resilience mechanisms and bring about positive change in people's lives.

> *If you want to understand something, try to change it.*
> — Walter Dearborn (in Bronfenbrenner 1979, p. 37)

In their target article, Kalisch et al. propose an overarching, transdiagnostic framework for the study of resilience that brings together several disciplines, most notably clinical psychology, psychiatry, and neuroscience. One discipline, however, has escaped the authors' attention: social psychology. Yet social psychology has unique potential for advancing understanding of resilience. An exciting development that illustrates this is the emergence of *social-psychological interventions* – sometimes called "wise" interventions – that target key mechanisms to yield broad and lasting improvements in health, well-being, and functioning (for overviews, see Cohen & Sherman 2014; Walton 2014; Wilson 2011; Yeager & Walton 2011).

What are social-psychological interventions? They are similar to clinical interventions (e.g., cognitive-behavioral therapy) in that they target key mechanisms. They are, however, typically more precise in focus, stealthier in design, and briefer in delivery. Traditional clinical interventions usually target several mechanisms at once, consist of explicit instructions to change how a person thinks or feels, and unfold over weeks or months. By contrast, social-psychological interventions usually target one key mechanism; consist of reading-and-writing exercises that, even as they change how a person thinks or feels, may not be experienced as "interventions"; and take an hour or less to complete. Consistent with Kalisch and colleagues' theorizing, social-psychological interventions often cultivate resilience by changing how people construe adversity – their subjective understanding or appraisal of adverse events (Yeager & Dweck 2012; Yeager et al. 2013). Indeed, subjective construal is a pillar of social psychology (Ross & Nisbett 1991). Let us consider two examples.

During the transition to college, students often struggle to make friends and connect with professors. Ethnic-minority students, an underrepresented and negatively stereotyped group in higher education, may view these social adversities as evidence that they do not belong in college. An ethnic-minority first-year student described: "Everyone is going out without me, and they didn't consider me when making their plans. At times like this I feel like I don't belong here" (Walton & Cohen 2007, p. 90). Such interpretations undermine health, well-being, and academic performance (Mendoza-Denton et al. 2002). Walton and Cohen (2007; 2011) designed a 1-hour intervention to encourage students to attribute social adversities to the common challenges of the college transition rather than to a fixed lack of belonging on their part or that of their group. Students read stories from upperclassmen indicating that all students worry at first about whether they belong and that these worries decline with time. To help students internalize this message, they were invited to write an essay and deliver a speech about why students come to feel at home in college over time. Over the next three years, the intervention improved ethnic-minority students' health and well-being and cut by half the achievement gap in grades with White students. This achievement boost was mediated by subjective construal: The intervention prevented ethnic-minority students from seeing social adversities on campus as a threat to their belonging.

Another form of adversity is academic failure. When students get poor grades, they can fear that other people will judge them

negatively and, hence, feel ashamed, insecure, and worthless (Leary & Baumeister 2000). Such negative self-feelings, in turn, increase students' risk for later depression and anxiety (Sowislo & Orth 2013). Brummelman et al. (2014a) designed a 15-minute intervention to prevent secondary-school students from seeing failure as a threat to their self-worth. Students reflected on times when they were accepted and valued by others unconditionally. One 14-year-old girl wrote: "I was working on a task with a friend of mine, and I made a lot of mistakes. But we are still good friends, and she still values me." To encourage students to fully reflect on this experience, they were asked to describe it in great detail. Would this exercise imbue students with the feeling of being valued for who they are, even when they perform poorly (Rogers 1961)? Three weeks later, students received the first report card of the school year. Without intervention, students who received poor grades experienced increased negative self-feelings; with it, they did not. Thus, the intervention buffered students' negative self-feelings in the face of distal academic failure.

How do seemingly small interventions yield effects that last weeks, months, or even years? The interventions do not shut people's eyes to adversity. Nor do they simply remain accessible in people's minds: the accessibility of messages wanes over time (Srull & Wyer 1979). Rather, the interventions set in motion self-sustaining processes, whereby small initial improvements compound over time (Cohen & Sherman 2014). When people are more confident about their belonging or their regard from others, they express more welcoming social behavior and thus build better relationships (Walton et al. 2014). These relationships, in turn, reinforce people's confidence in their social standing.

Kalisch and colleagues emphasize the need for longitudinal research on resilience. Mere longitudinal studies are not always sufficient, however. Psychologist Walter Dearborn remarked, "If you want to understand something, try to change it" (in Bronfenbrenner 1979, p. 37). Longitudinal field experiments such as those described above go well beyond nonexperimental longitudinal studies. First, they provide a causal test of resilience mechanisms, and they reveal how these mechanisms unfold over time to affect outcomes. Second, they enable researchers to investigate how contextual factors (e.g., timing, setting) moderate intervention effects. Research shows that interventions can be more effective when timed early (Cook et al. 2012; Raudenbush 1984). Interventions to combat loneliness in school, for example, might be more effective on students' first day of school than several days later, when students' relationships with peers and teachers have become more fixed (Brummelman et al. 2014b).

Researchers and policy makers increasingly recognize the power of brief, stealthy, and psychologically precise interventions to improve people's lives and society at large. Such "wise" interventions do not prevent adversity. Rather, they help people construe adversity in adaptive ways so as to promote growth and improvement. As such, they simultaneously provide a causal test of resilience mechanisms and bring about positive change in people's lives.

Rediscovering confidence as a mechanism and optimism as a construct

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Abstract: The target article asserts that resilience results from a generalized tendency to appraise stressful circumstances positively. Apparently unbeknownst to the authors, essentially the same idea has been advanced before and studied extensively from a different research perspective. This raises a broader issue: the critical need, when projects attempt to span disciplines, to fully examine work from all relevant backgrounds.

Kalisch et al. conceptualize resilience as resistance to adverse outcomes during and after experiences of threat (for greater differentiation concerning resilience as a concept, see Carver 1998). They seek to identify a mechanism underlying resilience, as opposed to developing a list of variables that are associated with resilience. That is, although resilience is affected by many situational variables and individual difference variables, it almost certainly reflects functions that are fewer in number than the many variables that influence those functions.

Consistent with many other people, Kalisch et al. treat stress as being a product of a subjective appraisal of the likelihood and intensity of a bad outcome in a given situation, either acute or chronic. Further, they note that given the perception that an adverse outcome is likely, the more important the outcome is, the greater is the resulting stress (cf. Carver 1998; Carver & Scheier 1998, Ch. 13, 16). This is all very consonant with many existing theories.

The core of the target article is Kalisch et al.'s assertion that the key to resilience is a tendency to make relatively positive appraisals of potentially threatening stimuli (sect. 4.2.1). Positive appraisals result in less emotional distress, less hypothalamus-pituitary-adrenal (HPA) activity, and more productive coping of various sorts. Kalisch et al. put it succinctly: "If a person has a tendency to see things negatively, she will more frequently be in a negative emotional state, and therefore more likely develop stress-related dysfunctions" (sect. 4.2.2). We regard that as a very reasonable assertion (Carver & Scheier 1998).

In our view, although Kalisch et al. never used the word *expectancy*, a large share of what they describe as "appraisal style" – maybe all of it, actually – appears to be captured by the concept of generalized expectancies for good versus bad outcomes. Equating the appraisals they discuss with expectancies regarding outcomes would link the appraisals directly to motivational processes (expectancy-value models of motivation have had a long history in psychology). This link to expectancies would account nicely for the emotional effects (and consequent HPA effects) that reflect resilience, and also for the coping effects associated with resilience (for a broader discussion of expectancy-value motivational ideas in the context of stress, see Carver 2007). Kalisch et al. also emphasize that it is desirable to think in terms of *generalized* appraisal tendencies – "the typical way in which [people] react to challenge" (sect. 4.2.2) – because a generalized tendency will pertain to reactions across a wide variety of stressors, rather than just a few.

From this point of view, then, the key to resilience would be generalized appraisals for positive versus negative outcomes from ongoing or upcoming life experiences. Confidence about outcomes would, in several respects, foster better results. Such a mechanism has a good deal to recommend it. Is it new? Are any existing constructs based on a similar mechanism? No, it is not new; and yes, there is a construct predicated on such a mechanism. It is termed *optimism* (Scheier & Carver 1985). It is based explicitly on the mechanism of generalized expectancies concerning life outcomes as an influence on diverse aspects of behavior. Over a period of nearly 30 years, it has been studied quite a lot, in relation to a great many emotional, coping, adaptational, and health outcomes (for reviews of various aspects of that literature, see, e.g., Boehm & Kubzansky 2012; Carver & Scheier 2014; Carver et al. 2010; Rasmussen et al. 2009; Segerstrom 2006).

Consistent with the reasoning that Kalisch et al. presented, but apparently completely unknown to them, a great deal of research has already shown that generalized optimism is associated with better emotional outcomes during stressful situations, more

adaptive profiles of coping with adversity, better adherence to health-promoting behaviors, lower frequencies of health-damaging behaviors, better life attainments, better social relations, and even better physical health (in several respects) over extended periods of time (Carver & Scheier 2014; Carver et al. 2010). Unfortunately, this considerable literature on the effects of generalized outcome expectancies was apparently unknown to either the authors or the reviewers of the target article.

This situation is unfortunate, and it illustrates a broader issue. A potential pitfall of multidisciplinary work, or of work that extends one discipline into a topic area that has been well explored by another discipline, is neglecting to consider the various constituencies and failing to review what they have already said. The target article clearly was more grounded in neuroscience and animal research than in human behavioral research and theory, and the failure to thoroughly examine the latter is a serious weakness.

Nonetheless, Kalisch et al. do add to the conceptual conversation. They emphasize that the appraisal processes are not fully conscious, and that they are fluid in operation (we agree with both points; these are ideas that, to our knowledge, have not been widely examined, and they should be). Kalisch et al. appear to be more interested in the neural circuits that support appraisal than in the subjective experience of appraisal, which presumably reflects their background in neuroscience. To their credit, they appropriately acknowledge that there often is a good deal of ambiguity about the meaning of neural activation (sect. 4.3.2). That is, in this case, there is ambiguity (among other ambiguities) about whether neural activation reflects appraisal *contents* or *processes*.

We are not as sanguine as they are about the prospects of gaining useful information about positive appraisals from neuroscience research or from animal research. But it is probably wisest to let a hundred flowers bloom and see what emerges. After all, it is widely known that positive appraisals are generally better than negative ones.

The challenges of forecasting resilience

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Abstract: Developing prospective models of resilience using the translational and transdiagnostic framework proposed in the target article is a challenging endeavor and will require large-scale data sets with dense intraindividual temporal sampling and innovative analytic methods.

Kalisch et al. present a thought-provoking translational and transdiagnostic framework for studying resilience. In this commentary, we apply their theoretical framework toward *prospective prediction of* resilient responses to negative life events. Prospective prediction is employed in many domains that depend on accurately forecasting a future state. For example, investors develop models to predict the future value of companies and markets, and epidemiologists develop models to predict the spread of disease. In the area of resilience, a well-formulated model should be able to both forecast the trajectory of an individual's resistance and recovery and generalize across forms of psychopathology and contexts. Such models could transform the study of mental health, but it is not clear how close we are to developing them.

Here, we describe three conceptual challenges for applying Kalisch et al.'s model of resilience in a forecasting framework: (1) resilience is a process unfolding over time, not an outcome that can be measured at a discrete time point; (2) cognitive processes alone are unlikely to predict resilience accurately; and (3) low base rates pose a challenge to predictive accuracy. To help overcome these challenges, we will need studies with large, diverse samples and dense intraindividual temporal sampling.

1. Defining resilient outcomes. Kalisch et al. define resilience as the empirically observed absence of lasting mental health problems following adversity and propose that it can be operationalized as the change in mental health symptoms before and after an adverse event, with a slope of zero indicating a resilient outcome. But at which time points should such a slope be measured? As time passes after a stressful event, the likelihood of returning to a baseline measure becomes greater, increasing the apparent "resilience" independent of any characteristics of the individual. Alternatively, we could estimate the functional form, or shape, of symptom severity as it unfolds across time.

As resilience is likely a dynamic process reflecting multiple mechanisms operating on different timescales, modeling the temporal trajectory may be particularly informative about which mechanisms are involved. This endeavor will require dense sampling of intraindividual data across time and the application of emerging statistical techniques for modeling trajectories, such as functional data analysis (Lindquist & McKeague 2009).

2. Multiple resilient processes. Kalisch et al. adopt a predominantly cognitive view of resilience, proposing a fundamental role for positive appraisal style, which comprises three distinct intrapersonal processes: (1) the initial appraisal, (2) subsequent reappraisal, and (3) inhibiting alternative interfering appraisals. We agree that appraisal and reappraisal are critical (Wager et al. 2008); however, to develop accurate, generalizable models of resilience, we will likely need to incorporate a broader set of mechanisms, including *inter*personal ones. Social support can attenuate negative affective responses (Coan et al. 2006; Master et al. 2009) and has been associated with positive long-term health benefits (House et al. 1988; Uchino et al. 1996). These processes are likely not fully describable in terms of intrapersonal appraisals, but rather will require models of bidirectional, interpersonal feedback loops (Butler & Randall 2013; Schilbach et al. 2013; Zaki & Williams 2013). For example, our feelings of happiness appear to be directly influenced by our peers and can propagate dynamically through our social network over time (Fowler & Christakis 2008).

Therefore, as we move toward prospective models of resilience, it will be important to incorporate both intra- and interpersonal processes. Ensemble algorithms from statistical learning offer a promising approach to integrate multiple mechanisms into a single model (Hastie et al. 2009; Schapire 1990).

3. The base rate problem. One of the challenges of selecting training data for a predictive model is dealing with a very high base rate of resilient outcomes and an extraordinarily low base rate of significant negative life events on a daily basis. To make this more concrete, based on the lifetime prevalence of depression (Kessler et al. 2005), the probability of an individual *not* being depressed on a given day is roughly 99.99%. Using Bayes' rule to combine this high base rate of not being depressed with a low frequency of significant traumatic life events (0.002%; Kessler et al. 1995) reveals a very low conditional probability that an individual will not be depressed given an adverse life event (less than 5%). Therefore, in the general population, resilience defined as a null change across time is actually the standard response, and it will be difficult to identify when true resistance to and recovery from adversity occurs (King & Zeng 2001; Weiss 2004).

To account for these statistical issues, trauma researchers typically have focused on examining resilience to shared traumatic events such as the collapse of the World Trade Center. Such an

approach will not be sufficient to develop *predictive* models of resilience, however, as these events are sampled a posteriori rather than prospectively, precluding baseline assessment, and it remains unclear how well mechanisms generalize beyond this experience. Therefore, to increase the predictive power of such forecasting models, it will be necessary to collect large-scale data sets and find a way to increase the frequency of events to train the model (Kanner et al. 1981). Concerted, nationally funded efforts such as the 500,000-person UK Biobank project will help (Allen et al. 2014), and new avenues to large-scale data collection are continually developing with the rapid proliferation of social media, mobile sensing, and cloud computing. For example, using experience sampling of mood from mobile devices, researchers recently collected more than 500,000 samples from approximately 30,000 people (Killingsworth & Gilbert 2010; Rutledge et al. 2014). Furthermore, general public mood can be assessed by mining Twitter feeds, and these metrics appear to modestly predict other global metrics such as the Dow-Jones Industrial Average (Bollen et al. 2011).

4. Conclusion. Though the challenges we have raised in developing predictive models of resilience are substantial, they are inherent to many other problems (e.g., predicting the stock market, forecasting weather, etc.) and are by no means insurmountable. Resilience research can learn from other fields outside of psychology and neuroscience, which have addressed parallel problems with predicting complex and rare events. Billions of dollars are poured into financial markets, and the most powerful supercomputers in the world are continually running simulations to improve our weather forecasts. Why should improving our mental health by predicting resilience be any less important?

Cognitive trade-offs and the costs of resilience

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Abstract: Genetic, endocrinological, and psychological evidence demonstrates that resilience commonly trades off with sensitivity. The existence of such trade-offs indicates that resilience bears costs as well as benefits, and that some disorders can best be conceptualized in terms of extremes of trade-offs rather than expression of deficits. Testing for cognitive trade-offs should be a priority for psychiatry, psychology, neuroscience, and genetics.

In the year 2371, the android robot Data from *Star Trek: The Next Generation* has an "emotion chip" installed in his brain, to aid in his quest to understand humanity. The experiment is successful to a fault: Data become overwhelmed with wildly positive, negative, and erratic feelings in response to pleasurable or stressful events. The lesson is clear and supported much further by the empirical evidence described below: Resilience trades off with sensitivity, even at the level of the brain. Why, then, are cognitive trade-offs virtually unstudied in psychology and psychiatry?

Trade-offs can be considered as balances between two beneficial but incompatible phenotypes. Resilience, as conceptualized by Kalisch et al., can be favorable, because it reduces cognitive and emotional sensitivity and vulnerability to stressful events; however, it may also reduce sensitivity to beneficial opportunities. In turn, sensitivity, as a state that trades off with resilience, increases both gains from opportunity and losses from threat. These two opposite concepts form the core of the "vantage sensitivity" model developed by Pluess and Belsky (2013), whereby some individuals are relatively more sensitive than others with
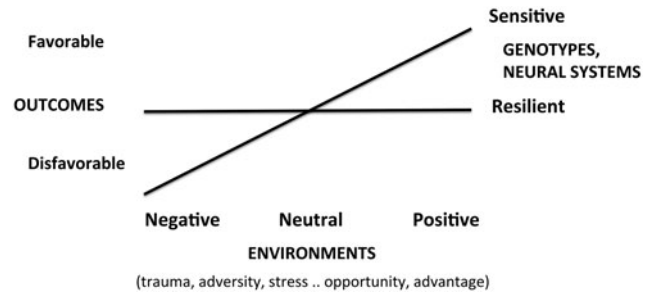

Figure 1 (Crespi).   Cognitive trade-offs under a vantage sensitivity model, whereby resilience engenders benefits in poor environments but costs in good ones.

regard to psychological responses to environmental events, whether those events are negative (as in diathesis-stress models) or positive (Fig. 1). Under this paradigm, less-sensitive individuals are simply more resilient. In contrast, the cognitive-resilience model of Kalisch et al., in its reliance on "any mechanism that helps the organism fine-tune stress responses to optimal levels … and remain flexible" (sect. 1.3), implicitly denies the existence of such cognitive trade-offs. So: How important are they?

At the genetic level, cognitive trade-offs are strongly supported by evidence showing that certain genotypes increase liability to psychopathology for individuals in poor environments but confer benefits to individuals in good environments (review in Pluess & Belsky 2013). By contrast, individuals with alternative, "resilience" genotypes at these loci exhibit neither the costs of adversity nor the benefits of advantage. The well-known COMT Val^{158}Met polymorphism provides another case of trade-offs: The Met allele mediates lower flexibility, but increased stability, compared with Val (e.g., Markant et al. 2014); strong trade-offs also have been demonstrated from these alleles for executive compared with emotional tasks (Mier et al. 2010). Comparable results obtain from studies of human polymorphisms in mice: For example, mice bearing the autism-associated R^{451}C mutation exhibit impaired social interactions, but enhanced spatial learning (Tabuchi et al. 2007).

At the level of physiology, trade-offs are controlled by condition-dependent effects of hormones, and for some hormones, these influences extend to the brain. For example, intranasal oxytocin administration leads to reduced analytic thinking, but also increased "holistic processing, divergent thinking and creative performance" (De Dreu et al. 2014, p. 1). Similarly, serum estradiol relative to testosterone exhibits a negative relationship with spatial ability, but a positive association with verbal fluency (Kocoska-Maras et al. 2013).

Finally, at the level of psychiatry, cognitive trade-offs can be analyzed by determining whether increased risks for one disorder coincide with decreased risks for another. For example, three well-documented factors confer protection from schizophrenia: large birth size (Byars et al. 2014), congenital blindness (Silverstein et al. 2013), and duplications of the 22q11.2 copy number locus (Rees et al. 2014). Each of these three factors that reduces schizophrenia risk also *increases* risk for autism (Byars et al. 2014; Hobson & Bishop 2003; Rees et al. 2014), providing evidence that these two disorders trade off in their causes and can be conceptualized as diametric (Crespi & Badcock 2008). More generally, social abilities commonly trade off with spatial skills, in autism as well as neurotypical individuals (e.g., Keehn et al. 2013; Russell-Smith et al. 2012), and schizophrenia genetic risk is positively associated with higher verbal relative to spatial skills (Kravariti et al. 2006). Perhaps most important, these findings also suggest that some disorders themselves represent dysfunctions mediated by extremes of cognitive trade-offs, as between empathizing and systemizing in Baron-Cohen's (2009) model for autism.

Bipolar disorder and depression represent paradigmatic disorders underlain by cognitive-affective sensitivities, in that overly positive appraisals of events and self-capabilities mediate the emergence of mania and hypomania, whereas overly negative appraisals mediate the onset and maintenance of depression (e.g., Beck 2008; Lee et al. 2010). In this framework, the positive-appraisal bases for resilience postulated by Kalisch et al. may, paradoxically, overlap with risks for mania and hypomania. Bipolar disorder can indeed be considered in terms of overly developed goal seeking, driven by high reward-sensitivity; however, it also is associated with pronounced enhancements, including elevated IQ (e.g., Koenen et al. 2009) and high social and academic achievement (e.g., Johnson et al. 2012; MacCabe et al. 2010). Such benefits presumably accrue primarily to individuals who are highly motivated and sensitive to successes, but also fortunate enough to develop in a favorable environment.

The upshot of these considerations is that diverse evidence supports a model of resilience trading off with sensitivity, such that Kalisch et al.'s quest for purely beneficial neural resilience to stress-induced mental disorders becomes challenging at least, and at most, quixotic. Where do these considerations leave us, with regard to reducing risks for such disorders?

First, increased resilience certainly can be fostered among high-sensitivity individuals beset by environmental stress, once we know how. Determining the mechanisms for resilience, by comparing neural and cognitive phenotypes across resilient genotypes for multiple differential-susceptibility loci, offers a simple way forward.

Second, we must improve our understanding of cognitive trade-offs, by realizing that many psychological deficits are intrinsically linked with corresponding strengths, and that psychiatric risk genotypes of many genetic polymorphisms also should confer benefits. Such strengths, and benefits, will be overlooked if the study of psychopathology continues its usual litany of characterizing dysfunctions rather than testing for trade-offs.

With the help of the psychological counselor Deanna Troi, the android Data eventually develops some measure of control over his emotions. His emotion chip is later removed, however, because it renders him vulnerable to confusion, fear, depression, rage, and manipulation by others. He learns, as may we someday, that the costs of sensitivity, like the costs of resilience, can sometimes exceed the advantages.

Does a positive appraisal style work in all stressful situations and for all individuals?

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Abstract: Kalisch et al. posit that a positive appraisal style is the key to resilience. I will argue instead that the adaptiveness of a particular emotion-regulation strategy is determined by contextual factors. Hence, a positive appraisal style might not always result in positive consequences and is most likely not the only mediator of resilience.

I will begin with a positive appraisal by saying that the target article by Kalisch et al. has many features that I applaud: strong arguments for a transdiagnostic and quantitative analysis, clear and straightforward terminology, a plea for measures beyond self-report, and last but not least, the boldness to posit a unified general theory of resilience, applicable for humans and animals alike. In contrast to Kalisch et al., however, I will argue that it seems unlikely that one specific emotion-regulation strategy –

namely, a positive (non-negative) appraisal style – would be the key to resilience (i.e., the only mediator of it). Evolution has shaped several coping mechanisms, all of which show some benefits and some shortcomings depending on the context. I will illustrate this main argument by discussing studies that stem from the psychology of (human) emotion regulation and by focusing on cognitive reappraisal, the second class of cognitive processes that shape appraisal style specified by Kalisch et al.

Without a doubt, cognitive reappraisal shows reliable positive effects on subjective, behavioral, and physiological outcomes in most situations, whether instructed (Gross 1998), spontaneously chosen (Egloff et al. 2006), or assessed as a personality disposition (Gross & John 2003). There are circumstances, however, where reappraisal is less adaptive or even maladaptive, therefore calling into question its unconditional link to resilience. I will elaborate on two situational boundary conditions (intensity of stress and controllability), cultural moderators, and whether enhanced memory for the situation might be maladaptive when dealing with effects of traumatic experiences.

Regarding the intensity of the stressor, Sheppes et al. (2009) and Sheppes and Meiran (2008) showed in a series of studies that cognitive reappraisal was less successful (as compared with distraction) in terms of physiological and cognitive indicators of the stress response during the regulation of sadness in situations of high emotional intensity. Specifically, reappraisal was associated with increased skin conductance and decreased finger temperature (indicating increased sympathetic activation; Sheppes et al. 2009) and stronger Stroop interference (indicating an expenditure of self-control resources; Sheppes & Meiran 2008). By contrast, reappraisal was adaptive in low-intensity situations, especially when implemented early in the emotion-regulation process. Thus, it might be more adaptive to cognitively and emotionally "block" high-intensity stressors than to reappraise them. Consequently, individuals prefer to choose distraction over reappraisal in these situations (Sheppes et al. 2011).

Troy et al. (2013) showed that controllability of the stressor constitutes another moderator of the relation between reappraisal and the success of the regulation effort: For individuals facing uncontrollable stress in their daily lives, higher cognitive-reappraisal ability – as assessed during an independent experiment using subjective and objective (non–self-report) indicators – was associated with fewer depressive symptoms, whereas persons facing controllable stress showed a positive correlation between cognitive-reappraisal ability and depression. Hence, it seems that reappraisal is maladaptive when stressors can be controlled (i.e., when the situation can be modified by means of active coping), therefore calling into question the "unconditional" link between reappraisal and resilience. Perhaps as a consequence of these moderator effects of both intensity and controllability of the stressor, individuals surprisingly rarely chose cognitive reappraisal as an emotion-regulation strategy when they were free to do so (Suri et al. 2014).

Culture might constitute another moderator of the effectiveness of particular emotion-regulation strategies. For example, Butler et al. (2007; 2009) observed that emotional suppression – a strategy that is usually associated with negative social consequences (Butler et al. 2003) – was an adaptive regulation strategy for Asian American participants as compared with European American participants. As culture and cultural values (e.g., independence vs. interdependence) are differentially associated with the frequency and intensity of the use of reappraisal and suppression, and the relationships between these emotion-regulation strategies and adjustment differ across countries and cultures (Matsumoto et al. 2008), a universal and exclusive reappraisal-adjustment link as posited by Kalisch et al. also seems unlikely from this perspective.

Another issue that calls into question the unconditional and exclusive link from reappraisal to health stems from the finding that cognitive reappraisal – as compared with emotional suppression and distraction – enhances memory for the situation (Egloff et al. 2006; Richards & Gross 2000; Sheppes & Meiran 2008).

This effect of reappraisal is considered beneficial in everyday situations because it may enhance the predictability of future similar moderately stressful encounters. When one has been confronted with potentially traumatic stressors, however, the memory-enhancing effect of reappraisal might be maladaptive at least for some individuals because it may contribute to the consolidation of fear memory that, in turn, may lead to posttraumatic stress disorder (Kearns et al. 2012).

As a logical consequence of all these considerations, a flexible implementation of different emotion-regulation strategies dependent on person characteristics and situational demands should lead to optimal coping with both daily hassles and traumatic experiences. In the coping and emotion-regulation literature, this capability is termed *coping flexibility* (Cheng 2001), *regulatory flexibility* (Bonanno & Burton 2013), or *psychological flexibility* (Kashdan & Rottenberg 2010). For intellectual honesty, I would like to add that a recent meta-analysis, however, showed only small to moderate coping flexibility effect sizes (Cheng et al. 2014) that were comparable to those of reappraisal in another meta-analysis (Webb et al. 2012). Therefore, much theoretical and empirical work has to be done to demonstrate that coping flexibility is the most adaptive way of dealing with stressors in everyday life.

Taken together, any particular emotion-regulation strategy is not adaptive or maladaptive per se – its adaptiveness depends on several contextual factors. As a consequence, it seems unlikely that a positive (non-negative) appraisal style *always* will have positive consequences and is the *only* mediator of resilience.

The value of "negative" appraisals for resilience. Is positive (re)appraisal always good and negative always bad?

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Abstract: In contrast to the PASTOR model by Kalisch et al. we point to the potential negative long-term effects of positive (re)appraisals of events for resilience. This perspective posits that emotional reactions to events provide important guidelines as to which events, environments, or social relations should be sought out and which ones should be avoided in the future.

There is no doubt that positive (re)appraisals of negative events can contribute to a person's affective and subjective well-being. The PASTOR model proposed by Kalisch et al. elaborates the central role of such positive (re)appraisals for understanding the processes contributing to resilience in the face of stressors and adversities. Although we agree with the main tenets of this model, we believe that this perspective overlooks the potentially negative effects of positive (re)appraisals as well as the potentially positive effects of negative appraisals of a given event or situation with regard to functional outcomes such as mental health. In contrast to Kalisch and colleagues, we maintain that emotional reactions to events provide important information as to which events, environments, or social relations should be sought out and, importantly, which ones should be avoided.

The question of the optimal margin of positive illusions – in the context of the present paper, you may say of positive (re)appraisals – is not new, with some of it dating back to a heated debate in the late 1980s and early 1990s conducted by Taylor and Block (Colvin & Block 1994; Taylor & Brown 1988; see also Baumeister 1989). Too much realism is related to depression (Alloy & Abramson 1987), but too many illusions are linked with a loss of motivation (e.g., Colvin & Block 1994). Not surprisingly, it has not been possible to define or quantify where exactly the optimal margin between realistic and overly positive appraisals of an event lie. Also, it is still unclear: Is the relationship linear between positive (re)appraisals of negative events and short-term as well as long-term well-being and mental health? Or – more likely – is the relationship more complex, such that the association is linear up to a certain level of positive reappraisal, beyond which people fall out of touch with a given negative reality, which is then indicative of a delusion rather than an illusion?

Furthermore, it also may be useful to consider that different types of outcomes can be at stake when it comes to reappraisal. One distinction proposed by Staudinger (Staudinger & Kessler 2009) is between adjustment (i.e., fending off negative effects of negative events in order to regain or maintain subjective well-being) and growth (i.e., facing the negative and thereby being able to learn from negative events and gaining life-insight). In their lifespan model of resilience, Staudinger and colleagues define resilience, in the sense of adjustment, as one kind of developmental plasticity and distinguish it from growth as another kind of plasticity (Greve & Staudinger 2006; Staudinger et al. 1995). This definition of resilience is akin to the biological notions of homeostasis and allostasis. According to McEwen and Wingfield (2007), allostasis refers to the active process of achieving stability through change when faced with events that challenge the basic maintenance of functioning (i.e., homeostasis). Both concepts, homeostasis and allostasis, include the possibility of changing the functional set-points in order to adapt optimally to a changing environment. In this way, resilience can be considered as the basis for growth, including the setting of future goals that motivate behavior to change oneself and/or the environment in a way that promotes optimal development or even progress toward wisdom (Freund 2008; Staudinger & Kessler 2009).

Continuous positive reinterpretation of negative events might help a person to feel better, but also jeopardizes the veridicality of judgment. In other words, appraising challenging or threatening events as such (i.e., in a "negative" or realistic way) may be experienced as aversive but motivate a person to actively change the aspects of the situation/event or to acquire resources that will help him or her adapt successfully to the situation/event (Carver & Scheier 1998). Imagine a person who does not acknowledge the negative information of having been diagnosed with a malignant form of cancer. Exclusively appraising this situation as positive (e.g., as a message that highlights the value of life and to enjoy every moment of it), rather than also acknowledging that certain steps, even though aversive (e.g., undergoing chemotherapy), will have to be taken to cope with the life-threatening situation, might drastically shorten the person's chances of actually beating the cancer. Or imagine (re)appraising the negative critique of your behavior by your partner as an expression of his or her insecurity, rather than facing the negative critique. The latter will motivate you to work toward changing your behavior that causes the partnership problems. In contrast, the former might upregulate your positive emotions and downregulate your negative emotions in the short run, but jeopardize the goal of maintaining a good relationship with your partner in the long run. In other words, resilience defined as the ability to maintain well-being and mental health in the face of daily hassles as well as more dramatic negative events might require acknowledging the negative in order to stay tuned with reality and change one's behavior or the environment if necessary.

This view is consistent with the notion that emotional reactions, and in particular negative ones, serve as information that something in the person-situation-interaction requires to be changed (e.g., Clore & Storbeck 2006). Just appraising negative events differently (i.e., positive reframing) might in fact prevent such more active ways to change the situation or to acquire new resources or to extend one's behavioral repertoire in order to achieve a better person–environment fit.

Taken together, resilience defined as adjustment to negative events and resulting in stable mental health is likely to profit from positive reappraisals that help to maintain positive well-being, as assumed in the PASTOR model put forth by Kalisch and colleagues. We posit, however, that facing the negative – and, as a consequence, experiencing negative emotions – lies at the heart of the ability to adapt flexibly to one's environment, and thereby, to change oneself or one's environment in a way that promotes long-term resilience and serves as the basis for personal growth.

Rethinking reappraisal: Insights from affective neuroscience

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Abstract: Kalisch et al. argue that appraisal and reappraisal are key mechanisms promoting resilience; however, experimental findings seem to contradict this simplistic view. We argue that a deeper look at affective neuroscience may provide complementary and stronger evidence on how emotional reactivity and emotion regulation may affect resilience.

In their target article, Kalisch et al. offer both a parsimonious theoretical approach to understanding the basic mechanism underlying resilience and a wide-ranging body of evidence in support of this position. A cornerstone of the paper is the theory of positive appraisal style as the key mechanism that buffers individuals from developing detrimental effects of stressors. Appraisal style is broken down into a set of three cognitive processes: (1) positive situation classification, (2) reappraisal, and (3) interference inhibition. The attempt to analyze resilient factors in terms of some simpler, underlying mechanisms is worthwhile and captures a portion of the variance in the measurement of resilience. We see two major problems in this approach, however, as it underestimates the role of emotional factors, on the one hand, and on the other, it overestimates the role of appraisal and reappraisal as the best and fundamental mechanisms in establishing resilience.

Appraisal theories rely on the simplistic assumption that events generate first appraisals and then emotional reactions, an assumption not supported by several neuroscientific studies of affect (see Panksepp & Biven 2012 for a discussion). Kalisch et al. downplay the role of basic emotional reactivity and regulation as important factors leading to resilience and readily jump to the "cognitive" side of resilience (appraisal and reappraisal mechanisms). Emotion, however, has a neurobiological primacy over cognition in terms of temporal dynamics (information is first received by subcortical emotional structures; see LeDoux 1998) and anatomical circuitry (direct links between perceptual systems and emotional structures; see Panksepp & Biven 2012).

From a developmental point of view (of great relevance when considering resilient mechanisms), it is now a matter of fact that early in infant development, all animals are more dependent on the functions of lower emotional rather than higher cognitive brain structures (Chugani 1998). Early perturbations of such primary processes lead to their sensitization (Panksepp & Biven 2012) and late mental health problems (Heim et al. 2010), before cognition can have any (protective) role over the development of stress responses. These and other data point toward the direction of studying very basic emotional processes and basic (rather than high-level cognitive) regulation. Without a clear understanding of emotional reactivity and regulation, we can easily lose the focus of what really matters in terms of creating resilience.

Kalisch et al. claim that "reappraisal processes are particularly important in strongly aversive situations" (sect. 4.2.8, para. 3). Behavioral and neuroscientific evidence supports the idea that this strategy in the laboratory setting is effective in reducing psychological and physiological indexes of emotional reactions (Grecucci et al. 2013; Ochsner & Gross 2005). Extending these findings outside the laboratory, it was found that the frequency of use of reappraisal correlates with well-being and positive emotions (Gross & John 2003). This claim is in line with another set of observations coming from the clinical field, according to which there is a negative correlation between reappraisal and psychological disorders (Martin & Dahlen 2005). Such a pattern leads Kalisch et al. to propose that reappraisal is the key to wellness; however, such a conclusion simply is not justified by the available evidence. Not only does a correlation not mean causation, but at least three lines of evidence contradict this conclusion.

First, experiments in emotion-regulation choice, an emergent field that aims at understanding how we choose which strategy to adopt in a given situation (Sheppes et al. 2011), undermine the importance of reappraisal as a resilient mechanism. Sheppes and colleagues (2011) demonstrate that participants used reappraisal to regulate only low-intensity emotional stimuli, and used distraction for high-intensity stimuli. This result casts doubts on the use of reappraisal during stressful events that are by nature highly emotional. From a neurobiological point of view, experimental studies show a decrease in BOLD signal during induced emotional states in regions such as the prefrontal cortex (known to implement regulatory strategies) (Mayberg et al. 1999). Other studies demonstrate an inhibition of prefrontal cortex activity for emotional stimuli (Dolcos & McCarthy 2006). Hence, it may be unlikely that during highly emotional events reappraisal-based strategies may be fully available for regulating the experienced emotion.

Last but not least, from a developmental point of view, the evidence for the successful use of reappraisal as a regulation strategy is scant in children (DeCicco et al. 2014) and nonexistent in infants (for obvious reasons of immaturity of prefrontal regions necessary for reappraisal to happen). It follows that other protective emotion-regulation strategies may guarantee resilience in the face of early stressors.

Emotional reactivity and regulatory mechanisms (cognitive, but also experiential; see Grecucci et al. 2015) are keys to understand both pathological and resilient processes (Kring & Werner 2004; Tracy et al. 2014; Troy & Mauss 2011). We are very far, however, from a complete taxonomy of emotion-regulation strategies and from a sufficient knowledge of their efficacy, optimal frequency before becoming detrimental, short- and long-term effects, and other relevant variables.

To this end, a critical distinction should be made between functional and dysfunctional emotion-regulation strategies (F/DERS). DERS may be related to psychopathology; however, as pointed out by Alado and colleagues (2010), the relationship between emotion-regulation strategies and psychopathology is not linear, and varies as a function of type of strategies and type of psychopathology. When an emotion is elicited, self-regulatory mechanisms spontaneously reduce the emotional response. A failure in such regulation may be due not necessarily to the lack of FERS, but

instead to the intervention of DERS that leads to emotional dys-regulation (Grecucci et al. 2015).

Our view is that Kalisch et al.'s proposal, to be viable, should take into account the role of basic emotional reactivity, self-regulatory mechanisms, and DERS. We believe that just as a genetic profile can be predictive of developing a physical disease, the creation of an "emotional profile" rather than an "appraisal profile" may be useful as a predictor of resilience.

Heterogeneity of cognitive-neurobiological determinants of resilience

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Abstract: In their target article, Kalisch and colleagues advocate a paradigm shift in research on stress-related mental disorders away from vulnerability factors and toward determinants of resilience. We endorse this shift but argue that their focus on "appraisal style" as the ultimate path to resilience may be too narrow. We illustrate this point by examining recent literature on the role of corticosteroids in resilience.

The vast majority of people do not develop psychopathology after exposure to highly stressful or life-threatening events (Feder et al. 2009). Fascinatingly, having experienced some adversity may even have advantages for mental health and well-being (Seery et al. 2010). Although research into stress-related disorders historically has focused on identifying factors that confer vulnerability, it is becoming increasingly clear that resilience is not simply the absence of vulnerability. In their target article, Kalisch et al. therefore propose a paradigm shift in research into risk factors for stress-related mental disorders to redirect attention to factors that uniquely determine resilience. This is a welcome development because an understanding of resilience factors is critical for the promotion of mental health, one of the most urgent contemporary challenges for modern societies (Malenka & Deisseroth 2014).

The theoretical framework proposed by the authors draws on an ongoing shift toward transnosological understanding of stress-related mental disorders as heterogeneous clusters of dysfunctions in multiple cognitive-neurobiological systems. Kalisch et al. invoke the classical concept of appraisal (Lazarus 1993b; Scherer 1994) as a causal factor determining whether a given situation triggers a stress response. They acknowledge the possibility that a variety of appraisal processes may occur in parallel in different neural and cognitive systems, which even may lead to conflicting appraisals. Nonetheless, they propose a single mediating mechanism that constitutes the final common path to resilience: a positive "appraisal style."

Kalisch et al. define this concept as a stable trait that determines how a person generally interprets threatening situations. This theoretical framework is reminiscent of cognitive models of vulnerability to stress-related disorders (Beck 2008), which assume that development and maintenance of psychopathology ultimately is determined by maladaptive beliefs and cognitive biases, albeit in interaction with biological factors. We think that this strong emphasis on cognitive factors falls short in appreciating the heterogeneity of the cognitive-neurobiological determinants of resilience and may therefore potentially hamper progress. Below, we will illustrate our point by examining the paradoxical role of corticosteroids in adaptation and resilience to stressors.

It is becoming increasingly clear that corticosteroids, which are released through activation of the hypothalamus-pituitary-adrenal (HPA) axis and are commonly seen as the hallmark of the stress response, play a dual role in regulating the central response to stressors. Corticosteroids can act centrally in concert with faster-acting agents such as catecholamines to produce a state of heightened arousal and vigilance (Hermans et al. 2011; Joëls & Baram 2009). Effects that last beyond the time window of concurrent catecholaminergic activation, however, can be different and even go in an opposite direction (de Kloet et al. 2005; Hermans et al. 2014).

For example, administration of synthetic corticosteroids (hydrocortisone) in humans can reduce fear responses to phobic stimuli (Soravia et al. 2006). Hydrocortisone administration furthermore leads to reduced vigilance for threat-related stimuli, even when these stimuli are presented below conscious perceptual thresholds by means of backward visual masking (Putman et al. 2007). Similar administrations prior to induction of acute stress have furthermore been shown to have a protective effect on mood changes elicited by stress (Het & Wolf 2007). In line with these experimental findings, another study demonstrated that pretreatment with hydrocortisone increased the efficacy of exposure therapy for acrophobia (fear of heights; de Quervain et al. 2011). Further clinical studies have provided initial evidence for the effectiveness of hydrocortisone in preventing stress-related mental disorders such as posttraumatic stress disorder (Schelling et al. 2001; Weis et al. 2006). A recent review even concluded that hydrocortisone is so far the only effective drug for this indication (Amos et al. 2014). For this reason, the ability to contain and terminate the central stress response through corticosteroid signaling may form an important biological resilience factor.

Such dynamic effects of corticosteroids and other stress-sensitive neuromodulators on appraisal processes can be understood within a neurobiological framework of fear and safety learning. Whereas acquisition of conditioned fear requires the amygdala, extinction of conditioned fear underlying safety learning depends on the prefrontal cortex (Milad & Quirk 2012). Rather than replacing a fear memory, extinction training appears to produce a new memory that competes for expression whenever a cue is encountered that previously was associated with the threat (Bouton 2004). Increasing evidence shows how the amygdala and prefrontal cortex are part of distinct larger neural systems that are differentially affected by stress (Arnsten 2009; Hermans et al. 2014). Induction of acute stress (Cousijn et al. 2010; van Marle et al. 2009), as well as elevation of central levels of norepinephrine using reboxetine (Onur et al. 2009), enhances amygdala responsiveness to biologically threat-relevant stimuli such as negative facial expressions. Similar stress induction procedures impair prefrontal cortex function (Qin et al. 2009). This shift in dominance between these two systems may explain why acute stress blocks recall of extinction memory (Deschaux et al. 2013; Raio et al. 2014) and impairs the ability to apply previously learned strategies for cognitive reappraisal of conditioned stimuli (Raio et al. 2013).

In line with the dual role of corticosteroids explained above, slow effects of corticosteroids (i.e., beyond the time window of concurrent catecholaminergic activity) on these neural systems are the opposite of the rapid effects. Administration of hydrocortisone decreases amygdala responsiveness to threat-relevant stimuli (Henckens et al. 2010) and increases prefrontal cortex function (Henckens et al. 2011). Hence, resilience to stressors can be understood as the ability to adaptively engage stress-related neuromodulators to balance neural systems that produce conflicting appraisals.

In conclusion, we strongly endorse the research agenda focusing on resilience factors put forward by Kalisch and colleagues. The assumption that a positive "appraisal style" is the final common path to resilience may prove too narrow, however. Our example of research on corticosteroids is just one illustration of how neurobiological investigations are beginning to reveal the intricate complexity of the biology of stress resilience (Enman et al.

2015; McEwen et al. 2015). We are optimistic that this effort will lead to the emergence of an integrated understanding of the cognitive and neurobiological determinants of resilience.

The self in its social context: Why resilience needs company

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Abstract: In their target article, Kalisch et al. explicate an appraisal-based model to explain how people bounce back from stress. We posit that for their model, it is crucial to understand the begin-state φ (the "self") – a state that is shaped by early social thermoregulation and through the social network.

In their target article, Kalisch et al. provide an appraisal-based model to explain resilience from stress. Three cognitive classes shape their posited individual's appraisal style: positive situation classification, reappraisal, and interference inhibition. They posit that a positive appraisal style is "the primary pathway to resilience" and that their model provides new avenues for prevention. We concur with the authors that we need to rely on biosocial models to understand the development of resilience. In our view, however, the model misses an important component: the functional relevance of the agent's relational experiences.

We concur that stress, and, more broadly, emotions have adaptive functions. But for their model and for interventions, it is crucial to know whether emotions should be reappraised or whether they can actually *contribute* to resilience. We think that for answering this question, we need to extend Kalisch et al.'s biosocial model by adding the agent's begin-state φ – a resilience factor they ponder about. Prevention interventions that are focused solely on individual facets and ignore the agent's relational context (the two indeed being nonindependent) may well lead to alienation in some instances – and, we think, to greater stress, poorer resilience, and worse health instead.

Where does the "self" (φ) come from?. The begin-state φ may just as well be defined as "self." Positive situation classification, reappraisal, and interference inhibition typically are regarded under a larger umbrella that researchers have dubbed *self-regulation*, a crucial factor in resilience (Hofmann et al. 2012; Lindenberg 2013). But the nature of this self is "obscure" and "mysterious even" (Swann & Buhrmester 2012, p. 424), and the reflection on our own experiences is even often wrong (Nisbett & Wilson 1977). What is it then that makes a begin-state φ that, in turn, influences the functionality of emotions for resilience? Humans cannot function without others, and evolution has likely "designed" humans with a biological bias to "assume that [they are] embedded within a relatively predictable social network characterized by familiarity, joint attention, and interdependence" (Beckes & Coan 2011, pp. 976–77).

From this standpoint, facing the world alone is more challenging than with others, and the development of self is virtually impossible without being with others. It is nearly impossible to find individuals who are simultaneously well adjusted, healthy, and socially isolated. In other words, the self, which "regulates various reactions and activities" and "experiences life and attempts to make sense of it" (Swann & Buhrmester 2012, p. 423, 424) should emerge from basic relational structures.

Extending the biosocial model: The emergence of begin-state φ. A more complex and coherent self is related to a more predictable social world, and we agree that biosocial models are vital to understand its development. Indeed, this aspect of a predictable world can be profitably unpacked in light of findings on rodents. One of the two evolutionary causes of group living in rodents is social thermoregulation, the idea that others are involved in regulating one's body temperature (Ebensberger 2001) and therefore metabolic resources (Beckes & Coan 2011). As others – also for humans – are crucial in regulating our energetic resources in early life (Beckes & Coan 2011), social thermoregulation can help us regulate energetic resources, incidentally and throughout development (Beckes et al. 2014; IJzerman et al. 2014a). And social thermoregulation may free energy to be dedicated to other parts of the brain. To take but one example, maternal thermoregulation in rats extends the stress hyporesponsive period, protecting the developing infant brain and allowing it to mature (Suchecki et al. 1993). Social thermoregulation is a potential candidate for aiding the *emergence of* φ, through specific, dedicated social regulation structures.

Alienation – understanding the early social network. Some research on humans supports what we theorize above. For example, kangaroo care (keeping the infant skin-to-skin, allowing for comparable maternal thermoregulation) has been found to lead to increased executive functioning in the child (Feldman et al. 2014). Further, certain types of self-control lead to alienation (i.e., a state in which the individual neglects its own needs and desires; Koole et al. 2014), which is supported by the finding that individuals from countries that are less (vs. more) socially integrated are more vulnerable to becoming alienated when they are under severe stress such as post-traumatic stress disorder (Jobson & O'Kearney 2009). We also found that an ability that leads to better reappraisal – interoception (Carlson & Mujica-Parodi 2010; Füstös et al. 2013) – closely relates to social thermoregulatory processes: People's interoceptive abilities correlated significantly with the comfort they feel being touched by close others (IJzerman et al. 2014b).

So what do we need so as to make Kalisch et al.'s model sufficiently precise for interventions? The work we cite suggests that the begin-state φ indeed emerges from its relational context and that, in turn, φ influences the role of emotions for resilience. A first – but certainly not only – take on operationalizing this begin-state φ in the model is to use attachment style as proxy for predictability in early social thermoregulation. It is well known that securely attached individuals typically cope more constructively (e.g., Mikulincer & Florian 1995; Mikulincer et al. 1993) but, crucially, also reveal greater self-complexity (Mikulincer 1995). Comparably, state predictability – like secure relationships – allows for spontaneous facial emotion regulation, such as a spontaneous smile to a partner's angry face (Häfner & IJzerman 2011). We take from this that the secure agent's emotions directly inform how the agent should act in specific social situations, allowing it to maintain its social bonds. In addition, the display of emotions of securely attached individuals may play an important role in validating others' goals, which, in turn, leads to mutual reinforcement of secure attachment (Arriaga et al. 2014). We therefore propose that in such cases, *not* reappraising one's emotions leads to *greater* resilience.

The agent's begin-state φ, itself dependent on social thermoregulation, is in this way vital in determining whether the agent's emotional state is likely to *inform* or *distract* the agent. We think therefore that, paradoxically, intervening in the secure agent's emotional life leads to its alienation, potentially causing worse resilience, greater stress, and poorer health instead.

Personality science, resilience, and posttraumatic growth

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Abstract: PASTOR represents an innovative development in the study of resilience. This commentary highlights how PASTOR can help both clarify critical questions in and benefit from engaging with new research in personality science on behavioral flexibility across situations in addition to stability over time, and also clarify the relationship between resilience and posttraumatic growth.

The positive appraisal style theory of resilience (PASTOR) outlined by Kalisch et al. represents an innovative development in the study of resilience, capturing another step in the paradigm shift from investigating disease to health (Jayawickreme et al. 2012). The goal of this commentary is to highlight how PASTOR can both help clarify critical questions in and benefit from engaging with new research in personality science in developing a coherent theory of resilience.

Recent advances in personality psychology have provided new perspectives on behavioral flexibility – and consistency – across situations (Fleeson & Jayawickreme 2015). Such flexibility can serve as a tool for promoting resilience as defined by PASTOR. Despite the widespread belief that personality is stable, a large literature has revealed that on average, most people display moderate, mostly positive, amounts of trait change across the lifespan (Roberts et al. 2006). Hence, individuals may be able to influence the degree to which their personality varies and changes (Edmonds et al. 2008). In addition, studies using experience sampling methods have demonstrated a surprisingly high level of variability in trait-relevant behavior in everyday life, with most individuals acting in ways that span the entire continuum of each trait dimension (Fleeson 2001). Furthermore, individuals have the ability to convincingly change their trait-relevant behavior (or personality "state") in the moment, when instructed to do so (Fleeson et al. 2002; McNiel & Fleeson 2006). Of note, people can change their levels of happiness by "enacting" personality states associated with happiness, such as extraversion (Fleeson et al. 2002; McNiel et al. 2010; Zelenski et al. 2012). It should be noted, as well, that personality states have the same content as a trait but for shorter duration, and that states and traits are isomorphic in some regards. Part of having a trait is simply acting that way somewhat more often, and acting a certain way is similar to being that way (Jayawickreme et al. 2014).

Hence, personality traits are stable in the sense that there is reliable between-person variation in aggregate over time, and flexible in the sense that there is also substantial within-person variation in an individual's trait-relevant behavior (or personality states) depending on situational and internal cues (Fleeson 2001; 2004). We need more research on which specific personality traits (or "resilience-conducive" traits, as Kalisch et al. term them) might promote a flexible and positive reappraisal style as posited by PASTOR. Moreover, it's an exciting idea for new research: harnessing behavioral variability (Blackie et al. 2014; Fleeson & Jayawickreme 2015) to develop flexible, PASTOR-based interventions, resulting in lasting changes in the cognitive machinery that boosts resilience (see also Blackie et al. 2015).

Relatedly, PASTOR has implications for helping researchers understand empirical overlap between resilience and closely related constructs. To illustrate this point, we propose that PASTOR may help clarify the relationship between resilience and posttraumatic growth – positive psychological change experienced as a result of the struggle with highly challenging life circumstances (Jayawickreme & Blackie 2014). Whereas resilience generally is defined as the absence of negative outcomes during or following potentially harmful circumstances (e.g., Seery et al. 2010), posttraumatic growth corresponds to increases in positive outcomes after adversity. (We note that Kalisch et al.'s definition of resilience conflates these two distinctions, as they define resilience as "any trajectory that eventually leads to levels of functioning that are comparable to *or even better* than at the outset"; sect. 2, para. 3; emphasis added.) Posttraumatic growth is purported to occur in five distinct life domains – individuals report experiencing a greater appreciation of life, more-intimate social relationships, heightened feelings of personal strength, greater engagement with spiritual questions, and the recognition of new possibilities for their lives (Tedeschi & Calhoun 2004). Posttraumatic growth is generally viewed as both a set of processes (e.g., coming to terms with adversity; identifying and experiencing cognitive, behavioral, and affective changes) and a set of outcomes (e.g., great satisfaction with life, wisdom).

In spite of the theoretical differences between resilience and posttraumatic growth, empirical evidence has shown that people high in traits such as cognitive complexity, self-efficacy, and dispositional hope are more likely to report growth (Tedeschi & Calhoun 1995; Tennen & Affleck 1998). In other words, people who report growth may in fact be those who were more resilient to begin with. As a result, much debate remains concerning the exact nature of posttraumatic growth – an issue that the PASTOR framework may help clarify. To date, most of the scholarship in this area has focused on documenting self-reported retrospective changes (i.e., perceptions of past changes). Ongoing and future research in this area is seeking to determine whether or not retrospective self-perceptions of change also correspond to changes in behavior and cognition measured longitudinally (Jayawickreme & Blackie 2014; Roepke et al. 2014; Schueller et al. 2015). This research can tease out the degree to which resilience precedes growth, and the extent to which both resilience and growth are brought about by or associated with the flexible and positive reappraisal style as proposed by PASTOR. Hence, PASTOR has critical implications for meaningfully distinguishing between the two constructs and pushing further the study of psychological functioning under conditions of adversity.

In addition, and related to this, PASTOR can help researchers design thoughtful experiments and/or interventions aimed at promoting growth following adversity. More specifically, future research may examine the usefulness of fostering selected personality states (as described above). For example, a review of past research suggested that openness to experience, extraversion, and agreeableness (candidate "resilience-conducive" traits) predict adaptive outcomes following adversity (Linley & Joseph 2004). Future research could assess whether experimental interventions promoting open, extraverted, and/or agreeable behaviors may lead to positive and flexible cognitive styles described by PASTOR, and in turn, to resilience or growth.

Resilience: Mediated by not one but many appraisal mechanisms

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Abstract: Kalisch et al. discuss the causal process underlying stress in terms of a multidimensional goal-appraisal process, but there are several mechanisms at various levels of the brain that use different types of

information to guide behavior. Depending on the mechanism, the characteristics of the process are different. Hence, both research and prevention must deal with appraisal in mechanism-specific ways.

Kalisch et al. offer a novel framework for resilience research, wherein appraisal is regarded as the "global" resilience mechanism *par excellence*, serving as the "proximal cause" for mental health. I applaud their transdiagnostic approach and the focus on resilience mechanisms over resilience factors.

By their own admission, however, the authors make some radical claims, and sometimes they go too far. The notion that a "positive appraisal style" mediates all other resilience factors is a bold one, but it cannot be true. For example, genetic factors may influence the stamina of an individual, which in turn may affect cortisol levels in the body. This is not mediated by appraisal. Similarly, Kalisch et al. claim that there is no other route between an event and an emotion than appraisal, but it is possible to arouse emotions through pharmacological agents (Izard 1993). This does not detract, though, from the fact that most emotions *are* produced by some kind of stimulus evaluation.

Here the authors make another radical claim, which is the primary focus of this commentary: "that there is a single mediating mechanism" (Figure 2B). I will argue that resilience researchers need to consider a range of mechanisms for stress and emotion in a more process-specific manner, because each of the mechanisms influences emotions and stress in a different manner. Kalisch et al. seem aware that the evaluation of potential stressors can involve many different cognitive processes (sect. 4.3.5). Yet they do not appear to realize the consequences. The noted confusion about whether neural measures show appraisal content or process reflects the fact that studies have neglected specific mechanisms. Hence, LeDoux (1995) suggested that we should "abandon discussion of cognitive-emotional interactions in terms of vague monolithic cognitive processes, and instead consider exactly which cognitive processes are involved" (p. 224).

A recent framework along these lines aimed at explaining musical emotions, but with much wider applicability, might serve to illustrate this approach. The framework posits nine mechanisms, which range from simple reflexes to complex judgments and which are implemented by several, partially overlapping brain networks that developed in an evolutionary progression: BRECVEMAC – *b*rain stem reflex, *r*hythmic entrainment, *e*valuative conditioning, *c*ontagion, *v*isual imagery, *e*pisodic memory, *m*usical expectancy, *a*esthetic judgment, and *c*ognitive appraisal (Juslin 2013; see also Juslin & Västfjäll 2008).

One implication of this framework is that because several of the mechanisms are "implicit" in nature and may occur in parallel, researchers cannot rely only on phenomenological report to explain how events cause emotions. Moreover, conflicting outputs from mechanisms that use different "data" to evoke emotions may explain the occurrence of "mixed emotions".

Much of the discussion in the target article revolves around various appraisal dimensions, yet many of the mechanisms do not operate in terms of dimensions. Whether appraisal dimension is the right unit of analysis depends on the mental representation involved in each mechanism (see Table 2 in Juslin 2013). If appraisal dimensions are applied to emotion episodes aroused by mechanisms other than "cognitive appraisal," the dimensions lack grounding in reality, and they take on a purely "metaphorical" status. This can explain the occasionally poor correspondence between specific emotions and predicted appraisal patterns (Frijda & Zeelenberg 2001).

A multimechanism framework has important consequences for the question of how appraisal style can be operationalized and measured. Empirically determining which emotion-induction mechanism is responsible for a stress response, and which information produced the outcome, is difficult. Current evidence of cognitive appraisal comes mostly from *post hoc* verbal reports regarding appraisal dimensions, but these do not warrant causal conclusions, because subjects may infer the "appropriate" appraisal pattern from the affective state (e.g., fear, stress) they are experiencing. Because verbal report may not be able to distinguish

between various mechanisms, we simply do not know the precise proportion of instances in everyday life when emotions are caused by, say, conditioning, as opposed to a cognitive appraisal. To draw causal conclusions, we have to *manipulate* mechanisms under controlled conditions.

A multimechanism framework also has some implications for the development of new and better prevention strategies: It does not make sense to subsume different negative appraisal patterns under an umbrella term of "negative appraisal bias." The same person could have a different "appraisal style" for each emotion-mechanism. To measure all of these would be a challenge indeed! It also means that a specific intervention (e.g., active reappraisal) will be ineffective if it targets the wrong psychological mechanism.

In addition, how does one decide that an appraisal style is "overly negative"? Is the resilience outcome (e.g., subjective well-being) the criterion? If so, the test is circular. Or is the style to be evaluated in relation to "objective" circumstances of the individual? If so, "realism" is key, rather than mere "aversion reduction." Positive appraisals of potentially aversive events could indeed arouse less stress *now*, but might lead to negative consequences and hence more stress *later*. One could argue that, more important than the original appraisal of an aversive event, is how, if at all, the ensuing emotion leads to adaptive behavior to resolve the problem. In some situations, resilience as an outcome might be more effectively achieved by changing external life factors of the individual than by trying to change the appraisal styles at multiple levels of cognitive functioning. It remains to be seen which of these – appraisal style or external factors – will explain most variance in resilience outcomes.

My claim – that appraisal cannot be meaningfully addressed at a global level, disregarding the specific mechanisms involved – does not undermine the overall validity of the novel approach, but shows that researchers must make choice: Either they deal with the mechanisms and their characteristics at a "global" appraisal level, in terms of "appraisal dimensions" that might have little reality and lack the required precision to develop effective interventions; or they address appraisal at the level of specific mechanisms – even though this adds considerable complexity to the whole endeavor. The latter alternative is clearly more in line with the kind of ambitious approach advocated by Kalisch et al.

Careful operationalization and assessment are critical for advancing the study of the neurobiology of resilience[1]

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Abstract: The authors' definition of resilience is too narrow and essentially defines resilience as the absence of psychopathology. Consequently, it is not clear how quantitatively defined resilience differs from quantitatively defined psychopathology according to the authors' definition. We believe the conceptual model would be improved by a broader definition of resilience. There is also a significant need for improved measures of stressor load.

We greatly enjoyed reading Kalisch and colleagues' proposed conceptual framework for studying the neurobiology of resilience. As quantitatively oriented researchers, we strongly concur with their argument that quantitative measures are likely a better reflection of the underlying neurobiology of resilience and psychopathology

compared with traditional psychiatric diagnostic categories. We also appreciated their emphasis on studying dysfunctions over disorders; however, there were also several aspects of the model that we believe would benefit from further refinement. In particular, we had concerns about the authors' definition of resilience as "an empirically observable phenomenon, namely that someone does not develop lasting mental health problems although he or she is subject to adversity" (sect. 2, para. 2).

Although this definition is laudable because of its simplicity, it is also an extremely narrow view of resilience. In contrast, Windle defines resilience as:

> The process of effectively negotiating, adapting to, or managing significant sources of stress or trauma. Assets and resources within the individual, their life and environment facilitate this capacity for adaptation and "bouncing back" in the face of adversity. Across the life course, the experience of resilience will vary. (Windle 2011)

Whereas Windle (2011) explicitly excludes mental health from her definition of resilience, the authors' definition is entirely dependent on the absence of mental health.

We believe that this overreliance on mental health to define resilience is problematic. First, it is unclear to us how studying a construct defined entirely by another construct can yield new findings. For example, the authors propose that a general self-report measure of psychopathology would be an ideal measure of resilience within their framework. If a measure of psychopathology is used to define resilience, however, are we not still just studying psychopathology? Any association between a given predictor and "resilience" defined in this manner will have an association of identical magnitude in the opposite direction with "psychopathology" using the very same measure. Hence, it is not clear how quantitatively defined resilience differs from quantitatively defined psychopathology in the proposed model.

Another notable difference between the two definitions is that Windle's (2011) is focused on adaptation to stress and also considers assets and resources that might be available to the individual. In contrast, Kalisch et al.'s definition does not seem to consider the very significant role that assets and resources play in resilience, and it fails to recognize the well-replicated finding that people with more resources are better able to adapt to stressful conditions (e.g., Hobfoll 2002). The latter point is critical for researchers interested in studying the neurobiology of resilience, as it is very likely that resources (e.g., social support, level of education, finances) and many other environmental factors moderate the influence of neurobiological factors (e.g., genetic and epigenetic factors) on resilience to stressful life events (e.g., Koenen et al. 2008; Moffitt et al. 2005).

We also were surprised by the authors' argument that "resilience-conducive traits" (i.e., traditional measures of resilience and hardiness, such as the Connor-Davidson Resilience Scale (CD-RISC); Connor & Davidson 2003) should not be used as measures of resilience within their model. We disagree with the authors on this point. We think that the inclusion of traditional measures of resilience is an ideal way of broadening the definition of resilience beyond the rather simplistic "absence of psychopathology" approach that the authors seem to advocate. An additional advantage of including these types of measures in studies of resilience is that it enables researchers to consider whether the manner in which self-reported resilience is defined (e.g., "absence of psychopathology" vs. "ability to bounce back") influences their findings.

A third advantage of broadening the resilience construct to include traditional measures of resilience is that it would enable researchers to construct latent factors that include both "trait" and "state" resilience characteristics. To illustrate this point, we conducted a confirmatory factor analysis (CFA) on the CD-RISC, the Davidson Trauma Scale (Davidson et al. 1997), and the Symptom Checklist-90 Global Severity Index (Derogatis et al. 1973) in a sample of 2,339 U.S. veterans. The CFA model exhibited exceptionally good fit to the data, $\chi^2(3) = 3875.020$, RMSEA = 0.00, CFI = 1.00, and factor loadings were high

across measures ≥ 0.65, providing strong support for this type of latent variable modeling approach to quantitatively define resilience. We believe that this approach could be further extended to include self-report measures of functional impairment (e.g., Üstün 2010) and quality of life (e.g., Burckhardt & Anderson 2003), as well as measures derived from behavioral, physiological, and neuroimaging paradigms.

A final issue concerns the measurement of stressful life events. The authors provide a nice summary of the many difficulties associated with the assessment of both traumatic stress and daily hassles. We agree with many of their points, as we have spent a great amount of time trying to quantify the impact of one particular type of stressful experience (i.e., combat exposure) on returning veterans' mental health (e.g., Kimbrel et al. 2014). Although we recognize the difficulties in quantifying trauma exposure that researchers face, we also believe that there is currently a great need to quantify stress exposure across a wide range of different populations if we truly wish to improve our understanding of genetic and epigenetic influences on resilience. For example, efforts are currently under way to begin conducting meta- and mega-analyses of genome-wide association study (GWAS) data through the posttraumatic stress disorder (PTSD) working group of the Psychiatric Genomics Consortium (Koenen et al. 2013); however, a key challenge currently facing researchers interested in combining GWAS datasets of PTSD is how to characterize trauma load, trauma type, and the timing of the trauma across different trauma populations (Koenen et al. 2013). Both traumatic stress and stressful life events are robust predictors of a wide range of psychopathology. Given that, it is clear that the development of universal measures of stressful events that can accurately quantify traumatic load for a wide range of stressful experiences across different populations is a crucial next step in advancing our understanding of the neurobiology of resilience.

Appreciating methodological complexity and integrating neurobiological perspectives to advance the science of resilience

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Abstract: Kalisch and colleagues identify several routes to a better understanding of mechanisms underlying resilience and highlight the need to integrate findings from neuroscience and animal learning. We argue that appreciating methodological complexity and integrating neurobiological perspectives will advance the science of resilience and ultimately help improve the lives of those exposed to stress and adversity.

Researchers have made big strides in investigating and understanding resilient responding in the face of stress and adversity. Resilience is best understood as a process that unfolds over time in response to a stressor or potentially traumatic event (Bonanno 2005; Bonanno & Diminich 2013). There is now accumulating evidence that resilience, defined as a trajectory of limited or no decreases in functioning over time, is a common response to such events. This approach entails an empirical characterisation of heterogeneous stress responses (Galatzer-Levy 2014). Numerous studies have since adopted this approach through the use of modeling methods such as latent growth mixture modeling (LGMM), and they consistently have confirmed that resilient individuals compose the largest group following various types of stressors and traumas (e.g., Berntsen et al. 2012; Bonanno et al. 2006; 2012; Galatzer-Levy & Bonanno 2012; 2014). These findings have led to a conceptual shift that Kalisch et al. take up in their present article, away from a focus on risk factors and psychopathology and towards a focus on protective factors and resilience.

The critical questions to be tackled, however, remain: Who adopts such a resilient response trajectory? What are the precise mechanisms leading to a resilient response? As empirical studies have indicated, multiple pathways to resilience exist, and these may sometimes be unexpected and achieved by means that might not be adaptive under other circumstances (Bonanno 2005). Kalisch et al. identify several routes to a better understanding of such mechanisms and highlight the need to integrate findings from the neurosciences and animal learning.

Key neurobiological processes, often in interaction with environmental factors such as adverse experiences during childhood or trauma load, have been shown to affect psychological adjustment in the aftermath of exposure to trauma. A major challenge will be to integrate and translate such findings to clinical interventions and prevention efforts. We may, on the basis of neuroscience findings, be able to characterise individuals in the early aftermath of exposure to stress and adversity and to discriminate those who are likely to be resilient from those likely to succumb to stress (Galatzer-Levy et al. 2014a). Neurofeedback methods have been developed that may directly target patterns of brain functions that support resilience (Stoeckel et al. 2014). Further strides will be necessary to pave the way for such efforts and to put research findings into practice by developing effective interventions that boost resilience.

Finally, human studies need conversely to inform preclinical animal learning studies. For example, it is increasingly understood that pathways to resilience and susceptibility to stress-related disorders are, at least in part, distinct in males versus females. Despite these findings and that stress-related disorders are significantly increased in women compared with men, the vast majority of animal models, however, have been conducted in male animals (Lebron-Milad & Milad 2012; Shanksy 2015), which hampers transferability to both sexes in humans.

The task of identifying complex resilience mechanisms clearly benefits from a collaborative effort of researchers from different domains; that is, neuroscience, behavioral and cognitive science, and others. As pointed out by Kalisch et al., a common language and a shared conceptual framework will be critical to advancing the field. Resilience has been conceptualized many ways, but a straightforward and face-valid approach has been to identify a population that demonstrates positive adjustment in the face of adversity by disaggregating those individuals who demonstrate only transient stress or symptom responses following trauma, using methods such as LGMM (Bonanno & Diminich 2013). This same approach can be used to identify distinct trajectories of response in animal models of threat learning, extinction, and motivated behavior, thus increasing the translatability of such models to understand patterns of stress response including resilience, as animal models are key to the identification of neurobiological mechanisms (Galatzer-Levy et al. 2013; 2014b). From molecules to circuits, to behavior and neuroendocrine response, to conscious and non-conscious cognitions and emotions, the

responses to environmental threats and their aftermath unfold and interact in complex and dynamic ways over time, leading to sustained responses, or *global organismic states* (LeDoux 2014). To add to the complexity, trauma exposure is not amenable to tight experimental control, therefore necessitating, at least in part, the use of naturalistic cohorts such as soldiers, natural disaster survivors, and individuals identified in emergency medical settings.

Given such complexity, the ability to identify causal mechanisms and develop predictive models for early identification may be hindered by traditional data analytic approaches and can benefit from recent advances in machine learning. These methods can integrate large sets of heterogeneous sources of information to predict, classify, and identify unique causal mechanisms leading to distinct trajectories of response (Aliferis et al. 2010; Galatzer-Levy et al. 2014a). These approaches have potential to address the nagging limitations of traditional statistical approaches such as large variable-to-sample ratios, heterogeneous underlying distributions, the need for individual-level predictive accuracy, redundancy in data sources, and the need to discover relationships in the data that are not hypothesized a priori.

Such methodological innovations in the study of posttraumatic stress and resilience inevitably will shift the field from asking relatively limited questions regarding the direct effects of individual factors on resilient responding, to more-complex questions, such as when, how, why, and who is resilient. Ultimately, such an approach will improve the lives of those exposed to stress and adversity.

Resilience is more about being flexible than about staying positive

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Abstract: Kalisch et al. propose a positive appraisal style as the key mechanism that underlies resilience. The present authors suggest that flexibility in emotion processing is more conducive to resilience than a general positivity bias. People may achieve emotional flexibility through counter-regulation – a dynamic processing bias toward positive stimuli in negative contexts and negative stimuli in positive contexts.

People display a remarkable capacity for bouncing back from negative life events. To be sure, tragedy, threats, and other adverse conditions may give rise to considerable emotional upheaval. In most cases, however, the emotional impact of such events endures only for a limited period of time, after which well-being returns to baseline (Brickman et al. 1978; Luhmann et al. 2012; Lyubomirsky 2011). Such positive adaptation in the face of significant adversity is widely referred to as *resilience* (Luthar et al. 2000; Masten et al. 1990).

From the 1970s onward, resilience has become the focus of a growing number of scientific investigations (for an overview, see the recent volume by Kent et al. 2014). Originally, researchers sought to locate resilience factors, variables that statistically predict resilient outcomes. Among the most widely studied resilience factors have been personality traits such as hardiness (e.g.,

Maddi 2013) and social support (e.g., King et al. 1998). In more recent years, however, attention has shifted toward underlying mechanisms; that is, the question of just how resilience factors allow people to achieve resilient outcomes. For example, some researchers have tried to link resilience to neuroendocrine functioning (Russo et al. 2012), whereas other researchers have related resilience to dynamic shifts in affective processing (Schwager & Rothermund 2014b).

Building on and extending the trend toward more-mechanistic theories, Kalisch et al. propose a new conceptual framework that bridges basic and applied research on resilience. One of their most important innovations is their systematic elaboration of general resilience mechanisms and dysfunctions in these mechanisms that are not restricted to specific forms of disorders. Such a transdiagnostic approach makes eminent theoretical sense, given the high overlap that exists at functional, behavioral, and neurobiological levels between disorders that are treated as categorically different by current diagnostic systems. A transdiagnostic approach therefore holds the key to a unified understanding of resilience research and its clinical applications.

Chief among the global resilience mechanisms that Kalisch et al. distinguish is a positive (or non-negative) appraisal style, which the authors regard as "the key mechanism that protects against the detrimental effects of stress and mediates the effects of other known resilience factors" (Abstract). From this perspective, resilience is first and foremost a matter of staying positive in the face of adversity. Being biased toward positive outcomes is not always beneficial, however. First, positivity biases may lead people to close their eyes to real dangers, leading to inaccurate beliefs that may have severely negative consequences (e.g., Colvin et al. 1995). Second, positivity biases may set up people for unnecessary disappointments, in cases when negative feedback is inevitable (Norem 2001). Third and last, positivity biases may promote intense positive emotional states that are inherently volatile (Diener et al. 1991) and pose a physiological burden (Pressman & Cohen 2005).

In view of these considerations, we suggest that psychological adaptation is best served by maintaining a steady emotional balance. If this view is valid, then people's ability to stay positive in the face of adversity may not be driven by a general positivity bias. Instead, it may be part of a broader tendency to respond to negative *and* positive emotional events with an opposite tendency in affective processing. We refer to this dynamic mechanism as the *counter-regulation principle* (Rothermund 2003; 2011; Rothermund et al. 2008). Counter-regulation leads affective processing to become automatically biased toward information that is contrary in valence to the current context or affective-motivational state of the person. In negative contexts, counter-regulation activates positive states; in positive contexts, however, counter-regulation activates negative states. We regard counter-regulation as a vital psychological mechanism that allows people to maintain a balanced receptiveness to positive and negative information. As such, counter-regulation should foster resilience (Schwager & Rothermund 2014b).

On the basis of the counter-regulation principle, we would expect people's attention to become directed toward information that is opposite in valence to anticipated or experienced positive and negative outcomes. This prediction is supported indirectly by many studies showing that positive and negative events tend to have only short-term consequences for people's emotional states (e.g., Brickman et al. 1978; Gilbert et al. 2004; Taylor 1991). Importantly, controlled experimental studies have confirmed the existence of attentional biases in the opposite direction to people's current emotional-motivational states (Derryberry 1993; Rothermund et al. 2008; Tugade & Frederickson 2004).

Counter-regulation not only activates positive appraisals in negative contexts, but counter-regulation also activates negative appraisals in positive contexts (Rothermund 2003; Rothermund et al. 2008; 2011; Schwager & Rothermund 2013a; 2013b; 2014a). Moreover, consistent with the resilience-promoting

function of counter-regulation, various studies have shown that counter-regulation tendencies are most pronounced among people with resilient personality traits (e.g., Koole & Fockenberg 2011; Koole & Jostmann 2004; see also Koole et al. 2012). Conversely, emotional inertia represents a risk factor for the emergence of psychopathological symptoms (Kuppens et al. 2010; 2012). Adaptive responding to life events therefore presumes that people are able to recruit not just positive emotions, but a wide range of positive and negative emotional responses. This emotional variability implies that people are able to change and counteract emotional states before these states become chronic.

Taken together, we suggest that resilient coping is not merely a matter of maintaining a positive outlook on life. Rather, resilient coping involves a more context-sensitive approach, which increases the salience of either positive or negative information depending on currently activated motivational or emotional states. Resilience is traditionally defined as an adaptive response toward adverse events. The counter-regulation mechanism that underlies resilience, however, is not restricted to negative events. Instead, counter-regulation represents a more general way of responding to emotionally extreme events, regardless of whether such events are positive or negative. Counter-regulation thus helps to prevent rigidity or extremity in emotional functioning. In short, resilience is more about being flexible than about staying positive.

Knowledge and resilience

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Abstract: Kalisch et al. regard a positive appraisal style as the mechanism for promoting resilience. I argue that knowledge can enhance resilience without affecting appraisal style. Furthermore, the relationship between positive appraisals and resilience ought to be mediated by knowledge and is not monotonic. Finally, I raise some questions about how appraisals fit into the dual-process model of the mind.

According to Kalisch et al. there is a single general resilience mechanism that protects against the adverse effects of stress. The key mechanism consists of a positive appraisal style, and it mediates all other known resilience factors. I find their framework very fruitful in thinking about the relationship between appraisals and resilience. In this commentary, I focus on the special role that knowledge plays in promoting resilience and see whether it helps us understand and evaluate their proposal.

Knowledge obviously can affect appraisal style, as a person might feel more positive about an aversive situation if she knows how to overcome it. Presumably a difference in knowledge by itself, however, does not necessitate a difference in appraisal style. So let us imagine two similar subjects with exactly the same appraisal style. Given identical stimuli, they would have appraisals of the same strength, and emotional responses of the same valence. (They also can have the same dispositions when it comes to reappraisals and interference inhibition.) But suppose one of them knows more about how to achieve her goals, and has better metacognitive knowledge about her own weaknesses and motivators. Using her knowledge, she is more skillful in avoiding temptations, overcoming obstacles, and maneuvering herself into situations that trigger positive appraisals. Consequently, she encounters fewer stressors and is more resilient than her counterpart in the long run. But their appraisal tendencies are supposed to be identical. If this is right, knowledge as a promoter of success

is a powerful individual factor that can enhance resilience without altering appraisal style.

In fact, we might go further and suggest that the protective function of a positive appraisal style is not without qualification, and needs to be moderated by knowledge. Although elevated positive emotions might serve important protective and motivational functions, it is also possible that unrealistic expectations can increase the likelihood of failures and frustrations, and make them more difficult to cope with. Positive valence has been linked to more-optimistic perception of risk (Johnson & Tversky 1983), which can lead to failure to take precautions or engagement in risky behavior. For example, an athlete who is wildly confident of his ability and downplays pain and other danger signs is susceptible to burnout and serious injury. This can exacerbate stress and depression later on. More generally, human beings are prone to cognitive biases, such as overestimating their own competence (Kruger & Dunning 1999) and being too optimistic about the future (Helweg-Larsen & Shepperd 2001). It is worth noting that individuals afflicted by mania have abnormally intense positive emotions, but the condition is associated with dysfunctional behavior and heightened irritability (Gruber et al. 2011). In short, positive appraisals and resilience need not have a straightforward monotonic relationship.

The underlying point is the familiar Aristotelian idea that actions and feelings should display moderation and appropriateness. Interestingly, Aristotle argued that not all pleasures are worth having, because they interfere with one another. Choosing the right pleasures is based not on the pleasures themselves, but with reference to the goodness and badness of the activities they are associated with. Similarly, positive appraisals are not all equally worth having for the sake of resilience. Resilience is better promoted not by inflating positive appraisals, but by using knowledge to calibrate appraisal valence that is appropriate to the situation, making it more effective to achieve a goal or remove a stressor. Given the interaction between knowledge and appraisals, I am not sure why the latter should be regarded as the more central resilience mechanism.

The connection between knowledge and appraisals also raises questions about how to understand potential conflicts between them. Consider someone fearful of a dead spider next to him, although knowing too well there is nothing to be afraid of. According to the popular dual-process model of the mind, this is a case where our fast, automatic, and intuitive system 1 is in conflict with the more analytic and deliberate system 2 (Kahneman 2011). If this picture is right, where are appraisals supposed to be located? At one point, Kalisch et al. offer a functional definition of appraisal as a state that causes an emotional response given a stimulus. This suggests that appraisals are more closely related to system 1. (This is not to say that system 2 reasoning cannot lead to emotions.) Perception of the dead spider triggers a highly negative appraisal of danger, which causes the emotion of fear. But presumably it is sometimes possible for system 2 to override such appraisals, as when the subject forces himself to remain next to the spider. This suggests there is a different kind of evaluation of the situation at work, perhaps corresponding to the consciously available judgment that it is perfectly safe. It is not clear whether Kalisch et al. will regard this evaluation as an appraisal, as it does not seem to generate any emotion stronger than the fear. (So I am not sure whether their discussion of competing appraisals in interference inhibition applies here). Apart from the present example of a positive evaluation overriding a negative appraisal, it also is possible to have negative evaluations overriding positive appraisals, as when we successfully resist temptations. But if these evaluations can alter behavior and change exposure to stressors, they constitute a different causal pathway that can affect resilience independently of the appraisal mechanism.

Of course, we can expand the term *appraisal* to include such evaluations. But this might mean severing the essential link between appraisals and emotions. Also, given the very different nature of these two types of appraisals, it might be more accurate

to speak of a dual-mechanism model of resilience. Obviously, the dual-process model of the mind still is evolving and not without its critics. But given that Kalisch et al. are interested in pursuing psycho-biological mechanisms, I think it is not premature to see whether the model helps us clarify the concept and functional role of an appraisal.

Adding network approaches to a neurobiological framework of resilience

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Abstract: In their paper, Kalisch et al. make an important attempt to create a unifying theoretical framework for the neuroscientific study of general resilience mechanisms. We suggest that such attempts can benefit tremendously by incorporating the recently emerging network approaches that enable the characterization of complex brain network architecture and dynamics, in both health and disease.

In this commentary, we will demonstrate the usefulness of network approaches to the development of a neurobiological framework for resilience research, by relating to two points discussed in Kalisch et al.'s paper. First, we show that the paradigm shift to a transdiagnostic approach, emphasized by them, is prompted in light of recent brain network studies. Second, we propose that the network perspective may serve as a unifying framework to various resilience mechanisms, including the appraisal mechanism suggested by Kalisch et al.

Recent years have seen a surge of neuroscientific studies applying network approaches to imaging and electrophysiological data, offering a novel perspective to study brains, both in health and in psychopathology. These studies emphasize the use of graph theoretical tools to investigate brain networks. These tools characterize not only the network's architecture and possible physical dynamics but also its emergent properties, including how it copes with stressors (Sporns 2011).

Converging evidence indicates that healthy brains self-organize toward so-called small-world networks. A small-world architecture enables an optimal balance between local (segregation) and global (integration) structural characteristics, which is essential for global and fast information transmission (Fekete et al. 2014).

Relevant to the field of resilience research is the fact that the architecture of a network affects not only its function, but also its robustness to perturbations (Kaiser et al. 2007). With regard to the brain, network analysis of both structural and functional data suggests that brains are highly robust systems (Kaiser et al. 2007). When abnormalities in network metrics occur, however, leading to deviation from healthy architecture, general network failure can result (Sporns 2011). Such network failure can affect network robustness as well as efficient information transfer; it also can cause deficits in the access, engagement, and disengagement of large-scale networks supporting cognition and behavior (Dosenbach et al. 2008). This understanding has led us recently to suggest that network architecture is directly associated with mental resilience (Levit-Binnun et al. 2013; Levit-Binnun & Golland 2011).

With the understanding how deviations from healthy architecture can have profound consequences on brain function and robustness, we now can proceed to explain why the network perspective prompts a shift to a transdiagnostic approach.

According to the network perspective, brain diseases are cases of deviation from healthy architecture (Menon 2011). Indeed, deviations from healthy architecture have been found across a wide range of psychopathologies, including developmental (e.g., attention deficit hyperactivity disorder and autism), psychiatric (e.g., schizophrenia, major depression, posttraumatic stress disorder, and obsessive-compulsive disorder), and neurological disorders (e.g., Alzheimer's and other dementias) (for a review, see Levit-Binnun et al. 2013).

Even more interesting, these deviations from healthy network architecture are evident already in individuals who are at risk for psychopathology but who do not present clinical signs. Hence, neonates at genetic risk for schizophrenia, individuals presenting autistic traits or carrying an autism risk gene, individuals with familial risk for ADHD, children at risk for anxiety and depression, and individuals with mild cognitive impairments all present networks that deviate from healthy architecture (for a review, see Levit-Binnun et al. 2013).

That deviations from healthy network architecture are found across different psychopathologies and in at-risk populations supports the need for the transdiagnostic approach in resilience research that Kalisch et al. describe. Moreover, this suggests that aberrations in network metrics may be indicators of global vulnerability-conducive traits (Fekete et al. 2014; Levit-Binnun et al. 2013). Indeed, we recently showed that psychopathological networks (schizophrenia) that deviate from healthy structure respond abnormally to a controlled perturbation induced by transcranial magnetic stimulation pulses (Arzouan et al. 2014).

The network perspective also supports the attempt made by Kalisch et al. to develop a unifying framework for the study of general resilience mechanisms. Indeed, various internal and external resilience factors (e.g., cognitive abilities, personality traits, (epi)genetics, age, sex, spirituality, social support, and socioeconomic status – all factors mentioned in the target article) can be framed within the network perspective. For example, individual differences in cognitive ability have been linked with variations in network metrics (van den Heuvel et al. 2009). Personality traits, such as low effortful control, have been associated with compromised small-world connectivity (Fekete et al. 2014). Genetics, age, and gender are all factors that have been found to influence network architecture (Gong et al. 2009; Stam & van Straaten 2012). Other resilience-related factors (e.g., social support, socioeconomic status, and spiritual activities) have not been directly studied within a network framework. As most of them have been related to distributed changes in the brain (Hölzel et al. 2011; Kanai et al. 2012; McEwen & Gianaros 2010), however, one may hypothesize that these changes also would manifest at the level of network metrics and global architecture.

Such framing of resilience-related factors within the network perspective also can be extended to the specific appraisal mechanism suggested by Kalisch et al. We suggest that a healthy and optimal network architecture is a necessary neurobiological condition for intact appraisal mechanisms. Abnormalities in network metrics (whether inherited or developed) lead both to the disruption of dynamic balance and to deficient information integration and transfer. This can lead to irregularities in low-level functions such as sensory, motor, and regulatory processes (Levit-Binnun et al. 2013; Levit-Binnun & Golland 2011), which can, in turn, lead to abnormalities in the way one evaluates and reacts to stressors. Moreover, as the authors state, appraisal is not a single process but probably multiple, dynamic, and interactive operations. Abnormalities in network architecture may cause deficits in the access, engagement, and disengagement of these complex operations (Dosenbach et al. 2008) leading to deficient appraisal mechanisms.

In sum, we suggest that a network perspective supports a transdiagnostic approach to resilience and can contribute to the development of a unifying framework for studying global resilience mechanisms. Notably, a direct link between network architecture

and mental resilience remains to be demonstrated. The accumulating evidence nonetheless suggests that network approaches are highly relevant to the search of a neurobiological framework for the study of resilience.

Positive appraisal style: The mental immune system?[1]

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Abstract: Instead of converging to one, all-embracing resilience mechanism – that is, positive appraisal style – we encourage complementary research strategies, exploring both vulnerabilities and resilience factors, much like the biomedical sciences combine insights from pathophysiology and immunology. Furthermore, we argue that research with a strong focus on one central resilience mechanism may overlook or undervalue other processes that can aid in maintaining mental health.

Kalisch et al. break a lance for more resilience-focused research and make the strong claim that positive appraisal style is the single mechanism that can prevent the development of stress-related disorders. We can only applaud a transdiagnostic approach that explicitly combines research on brain and behavior in a well-considered translational framework. We have a few comments, however, that may dampen some of the initial enthusiasm about this proposal. Our three main points concern the question of whether a focus on resilience will result in the anticipated paradigm shift, some methodological considerations, and the appropriateness of one, "all-in" resilience mechanism.

The authors' description of resilience inspired us to an analogy with human immunology. Resilience is defined as maintaining mental health despite exposure to stressors, and it can be seen as the analogue of actively preserving physical health despite exposure to pathogens such as bacteria or viruses. If we pursue this comparison, positive appraisal style would correspond to the human immune system, because the authors claim that this is the one, central resilience mechanism.

Our first main comment pertains to the desirability and de facto impact of radically focusing on resilience. In contrast to the authors' suggestion of a complete shift away from conventional disorder-focused research, we argue that it is important to understand the pathogen's mechanism of action in order to appreciate the immune response. In other words, we are advocates of complementary research strategies, exploring both vulnerabilities and resilience factors.

From a therapeutic point of view, it seems that this hand-in-hand approach may already have been set in motion. Over the past 15 years, several psychotherapeutic methods implicating positive (re)appraisal have been developed; for example, positive psychotherapy (Seligman et al. 2006), well-being therapy (Fava & Tomba 2009), strengths-based cognitive behavioral therapy (Padesky & Mooney 2012), and to a certain extent maybe even mindfulness (Segal et al. 2002). (It is noteworthy that the neural correlates of mindfulness and cognitive reappraisal are virtually the same; Opialla et al. 2014.) Interestingly, all these treatment strategies are being put forward as helpful adjuncts that should not necessarily stand alone, but may be integrated with other therapies. This indicates that the positive appraisal angle is valuable, but mainly as a complement to the traditional approach.

On top of that, psychopathology and resilience researchers will often (admittedly, not always) be looking at two sides of the same coin. For example, depressive rumination is characterized by an abstract processing style (i.e., thinking about the causes, meanings, and implications of an event). In line with this finding, recent studies have found that a concrete processing style (i.e., focusing on the specific perceptual details of an event) counteracts dysphoria (Watkins et al. 2009) and depression (Watkins et al. 2012). These examples illustrate that it seems advisable not to completely discard pathology research, but rather to combine it with the proposed resilience approach.

Our second main remark relates to some of the methodological innovations proposed by the authors. First of all, we are not sure whether abandoning self-report measures in laboratory settings, and replacing them completely with physiological or behavioral parameters, will prove to be a fruitful approach. Whereas physiological measures might have the advantages of being more objective and translatable to animal research, self-report-based measures provide valid information about the subjects' experience, which could be viewed as the ultimate criterion when aiming to improve mental health (Boddez et al. 2013b). Moreover, subjective measures might be useful in the investigation of high-level appraisal mechanisms, which appear to have neural correlates that differ from low-level mechanisms (Kalisch et al. 2006b).

In addition, we would like to scrutinize some of the laboratory procedures that the authors propose as examples of reappraisal. Although we recognize that an extinguished stimulus is ambiguous (Bouton 2002) and may be subject to appraisal, we would be wary of a priori equating extinction, a procedure in which the subject experiences that the outcome is changed externally, with a situation where the objective value of an event does not change (e.g., the sacked employee does not get his job back). The same holds for the counterconditioning procedures that the authors mention. We do not preclude that extinction or counterconditioning can be framed as reappraisal, but this awaits empirical demonstration; for example, by showing that extinction performance is affected by manipulation of the well-known appraisal dimensions. Given our consideration about the actual change of stimulus outcome, we suggest that it may be (more) interesting to focus on conditioning procedures in which the threat value of a stimulus is changed in the absence of new direct experience with this stimulus, the so-called retrospective revaluation procedures (e.g., backward blocking; Boddez et al. 2013a).

Our third main point concerns the potential risk of putting all one's eggs in the same positive appraisal basket, and this for at least two reasons. First, even though it may be meaningful to look for general, integrative principles (Meiser 2011), a priori focusing on only one overarching mechanism can make researchers lose sight of other important resilience (sub)mechanisms that may prove instrumental in the development of new treatment options. Two promising examples of such (sub)mechanisms are memory and attention. Pilot data suggest that memory specificity training reduces depressive symptoms (Raes et al. 2009). In addition, positive mood produces a broadening of attention that may play an important role in the resilience against stressful events (Grol et al. 2014). Kalisch and colleagues can of course claim that these factors have an effect because they converge to positive appraisal; but in such argumentation, appraisal itself becomes an explanandum, again underlining the importance of other, explanatory (sub)mechanisms. In this regard, we also fear that broadening the definition of positive appraisal to a point where it includes everything would render it a useless concept.

Second, we argue that it might sometimes be worthwhile to look for resilience mechanisms that may protect only against specific pathological processes (Rutter 1993). For example, strong perceptual discrimination abilities may protect against overgeneralization (Lommen & Ehlers 2014), but not against any pathological process. Or, if we return to our immunology analogy: Just like the development of highly specific vaccines has been of vital importance to improving immunity to particular diseases, it may be valuable to not exclusively focus on general protective mechanisms.

NOTE
1. The authors contributed equally to the preparation of this commentary.

Are positive appraisals always adaptive?

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Abstract: The authors provide an original and integrative framework for understanding the complex array of factors that contribute to resilience. Their faith in the uniform benefits of positive appraisals neglects the potential costs of overly positive appraisals, however. As a result, their theory may have difficulty capturing the complexity of appraisal's role in determining resilience.

What makes a person resilient to stress? As Kalisch et al. correctly point out, the predictors of resilience are many, spanning individual differences (e.g., intelligence, emotion regulation, neuroticism), social dimensions (e.g., perceived and received support, social integration), and contextual factors (e.g., severity of exposure, material resources, and current stress). In this stew of influences, no single resilience ingredient has predominated, and resilience usually is thought to derive from a complex array of risk and protective factors (Bonanno 2004; Masten 2001). Although theorists have made preliminary attempts to integrate these factors along the lines of shared mechanisms (Benight & Cieslak 2011; Mancini & Bonanno 2009; Masten et al. 2003), the need for a better theoretical understanding of resilience remains clear. In the target article, Kalisch et al. provide that understanding, making expansive use of a concept long recognized in the stress and emotion literatures: appraisal (Lazarus & Folkman 1984; Russell 2003). The authors have shaken the dust off appraisal, provided a scholarly and sophisticated overview of it, and given it a new pride of place as the single explanatory mechanism of resilience. In the process, they have provided a compelling and generative framework for the study of resilience.

Any single-mechanism theory has the virtue of parsimony. By the same token, any single-mechanism theory has the potential vice of oversimplification. The authors' account synthesizes an unwieldy resilience literature, provides a variety of falsifiable hypotheses, and explains the heterogeneous nature of resilience predictors. But it also relies excessively on a simple evaluative distinction between positive and negative appraisal that neglects, in my view, the more complex situational and contextual demands that must be accommodated (and appraised) in order to achieve resilience. I will address my comments to this point.

The key contributions of Kalisch et al. are twofold. First, they introduce an appraisal "style" that characterizes individuals'

habitual interpretation of stressful experiences. Second, and more important, they argue that appraisal is the single mediating mechanism of resilience. This last is a radical and deeply interesting proposal. Thus, all of the varied predictors of resilience – perceived social support, worldviews, self-enhancement, repressive coping, perceived coping efficacy, hardiness, mastery, and material resources – are hypothesized to contribute to resilience through their influence on a more positive or benign appraisal of stressful experiences. For individuals with a more positive appraisal style, stressful events usually are interpreted more benignly, either through positive situation classification (for minor stressors) or through positive reappraisal (for stressors that are objectively negative). For those with a more negative appraisal style, stressful events are viewed in a more threatening light, resulting in minor stressors being viewed as threatening and major stressors as more catastrophic.

The authors' argument on these points is straightforward and, in the main, persuasive. But despite their assertions of the multidimensional nature of appraisal, their theory relies on a key assumption: that positive (or non-negative) appraisal = positive adaptation. Are positive appraisals always adaptive for functioning? A compatible literature suggests that emotions, both positive and negative, are adaptive to the extent that they are sensitive and appropriate to the context (Bonanno et al. 2007; Coifman & Bonanno 2010). By extension, appraisals of an acute stressor are likely also adaptive to the extent that they promote coping behaviors appropriate to the context, not simply whether the appraisal is positive or negative (though it seems clear that positive appraisals hold a general adaptive advantage). For example, a person who views a significant stressor in too positive of a light (through either positive situation classification or easy positive reappraisal) might fail to mobilize his coping efforts and to anticipate significant obstacles ahead. In effect, too positive of an appraisal, either of the person's capacity to cope or of the event itself, would have potentially negative consequences for long-term adaptation. Conversely, an excessively negative appraisal of an event would likely lead to a defeatist response that also fails to mobilize coping efforts. In both cases, it is not simply the positive or negative valence of the appraisal but the degree to which it supports, through an optimistic and realistic appraisal of the objective circumstances, adaptive coping behaviors.

Is there any evidence for this perspective? My colleagues and I examined survivors of traumatic injury that required surgery at a Level 1 trauma center (deRoon-Cassini et al. 2010). They were assessed while in the hospital and at 1, 3, and 6 months post-surgery. We identified four distinct trajectories of post-traumatic stress disorder (PTSD) and depression symptoms: resilient, gradual recovery, chronic distress, and delayed. A robust differentiator of these trajectories was the person's early perceived coping efficacy, an index of his or her appraisal of the event. To our surprise, both excessively positive and excessively negative appraisals of coping efficacy were maladaptive. Specifically, the group who eventually showed a delayed PTSD response reported the *highest* levels of perceived coping efficacy, substantially higher than the resilient group; whereas the group that reported chronic distress showed the *lowest* levels of perceived coping efficacy. In between these extremes were resilient persons, who viewed their coping efficacy as neither excessively positive nor negative. These findings indicate that an appraisal of one's coping that fails to take full stock of the realities of the situation puts that person at risk.

Indeed, despite my broad agreement with the authors' theoretical framework and my belief that it is an important advance, their emphasis on the uniformly adaptive value of positive appraisal fails to contemplate the adaptive implications of negative appraisals. In short, simple positive appraisal (and reappraisal) has difficulty providing a full accounting of the flexible and adaptive union of subjective experience and objective reality that is the hallmark of resilience.

When at rest: "Event-free" active inference may give rise to implicit self-models of coping potential

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Abstract: Kalisch and colleagues highlight coping potential (CP) as a principle resilience mechanism during event engagement. We complement this discussion by exploring generative implicit CP self-models, arguably emerging during "resting-state," subsequent and prior to events. Resting-state affords a propitious environment for Bayesian learning, wherein appraisals/reappraisals may update active inferential CP self-models, which then mediate appraisal style organization and resilience factor valuation.

Kalisch et al. provide an impressive model that considers resilience in terms of "quantitative outcome variables," resulting from events. Accordingly, events elicit mental representations, which generate primary and secondary appraisals, the latter comprising coping potential (CP). Here we wish to underscore the possible regulatory value of "event-free" resting-states regarding implicit CP self-models and their role in mediating appraisal styles and resilience factors. Resting-state is a critical period, when we disengage from cognitively/affectively demanding environmental cues and tasks, and where the brain is "free" to process information from previous environmental interactions (Spreng & Grady 2010) and to prepare for future engagements. Neuroimaging data have implicated resting-state in the role of maintaining coherent and cohesive conceptual representations of self, or self-models (e.g., D'Argembeau et al. 2005; Schneider et al. 2008). We propose that CP self-models assist in organizing resource allocation strategies for adaptive appraisal styles and in constructing value-based resilience factor representations. Resting-state may therefore permit automatic recursive affirmations and updating of implicit self- and world-representations per retrospective/prospective mental projections (Ostby et al. 2012). These representations then organize appraisal styles and attribute self-relevant value to resilience factors for future event engagement.

Using a Bayesian approach (Friston 2012; Helmholtz & Southall 1962), we infer that during resting-state, implicit CP self-models incorporate beliefs generated posterior to experiencing the world. These self-models are then updated to maximize prediction accuracy for future events (Bengtsson & Penny 2013). This prospective mental projection can occur explicitly, but also implicitly (Gerrans & Sander 2014). From Bayesian learning theory, it follows that implicit CP self-models may emerge from active inference of the world's potential to elicit affective self-states, promote/prevent goal achievement, and confer reward/punishment (Moutoussis et al. 2014). Accordingly, active inference uses previous experiences to generate implicit (and explicit) representations of "efficacy expectancies."

These representations, or *empirical priors* (Friston et al. 2013), hence constitute implicit self-models of CP and include

representations of others' capacity to help effectively in resolving conflict ("other-efficacy"). Implicit CP self-models reflect non-conscious attitudes and predictions toward one's capacity to cope/adjust to a situation. Behavioral and neuroimaging data illustrate the existence of implicit self-models (Back et al. 2009; Rameson et al. 2010), which may organize appropriate action tendencies and cognitive strategies necessary for elaborating positive protective appraisal/reappraisals. In alignment with the authors' PASTOR model, implicit CP self-models and world-models (e.g., other-efficacy, outcome expectancies) would organize beliefs, attitudes, and interpretive biases, which define appraisal styles, into a coherent narrative to minimize inconsistent future predictions (e.g., Bengtsson & Penny 2013). According to Kalisch et al., appraisal styles represent important variables predicting a resilient outcome and are mediated by unconscious (and conscious) processes. Likewise, we suggest that appraisal styles arise extensively from implicit CP self-model representations.

Event-free resting-states provide a unique opportunity for implicit CP self-models to renew and update per retrospective and prospective self-state projections, although this renewal/updating could not occur without appraisal/reappraisal mechanisms. Whereas bottom-up active inference may give rise to empirical priors of self, resting-state would equally permit top-down appraisals, evaluating expected outcomes of self, as an effective agent in the world. This dovetails nicely with neuroimaging evidence suggesting iterative resting-state mental time travel, from retrospective to prospective self-states (Ostby et al. 2012) as well as resting-state default mode network comprising self-referential substrates (Qin & Northoff 2011).

Hence, CP self-models may rely on the very appraisal styles they previously elaborated. For instance, appraisals of empirical priors and ensuing efficacy expectancies (Ellsworth & Scherer 2003) may yield "pessimistic" predictions (e.g., punishment), thus eliciting negative affective states. Consequently, reappraisal operations may ensue, where empirical priors are re-evaluated/re-interpreted and positive self-memories of coping and self-efficacy are incorporated. This parallels the authors' proposal for a memory-based "positive situation classification" process. Consequently, effective reappraisals would update empirical priors, which give rise to self- and world-models, and would minimize negative affective states experienced during rest. Hence, implicit CP self-models may be maintained thanks to appraisal styles elaborated previously by earlier self-models.

In order to benefit from positive appraisal styles, however, one must equally benefit from the value of resilience factors, an additional variable predicting a resilient outcome. CP self-models may serve as a valuation mechanism for resilience factors such as social support. Specifically, empirical priors may predict "other-efficacy," as ensuing implicit CP self-models determine its self-relevant value. It is not sufficient to acknowledge one's network of close others; one must also appreciate the value in relying upon these close others. The authors' discussion of social support as a resilience factor is very relevant to the ongoing neurocognitive research in social anxiety disorder (SAD). SAD's symptomatology is distinguished by elevated fear and avoidance of future social interactions, and may reveal inadequate implicit CP self-models in social settings. In a review paper currently under preparation, we present published SAD event-free neuroimaging data to inform our theory of discrepant generative SAD CP self-models (Murray et al., in preparation). We highlight key self-related neural substrates (e.g., pregenual anterior cingulate (Murray et al. 2012) and putative social-valuation regions (e.g., orbitofrontal cortex [Ruff & Fehr 2014]), which illustrate structural/connectional aberrancies in SAD during event-free states. Our preliminary framework articulates SAD symptomatology as arising from static and poorly defined implicit event-free CP self-models, the validation of which may depend disproportionately on social information. Nevertheless, these self-models may prove incapable of exploiting positive social feedback in order to

update empirical priors. This may potentially result from deficient valuation and appraisals/reappraisal mechanisms effectuated during event-free states (Murray et al., in preparation). Our recent work reviewing neurocognitive evidence of SAD symptomatology would therefore lend support to our claim that event-free implicit CP self-models may mediate the self-relevant value of resilience factors such as social support.

Today, there exists increasing neurocognitive literature validating appraisal theory predictions (cf. Brosch & Sander 2013). Although efforts to elucidate the neural substrates underlying CP are still in their infancy, Kalisch and colleagues have set forth a pragmatic framework for its future testing and analysis. We hope to contribute to this discussion by promoting event-free resting-state as an area of focus for the renewal and updating of implicit CP self-models.

Phenotypic programming as a distal cause of resilience

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Abstract: During early childhood, individuals with high sensitivity to early programming adjust their phenotype in a way that is expected to be adaptive in their later environment. These adaptations are hypothesized to result in resilience in environments that match the early environment. As appraisal style is a putative target of adaptive programming, early experiences could be a distal cause of resilience.

Kalisch et al. make a convincing case that a positive appraisal style is the proximal cause of transdiagnostic resilience. Another relevant question is, what causes positive appraisal? In other words, what is the distal cause of resilience? In my commentary, I argue that early experiences determine an individual's appraisal of a certain situation and are therefore a distal, or ultimate, cause of resilience.

Animals, including humans, have been shown to have considerable phenotypic plasticity. That is, individuals are able to adjust their phenotype to meet environmental demands. This phenomenon has been extensively studied in developmental contexts. During early childhood, including the fetal period, individuals are especially sensitive to programming effects of their environment (e.g., Gluckman et al. 2007; Lupien et al. 2009).

Individuals sample their environment for cues that more or less reliably predict their future environment (Kuzawa 2005). Through these cues, they learn about their environment and gradually adjust their phenotype to match specific demands (Frankenhuis & Panchanathan 2011). For example, humans are hypothesized to adjust their stress-responsivity, which is closely tied to their appraisal of stressful situations (Del Giudice et al. 2011; Ellis & Del Giudice 2014). Although phenotypic programming might result in resilience in environments that match the phenotype adjustment, it is known also to have an important trade-off. If the later environment turns out differently than predicted, a phenotype-environment mismatch can have detrimental effects (Frankenhuis & Del Giudice 2012; Nederhof & Schmidt 2012).

Early in life, individuals are most likely to adapt their phenotype to meet future environmental demands, compared with any other period in life. Traditionally, this has been seen as a window of vulnerability. More recently, researchers have started to appreciate the possible positive implications of such a period of increased sensitivity (Andersen 2003). The window of vulnerability has become a window of opportunity. During this window of

opportunity, individuals are most sensitive to both positive and negative cues in their environment, either to profit optimally from the environment or to arm oneself optimally against it (Boyce & Ellis 2005; Del Giudice et al. 2011).

Several animal studies also support the notion of resilience in matched and vulnerability in mismatched situations. For example, Champagne et al. (2008) showed in rats that offspring of low-licking and -grooming dams performed better in a contextual fear-conditioning paradigm compared with offspring of high-licking and -grooming dams. Variation in licking and grooming behavior occurs naturally and can be influenced by stressfulness of the environment (Ivy et al. 2008). Other studies showed similar effects (Daskalakis et al. 2012), also when using other stress-paradigms, such as maternal separation (Biggio et al. 2014; Zalosnik et al. 2014), limited nesting material (Santarelli et al. 2014), or prenatal stress (Van den Hove et al. 2014). It must be noted, however, that not all animal studies support the mismatch hypothesis (see Nederhof & Schmidt 2012).

This might point in the direction of adversity having adaptive programming effects in some but damaging effects in others. Nederhof and Schmidt (2012) proposed that programming sensitivity might differ between individuals. This suggestion was based on the observation that natural selection favors diversity, because the future is uncertain. Indeed, it has been suggested that, from an evolutionary perspective, it makes sense to invest in offspring that differ in sensitivity to programming effects (Belsky et al. 2007; Ellis et al. 2011). Individuals with high programming sensitivity are hypothesized to adjust their phenotype, including appraisal, in a way that is expected to be adaptive in their later environment (Nederhof & Schmidt 2012). As a consequence, appraisal styles are expected to be more positive in matched compared with mismatched situations in these individuals, resulting in resilience in matched situations and vulnerability in mismatched ones. In individuals with low programming sensitivity, stressful events are hypothesized to accumulate and increase the risk for stress-related diseases (Nederhof & Schmidt 2012).

Recent evidence prudently supports this notion. Oldehinkel et al. (2014) showed that early adversity increased the risk for early-onset depression, but not for later onsets. They also showed that those who experienced adversity but were not affected by depression before the age of 16 seemed more resilient under stressful conditions compared with others who did not experience early adversity. A similar finding was published by Nederhof et al. (2014), who showed that the interactive effects of early and recent adversity depended on attention style, assuming that attention style could be the result of programming effects. It must be noted, however, that these two studies were conducted in the same sample.

As far as I am aware, there is one other study in humans providing evidence for resilience in matched and vulnerability in mismatched situations. Brody and colleagues (2013) showed that African-American youth from high-risk backgrounds with high self-control and social/academic competence had more physiological risk factors than did youth with similar backgrounds but low self-control and competence. On the other hand, these high-risk/high-self-control youth showed fewer depressive symptoms compared with high-risk/low-self-control youth.

Unfortunately, in none of these studies was appraisal style used. Future research should investigate whether appraisal style is affected by early adversity in an adaptive way that could constitute resilience later in life. If such a notion would be supported, we would come closer to an answer to the question of what the distal cause for resilience might be.

Integration of negative experiences: A neuropsychological framework for human resilience

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Abstract: We propose that the fundamental mechanism underlying resilience is the integration of novel or negative experiences into internal schemata. This process requires a switch from reactive to predictive control modes, from the brain's salience network to the default mode network. Reappraisal, among other mechanisms, is suggested to facilitate this process.

Although we agree with Kalisch and colleagues that positive appraisal is an important mechanism of facilitating resilience, we propose a more fundamental mechanism underlying resilience. Specifically, based on a neurobehavioral framework (predictive and reactive control systems theory; cf. Tops 2014; Tops et al. 2013a; 2013b; 2014a; 2014b), we propose that integration of novel and negative experiences into coherent internal models (or "schemata") of already integrated experiences is central to resilience (see also Kent 2012; Kuhl 2000; 2011; Kuhl et al. 2015), with positive (re)appraisal and other mechanisms facilitating such integration (cf. Fig. 1).

According to this framework, two control systems in the brain can be distinguished: reactive versus predictive networks. Reactive control appraises novel (schema-incongruent), salient, and degraded stimuli and guides attention, emotions, and behavior in immediate and continuous response to such stimuli. Reactive control is typically accompanied by tense arousal and negative affect, particularly when the stimulus is assessed as a potential threat. This system includes brain areas overlapping with the "salience network" (cf. Downar et al. 2002). By contrast, predictive control is typically activated in the relative absence of threats, or when the individual perceives the threat as predictable and manageable. This system includes brain areas overlapping with the "default mode network" (DMN; cf. Buckner & Carroll 2007).

During predictive but not reactive control, negative experiences can be readily integrated into internal models representing relationships between entities, motivations, actions, and outcomes (also referred to as "the self-system"; e.g., Kuhl 2000; Kuhl et al. 2015; see also Koole & Jostmann 2004; Quirin et al. 2011). This integration process puts negative experiences and concomitant emotions in perspective, and it provides the individual with a sense of coherence (Antonovsky 1987), controllability (Bandura 1977; Deci & Ryan 1980; Rotter 1954), and meaning (Frankl 2004). When the individual is confronted with similar situations in the future, integrated experiences can be recalled and will provide context and perspectives for perception and appraisal of the situation. Individuals can thus more readily and flexibly switch from stressful reactive control, with its narrow focus on the salient stimulus, to more relaxed predictive control, with its prudent, mindful, attentional mode, in order to "keep their heads" (Kuhl 2000; Tops et al. 2013b). In the end, this results in affective relief and thereby facilitates resilience.
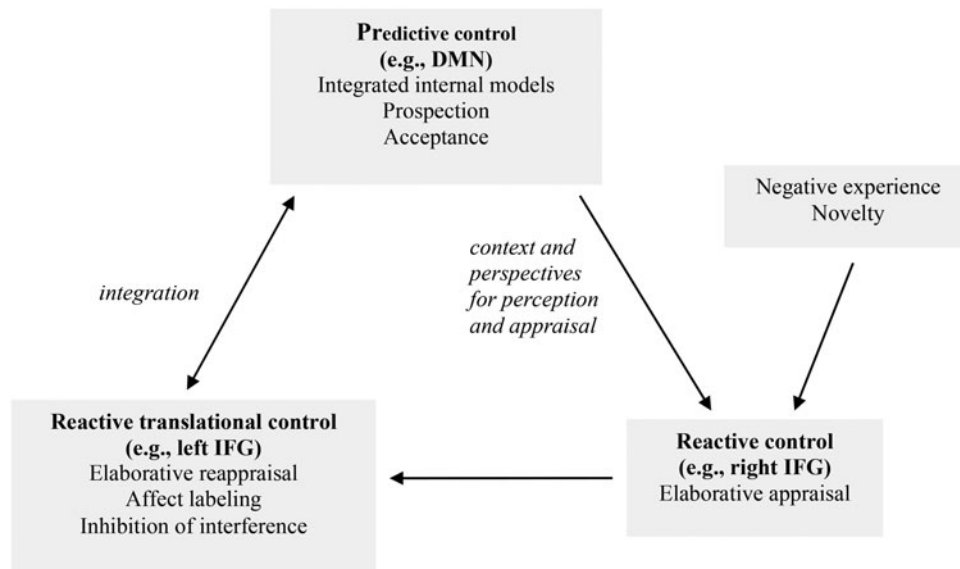
Figure 1 (Quirin et al.).   A neurobiological model of resilience based on the integration of negative experiences, derived from predictive and reactive control systems theory. DMN=default mode network; IFG=inferior frontal gyrus.

Consequently, individual tendencies to accept and integrate negative experiences (rather than to deny, repress, sensitize to, or avoid them) constitute the basis for a continuous formation of extended, integrated, and differentiated internal models and, therefore, for personal growth and sustained resilience throughout life (Kuhl 2000; 2011). Indeed, acceptance of negative experiences has been related to physiological indicators of health and has been shown to foster resilience following exposure to trauma (Thompson et al. 2011).

Although the availability of well-integrated internal models may be a prerequisite for resilience, highly incongruent emotional or traumatic information may challenge internal models and resist immediate integration. We suggest that in such situations, adaptive switches from reactive to predictive control and concomitant integration can be facilitated by reappraisal, and by other subsidiary mechanisms such as prospection or labeling of emotions, as those involve effortful elaboration and semantization necessary for incongruent experiences to become integrated. Prospection refers to the mental representation and evaluation of possible futures, often including planning, prediction, or construction of hypothetical scenarios. Indeed, prospection yields physical and psychological benefits in daily life and in resilience treatment approaches (Kent 2013; Seligman et al. 2013). Finally, labeling emotions verbally (Burklund et al. 2014; Pennebaker 1993) or sharing them with others (Rimé 2009) alleviates stress and facilitates integration, much like reappraisal does. For example, when incongruent or unfamiliar experiences challenge collective knowledge and elicit negative emotions, affective sharing can accommodate and absorb these experiences into socially shared internal models, thus reducing their negative valence and concomitant negative emotions (Rimé 2009) by facilitating predictive control.

In terms of the neural underpinnings of the capacity to shift from reactive to predictive control modes and to integrate negative experiences, the inferior frontal gyrus (IFG) plays a key role, with partly different functions for left and right IFGs. The right IFG is implicated in elaborative appraisal of novel (emotional) stimuli and is more strongly interconnected with limbic (emotional) areas such as the amygdala and the striatum. The left IFG is implicated in translation of novel emotional experiences into semantic information that later can be integrated into existing internal models of the predictive control system (as supported by DMN areas such as posterior cingulate and medial prefrontal cortex, precuneus, and posterior hippocampus; Tops et al. 2014b).

There is indeed evidence that the resilience mechanisms considered subsidiary in the present framework also may be facilitated by the left IFG. For example, this area often coactivates with areas of the DMN during prospection (Spreng et al. 2009). Also the left IFG has been implicated in successful encoding of negative memories during reappraisal (Hayes et al. 2010) and in the inhibition of interfering appraisals or other distractors (Andrews & Thomson 2009), a process that contributes to reappraisal. Further, individuals who accept negative experiences, but not those who deny them, show left IFG activation in anticipation of uncontrollable pain (Salomons et al. 2007). Finally, similar to what is found in studies of reappraisal, during verbal labeling of unpleasant emotions, activation of the left IFG (including Broca's area) increases, whereas amygdala activity and bodily arousal decrease (Torrisi et al. 2013; cf. Bach et al. 2008; Creswell et al. 2007; Frühholz et al. 2012; Herwig et al. 2010). Hence, particularly the left IFG appears to have an intermediate status between reactive and predictive control, allowing for important switches between modes of control, which in turn promote resilience.

In sum, our neurobehavioral framework emphasizes integration of negative experiences as a fundamental neurocognitive mechanism underlying sustainable resilience, while not ignoring the relevance of (re)appraisal or other resilience mechanisms. Although this framework is functional in nature, it is nonreductionistic, because it considers a broad array of psychological processes. Consequently, our framework has the potential to integrate psychologically and biologically oriented approaches toward resilience.

Animals can tell us more

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Abstract: From a behavioural biologist's point of view, we argue: (1) The study of resilience in animals should not be restricted to neuronal mechanisms. Rather, questions of ontogeny, function, and evolution also

should be addressed to achieve a comprehensive understanding. (2) Implementing new paradigms from animal welfare research in studies of resilience would allow an assessment of appraisal styles in animals.

In their target article, Kalisch et al. propose a theoretical framework for the neuroscientific study of general resilience mechanisms that are applicable to both human and animal research. In this commentary, we argue from a behavioural biologist's point of view that animals could tell us more if (1) this framework were extended and (2) new paradigms were included to assess appraisal styles in animal research, as well.

Concerning (1), more than 50 years ago, in his seminal publication "On Aims and Methods of Ethology," Nobel prize winner Nikolaas Tinbergen (1963) argued that a comprehensive understanding of behavioural phenomena should give equal attention to the questions of *causation*, *ontogeny*, *survival value,* and *evolution*, and to their integration. We recommend the Tinbergen framework be applied to the study of resilience in animals as well, because the broader our understanding of resilience, the more successfully we can apply that understanding to humans. Accordingly, the study of resilience in animal research should not be restricted to elucidating the underlying neuronal, cellular, and molecular mechanisms in adult individuals (*causation*). Rather, it is likely that these mechanisms are shaped by environmental stimuli and genes during sensitive phases of life (*ontogeny*). Typically, this shaping process is not confined to the early postnatal period, but occurs from the prenatal phase through to adolescence and beyond (Sachser et al. 2013). We therefore recommend that ontogenetic perspectives be integrated into future experimental animal research on resilience mechanisms.

In the target article, a positive appraisal style is considered the key resilience mechanism, and therefore, optimism is regarded as the common final path to mental health. Given that these traits are shaped by natural selection, the question concerning function (*survival value*) arises. At first sight, it seems plausible that a positive appraisal style would maximize Darwinian fitness. But if a positive style was superior to other appraisal styles, natural selection ought to have selected against non-positive versions. The empirical data available from animals show, however, that as in humans, various appraisal/coping styles exist (e.g., Koolhaas et al. 2010). From this it follows that a positive appraisal style cannot always be the best option in all environmental situations, and hence, cannot be regarded as the only path to mental health. Animal studies addressing the costs and benefits of different appraisal styles could, therefore, make a valuable contribution to the debate on this topic in humans (e.g., Sweeny & Shepperd 2010).

Current biomedical animal research focuses strongly on so-called model species, and most experimental work on resilience probably is performed using laboratory mice. Addressing the question of *evolution* by conducting comparative studies with a range of species would broaden this approach and improve our understanding of resilience significantly. Members of any given species are equipped with physiological, motivational, behavioural, and resilience mechanisms to cope with the demands of their specific ecological niche. Because different species inhabit different ecological niches, we also should expect different coping mechanisms to have evolved. This also means that it is very unlikely that a single animal model would reflect human resilience in a comprehensive way. It is, therefore, important to understand resilience mechanisms in a variety of species. This would significantly facilitate translation from animal research to humans.

Concerning (2), Kalisch et al. suggest that a resilience readout in an animal experiment would require two elements: a battery of stressors that adequately models human-life stressors, and a "mental health" testing battery assessing the animal's functioning before and after having experienced the stressors. Such testing may indeed shed light on behavioural and neurobiological pathways to resilience, but it is unlikely to provide a good understanding of the role of stimulus appraisal in the generation of emotional responses. We note that appraisal style can be assessed directly in animals, as well.

In 2004, Harding and colleagues developed methods to determine emotional states by measuring differences in judgement bias in rats. The animals were trained to press a lever to obtain a food reward in response to one tone ("positive tone"), and to refrain from pressing the lever in response to a different tone ("negative tone") to avoid the presentation of white noise. Having learned to discriminate between these two "reference tones," the rats' responses to ambiguous, intermediate tones were investigated. Animals that were housed in unpredictable conditions responded less often to the "ambiguous tones" and showed longer response latencies to such tones than did animals that were housed in a predictable environment. Hence, rats in unpredictable – that is, more stressful housing conditions – show behaviour indicating reduced anticipation of a positive event, reflecting a pessimistic judgement bias. They judged "the glass is half empty and not half full."

Meanwhile, such cognitive bias investigations have been performed in a wide range of species including mice, dogs, sheep, and rhesus macaques (e.g., Mendl et al. 2010) and clearly show that positive and negative appraisal styles exist, and can be assessed also in animals. The use of such techniques in studies of resilience would, in this way, help to detect emotional biases in judgements similar to those found in humans.

In summary, the Tinbergen framework provides us with an excellent road map for a thorough investigation of resilience mechanisms in animals. In addition, new behavioural paradigms such as cognitive judgement bias tests allow the assessment of degrees of "optimism" and "pessimism"; that is, different appraisal styles in nonhuman animals. The adoption of a broader range of questions and research tools will significantly advance our understanding of this topic, and thus, contribute to a broader understanding of resilience in humans – because the animals are able to tell us more.

Stability through variability: Homeostatic plasticity and psychological resilience

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Abstract: According to Kalisch et al., adopting a cognitive positive appraisal style promotes internal bodily homeostasis and acts as a safeguard against the detrimental effects of stress. Here we will discuss results from recent noninvasive brain stimulation studies in humans to illustrate that homeostatic plasticity provides a neural mechanistic account for the positive appraisal style theory of resilience.

The expression of behavioural adaptive responses to stress is proposed to reflect an important evolutionary principle by which individuals are able to maintain stable behaviour or display behaviour that meets environmental demands as a function of their available internal resources. The degree to which individuals can meet the continuing challenge between stressors and available internal resources depends on a complex interplay among environmental load, experience, and cognitive capacity. The organism's ability to display situation-appropriate responses and downregulate stress is argued to reflect processes of adaptation. These processes of adaptation actively contribute to resilience and psychological well-being by enabling the organism to deal better with comparable stressful situations in the future (McEwen 1998). In fact, Kalisch et al. propose that a cognitive positive appraisal style serves as a protecting factor against the damaging effects of stress and promotes resilience and well-being.

The degree to which an individual can adopt a cognitive positive appraisal style is arguably determined by the flexibility of the central nervous system for maintaining internal bodily homeostasis. In particular, the dynamic range of changes as a result of context-related demands is known as brain plasticity, and it provides a neurobiological basis for the individual's ability to generate, select, and execute situation-appropriate behavioural (coping) strategies. More specifically, the up- and downregulation of cortical excitability levels reflect an important aspect of brain plasticity that is considered fundamental to humans' ability to adapt and anticipate to their surroundings on the basis of experience (Lourenco & Casey 2013). Long-term potentiation and long-term depression, also known as input- and synapse-specific Hebbian plasticity, have been identified as basic neurobiological principles by which cortical excitability and synaptic signal transmission can be respectively enhanced or reduced (Barrionuevo et al. 1980; Lømo 1966; Pascual-Leone et al. 1998).

The modulation of neuronal excitability levels arguably depends on an intricate balance between excitatory (glutamatergic) and inhibitory (GABAergic) circuits (Lui & Lachamp 2006). In general, increased cortical excitability has been linked to greater plasticity and being beneficial to adaptive behaviour, whereas enhanced inhibition of cortical excitability levels has been associated with impaired plasticity and behavioural impairments (Johnston 2009). Importantly, however, the regulation of the balance between inhibitory and excitatory systems keeps neural circuits within a functional range (Whitt et al. 2013). This regulatory process is called homeostatic plasticity and satisfies two necessary conditions for successful adaptation, namely stability and variability, and prevents states of excessive neuronal hypo- and hyperexcitability (Bienenstock et al. 1982; Quartarone et al. 2006).

A typical example of an organism's adaptive response to stress is the fight–flight response, which, among many other physiological reactions, includes activation of the hypothalamus-pituitary-adrenal cortex (HPA) axis and the release of the hormone cortisol. Several studies have found that cortisol negatively affects brain plasticity by influencing the inhibitory system (Milani et al. 2010; Sale et al. 2008). In a paired associative stimulation (PAS) study in which peripheral nerve stimulation is combined with transcranial magnetic stimulation of the cerebral cortex to elevate neural excitability levels, it was shown that the administration of cortisol in healthy volunteers interferes with PAS-induced increases in cortical excitability (Sale et al. 2008). The observed reductions in cortical excitability were interpreted as effects caused by increased inhibitory activity, which, at first glance, seems at odds with more-recent findings showing that cortisol administration increases cortical excitability levels (Milani et al. 2010). In the latter study, cortisol administration reduced intracortical inhibition and was interpreted as a cortisol-driven decrease in GABAergic activity (Milani et al. 2010).

This paradoxical finding can be explained by homeostatic plasticity: Cortisol administration increases cortical excitability, but when combined with another excitatory intervention, such as PAS, the effects of cortisol become inhibitory to prevent cortical hyperexcitability (cf. Siebner et al. 2004). Furthermore, it is possible that cortisol promotes brain plasticity acutely but has a disruptive effect when circulating levels are chronically elevated. How these temporal effects exactly translate to the behavioural domain remains an open question. Nonetheless, in agreement with Kalisch et al., homeostatic plasticity plays an important role for keeping the brain in a functional range in response to stress. Homeostatic plasticity thus provides a protective physiological mechanism, which promotes psychological resilience by allowing a certain amount of variability on top of stability.

Because abnormalities of inhibitory circuits and cortical plasticity have been repeatedly demonstrated in patients with depression (Bajbouj et al. 2006; Player et al. 2013), impaired homeostatic plasticity in response to stress can provide an account, at least in part, for the relation between lowered psychological resilience and presence of depressive symptoms. More indirect support

comes from a study showing a positive association between neuroticism and reduced intracortical inhibition in healthy volunteers (Wassermann 2001). These reductions may hint at an imbalance between inhibitory and excitatory circuits and provide a neurobiological basis for suboptimal coping strategies due to cortical hyperexcitability. That neuroticism is characterized by a lack of cognitive positive appraisal style and a susceptibility to experiencing anxiety and depression concurs with the inverse relation between neuroticism and psychological resilience (Campbell-Sills et al. 2006). Moreover, in stressful conditions, neurotic individuals tend to display a limited amount of coping strategies or reside in stereotypical responses that were successful on prior occasions (Parkes 1986). As brain plasticity in healthy individuals is a mechanism for initiating a more dynamical range of situation-appropriate coping behaviours, such maladaptive behavioural response patterns arguably are due to aberrant brain plasticity.

In this commentary, we have introduced homeostatic plasticity as a candidate neurobiological mechanism to explain the psychological effects of cognitive positive appraisal style on well-being. Suboptimal forms of homeostatic plasticity are argued to more easily lead to a dysfunctional imbalance between the inhibitory and excitatory cortical circuits that undermines behavioural flexibility and lowers psychological resilience. In addition to complementing the model of Kalisch and colleagues, homeostatic plasticity may further help set the physiological boundaries for studying the psychological mechanisms of resilience.

Quantifying resilience: Theoretical or pragmatic for translational research?

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Abstract: Quantifying resilience allows for several testable hypotheses, such as that resilience is equal to the number of mental health problems given a known quantity of stressor load. The proposed model lends itself well to prospective studies with data collection pre- and post-adversity; however, prestressor assessments are not always available. Challenges remain for adapting quantifying resilience to animal research, even if the idea of its translation value is significant.

In light of the National Institutes of Health–initiated paradigm shift toward dimensional approaches to measuring mental health outcomes, as defined in the Research Domain Criteria (RDoC; see Cuthbert 2014a; Insel et al. 2010), the current review offers a new framework nicely aligned with this approach. Kalisch et al. provide not only a dimensional perspective but a quantifiable one. The review focuses on resilience rather than illness and suggests that resilience should be transdiagnostic, another tenet of the RDoC initiative. Of course, true resilience would necessarily be transdiagnostic – patients who compensate for deficits in one domain by showing impairments in another would not be considered resilient (e.g., post-traumatic stress disorder patients who successfully reduce hyperarousal symptoms by abusing substances; Bremner et al. 1996).

Quantifying resilience allows for several testable hypotheses, such as that resilience is equal to the number of mental health problems given a known quantity of stressor load. Although cataloguing stressor load may seem problematic, most studies assess stressors along a continuum – for example, post-traumatic stress

disorder researchers quantify trauma load with questionnaires that assess degree of trauma exposure (Elhai et al. 2005). A comprehensive measure of total stress exposure (both major and minor, as the authors suggest) may not always be possible, however; if the outcome of interest is resilience in the face of trauma, for example, a measure of trauma load may suffice.

The proposed model lends itself well to prospective studies with data collection at two time points (i.e., pre- and post-adversity); however, not all studies have the luxury of prestressor assessments. In such cases, the authors argue that the cumulative mental health problems post-stressor represent the individual's response, which assumes that there were no problems prior to the stressor. Although this ignores a host of predisposing risk factors, it may still provide a heuristic model to study – that is, the inverse ratio of problems to stressor load.

Kalisch et al. also suggest focusing on resilience *mechanisms*, rather than *factors* – an important distinction inasmuch as a number of factors could operate through the same mechanism, thereby reducing the number of analysis units. In fact, risk/resilience factors are many, including but not limited to genetic (Binder et al. 2008), epigenetic (Norrholm et al. 2013), endocrine (Glover et al. 2012; Morgan et al. 2000), neuroanatomical (Admon et al. 2013; Etkin & Wager 2007), and social (Feder et al. 2013). Yet they may converge on a limited number of mechanisms. Further, the authors argue for a single *global resilience mechanism*, that is, positive appraisal, as an explanatory model for resilient outcomes. This is an attractive notion, but it may be overly simplistic and yet at the same time involve complex cognitive demands. In most cases, positive appraisal may be difficult to observe directly and is unlikely to model well in animal research, thereby decreasing its translational applications. Other alternate resilience mechanisms, however, such as less-sensitive amygdala reactivity to threat (Rauch et al. 2000), better emotion regulation (Etkin et al. 2006), or prefrontal inhibition of fear memories (Milad et al. 2009), can be applied to the same quantifiable framework without invoking higher cognitive function.

The innovative contribution of the positive appraisal style theory of resilience (PASTOR) may be less in the specific mechanism proposed than in the mathematical formulation of the resilience phenomenology. Although still largely theoretical in nature, the formula offers a guiding framework in which to organize the variables used in the study of resilience.

As stressors may vary and include physical threat or injury, pain, diseases, and challenges to immune system, to name a few, they impose various types of psychological and physical overload in an acute or chronic way – hence, various mechanisms may underlie coping responses. The idea of a global resilience mechanism can help put in perspective interpretations of studies of the anatomic, cellular, and molecular pathways underlying an improvement in survival and fitness. This can be instructive, as the molecular and cellular mechanisms are divided into those that are common versus those that are specific across different cell types, brain regions, and behaviors.

The idea of being resilient to many and not to just a few stressors can be used to calculate an overall resilience index to be compared with an index representing an animal's general behavioral flexibility. It has been argued that improving overall memory strength may improve the capability of coping with various mental disorders. Some of the biological mechanisms underlying general resilience may involve better control of the environment or be induced by exposure to an enriched environment.

Interpretations of the animal behavioral responses to stress as maladaptive can change as we learn more about their biological significance. For example, when the forced swim test is used repeatedly, an increase in the extent of the immobility during the re-test is often interpreted as despair or learned helplessness. Animals may show enhanced behavioral immobility in the re-test as an adaptive response, however: They display more immobility in the warmer water, but swim more in the colder water to combat the body temperature loss (Reul et al. 2014).

Another caveat is that an organism may be resilient to certain adversities, but vulnerable to others. For example, an individual can be resilient to food deprivation or physical pain but sensitive to losing a mate. Would this suggest that there is vulnerability in the specific pathway related to empathy and reproductive function, or resilience to hunger and pain?

In conclusion, individual differences in coping with stress may allow "testing" different coping strategies both at the individual and species levels. Some maladaptations for an individual can be viewed as helpful and protective for species survival. For example, for an alpha male in some species, losing competitiveness because of inability to cope with stress or threat from other males can lead to a downgrade of the position in the hierarchy that is helpful for the survival of the population, even though it can be viewed as a loss for the individual.

Toward a translational neuropsychiatry of resilience

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Abstract: Neuropsychiatry integrates neuroscience and clinical pathophysiology of the human brain-mind interface. Kalisch et al. provide an important advance with a clear, quantitative, unified neuropsychiatric model of resilience, a crucial adaptive response to adversity. They highlight positive appraisal style, describing underlying neural circuitry and mechanisms. This provides a foundation for the development of biomarkers and targeted therapeutics across the range of neuropsychiatric disorders.

Resilience is a crucial component of the success of complex biological systems. The importance of psychobiological resilience in human health is increasingly appreciated in contemporary medicine. Recent neuroscientific methodologic developments and findings are building on classic observations and starting to elucidate elements and mechanisms of resilience (Wu et al. 2013). The time is therefore ripe for a synthetic conceptual framework to guide and be refined by empirical work at the brain-mind interface. Kalisch et al. have put forth an impressive integration of ongoing work in the context of a clear model and approach that can advance care across the range of neuropsychiatric disorders, which produce tremendous suffering and constitute an enormous global disease burden.

The homeostatic systems that maintain functioning and success, despite adversity, have been refined over the course of evolution (Bernard 1878/1974). Kalisch et al. provide a sophisticated overarching account of the functions, processes, and neural circuits involved. They also posit a key role for positive stimulus appraisal processes in shaping adaptive emotional responses to stressors. In so doing, they bring mechanistic focus to a potential fulcrum for optimizing mental health.

Two general aspects of their approach are notable from a psychiatric research agenda perspective. First, the perspective is transdiagnostic. This is timely and important; psychiatry is moving from a categorical, descriptive classification of disorders to a dimensional, biological approach (Cuthbert 2014b). Such an approach is more aligned with the rest of medicine, and it will permit the development of biomarkers and the identification of new disease mechanism-based subtypes of illness and subgroups of patients (Silbersweig 2013). Biomarkers will, in turn, allow the development of more-targeted therapeutics, as well as the development of predictors of which individual patients will respond to them.

Second, the approach represents a shift from a focus on understanding and reversing negative emotional-behavioral processes toward a (not mutually exclusive) focus on understanding and enhancing positive emotional-behavioral processes (Epstein et al.

2006). This not only provides new avenues for therapeutic development, but also is consonant with patients' desires to think in terms of maximizing health and well-being.

From a psychological perspective, the highlighting of the protective role of positive appraisal and reappraisal is consistent with current cognitive-behavioral therapy approaches that help patients identify maladaptive, negatively biased appraisal styles and learn skills to shift them toward more-objective, empowering styles (Smits et al. 2012).

From a behavioral, neuroscientific perspective, the top-down, prefrontal processes of cognitive appraisal, in the context of goals and experience, meet up with the bottom-up processes in the sensory, subcortical, and limbic processing stream that label the salience of stimuli, events, or experiences (Cutuli 2014). This connectivity plays an important role in mediating motivation and response selection. Kalisch et al. perform a great service to the field by clarifying terms; by being specific about the mediating neuroanatomy at the sub-region level; and by developing a quantitative, testable resilience equation relating stressor load and mental problem burden, using measures, factors, interactions, and outcomes in a unified, probabilistic model.

From a behavioral, neuroscientific point of view, it is also notable and important that Kalisch et al. seek to identify common underlying and higher-level processes regulating resilience. Doing so makes evolutionary and neurodevelopmental sense, and it is consistent with physiological feed-forward and feedback mechanisms underlying homeostasis and allostasis, for acute and chronic stress (McEwen 2013). It also creates a path toward the development of new interventions, whether biological or cognitive-behavioral. In fact, current models of gene-environment interactions are incorporating epigenetics and synaptic plasticity (Desplats 2015), and they also provide temporally dynamic mechanisms by which emotional experience-dependent learning occurs, and by which either somatic or psychological interventions can modulate the relevant final common neural pathways to reduce maladaptive fear and stress responses or enhance safety responses, or both (Johansen et al. 2011).

Neurophysiologically, these processes may involve altering the balance between activation and inhibition; modifying response thresholds, magnitude, and duration; switching sets for approach and avoidance behaviors; and altering overall processing capacity and flexibility. Such processes may be automatic and unconscious or volitional. All of this is consistent with the brain's role in real-time integration of its two overarching functions – being the highest-order orchestrator of the changing internal milieu and needs of the organism, and mediating interactions with the changing contingencies of the external (including social) world (Mesulam 2000; Rolls & Grabenhorst 2008).

Kalisch et al.'s metalevel, yet still granular, approach also can provide a foundation for screening capabilities that may be able to distinguish who will develop difficulties in the setting of adversity, trauma, abuse, or neglect. Such biological risk–resilience profiling is a prerequisite for trajectory-altering early intervention and for the ultimate goal – prevention of profound and potentially transgenerational mental and physical disease sequelae.

Broadening the definition of resilience and "reappraising" the use of appetitive motivation

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Abstract: Kalisch et al.'s PASTOR model synthesizes current knowledge of resilience, focusing on mechanisms as a common pathway to outcomes and highlighting neuroscience as a method for exploring this. We propose the model broaden its definition of resiliency to include positive indices of recovery, include positive affect as a mechanism, and approach motivation as distinct from overcoming aversive motivation.

Kalisch and colleagues define resiliency as "an empirically observable phenomenon, namely that someone does not develop lasting mental health problems although he or she is subject to adversity" (sect. 2, para. 2). By limiting the definition of resilience to *not* developing mental health problems, Kalisch et al. have included only half of the picture. More-expansive definitions of resilience include individuals who are doing particularly well in the face of negative life events. For example, Tugade and Fredrickson (2004) define resilience as "characterized by the ability to bounce back from negative emotional experiences by flexible adaptation to the changing demands of stressful experiences." (p. 320). This definition includes mechanisms such as the experience of positive affect, nurturing social interactions, creativity, a focus on positive memories, and even physical health. Although Kalisch et al. submit some of these as resilience mechanisms, they also can be outcomes indicative of resilience. The possibility that someone may actually show increased well-being following a negative life experience is not addressed in the PASTOR definition and measurement of resiliency. Frazier et al. (2009) found that 25% of participants who had experienced a traumatic event actually reported increases in life satisfaction from pre- to post-trauma. Including positive outcomes will more accurately reflect the goals of resiliency research to study individuals who are flourishing rather than struggling.

Further, some of these mechanisms, such as positive affect, should themselves be considered general mechanisms. According to Fredrickson's (1998; 2001) broaden-and-build theory of positive emotion, positive emotions are thought to facilitate recovery from negative life events by broadening people's attention (Fredrickson & Branigan 2005), inducing more-creative thinking (Isen et al. 1987), and contributing to a broad-minded coping style (Fredrickson & Joiner 2002). In this way, positive affect is similar to, but independent from, a positive appraisal style. Positive affect may mediate the relationship between resilience factors – such as social support, personality, coping style, and physiological variables such as vagal control (Oveis et al. 2009) – and outcomes related to resiliency – such as decreased susceptibility to mental and physical illness.

Similarly, Kalisch et al. describe resilience mechanisms as those that reduce aversive motivation. Recent research suggests that appetitive motivation may be just as important a focus of resilience mechanisms. Orthogonal to aversive motivation, humans decide whether to engage in appetitive motivation separately. As one example, although finding an event aversive, someone who experiences anger may move toward and engage with it. In the context of appraisal or reappraisal processes, appetitive motivation represents an important driving force.

In some cases, rather than minimizing the averseness of a stressor through reappraisal, the reappraisal process may focus attention on certain positive aspects of the stressful experience, motivating appetitive action. For example, someone who experiences the death of a loved one may focus on reminders of the deceased in an effort to maintain a connection and call up the positive feelings associated with the loved one. O'Connor et al. (2008) found that when individuals classified as having *complicated grief* (characterized by a chronic and intense sense of longing and searching for the deceased and preoccupation with thoughts of the loved one) are shown photos of their deceased loved one, neural networks associated with rewards and appetitive motivation in the nucleus accumbens are activated. This supports the idea that the coping process broadly, including appraisal and reappraisal, includes appetitive motivation in addition to simply minimizing aversion.

If we think about the role of appetitive motivation in relation to interference inhibition, we see that rather than inhibiting negative appraisals, resiliency may involve inhibiting reward processes that can undermine efforts at moving forward from a stressful experience. For individuals with complicated grief, appetitive motivation driving the desire to focus on a lost loved one interferes with their ability to accept the reality of the loss and contributes to symptoms of painful yearning and preoccupation with thoughts about the deceased. In this case, inhibition in the service of resilience necessarily involves inhibiting this reward process. What is typically thought of as a positive reward motivation can have a negative impact on recovery. Hence, in cases where an individual's reappraisal may conflict with reality, the appetitive motivation (e.g., engaging in reveries about the deceased as self-soothing) actually may result in poorer mental health outcomes (O'Connor et al. 2008).

Resilience also may depend on mechanisms outside of the individual's own appraisal. Shared meaning around the stressful experience may be determined collectively in a community or group. If an individual's positive appraisal or reappraisal is in conflict with the appraisals of the group, it likely will lead to neither mental stability nor resilience. The experience and expression of positive emotion in the context of certain traumatic events are neither always adaptive nor associated with recovery. For example, Bonanno et al. (2007) found that women who smiled when disclosing experiences of childhood sexual abuse reported higher levels of social withdrawal, illustrating the important role of context in the relationship between positive emotion following a negative life event and recovery. Similarly, Soenke et al. (under review) found that individuals described as experiencing the death of someone close and responding with a positive emotion activity were rated less favorably than those engaging in activities that directly focused on the loss.

The PASTOR model produced by Kalisch and colleagues is an excellent synthesis of the current state of knowledge on resilience, focusing on mechanisms as a common pathway to outcomes, and highlighting how neuroscience could be used to advance our knowledge in this area. Our criticism is simply that they do not go as far as they could – they fail to include positive affect as a mechanism, and they approach motivation as distinct from overcoming aversive motivation. The authors point out that interference inhibition is necessary as a mechanism; we also would add that certain stressful situations require inhibition of approach motivation and inhibition of positive appraisal, especially when they conflict with the contextual social appraisal or reappraisal of a situation. These suggestions do not undercut the PASTOR model, but extend the possible mechanisms the model should consider.

Resilience: The role of accurate appraisal, thresholds, and socioenvironmental factors[1]

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Abstract: Adding to the resilience model of Kalisch and colleagues, we suggest that resilience is associated with accurate rather than excessively positive or negative appraisal or reappraisal styles; that complex systems do not always change in linear fashion; that linkages of individuals, families, and communities markedly affect individual resilience; and that resilience research focus on specific factors or mechanisms as well as more global ones.

To date, most research on psychological resilience has identified individual biopsychosocial factors associated with this construct but has not investigated how these factors relate to one another and what common mechanisms may mediate their impact (Southwick & Charney 2012). Kalisch et al.'s ambitious "A Conceptual Framework for the Neurobiological Study of Resilience" makes an important contribution to the literature by proposing a comprehensive, theory-driven, and integrated approach to studying resilience. We agree with many points made by the authors, including: (1) the need for coherent and integrated models of resilience; (2) the limitations of a categorical versus dimensional and transdiagnostic approach to operationalizing resilience; (3) the need to assess a broad range of stressors and traumas when studying resilience; and (4) the importance of longitudinal studies.

In this commentary, we raise four issues for the authors to consider.

First, according to the authors, positive appraisal style is "the common resilience mechanism onto which all resilience factors converge and through which they exert their protective effects on mental health" (Table 1 of the target article). Although a substantial body of evidence does point to the resilience-enhancing effects of positive appraisal, negative appraisal (e.g., ability to detect and respond to danger) is also critical for resilience and survival. Positive attention or appraisal draws animals and humans toward stimuli that are pleasurable and rewarding and that sustain life, whereas negative attention or appraisal directs them away from threats and dangers. Both are essential to maintaining resilience.

In our view, both excessively negative and excessively positive appraisal and reappraisal styles can compromise resilience. On the one hand, as noted by the authors, when people with an excessively negative appraisal and reappraisal cognitive style face challenges, they typically overestimate the likelihood or magnitude of a negative outcome, or they underestimate their capacity to cope – or both. On the other hand, an excessively positive style can lead to inadequate preparation as the result of an underestimation of risk and an overestimation of ability (Schneider 2001). For example, as noted by Schneider (2001, p. 250), overly positive appraisals may "involve self-deception or convincing oneself of desired beliefs without appropriate reality checks." Similarly, it follows that higher appraisal scores (i.e., AS, continuous index of appraisal style) do not necessarily translate to greater levels of resilience, because the relationship between AS and resilience is likely curvilinear. Accordingly, we suggest that resilience can be fostered by appraisals and reappraisals that are generally positive but also accurate and realistic, which lead to stimulus-appropriate responses.

Second, the authors propose that resilience be operationalized as a continuous quantitative outcome. Complex adaptive systems do not always change in a linear manner, however. Thresholds abound in nature, from coral reefs (Fung et al. 2011) to brain circuits (Dietrich & Horvath 2011) to psychological performance (Dutilh et al. 2011; Krystal 1978); and when a threshold is crossed, a phase transition may take place that makes crossing back difficult or impossible because the system has undergone a fundamental change, a property known as *hysteresis* (Walker & Salt 2006). For example, an athlete may positively appraise his capacity to endure intense physical challenges, such as running marathons. But he may be unaware that his coronary arteries have gradually become occluded, until one day he has a massive heart attack, at which point he crosses a threshold and becomes far less physically and likely psychologically resilient. One definition of resilience is "the capacity to absorb disturbance; to

undergo change and still retain essentially the same function, structure and feedbacks, without crossing a threshold to a different system regime – a system with a different identity" (Walker & Salt 2006, p. 32). Applying this definition, resilience involves knowing where one's thresholds may lie and distance from these thresholds, understanding the primary drivers that cause the system or individual to cross a threshold, and finding ways to move the threshold or move away from it.

Third, by the authors squarely placing resilience in the individual and considering socioenvironmental factors as "distant influences" on mental health, we believe they underestimate the importance of complex linkages of individuals, families, communities, cultures, and the environment in fostering resilience. These systems and linkages are constantly adapting to change and interacting with one another. Although promoting positive cognitive appraisal/reappraisal style in the individual is important, we believe that it is critical to also intervene at other levels. For example, the most effective way to enhance resilience in children involves providing a safe, stable, and loving environment (Masten 2014). Accordingly, resilience-enhancing interventions for children might include affordable housing, safer neighborhoods, better schools, and classes in effective parenting.

Fourth, the authors' idea that resilience research "should focus not on any specific dysfunction or pattern of dysfunction but on global or average dysfunction" (sect. 1.4, para. 1) contrasts with a substantial literature on learning and the utility of assessing and fostering specific strengths and domains of functioning. For example, scenario-based training (Salas et al. 2006), a highly realistic form of training where the individual receives real-time constructive feedback while practicing a specific skill or set of skills, is one of the most effective ways to learn, and is essential for training firefighters, police officers, and soldiers. Although interventions to enhance overall well-being, such as exercise, meditation, and improved sleep hygiene, are known to enhance one's capacity to deal with stress (Southwick & Charney 2012), equally important are person-specific interventions, similar to personalized medicine.

The notion that resilience is not simply the absence of vulnerability, but instead a positive attribute that can be characterized, studied at a mechanistic level, and taught is, in its own way, a recent and revolutionary idea. We applaud the efforts by Kalisch et al. to advance a formal model for resilience that is grounded in cognitive neuroscience and that has a number of broad implications for the field of stress. In this commentary, we highlighted a number of directions that might be pursued in the further development of this and other models for resilience. It is critical that we progress in this area of research in order to prevent and alleviate suffering in people who, all too commonly, confront extreme challenges to their well-being.

NOTE
1. Parts of this commentary were written as an employee of the U.S. Government and such parts are not subject to copyright protection in the United States.

Reappraisal and resilience to stress: Context must be considered

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Abstract: Kalisch et al. propose that positive reappraisal constitutes a resilience mechanism for highly stressed individuals. Both empirical and

theoretical accounts suggest that this claim is too simplistic – the relationship between reappraisal and resilience depends on context. Indeed, there may be contexts in which reappraisal leads to harm, not resilience. Future research should examine multiple regulatory processes as well as context.

In their proposed PASTOR (positive appraisal style theory of resilience) framework, Kalisch et al. present a transdiagnostic model of resilience. This model is extremely timely, and I applaud the authors' efforts at unifying the existing literature and recommending a path forward for future research on resilience. Although there are several specific claims made in their article, I will focus specifically on one aspect of the PASTOR model: positive reappraisal. The authors claim that positive appraisal style is the sole mediating resilience mechanism. Further, they claim that in highly stressful situations where initial positive appraisals are difficult, positive *reappraisal* (changing one's appraisal to experience less negative emotion) constitutes one key aspect of positive appraisal style. They conclude that "positive reappraisal ability is therefore an inherent aspect of positive appraisal style as the one mediating resilience mechanism" (sect. 4.2.5, para. 6).

The idea that positive reappraisal is a key aspect of resilience is consistent with decades of research on emotion regulation, which has consistently documented the positive effects of reappraisal. For example, higher levels of reappraisal use have been associated with less depression, less anxiety, more social support, and more positive affect (Aldao et al. 2010; Gross & John 2003). In the context of high stress, individuals high in reappraisal ability reported lower levels of depressive symptoms (Troy et al. 2010). This body of work supports Kalisch et al.'s argument that the ability to use positive reappraisal when one is stressed may be one key mechanism contributing to resilience.

The argument that changing one's appraisal is the *sole* mechanism that causes resilience in all highly stressful situations seems too simplistic, however. Several theoretical models emphasize the idea that no process is universally adaptive in all contexts (Endler 1975; Lazarus 1993a; Mischel 1968). Instead, these perspectives suggest that we can only understand the utility of a process if we consider the specific context in which it is used. For example, consider an individual who is highly stressed because he is in danger of losing his job due to impending layoffs. Here, the use of reappraisal to try to down-regulate his negative emotions is likely to promote resilience. He can focus on how the job loss may provide an unexpected opportunity to explore a new career path. He may also remind himself of how highly qualified he is for a range of other jobs and so will likely find another job soon. Hence, in a largely uncontrollable context (he likely cannot do much to prevent the layoff), changing one's appraisals is likely to help the individual control one of the only things he can: his emotional response.

Importantly, however, reappraisal may not be useful in a *controllable* stressful context. For example, if a person is in danger of losing his job because of poor performance at work, changing his appraisal so he feels less negative may ironically impede resilience. If the situation causing stress is controllable, he should take direct action to change the situation (e.g., work harder). To the degree that a realistic negative appraisal of the situation (i.e., "this is a really bad situation, and if I don't do something to fix this soon, it will get much worse") motivates direct action, maintaining negative emotion may help promote resilience. Hence, the use of positive reappraisal to decrease negative emotions in this context may *prevent* rather than promote resilience because feeling better about a controllable situation may prevent the individual from taking the direct action that is needed to decrease the effects of the stressor.

Indeed, recent work from my colleagues and me supports this hypothesis (Troy et al. 2013). We found that in the context of relatively uncontrollable stress, reappraisal ability was associated with less depression. In the context of relatively *controllable* stress, however, reappraisal ability was associated with more

depression. These results support the idea that reappraisal ability may be a critical component of resilience, but only in some contexts. In the case of controllable stress, maintaining a negative appraisal of a situation may help lead to resilience, whereas using reappraisal to change one's emotions may impede resilience or even harm the individual. This argument is in line with functionalist accounts of negative emotion, which emphasize the idea that negative emotions can be useful because they can motivate us to take appropriate action when needed (Parrot 2002). Therefore, although Kalisch and colleagues argue that resilience is characterized by limiting negative emotion using reappraisal, in some contexts maintaining or even increasing negative emotion may be the most resilient course.

Although our research focused on just one aspect of context – controllability – it is likely that there are many other important contextual variables that moderate the effects of reappraisal on resilience. For example, Sheppes and Gross' (2011) process-specific timing model suggests that the emotional intensity of stressful situations also may moderate the effects of reappraisal, with reappraisal being least effective in the most intense contexts. Research on other emotion-regulation strategies (e.g., distraction, acceptance) also has shown positive links to resilience (Shallcross et al. 2010; Sheppes & Gross 2011). Together, these findings are consistent with a growing body of research that highlights the importance of context in resilience (Aldao 2013). These models of emotion regulation emphasize the idea that resilience is characterized by the flexible use of many different emotion-regulation strategies depending on contextual demands (Bonanno et al. 2004; Kashdan & Rottenberg 2010) and psychopathology may be characterized by the inflexible, context-inappropriate use of emotion regulation (Bonanno & Burton 2013).

Overall then, although it seems clear that reappraisal is *one* important mechanism that contributes to resilience, it is unlikely that it is the *sole* mechanism that causes resilience in all stressful contexts. Indeed, in some contexts, reappraisal might constitute a risk factor for negative outcomes. Moving forward, it seems that the best approach to elucidating the transdiagnostic mechanisms of resilience would involve examining multiple regulatory processes across a diversity of contexts, rather than focusing all of our scientific attention on just one process.

Social ecological complexity and resilience processes

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Abstract: A social ecological model of resilience avoids the reductionism of simple explanations of the complex and multisystemic processes associated with well-being in contexts of adversity. There is evidence that when stressors are abnormally high, environmental factors account for more of an individual's resilience than do individual traits or cognitions. In this commentary, a social ecological model of resilience is discussed.

The search for a unifying framework to explain resilience is a worthy goal, but Kalisch et al. have chosen an overly reductionistic explanation for positive adaptation under adversity. Research on resilience is showing that the protective processes that account for people's survival are not just individual, but are as likely to be social and ecological aspects of the individual's life (Masten 2011; Theron et al. 2015; Ungar et al. 2012). By its very nature, resilience implies the presence of a stressor, and the nature of

that stressor will influence how each protective process affects outcomes related to well-being. Whereas a positive appraisal style may be adaptive in some contexts where there is lower exposure to risk, it may lead to worse mental health outcomes, or be ineffective, in contexts where it produces faulty cognitions about the threats posed and the solutions required to resolve life's challenges (Seligman 2011). In this brief discussion, I will define resilience in social ecological terms, discuss the differential impact social ecologies have on resilience processes, and discuss the dangers that a focus on positive appraisal style may have for clinical processes and social policies that unintentionally place responsibility for change solely on the individual.

Whether we look at the work of the epigeneticist (Jaffee et al. 2007), the neuropsychiatrist (Perry 2009), the medical anthropologist (Panter-Brick & Eggerman 2012), or the clinical social worker (Sanders et al. 2014), there is general agreement: When individuals are exposed to significant amounts of adversity, the amount of variance in positive developmental outcomes that is accounted for by the person's environment will be equal to or greater than that accounted for by individual variables (Abramson et al. 2010; Cicchetti 2010; Kassis et al. 2013; Tol et al. 2011). For example, Romanian orphans did much better developmentally when they were adopted by well-resourced families in Britain (Beckett et al. 2006); young children who are burdened with risk factors that predict delinquency are more likely to avoid early school dropout and criminality when their environments (homes and schools) are loaded with resources to socialize them well (Brame et al. 2001).

In both cases – neglected orphans and potential delinquents – the locus of control for changes to life trajectory is external to the child, though a positive disposition and willingness to take advantage of these resources can help individuals develop in positive ways. For this reason, resilience is increasingly being thought of as the capacity of systems to adapt, rather than the capacity of individuals to overcome challenges. A social ecological model of resilience suggests that human systems help individuals navigate to resources, and negotiate for resources to be provided in meaningful ways (Ungar 2011).

Even if we make the assumption that it is possible to reduce resilience to a cognitive process, the environment/individual interaction (with the environment likely accounting for more of the variance in outcomes than individual factors such as cognitive style, intelligence, or personality) will influence the degree of successful coping that is achieved. For example, in a nonresponsive environment (e.g., chronic parental neglect) or a consistently oppressive environment (e.g., persistent racism), a positive appraisal may actually have the unintended consequence of undermining the experiencing of one's personal efficacy (Hopkins et al. 2012; Obradović et al. 2010). After all, children who are racially marginalized but who make an unrealistically positive appraisal of their capacity to resist oppression may actually be ill-prepared to cope with the challenges they face. Instead, an accurate appraisal of the world as grim and hopeless may cue children to emotionally withdraw in order to protect themselves from exposure to threats to their mental health (APA Task Force 2008).

In one sense, Kalisch et al. are correct. We require a transdiagnostic approach to resilience that identifies the process*es* (plural, not singular) that are associated with resilience. Unfortunately, a model that reduces resilience to purely internal cognitive processes overlooks the need for a differential "diagnosis" of resilience (Ungar 2015) that accounts for the complex patterns of environmental influence along with cognitive processes. In this sense, an experiment that models resilience with a rodent should never forget that the subject would do quite fine if the handler stopped imposing stressors in the first place. Rather than reducing our understanding of resilience, our models should be more systemic and ecological. Different factors matter more or less in different contexts.

A tentative model first published by Ungar (2011) accounted for these complex aspects of individuals' interactions with their social ecologies. To summarize:

In the context of above normal exposure to adversity ($\sum$A>average A for a population):

$$R_{1,2,3...} = \frac{f(P_{SC}, E)}{(O_{Av}, O_{Ac})(M)}$$

In the equation, *resilience* processes over time ($R_{1,\ 2,\ 3...}$) will vary by the interaction between a *person* (*P*) and his or her *environment* (*E*), while keeping in mind the person's *strengths* (*S*) and *challenges* (*C*). Processes are mediated by the *opportunities* (*O*) that are *available* (AV) and *accessible* (AC) for adaptive coping. They also are mediated by the socially constructed *meaning systems* (M) that shape appraisals of the risks and resources that individuals experience (e.g., whether they experience these resources as useful). This social ecological interpretation of resilience includes positive appraisal style as part of the denominator (M), but keeps it fully contextualized.

Although Kalisch et al. certainly expand the theory of appraisal style and generously note the complexity of appraisals that are related to resilience, their model's locus of control remains internal brain functions, when we know that changes to the environment can trigger brain functions that, quite literally, shape cognitions and resilience processes. This is more than a question of which comes first, trigger or cognition. Arguably, where there is significant risk exposure, it is the environment that accounts for the majority of the change in individuals' appraisals. Positive reappraisal is preferred, but unrealistic unless one is privileged enough to have opportunities (such as family supports) to justify optimism.

Beyond resilience: Positive mental health and the nature of cognitive processes involved in positive appraisals

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Abstract: Although the PASTOR model provides a comprehensive framework to study resilience, it faces some challenges. First, some higher-order concepts (e.g., meaning) may be difficult to model in the laboratory. Second, defining resilience as an absence of pathology might be conceptually restrictive. Finally, the proposal that the severity of the event is associated to different appraisal mechanisms needs further evidence.

With their PASTOR model, Kalisch et al. propose a unified translational model of resilience that can be applied to different disorders. They offer some compelling evidence for this translational model and also some valuable specific suggestions for planned research. Despite their conceptual attractiveness, however, translational models in psychopathology face some difficulties.

Using animal models, or experimental methodologies in general, to study some key higher-order processes (e.g., meaning) or secondary emotions (e.g., shame) can be problematic. An interesting parallel occurred with the learned helplessness model of depression, initially based on animal research. The initial model (Seligman 1975) suggested that unavoidable and unescapable aversive events were sufficient causes of depression. Yet, to extend the model to human depression (which includes specific symptoms such as guilt), the model had to be reformulated by including the attributional style (i.e., the way individuals typically attribute the cause of the event) as the mediating factor

between facing an uncontrollable aversive event and the onset of depression (Abramson et al. 1978). For example, the search for meaning (Park 2010) and the reconstruction of shattered core beliefs (Janoff-Bulman 1992) are key processes in human appraisal associated with resilience. It is difficult to foresee how these constructs can be adequately manipulated under experimental conditions. Furthermore, these complex processes also bring into sharp relief the fact that (re)appraisal often is associated with lengthy and complicated trajectories that develop over time (Bonanno et al. 2011). Also, (re)appraisal is not necessarily focused on the immediate evaluation of a situation, as it is typically studied when using experimental paradigms.

A second challenge for the PASTOR model is related to its definition of resilience. According to Kalisch et al., resilience is an outcome observed when "someone does not develop lasting mental health problems" after having been exposed to adversity. In other words, Kalisch et al.'s approach is anchored on a negative mental health framework (i.e., a view of mental health based on the presence/absence of symptoms). Accordingly, the way they propose to define and measure global resilience (e.g., by psychopathological instruments such as the General Health Questionnaire capitalizes on a restricted view of resilience focused on symptoms.

Yet despite the focus of the PASTOR model on symptoms, recent models of positive mental health emphasize that mental health must be defined not only in terms of symptoms, but also in terms of the presence of capacities, strengths, and well-being (Keyes 2005; Maddux et al. 2012). Any robust model of resilience should seriously integrate the perception of benefits (Helgeson et al. 2006) or even posttraumatic growth (Fredrickson et al., 2003; Calhoun & Tedeschi 2013) being a frequent experience among those exposed to adversity. Therefore, researchers should attend to the idea that positive dimensions of mental health (e.g., autonomy, self-acceptance, or sense of control; Ryff & Singer 1998) could be intrinsic aspects of a more comprehensive definition of resilience (Waugh & Koster 2014).

In terms of the quantification of PASTOR (sect. 3.1), restricting resilience to low presence of symptoms may reduce the variability of the observed data and the predictive power of the model. In other words, it is likely that simply not showing mental health symptoms is not a robust indicator of true resilience (e.g., a reduced vulnerability to develop future psychological crises in facing significant stressors).

Kalisch et al. convincingly state that research on resilience should focus more on mechanisms than on describing factors associated to it, on which there is already an abundant literature. It is easy to agree with the authors in their call for doing research beyond questionnaires and self-reports, thereby overcoming a limitation of research trends in psychology in the last decade (Baumeister et al. 2007). In terms of mechanisms, Kalisch et al. propose a model that takes into consideration both automatic and controlled processes in the appraisal of aversive situations (sect. 1.3). Although they pay more attention to conscious mechanisms of appraisal (sect. 4.2.5), there are relevant data, from experimental psychopathology, showing that automatic cognitive processes also may play an important role in the appraisal process. For example, using eye-tracking methodologies, Sanchez and Vázquez (2014) found that normal, healthy participants pay more attention to happy than sad faces. On the contrary, clinically depressed participants have difficulties disengaging from sad faces (Sanchez et al. 2013), as well as engaging with happy faces (Duque & Vázquez 2015).

Hence, automatic attentional processes do participate in initial stages of appraisal, and what is even more important, they have a significant impact on mood regulation. For example, after the induction of a depressed mood in the laboratory, the more time participants gaze at happy faces, the stronger their recovery from that negative mood (Sanchez et al. 2014). Therefore, appraisal/reappraisal mechanisms should be understood within the broader scope of voluntary and automatic emotion-cognition processes.

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Finally, also in relation to the cognitive processes involved in positive appraisals leading to resilience, one of the claims of the PASTOR model (sect. 4.2.5) is that positive appraisals are very common in minor or moderate aversive events, but very unlikely in strongly aversive situations. The evidence in the trauma literature does not provide a direct support for this hypothesis, however. It has been shown that a variety of positive emotions can be experienced in the immediate aftermath of stressful events such as a devastating earthquake (Vázquez et al. 2005), a massive terrorist attack (Vázquez & Hervas 2010), or in the first 72 hours after a myocardial infarction (Castilla & Vázquez 2011). These findings reveal that even in highly aversive situations, positive appraisal processes may be more common than expected, and also that they may emerge during the events (Vázquez et al. 2008).

In conclusion, the PASTOR model makes a valuable effort to create a framework to establish consistent bridges between animal and human research. Yet, human responses to adversity can be very complex, often including higher-order psychological constructs (e.g., reconstruction of shattered beliefs) as well as outcomes that go beyond resilience (e.g., psychological growth). A sound model of resilience should consider these intrinsic ingredients of human response to life adversities.

The temporal dynamics of resilience: Neural recovery as a biomarker

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Abstract: Resilience can be defined as the capability of an individual to maintain health despite stress and adversity. Here we suggest to study the temporal dynamics of neural processes associated with affective perturbation and emotion regulation at different time scales to investigate the mechanisms of resilience. Parameters related to neural recovery might serve as a predictive biomarker for resilience.

According to Kalisch et al. resilience should be considered a dimensional and quantifiable outcome; that is, sustained or improved mental health following stress and adversity, where stress is conceptualized in the broadest sense, as an aversive emotional response. Importantly, the authors emphasize the distinction between resilience factors and mechanisms, the latter being of prime interest given that these describe the general processes through which resilience can be achieved. Resilience mechanisms exert their influence by actively limiting aversion in order to adaptively achieve long-term functioning. According to their theory, the main resilience mechanism is positive (re)appraisal, which is supported by inhibition of negative appraisals under severe stress. Overall, we welcome the authors' well-informed effort to bring together research on emotion regulation, stress, conditioning, and extinction to understand resilience. In the following, we will first address a potential general problem of the theory. Second, we will suggest a way to investigate resilience mechanisms by focusing on the temporal dynamics of physiological recovery from stress and adversity.

Let us start with the potential problem. The theory of Kalisch et al. is rather ambitious – or, as the authors themselves state, radical. They suggest that there is a single, general resilience mechanism that serves as a common final path of all resilience factors, namely positive (re)appraisal. The appeal of such an approach is that it seems to explain much, from psychological phenomena down to intricate animal research on extinction.

Imagine, however, if we found out that resilience can be explained only by reduced sensitivity – a short perturbation within a negative appraisal system, with fast recovery to normal.. In our understanding, this would not by itself necessitate a positive appraisal style. Kalisch et al. probably would argue that this form of resilience is supported by the first claim of their theory (i.e., positive appraisal), as the threat is appraised (in the long run) "non-negatively." Defining positive appraisal as everything that is not appraised negatively, however, blurs the important distinction between positive and negative valuation that is realized by distinct brain circuits (Schardt et al. 2010; Staudinger et al. 2009; 2011) and also neglects the relevance of the time domain. We therefore think that the theory Kalisch et al. propose might rely too heavily on a specific interpretation of the psychological term *appraisal* and, as a consequence, the theory is difficult to define and to operationalize unambiguously from a neurobiological perspective.

Although we agree that it is necessary to unite psychological theories of resilience mechanisms with neurobiology, we think that it might be helpful to approach resilience in a more reductionist and physiological fashion: Once *stress response* is defined in physiological terms, we can monitor its signatures (e.g., heart rate and blood pressure increase, cortisol levels, amygdala activation, etc.) and investigate the neural processes by which an organism manages to recover from those changes. Such neural recovery processes can be considered (proxies of) resilience mechanisms in themselves. As such, they do not necessarily have to rely on a general ability, but could instead be domain specific as well; that is, sometimes relying on decreased sensitivity for aversion, sometimes on positive (counter)appraisal, and sometimes on inhibition of negative aversion. A focus on physiological changes and their recovery has several advantages: First, it is neutral on whether resilience is achieved by conscious/effortful or unconscious/automatic processes. Second, it can easily be quantified by measuring changes in physiological parameters.

The second point we want to make is closely related to the aforementioned argument and pertains to the relevance of temporal dynamics of resilience mechanisms on different time scales. A crucial element in resilience is the ability of an organism to achieve stability through change, a process known as allostasis (McEwen & Wingfield 2003) – in our case, to regain homeostasis after a stressful event. Importantly, allostasis can relate to both rapid (e.g., autonomic) and slower (e.g., cognitive) adaptations to a stressor, associated with specific neural markers; these processes, at the same time, all have a specific time course in their own respect. In other words, recovery (or lack thereof) is inherently a temporal phenomenon: (Neuro)physiological parameters of the stress response (reflecting a system state) may recover, may show sensitization, may be perturbed in the long range, or may even show aftereffects long after the acute stressor is gone. For example, it has been shown that the success of effortful emotion regulation in humans can be measured by a reduction of the amygdala signal (Erk et al. 2010b; Lamke et al. 2014; Walter et al. 2009), and that the dynamics of recovery of the amygdala signal are predictive of later amygdala responses to aversive stimulation (Walter et al. 2009). Circuits known to be involved in automatic as well as volitional emotion regulation (e.g., functional connectivity between the prefrontal cortex and amygdala) are affected by stressful situations, and changes within these circuits could be observed even long after the stress has waned (Veer et al. 2011). Moreover, aftereffects of aversive emotional responses could even be demonstrated a year after effortful emotion regulation (Erk et al. 2010a).

We therefore suggest that one way to foster resilience research might be to focus on the temporal dynamics of changes in those brain circuits on different time scales, and on the mechanisms that are involved in the recovery of brain responses to stressful situations. We hypothesize that the ability to recover from perturbations and the temporal pattern of recovery could serve as an index or biomarker that will be predictive of resilience in the long run. The mechanisms that contribute to such recovery might be

diverse, or they might indeed be of a more general nature, the latter being in keeping with the theory of Kalisch et al. In this sense, our proposed research strategy might be a natural extension of the generalized theory of resilience as proposed by Kalisch et al., but might also be of interest to other theoretical accounts of resilience.

Do we know how stressed we are?

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Abstract: I take issue with Kalisch et al.'s formulation of PASTOR, arguing that care must be taken in understanding what is meant by "appraisal." I examine the implications of PASTOR given two competing possibilities for what counts as an appraisal – first, if appraisal is restricted to conscious reflection on one's circumstances, and second, if appraisal is expanded to include subconscious mechanisms of evaluation.

The target article seeks to reorient psychiatric research from a focus on dysfunctions and illnesses to a focus on mental health, by proposing a view according to which the active process of resilience to variable and diverse stressors is what counts for mental health. It further suggests that a single unifying mechanism protects against stress and mediates resilience, namely, the style in which someone evaluates and reacts to a challenge. This is called the positive appraisal style theory of resilience (PASTOR). Although much depends on what constitutes an "appraisal," Kalisch and colleges say unfortunately little about it. On their picture, appraisal is a context-dependent process of evaluation that determines one's aversive or appetitive motivation toward a stimulus. As shown in their Figure 3, this involves an individual first representing and reflecting on a given situation, and then making judgments about, for example, its novelty, pleasantness, or compatibility with her goals. The individual's emotional response then follows directly from this appraisal.

Intuitively, this kind of judgment may include the kind of explicit, conscious reflection and deliberation familiar to philosophers in action theory. The portrayal of global resilience mechanisms as operating entirely via conscious reflection and evaluation is inconsistent, however, with a commonly endorsed picture of the mind that understands much of our cognition to be implicit and outside of conscious awareness. In many circumstances, we just do not know how stressed we are.

Using indirect methods, current research in social psychology has begun to reveal many interesting failures of self-knowledge. Wilson (2002), Gilbert (2009), and others have shown that this lack of awareness extends to the affective character of our own experiences. In his work on happiness Haybron (2008) calls this problem *affective ignorance*, stressing that, not only do we sometimes misjudge or mistake our feelings, but that we can be "essentially blind to hedonically important aspects of our experience" (p. 61). Whereas sudden, sharp changes in our affective state have a way of calling attention to themselves (e.g., accidentally hitting one's funny bone), persistent affects and moods are often diffuse and elusive. We even adapt to some pains and annoyances, failing to notice them at all (e.g., suddenly realizing how irritating the refrigerator sounds only when it turns off). In a recent study, Evans and Johnson (2000) demonstrate that low-intensity noise in an office space raised physiological and behavioral measures of stress, but did not affect workers' reports of *perceived* stress compared with a quiet office. This shows how affective and psychophysiological stress responses often come apart from self-report. An individual can be feeling anxious or depressed, while sincerely claiming, and believing themselves, to be happy.

In other words, affective response to the environment may have little to do with explicit, reflective evaluation of the environment. When it comes to stress and affect, we are not often able to recognize or articulate exactly which stimuli demand a response in the first place. Indeed, on this reading of appraisal, positive appraisal style does not seem to protect against stress at all. Because of this, our resilience mechanisms cannot plausibly depend solely on conscious reflection about our circumstances. Stress depends on more than just explicit judgment on whether conditions are favorable.

The PASTOR approach could be improved by expanding its notion of appraisal to include unconscious evaluative processes. The Evans and Johnson study is especially revealing in this vein, as it demonstrates how stressors often affect us without reflective awareness. Resilience research should be interested in discovering, for example, what differentiates those with a more resilient or positive stress response in a noisy office, regardless of how they reflectively feel about their work environment. This suggests that when it comes to resilience mechanisms, positive appraisal is simply positive affective or psychophysiological response relative to stressor load. To make a positive evaluation, on this picture, is just for an organism to make the best of its circumstances, whether challenging or routine. Resilience is normalized to individuals' actual performance in the face of various stimuli.

I would like to sound a note of caution here. Care should be taken in examining the philosophical implications of this kind of normalization for our understanding of mental health and well-being, especially if a normalized understanding of positive appraisal style is adopted into the very methodology of resilience research, as Kalisch et al. suggest when they propose that "it might be necessary…to choose study cohorts that are confronted with single classes of stressors" (sect. 4.2.8, para. 4). Contrary to what Kalisch et al. claim, socioenvironmental factors are not distant influences on mental health. In particular, in marginalized populations for whom mental health is a crucial concern, systemic inequality raises the magnitude of everyday environmental stressors, and limits many social support–based stress-aversion strategies (Satcher 2001). Therefore, regardless of how resilient an individual might be, it is possible that resilience mechanisms inevitably will collapse in certain environments. A population of individuals all suffering equally is not, colloquially speaking, doing fine. It simply cannot be the case, from an ethical perspective, that what is statistically normal in this case determines what counts as mentally healthy.

Authors' Response

Advancing empirical resilience research

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http://www.ftn.nic.uni-mainz.de/en/
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Abstract: We are delighted by the broad, intense, and fruitful discussion in reaction to our target article. A major point we take from the many comments is a prevailing feeling in the research community that we need significantly and urgently to advance resilience research, both by sharpening concepts and theories and by conducting empirical studies at a much larger scale and with a much more extended and sophisticated methodological arsenal than is the case currently. This advancement can be achieved only in a concerted international collaborative effort. In our response, we try to argue that an explicitly atheoretical, purely observational definition of resilience and a transdiagnostic, quantitative study framework can provide a suitable basis for empirically testing different competing resilience theories (sects. R1, R2, R6, R7). We are confident that it should be possible to unite resilience researchers from different schools, including from sociology and social psychology, behind such a pragmatic and theoretically neutral research strategy. In sections R3 to R5, we further specify and explain the positive appraisal style theory of resilience (PASTOR). We defend PASTOR as a comparatively parsimonious and translational theory that makes sufficiently concrete predictions to be evaluated empirically.

R1. Individual-level and social-level approaches: Friends, not foes

We begin this response as we ended our target article, by confirming again that we do not at all deny the important influence of social factors, namely of social support, in the protection against stress-related mental dysfunctions, and that we see great potential in interventions that target social and environmental variables (Janicki-Deverts & Cohen 2011; Reissman et al. 2011; Southwick et al. 2011; Zautra 2014). We merely dare conjecture that the unquestionable effects of social support and other nonindividual resources on mental health, emphasized in the commentaries by **Bennett & Windle**; **Chang, Reddan, Ashar, Eisenbarth, & Wager** (**Chang et al.**); **IJzerman & Lindenberg**; **Kimbrel & Beckham**; **Southwick, Pietrzak, Charney, & Krystal** (**Southwick et al.**); **Ungar**; and **Washington**, can be explained by how they shape stressor appraisal and how they affect stressor exposure. If this turned out to be true, what would be the consequences for the development of resilience-promoting interventions? And could these consequences be unethical, as Ungar and Washington imply?

First of all, we think that discovering new ways to promote mental health, including ways that involve directly changing appraisals or underlying neural processes, or both, can only be highly desirable in a field where scientifically grounded and empirically tested effective and efficient intervention programs are still scarce. We cannot choose from a rich basket of resilience interventions, and therefore, basically any new possibility to improve mental health should be welcome, regardless of what route is taken to achieve the effect. This pragmatic stance, and the sobering experiences we have had over the years working as psychiatrists and neuroscientists of how difficult it is to change appraisals and brain functions, includes the realistic prediction that it is highly unlikely that cognitive-neuroscientific resilience research ever will discover the "magic pill" that produces resilient robots that can be used and exploited for any kind of stressful activity. Positive appraisals may be protective but, as **Washington** notes, "regardless of how resilient an individual might be, it is possible that resilience mechanisms inevitably will collapse in certain environments."

That implies that new intervention methods that might be developed from the kind of research that our target article tries to promote will almost certainly never replace the need to work also at the socioenvironmental level.

Rather, individual-level interventions will complement social-level approaches. So, taking into account individual factors and better understanding the relationship between socioenvironmental and individual factors might have the advantage that we can better tailor socioenvironmental interventions to individual needs. For example, if the effect of social support on resilience indeed were mediated by appraisal, it would make much sense to provide social support–enhancing interventions specifically to those individuals who perceive their social support as low and suffer from this perception. By contrast, individuals who already feel well supported (regardless of whether this appraisal is correct or not), as well as those who do not value social support much and feel strong enough to cope without, would most likely not benefit from such an intervention.

Also, socioenvironmental interventions, even if well-tailored, may be limited in their efficacy and efficiency, for example, because they do not manage to change everyone's appraisals to the better (the skeptic or misanthropist might not be impressed by offers of better social integration) and hence do not achieve optimized stress responding in every participant. In these cases, socioenvironmental interventions might profit from augmentation by adjunctive enhancements through psychological or neurobiological routes of the positive appraisals they are intended to generate. Those enhancements might include pharmacological strengthening of positive memories of social support, similar to current attempts to augment psychotherapy with drugs that improve the formation of safety memories made during exposure-based treatments (Graham et al. 2014).

Positive appraisals might also be generated or enhanced independent from the intended effects of a socioenvironmental intervention, simply as an add-on, to improve overall outcome. For example, a socioenvironmental intervention that increases perceived social support could be supplemented with a cognitive-neuroscientific intervention that improves the ability to discriminate safety from threat.

Hence, individual tailoring, augmentation, and supplementation are possible clinical benefits of an individual-level approach to resilience. Let us also not forget that, in many cases, socioenvironmental factors simply will be out of the hands of the clinician, educator, or counselor working with at-risk individuals, and therefore, exclusively betting on socioenvironmental interventions is certainly not an option for resilience research. In this last scenario, indeed, replacement of socioenvironmental action is a fourth possible benefit of individual-level action.

There is even a wider political implication to an approach that involves strengthening individuals. One could argue that individual-level methods will increase the pressure on people to function in adverse environments and will allow those in power more easily to exploit those who are not. We believe that this risk needs to be weighed against the chances that an individual-level approach bears for helping individuals stay healthy, and in this cost-benefit analysis, we estimate the benefits to weigh more than the costs. Further, there is a paternalistic notion in seeing people as weak and dependent on help from more powerful others who might have the capacity to change the world for them.

We know that this is not a standpoint taken by any of our commentators, and we apologize in advance to those readers who might find the following political "manifesto"

ill-suited for a biobehavioral research article. But we would like to take this opportunity to emphasize that we believe that individual-level resilience research has a potential to empower individuals to lead freer and more autonomous lives and also to be more resistant to economic or political pressures, simply because they need less time and energy to stay healthy despite those pressures. Ultimately, resilient individuals will have a higher capacity to involve themselves in a constructive fashion in economic or political decision-making processes and to participate socially. This can only be beneficial for the flourishing of democratic societies, in particular when the stability of these societies is challenged by natural or man-made threats. We would thus make a bold claim (to be empirically evaluated by a different discipline of science than ours) that resilient individuals make resilient countries.

R2. Explaining the influence of social factors and of coping behaviors on mental health

In section 3.1 of our target article, we define the degree of resilience R someone exhibits at some timepoint T2 during or after stressor exposure by normalizing mental health changes $\Delta\Sigma P$ occurring between baseline (T1) and T2 to the stressor load incurred in between, as expressed in the equation: $R_{T2} = 1/(\Delta\Sigma P/\Sigma S) = \Sigma S/\Delta\Sigma P$, P signifying mental problems. (See also Fig. 1 in that section.) Normalization of mental health changes $\Delta\Sigma P$ to stressor load ΣS has practical and conceptual importance. This can be illustrated by assuming a case where stressor load ΣS between T1 and T2 is low in a subject (compared with other subjects or with other measurement intervals in the same subject). Here, a maintenance of mental health or even a decrease in mental problems over that interval (i.e., a small, range-corrected $\Delta\Sigma P$ value) would be a trivial effect that should not be considered a case of resilience. (Remember that resilience is not just mental health but mental health *in the face of adversity*.) Accordingly, in the equation, the subject's relatively small ΣS value would result in smaller R_{T2} scores than in subjects with higher stressor load ΣS but similarly stable mental health (who could rightly claim to be more resilient). When compared with subjects with higher stressor load and *increased* mental health problems, our subject would have a comparable R_{T2} score, provided comparable ratios of ΣS and $\Delta\Sigma P$. (This means that two subjects with different mental health trajectories would still be classified as similarly resilient.) Hence, to sum up this first point, our formalization avoids simply equating resilience with mental health, and thereby preserves the original meaning of the term *resilience*.

The subject in the example also could have a higher R_{T2} score than other subjects; for example, when another subject had a higher stressor load and the concomitant increase in mental problems in that subject outweighed the higher stressor load, or when another subject showed increased mental problems despite low stressor load. Another point to note about our formalization, therefore, is the relativity of the R score in terms of the stressor exposure and the mental stability of the sample. This certainly precludes comparing R scores between individuals from different types of samples (e.g., a soldier in combat versus a physician in internship), but it allows for comparing R scores between individuals from similar samples,

which can be very practical for multicenter or replication studies.

A third point is that our formalization permits a conceptualization of how social factors (and also coping behaviors; see further below) affect mental health and of how this relates to resilience. As explained in detail in section 4.2.4.1, section 4.2.4.2, and Figure 4 of the target article, we hypothesize that the influence of social factors can be explained by their influence on appraisals, while considering that they also affect stressor load ΣS. Hence, in our framework, social support (if perceived) can improve one's perceived coping potential, making a threat appear less threatening and thereby reducing the likelihood of exaggerated, inappropriately costly stress responses and ultimately of mental problems P. This happens without effects on stressor exposure ΣS. Therefore, compared with a subject with identical stressor load (!) but lower perceived social support, a subject with higher perceived social support is less likely to develop mental problems and will be classified as more resilient. Further, social support (if received) can factually reduce stressors S, likewise reducing the likelihood of costly stress responses and ensuing mental problems P. Better mental health, however, does not necessarily count as better resilience, as long as the mental health effect simply (trivially) reflects reduced stressor load, as discussed above.

Ungar rejects our hypothesis, arguing that we neglect the role of opportunities for adaptive coping offered, or not, by the environment. We would counter that coping opportunities do enter into our equation, namely by determining one's perceived coping potential and by additionally defining stressor load. So, when the stressed employee that we used as an illustrative example at several instances throughout the target article (starting in sect. 1.3) has the opportunity to cope with an externally caused increase in performance pressure (a stressor, S) by working harder – for example, because his family will take over some of his domestic obligations for a while – this will both increase his perceived coping potential and reduce stressor load (by avoiding excessive demands). This is another example where we do not deny the influence of social factors on mental health or resilience, but simply split that influence into those effect paths going via stressor appraisal, thus acting distally on resilience, and those going via stressor exposure.

IJzerman & Lindenberg argue that a secure, complex, and flexible self, shaped in early development by social thermoregulation and operationalized (in approximation) by a secure attachment style, among others makes people cope more constructively, that is, behave in a way that strengthens social bonds and activates social support. They propose that securely attached individuals spontaneously produce prosocial emotional responses that function to assure their social partners that they are understood and supported (such as when they respond to their partner's anger with a spontaneous smile rather than with retaliation, or when they display understanding and encouragement of their partner's goals). We have no objections against the idea that behaviors that promote perceived and received social support eventually promote resilience and mental health (see above). We merely want to point out again that our model deals with variables such as a secure attachment style, the associated adaptive coping behaviors, and the resulting social support as, one, reducing

stressor load ΣS and as, two, promoting resilience indirectly, by providing positive appraisals.

The examples of adaptive coping brought by **IJzerman & Lindenberg** are helpful in allowing us to clarify better than we may have in our target article the role of behavior, which we let affect mental health outcomes by bearing on stressor load ΣS (similar to received social support). In the target article's section 2 we defined stress (threat, aversive, fear) responses as adaptive reactions that serve to assure survival and reproduction by avoiding, removing, or minimizing threats. In our preceding phenomenological definition in its section 1.3, we included overt behavior – primary (defensive) or secondary (compensatory and recuperative) coping responses such as flight or fight, avoidance, impact preparation, support seeking, resource building, and so forth – among the many components of the stress response.

One such primarily adaptive behavioral stress response (best classified as defensive coping) is the increase in work efforts produced by the employee in the example in that same section 1.3. The response is adaptive because it minimizes chances of failure and of being exposed to additional and potentially more severe stressors such as being criticized, downgraded, or sacked. Hence, adaptive behavioral coping limits increases in ΣS and thereby promotes mental health. Adaptive coping behavior may be promoted by knowledge about how to achieve goals and by metacognitive insight into one's weaknesses and strengths and one's motivators – faculties that also may help avoid stressor exposure in the first place (**Lau**).

R3. On the adaptive nature of stress and on optimal stressor appraisal (specification of PASTOR)

This is also our response to several commentators who blame us for not acknowledging the adaptive nature of stress responses, and in particular the active behavioral coping aspect of stress responses (**Bennett & Windle**; **Egloff**; **Freund & Staudinger**; **Juslin**; **Mancini**; **Southwick et al.**; **Troy**). We think this is a misrepresentation of our theory, but we realize that we also may have invited this misrepresentation by imprecise wording, namely in the first paragraph of section 4.2.5 on reappraisal. We therefore emphasize here that because of the primarily adaptive nature of stress responses (pointed out in sects. 1.3, 2, and 4.2.4.1), we do *not* propose that stress responses should be avoided at any costs. What we say is that "although primarily adaptive, stress responses can become deleterious if they are very intense, prolonged, or chronic – by exhausting internal, but also social or monetary resources and interfering with the pursuit of other important goals, as summarized in the concept of allostatic load (McEwen & Stellar 1993)" (sect. 1.3, para. 3). We go on to argue that

> as a consequence, any mechanism that helps the organism fine-tune stress responses to optimal levels, to terminate them if no longer necessary, and to remain flexible enough to switch to possible alternative coping strategies, thereby facilitating efficient deployment of resources, is likely to protect all or most of the systems involved in the stress response and therefore to prevent a large range of stress-related dysfunctions. (sect. 1.3, para. 3)

We illustrate the importance of "optimized aversion," "optimizing stressor-induced aversion," "optimally regulat[ing] stress responses," and "react[ing] to…stressors with optimized aversion" (sect. 1.3); "flexibly adjust[ing] aversive motivation to appropriate levels" and "optimization of aversion" (sects. 2 and 4.2.8); and "limitation of…aversion" (sect. 4.2) by taking the example of the stressed employee to the point where he fails despite increased work efforts, and perseverance is not an option anymore. The employee develops "dislike for the job, decreased efforts or even avoidance of work, and diminished job-related self-efficacy perceptions" (sect. 1.3). These, too, are adaptive stress responses, precisely because they help preventing "pointless perseverance and [the resulting] exhaustion" (i.e., the costs of a more inflexible and unnecessarily prolonged stress response). If he is smart, the pitiable employee now will "search for alternative coping strategies, such as reducing ambitions and redefining work objectives or looking for another job." Looking for a better job therefore is another example of what may be considered an adaptive coping behavior (see sect. R2), which functions to contain stressor load S (e.g., unemployment).

The more important point to make here, however, is that an aversive over-reaction potentially can be harmful at two stages: It can make the employee persevere unnecessarily, until the point of exhaustion; or later, provided he earlier has chosen to give up, it can prevent the employee from looking for a smarter solution, and instead induce "a generalized amotivational, lethargic state" (sect. 1.3). Both exhaustion and lethargy would figure as increases in mental problems (ΔΣP) in our model. What could cause the harmful over-reaction? Or better, what could prevent it? The "dislike for the job" and the "diminished job-related self-efficacy perceptions" that stop perseverance are realistic appraisals that are neither negative (in the sense that they do not exaggerate the aversive consequences of failure) nor too positive (incorrectly appetitive). (Here, **Beer & Flagan**; **Crespi**; **Freund & Staudinger**; **Juslin**; **Koole, Schwager, & Rothermund (Koole et al.)**; **Lau**; **Mancini; Sachser & Richter**; **Southwick et al.**; and **Ungar** have a point in insisting that unrealistically appetitive or delusional appraisals are likely to be harmful, which not to have mentioned is clearly a weakness of our target article.) Similarly, to prevent generalized lethargy, the employee must "not extend [his] aversion and reduced self-efficacy perceptions to work life generally or even to any kind of challenging situation" (sect. 1.3). That is, he must avoid unrealistically aversive appraisals (as well as unrealistically appetitive appraisals). Avoiding such appraisals is key for producing adaptive stress responses, including at the level of behavioral coping. Such stress responses will come with costs, but these costs will be appropriate in relation to the costs of not responding.

From the comments, we realize that we have not adequately defined what we consider as "negative" and "positive." So what is an optimal appraisal style that assures adaptive stress responding? If *we understand "negative" as any appraisal that exaggerates the aversive consequences of a threatening situation*, in the sense of pessimism or catastrophization, then seeing a threat as what it is does not count as negative. Responding to a barking mastiff with staying still and keeping away is an adaptive stress response that is caused by a realistic appraisal of the threatening nature of the dog. This appraisal is not negative in our terminology. Responding to the mastiff with panic and running away is the result of an exaggerated, that is, negative or pessimistic appraisal that an attack is unavoidable and imminent and escape is the only, though small,
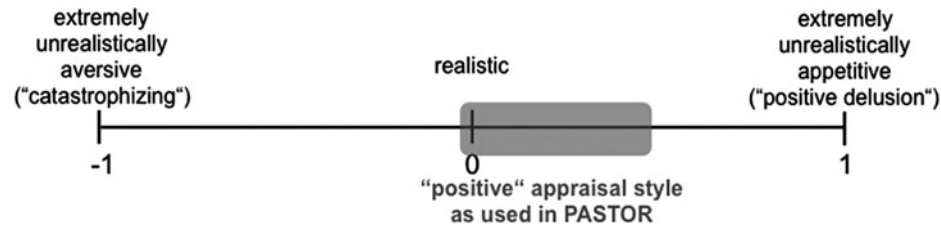
Figure R1. Range of appraisals considered protective by positive appraisal style theory of resilience (PASTOR) in relation to the realism of the appraisal. Realistic appraisals attach a correct emotional-motivational value to a situation, whether that value is aversive or appetitive. Unrealistic appraisals consist of seeing a situation as either worse than it is (negative sign on the realism axis) or better than it is (positive sign). For simplicity, the term *positive* is used for appraisals that are either completely realistic (both non-negative and non-positive, i.e., 0) or mildly unrealistically appetitive (moderate positive values). The adaptive nature of mildly positive appraisals results from the inherent unpredictability of the world, making realistic judgments difficult and conferring an advantage to optimistic, stress-reducing judgments.

chance to stay alive. It is the equivalent of an employee who has once failed on the job and now believes that he is unable to achieve anything, whether on the job or in any other difficult situation.

So the art is to avoid unnecessarily aversive motivational states because these cause unnecessary costs, including the costs of stupid decisions. According to this definition of the term *negative*, we have defined a negative appraisal style as might be found in a patient who "consistently overestimate [s] the aversive consequences of challenging situations (*outcome magnitude* dimension) or the probability of such aversive consequences (*outcome probability* dimension), or both; he may also consistently underestimate his ability to cope (*coping* dimension)" (sect. 4.2.2). To summarize this, we clarify here that *"non-negative" in PASTOR claim 1 signifies a realistic threat appraisal*. We thank the commentators for their scrutiny.

Nevertheless, we have not termed our theory "non-negative" or "non-pessimistic" or "realistic" appraisal style theory, but positive appraisal style theory. This was done only partly for simplicity. In part, also, we intended to take into account that the inherent unpredictability of life always limits the certainty with which we can estimate outcome magnitudes, outcome probabilities, and our coping potential. The realism of appraisal is an ideal that can only be approximated. Ultimately, appraisal must remain subjective and uncertain (sects. 4.2.1 and 4.2.5). (See also the argument that it is difficult to find an objective standard for realism in the criticism of depressive realism [Moore & Fresco 2012].) Further, the different appraisal dimensions are not independent, and any final appraisal outcome is always the result of a complex interplay of different appraisals along different appraisal dimensions (see our exemplary discussion in sect. 4.2.1). Therefore, especially in complex situations, "individuals [have] many degrees of freedom in evaluating" the situation (sect. 4.2.5). Unless the outcome of such a complex (often social) situation is potentially highly dramatic and irreversible (e.g., death), it may therefore be well adaptive to choose a more optimistic scenario among the many possible outcomes, simply because this reduces or avoids the costs of mounting anticipatory aversive behaviors. This might even be done knowingly, and it might be done also when a grimmer scenario appears slightly more likely but still within some confidence interval of the likelihood of the more optimistic scenario. Surely, clearly unrealistic positive appraisal choices are maladaptive (**Crespi**; **Freund &**

Staudinger; **Koole et al.**; **Lau**; **Mancini**; **Sachser & Richter**; **Southwick et al.**; and **Ungar**).

Figure R1 tries to illustrate the optimal range of appraisals on a dimension of realism where an ideal, completely realistic appraisal has a value of 0, an extremely unrealistically aversive appraisal has a value of −1, and an extremely unrealistically appetitive ("delusional") appraisal has a value of 1. It can be seen that the bulk of the appraisals considered optimal live on the positively signed side of the axis, which is why we think that *positive* is a suitable term to describe the type of appraisals we believe are protective. Disease-oriented, pathophysiological research traditionally is concerned with appraisals on the negatively signed side of the axis.

There is another reason why we think that *positive* is the best term for describing optimal appraisals. The inherent complexity of the world also implies that is it difficult to predict not only what is going to happen and how we are going to be able to cope with it, but also what this means for us. In order to choose his most adaptive response, not only is the pressured employee going to calculate the probability of failure and the probability and magnitude of the sanction that might follow failure, but he also will take into consideration the further consequences of a possible sanction. At first sight, being sacked appears clearly bad, but it also might be taken as a welcome opportunity for exploring a new career path (**Troy**) or making a more fundamental change to one's life, as a test of morale or faith, as a possibility to mature and grow personally, as an opportunity for chance entering one's life, and so forth. Although evolution has surely equipped us with mechanisms that make us avoid social exclusion, it is not objectively possible to determine the absolute value of a social-exclusion event such as being sacked. Again, "individuals [have] many degrees of freedom in evaluating" a situation (sect. 4.2.5).

So the employee may consider his chances to avoid sanction by increasing his work efforts as high, and he may be sure he will be sacked if he does not, but he still may choose not to work more, because he does not find being sacked particularly terrible. This might apply even if he does not appraise his financial or social resources to cope with unemployment as sufficient from a material point of view. And it is not guaranteed that this ostensibly maladaptive behavior will lead to mental dysfunction. A poor man can be healthy. (And is that not what resilience is about?)

Brummelman & Walton make a similar argument in their description of a girl performing poorly at school but

Table R1. *Positive appraisal style theory of resilience (PASTOR)*

Claim 1: Positive appraisal style

A generalized tendency to appraise potentially aversive stimuli or situations in a positive fashion is the proximal cause for resilience to stressors (adversity, challenge, trauma …). A positive appraisal style is the common resilience mechanism onto which all resilience factors converge and through which they exert their protective effects on mental health.

["Positive" refers to appraisals that do not overestimate the magnitude, probability, or uncontrollability of a potential aversive outcome (realistic or non-negative or nonpessimistic appraisals). In addition, "positive" refers to appraisals that attach appetitive value to ostensibly aversive outcomes.]

Claim 2: Positive reappraisal

In mildly aversive situations, positive appraisal is achieved easily by positive situation classification (comparison with earlier, successfully managed situations or activation of positive cultural stereotypes). However, in aversive situations that are strong enough to automatically trigger negative appraisals, protective (less negative) appraisals (see claim 1) result from positively reappraising the situation.

[Reappraisals may be invited externally, by improvements in the situation, or be generated internally, by reconstruing a situation. Reappraisal processes may occur at different levels of the cognitive hierarchy, from effortless, automatic, nonconcious, and nonvolitional to highly effortful, conscious, and volitional.]

Claim 3: Interference inhibition

The positive adjustment of appraisals in strongly aversive situations (reappraisal proper) requires a capacity to inhibit the interference resulting from competing negative appraisals and from the accompanying aversive emotional reactions.

The text in square brackets provides precise definitions of key terms in order to prevent possible misinterpretations (cf. Table 1).
Refer to the following sections from the target article for more details: 4.2.1 and 4.2.2. (for claim 1), 4.2.5 (for claim 2), and 4.2.7 (for claim 3).

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not appraising that as a threat. The point here is that a narrow evolutionary perspective, which we basically endorse as extremely useful for behavioral analysis, comes to its limits, by leaving out the essentially constructivist nature of human world interpretation (Raskin 2002) and the subjective importance of associated attitudes and value systems. Hence, if we define protective, resilience-promoting appraisals functionally as those that generate optimized stress responses, then this leads us not only to the conclusion that they range from realistic (non-negative, non-pessimistic) to mildly positively unrealistic (see above and Fig. R1). In addition, we have to acknowledge that some people do well (mentally) with what might appear irrational choices, perhaps because they confer a sense of comprehensibility or meaningfulness of life and the world, of authenticity, creativity, or transcendence (Antonovsky 1987; Frankl 2004; Maslow 1971; Seligman et al. 2006), "meta-needs" (Maslow 1971), or values that are not readily integrable into an evolutionary-biological perspective and originate from worldviews or personal philosophies that transcend a merely hedonistic perspective. And we also have to acknowledge that these people probably do well because of – and not in spite of – their choices. (Credit to **Quirin, Kent, Boksem, & Tops** [**Quirin et al.**] and **Vázquez** for highlighting these aspects.) Nonsatisfaction of meta-needs is aversive and can cause stress, and enduring the stresses of physical hardships or social conflicts can, in sum, even reduce stress if it leads to meta-need satisfaction. In other words, we appraise situations not only with respect to their (un)pleasantness and compatibility with or conduciveness to hedonic needs and goals, but also with respect to what they mean for our meta-needs and goals. Both can be subjectively relevant outcomes. And positive appraisal therefore can involve giving the pursuit of meta-goals more weight than the pursuit of hedonic goals, with a potential to reduce stress and its long-term

costs for mental health specifically in situations where hedonic need satisfaction is difficult or impossible.

The advantage of cultivating a meta-hedonistic worldview, then, is that it offers additional needs and goals against which the meaning of an anticipated outcome can be evaluated (for the importance of relative goal valuation, see also sect. 4.2.5). This wider range of criteria can be exploited to *appraise ostensibly aversive or "anti-hedonistic" outcomes as appetitive*, to "find the good in the bad." If an individual has a repertoire of such "positive" appraisal contents at her disposal and is used to employing them, the *process* of finding the good in the bad may be relatively effortless and automatic (positive situation classification; see PASTOR claim 2 and sect. 4.2.5). In many cases, especially under massive stressor exposure, however, it will be necessary to enforce these alternative, appetitive appraisals against the strong opposition of the aversive appraisals generated more or less spontaneously by vestigial appraisal systems that have been fashioned by evolution to assure hedonic need satisfaction. In this (but not only in this) reappraisal process (PASTOR claim 2, sect. 4.2.5), interference inhibition (PASTOR claim 3, sect. 4.2.7) is likely to be an important mental faculty. It remains to be mentioned that this "non-hedonistic" facet of positive appraisal can be assumed to be restricted to humans.

We were reluctant to discuss these definitional issues in so much detail in the target article for reasons of space, but also because we are more interested in the neurocognitive processes that bring about positive appraisals than in actual appraisal contents (see sects. 4.2.6, 4.2.8, and 6), and because we prefer to study appraisal style experimentally, by observing emotional reactions, rather than by employing questionnaires that ask about specific appraisal contents (sect. 4.3). We nevertheless now feel obliged to spell out more clearly our definition of *positive appraisal style*. We therefore supplement PASTOR claim 1, as in Table R1,

with an explanatory parenthesis. (Note also the explanatory parenthesis in claim 2, necessitated by a frequent misconception of reappraisal processes as being solely volitional and conscious; cf. sects. R4 and R5.)

With respect to the appraisal style (AS) score proposed as a self-report measure for assessing appraisal contents in section 4.2.8 and Figure 5 in the target article, we specify that it should index not the magnitude of the positivity of appraisals (which would lead to a curvilinear relationship between AS and R; **Southwick et al.**) but to what extent positive appraisals generalize across stimuli and situations.

R4. Comparison of positive appraisal style with other constructs or models

One demarcation to make is that positive appraisal style as defined in the target article and specified in the previous section is not merely optimism (**Carver & Scheier**; **Sachser & Richter**) but a broader construct. Most notably, it also includes seeing things as positive that are not (or do not seem to be; see above). But even when comparing positive appraisal style and optimism only on the realism dimension (Fig. R1), two additional differences must be noted. Given the many formulations of a definition of optimism that can be found in the literature, it seems wisest to rely on the accepted and widely used instrument for measuring optimism, the Life Orientation Test, or LOT-R (Scheier et al. 1994), when trying to understand the construct. The operationalization of optimism in the form of the LOT-R does not include the realistic (both non-negative and non-positive) estimates that are part of a positive appraisal style. And it does not include estimates of coping potential. (The LOT-R effectively invites people to think about the probability and magnitude of possible outcomes, although Scheier and Carver [1985] theoretically consider optimistic coping potential estimates as one attribute of the optimistic personality.)

This demarcation of positive appraisal style from optimism does not imply that behavioral paradigms measuring optimistic decision biases in animals (Mendl et al. 2010), as proposed by **Sachser & Richter**, cannot be a highly useful source of information on some of the neurobiological substrates of positive appraisal. But to more broadly study positive appraisal style in animals, paradigms such as discrimination, unconditioned stimulus (UCS) deflation, counter-conditioning, or extinction (which involve a realistic analysis of a nonreinforced stimulus as safe, or safer, than it used to be; see 4.3.3) or the study of response termination after stressor exposure also may be necessary.

We only briefly mention in this context that many or all of our appraisal systems presumably have evolved in more hostile environments than those provided by contemporaneous industrialized societies. In more hostile environments, where vital threats are frequent, it may be more adaptive to be negative by default (left side of the axis in Fig. R1). This has been expressed in the motto "better safe than sorry," which well characterizes the workings especially of our evolutionarily oldest appraisal systems, responsible for generating low-threshold defense responses (see sect. 4.2.5). It is therefore not surprising that natural selection has not eliminated non-positive versions of appraisal, as **Sachser & Richter** rightly note (though not denying that positive appraisals also may have survival

value). Our theory, however, tries to explain resilience in today's comparatively safe, developed societies, in accordance with our goal, formulated in the introductory paragraph of the target article, to promote mental health in the industrialized world.[1]

Koole et al., in their "counter-regulation" model, emphasize the potential dangers of intense and persistent positive emotional states and the corresponding importance of maintaining a steady emotional balance. Hence, it is adaptive to limit not only negative emotional states but also positive states. Positive emotional states can be limited by directing attention to negative information and activating negative appraisals. We find this idea very interesting and worth testing in an outcome-based study framework (sect. 3 of the target article; see also sect. R6 of this response). We nevertheless would like to remark that we do not recommend generation of "intense positive emotional states" (**Koole et al.**) as a way to resilience, and that we do not think that the type of cautiously optimistic appraisal style that we have defined as positive here (Fig. R1) is conducive to such states.

Soenke, O'Connor, & Greenberg (**Soenke et al.**), on the other hand, emphasize the resilience-promoting function of positive emotion. Importantly, in their model, the value of appetitive motivational states not only lies in their *not* being unnecessarily aversive (as in PASTOR, where avoiding negative appraisals will in many cases effectively lead to mildly appetitive states) or in inhibiting the aversive system via neural opponency mechanisms (see sect. 4.2.7, including Note 2). Rather, positive emotions have a series of adaptive consequences, such as broadening attention and allowing creative thinking and a more broadminded perspective. Thereby, appetitive motivational states constitute an independent, second way to resilience in addition to positive appraisal style, mediating the effects of a range of upstream resilience factors. But appetitive motivation also can result in poorer mental health outcomes, for instance, when they conflict with reality or keep people from disengaging from sources of distress. We think that a model, such as PASTOR, that focuses on avoiding the costs of unnecessary aversive responses is more parsimonious, and that effects of positive emotion can be understood as distal factors that work by facilitating positive appraisal (and thereby reducing unnecessary aversion). We nevertheless think that, as in the case of **Koole et al.**'s ideas, ultimately this has to be tested empirically.

Koole et al.'s and **Soenke et al.**'s models are two in a series of proposals that invoke a wider range of emotion generation and regulation processes as potential resilience mechanisms, including deployment of attention (i.e., distraction from negative information; see also **Luyten, Boddez, & Hermans** (**Luyten et al.**); **Egloff**; **Troy**; and **Vázquez**) and suppression of emotional expression (**Egloff**). Many of these models (see also Boden et al. 2014; Bonanno & Burton 2013; Cheng 2001; Kashdan & Rottenberg 2010; Opitz et al. 2012; Troy et al. 2013) stress the importance of flexibly using *different* strategies, depending on situational demands or personal characteristics (**Egloff**; **Troy**).

One argument to support the adaptive value of distraction is work by Sheppes et al. (2014), who show that distress ratings in response to high-intensity negative stimuli are more easily attenuated by volitional distraction than by volitional reappraisal (**Egloff**; **Grecucci & Job**; **Troy**). We

note that these commentators mistakenly reduce the notion of reappraisal in PASTOR to volitional ("cognitive," conscious, higher-level) forms of reappraisal, despite the explicit statement in PASTOR claim 2 that reappraisal also can occur at lower levels of the cognitive hierarchy (see also sect. R5 and the explicit explanatory parenthesis added to PASTOR claim 2 in Table R1). Leaving aside this misrepresentation, the commentators fail to appreciate that Sheppes and colleagues' studies investigate the downregulation of *acute* aversive states. It remains unclear from these studies whether distraction is also better than volitional reappraisal is in attenuating the aftereffects of stressor exposure (e.g., traumatization) or in dealing with repeated exposures to the same or similar stressors. Both effects are likely to be much more important for longterm outcome than acute regulation success. Interestingly, Sheppes et al. make the argument that

> the major cost of distraction is that motivationally it does not allow processing, evaluating, and remembering emotional information, which are crucial for one's long-term goals and adaptation…. Specifically, distraction is not conducive to emotional events being repeatedly attended to and provided with adequate explanation, a requirement that is at the heart of many long-term goals where an individual has to face difficulties and of adaptation. (Sheppes et al. 2014, p. 165)

In support, they cite evidence that distraction can produce rebound effects when stressor exposure is repeated (Thiruchselvam et al. 2011) and is maladaptive when longterm adjustment is required (Kross & Ayduk 2008), whereas repeated reappraisal efforts can gradually change stimulus evaluation (Blechert et al. 2012).

We do not want to exclude that distraction (or also expressive suppression) can be adaptive, in particular, by counteracting tendencies of perseveration or rumination. Hence, distraction and expressive suppression may be strategies that protect specifically against depressive-type dysfunctions (Joormann et al. 2007; Nolen-Hoeksema et al. 2008; see also Sheppes et al. 2014). However, they also may be maladaptive in other individuals or situations, especially when used frequently. As Sheppes et al. note:

> Common to several anxiety disorders is a tendency to overgeneralize a disengagement or avoidance regulatory response (see Campbell-Sills & Barlow 2007; Foa & Kozak 1986, for reviews). Avoidance usually starts in response to high-intensity emotional stimuli, but over time, it ends up spilling over to seemingly lowintensity stimuli … although disengagement strategies are helpful in providing short-term relief, they are maladaptive in the long run and can perpetuate anxiety and fears. (Sheppes et al. 2014, p. 177)

Hence, distraction and expressive suppression may be dysfunction-specific but not general resilience mechanisms in our terminology introduced in section 1.3, which is why we do not include them in our model. Whether *flexibility* in the use of different strategies (Egloff; Troy) is a better explanation than positive appraisal style is for resilient outcomes is yet another question. We would invite proponents of the idea to operationalize this construct and to make it amenable to empirical testing (Bonanno & Burton 2013).

The crucial question of the long-term effects of stressor exposure can be understood best within the global framework of allostatic plasticity (McEwen & Stellar 1993), that is, the cerebral and bodily adaptations that help the organism deal with future exposures to identical or similar stressors (sect. 1.3). Whenever an individual's appraisals are lastingly changed during or in the aftermath of a stressful situation (such as when an initially neutral stimulus becomes feared due to an aversive experience, or when one's perceived coping potential increases as the result of a successfully mastered challenging situation), this constitutes a case of allostatic plasticity (sect. 4.2.4.3). The latter example is an instance of positive reappraisal (sect. 4.2.5; process class 2, PC_2, in sect. 4.2.8 and Fig. 5) – that is, the appraisal value attached to the coping potential dimension of the situation increases. This increase will make coping easier the next time one encounters the situation (unless one has developed a delusional power perception; see section R3). In the best case, the increase in perceived coping potential is so profound and long-lasting that retrieving the new appraisal content is entirely automatic and effortless at the next situation encounter. In this case, reappraisal processes are no longer necessary, and the situation will be positively evaluated as a result of spontaneous positive situation classification (sect. 4.2.5; process class 1, PC_1). This makes the question of how new appraisal contents are written into memory, consolidated, and later retrieved particularly interesting, as exemplified in section 4.3.3 for the safety memories generated during the reappraisal process of fear extinction (which changes the value attached to the outcome probability dimension of a conditioned stimulus).

Discussing the important role of developmental factors in resilience (see also **IJzerman & Lindenberg**; **Sachser & Richter**), **Nederhof** reminds us that allostatic plasticity is particularly prominent during early childhood, and in particular during certain sensitive time windows and in individuals with high programming sensitivity (Belsky et al. 2007). She argues that individuals lastingly adjust their appraisal styles during these developmental periods to meet predicted future environmental demands. In the terms of PASTOR, then, appraisal style could be a mediator of the effects of early-life history (a resilience factor) on resilience. Perhaps, better understanding how appraisal contents are transformed into strong and stable memories in sensitive periods of life (or also in sensitive individuals) could help find ways to make appraisal styles more positive in vulnerable people, too.

Relatedly, **Luyten et al.** and **Vázquez** make the valuable comment that reappraisal also may occur after the event (such as in "retrospective revaluation"; Boddez et al. 2013a). This ties in with the idea by **Quirin et al.** that new experiences have to be integrated in a meaningful and coherent way into internal self-models, which sometimes is easier in the absence of acute threat (Quirin et al.'s "predictive control" mode). In a similar vein, **Murray, Gerrans, Brosch, & Sander** (**Murray et al.**) propose that event-free resting states provide an opportunity for updating implicit self-models via reappraisals (in particular, of one's coping potential) – in other words, for reorganizing one's appraisal style. Where self-model integration is successful to the extent that new appraisals become implicit and unconscious, this will result in spontaneous and effortless positive situation classification. Murray et al. invoke Bayesian learning principles to explain this integration process. We think these are excellent ideas that have the potential to advance importantly our mechanistic understanding of the allostatic plasticity of appraisal.

Finally, **Crespi** conceptualizes resilience as a trait (including "resilient genotypes"), which we explicitly do not (see our outcome-based definition of resilience in sects. 1.1, 2, and 3.1). Hence, we cannot endorse his juxtaposition of sensitivity (a personality marked by strong responses to both aversive and appetitive events; Pluess & Belsky 2013) and resilience. We do not want to exclude, however, the possibility that a positive appraisal style may be negatively associated with a tendency not only for overly aversive responses, but also for overly appetitive responses (see our reply to **Koole et al.** above). In other words, positive appraisers might be comparatively less-sensitive people in the terms of Crespi. This quality may keep positive appraisers as we define them from maximally exploiting the benefits of good environments, which, however, is a different story.

R5. Value of an appraisal-based theory for translational, neurobiological resilience research

Resilience research in animals has made tremendous progress in the past few years, including the identification of entirely novel molecular or cellular mechanisms that shape resistance to chronic social stress (e.g., Agudelo et al. 2014; Chaudhury et al. 2013; Dias et al. 2014; Friedman et al. 2014; Issler et al. 2014). With new findings arriving at a fast pace, animal research runs the same risk as human resilience research of losing itself in vast amounts of data. Already, neurobiological review papers on resilience are starting to enumerate long lists of molecules, physiological mechanisms, or brain systems (from glutamate receptors in the hippocampus, brain-derived neurotrophic factor [BDNF] or serotonin, over neurogenesis or prefrontal inhibition, to the hypothalamus-pituitary-adrenal gland [HPA] axis or the reward system, and so forth) (Feder et al. 2011; Franklin et al. 2012; Russo et al. 2012). (Compare our criticism of the human resilience literature in sect. 3.5). However, if this disparate knowledge is to contribute to the understanding of human resilience, it must be organized in a meaningful way and be related to human cognition and behavior. Clearly, BDNF or glutamate or any other molecule is involved in so many different functions that it can hardly be considered a "resilience molecule" in any narrow sense, and the same applies to any neurophysiological process or brain region or brain circuit. In the same vein, no molecular or neurophysiological manipulation will just make people resilient, if not appropriately designed and contextualized.

Understanding human resilience can succeed only if one acknowledges the brain's orchestrating role as an information processing machine whose job it is to find and organize appropriate responses to changes in the external and internal environment, as emphasized in more elegant language by **Silbersweig**. Hence, neurobiological or neurophysiological experiments in mouse or rat models can provide important insights if – and only if – they elucidate the inner workings of an information processing procedure that also exists in a homologous fashion in humans and plays a role there in supporting resilience to stressors. It is therefore of utmost importance to identify what those critical information processing procedures are and in which context they are used. And the process of identifying critical procedures should start at the functional level, asking on what type of information they work and what type of behavioral change they produce; in other words, what are they good for? Only after such fundamental clarification can one meaningfully analyze the identified procedures at the levels of their algorithmic and neural implementation (Marr 1982).

It is for this reason that we have proposed the concept of appraisal as a possible guiding principle for resilience research. Appraisal is functionally defined as the information processing procedure that translates a stimulus or situation into an emotional reaction. This definition derives from the empirical observation from both animal and human behavioral research that emotional reactions are not simply determined by stimulus input, and therefore cannot be conceived as mere stimulus-response phenomena (sect. 4.2.2; Moors 2009). Appraisal theory very plainly argues that one must assume a step (or steps) of evaluation between the stimulus and the response, in order to explain that the same stimulus can induce very different reactions in different individuals or at different time points or in different contexts in the same individual (e.g., Arnold 1969; Moors 2009; Scherer 2001; see sect. 4.2.2 for more references). This functional definition is entirely agnostic as to the nature of the evaluation process (its algorithmic or neural implementation) and it applies both to how humans and to how non-human animals "make" emotions.

If one accepts that appraisal, by explaining the generation and manifestation of stress responses, is the key information processing procedure for resilience, then it becomes relevant what type of appraisals there are (algorithmic level) and how they are implemented in the brain (neural level). We emphasize in various places in our target article that current knowledge strongly indicates that *there is not just one appraisal process, but many*, and that *these different types of appraisal processes can be found at different levels of the cognitive hierarchy, from very effortless, automatic, nonconscious, and nonvolitional processes to those highly effortful, controlled, and conscious processes that presumably exist only in humans* (cf. sects. 4.2.2, 4.2.5, and 5.1 and Leventhal & Scherer 1987; Moors 2009; Robinson 1998). (To **Lau**, this description is reminiscent of Kahnemann's [2011] dual-process model, with its fast intuitive system 1 and an analytic and deliberate system 2, although we should say that we do not make a claim that appraisals in humans are organized in this simple dichotomic fashion. Some commentators [**Egloff**; **Grecucci & Job**; **Washington**] incorrectly assume we consider appraisal to involve only high-level, conscious ["cognitive"] processes. Others [**Beer & Flagan**] incorrectly assume the contrary.) Animal research is valuable in elucidating the neural bases of the more lower-level appraisal processes that can be assumed to be highly homologous between humans and, for example, rodents.[2] Exactly defining those processes and creating the best-suited behavioral paradigms to study them requires the careful ethological-analytic approach described by **Sachser & Richter.**

If used in this way, animal research can be a valuable tool in resilience research. Nevertheless, animal models can never free the human resilience researcher from the obligation to ask which role an appraisal process, defined ethologically and studied neurally in animals, plays in humans and how it is complemented (or sometimes antagonized) by higher-order appraisal processes that are reserved to the

human species. A good example is provided by **Vázquez,** who reminds us that the principle of learned helplessness (in human, psychological terms: *diminished perceived self-efficacy*) was highly successful in explaining certain depression-like behaviors in rodent models but was insufficient to deal with the complexities of the human disorder (Abramson et al. 1978). In such cases, an appraisal-based analysis can be a useful guide, allowing researchers to ask which other appraisal dimensions on top of coping potential are relevant in determining which types of emotional reaction (lethargy, sadness, anxiety, and so forth), how these dimensions interact, and which human-specific neurocognitive processes are involved in producing these appraisal contents, on top of conserved, vestigial processes. Our much-used example of the stressed employee served to demonstrate the value of such an appraisal-based analysis for enlightening human resilience research, too.

To our great pleasure, many commentators have made a variety of specific suggestions about potential (neuro)biological resilience mechanisms – the effects of cortisol on neural function (**Hermans & Fernández**; **Schutter, Wischnewski, & Bekkering** [**Schutter et al.**]); cortical excitability and its regulation through (cortisol-sensitive) homeostatic plasticity mechanisms (Schutter et al.; see also **Silbersweig**); neural network properties (**Levit-Binnun & Golland**); neural reorganization during resting state (**Murray et al.**); neural mechanisms of stress response termination (**Walter, Erk, & Veer** [**Walter et al.**]); lateralizations in prefrontal function (**Quirin et al.**); and orbitofrontal-striatal functional connectivity (**Beer & Flagan**). It was beyond the scope of our target article to flesh out PASTOR in any neurobiological detail. (Beginning in section 4.3.2, we briefly mention some brain regions or circuits that we think are likely to be relevant, based on their association with some of the process classes posited by PASTOR, but without attempting to be exhaustive or formally integrating neural elements into the theory.) Similarly, here, for reasons of space and focus, we will not exhaustively discuss these many fascinating ideas. We will limit ourselves to commenting in a few cases where we think the authors have underestimated the value of our appraisal-theoretic approach for informing and organizing (neuro)biological resilience research.

The case of amygdala "reactivity" or "responsiveness" or "activation" to threat (**Hermans & Fernández**; **Shumyatsky, Jovanovic, & Handler** [**Shumyatsky et al.**]; **Walter et al.**) is a good opportunity to apply an appraisal-based analysis in order to make sense of an empirically observed neural phenomenon. Within the appraisal framework, amygdala reactivity no longer comes out of the blue but is either part of the appraisal process or its result (i.e., part of the subsequent execution of the emotional response). On this basis, one can ask further questions, such as to which appraisal dimensions amygdala activity is sensitive (e.g., outcome magnitude? probability? coping potential?); at which processing level (nonconscious? conscious?) these dimensions are determined; how, neurobiologically speaking, the amygdala constructs appraisals and response execution; and which other neural systems cooperate or compete with the amygdala in the emotion generation process. Hence, a theory-guided analysis is able to confer meaning to observations of amygdala reactivity (or other neural phenomena) in specific experimental settings and specific groups of subjects and to inspire further

experiments. In a second step, it then permits one to formulate reasonable hypotheses about what amygdala reactivity under defined experimental circumstances implies for an individual's resilience. For example, if the amygdala is found to be sensitive to changes in outcome probability as implemented in a fear conditioning and extinction experiment, and if resilience theory posits extinction learning ability as a potentially critical reappraisal faculty (sect. 4.2.7), then it is promising to ask whether changes in amygdala activity during extinction predict resilience; whether they mediate life-history effects on resilience (e.g., because stressor exposure during critical ontogenetic time windows shapes amygdala function; Hartley & Lee 2015); or how molecular or cellular features of amygdala function during extinction contribute to resilience.

Another change in stimulus input inviting an adjustment of responding is when a stressor ceases to exist, and being able to terminate stress responses after stressor termination is likely to be adaptive. PASTOR explains such response adjustment as an adjustment of outcome appraisals, allowing for using response termination as another way to assess (re)appraisal style (sect. 4.3.3). **Walter et al.** assign a particularly prominent role in resilience to these recovery processes, both in the short term (acute stress response) and in the long term (aftereffects of stress; cf. the themes of allostatic plasticity and appraisal memories discussed in sect. R4). Interestingly, to advance this important topic, they recommend a more atheoretical, primarily neurophysiological analysis of recovery phenomena in the different systems that participate in stress responses (autonomic nervous system, HPA axis, brain circuits, etc.), including also amygdala response recovery.

On a general note, first, we would reply that there is nothing like atheoretical neuroscience. Every neuroscientific experiment is by necessity based on a large number of, often implicit, theoretical assumptions. For example, to choose only the threat stimulus used in a stress experiment to evoke amygdala activation (or heart-rate increases or cortisol release) requires a conceptualization of the model organism's goals and its needs, and of how the experimental stimulus might interfere with them. In the same vein, focusing on certain readouts (amygdala activity, heart rate, cortisol) always implies assumptions about the functions of the systems that produce the readouts. Inevitably, these considerations will have to be made when trying to establish a recovery measure that could serve as a "biomarker that will be predictive of resilience in the long run" (**Walter et al.**). More specifically, then, one could easily think of an example where quickly recovering is not adaptive at all, for instance, because the environment is highly unpredictable and stressor termination cannot be trusted (unclear outcome probability), or because the consequences of outcome occurrence could be disastrous (high outcome magnitude), or because one has no ways of managing the occurrence of the feared outcome (low coping potential). Here, benignly but not unrealistically optimistic appraisals in the sense of PASTOR's positive appraisal style (sect. R3, Fig. R1) preclude quick recovery, which would have to be considered in the planning of a recovery experiment. Hence, making underlying assumptions explicit and designing and interpreting experiments based on a theoretical framework are likely to improve neurobiological investigation.

Another very good example, we found, of how an appraisal framework can organize the interpretation of biological data was **Hermans & Fernández**'s analysis of the (presumed) effects of cortisol release during acute stress on resilience. They suggest that cortisol modulates the function of neural appraisal systems, notably by affecting the balance between subcortical (including amygdala) and prefrontal processing, and thereby may determine resilience. Although Hermans & Fernández seem to consider this biological explanation as competing with PASTOR, we note that they reserve a proximal place in the causal chain toward resilience to appraisal and that it is by cortisol's effects on appraisal that cortisol's (presumed) effects on resilience are understood. Providing a conceptual link between biological determinants of appraisal and of individual differences in appraisal, on the one hand, and resilience, on the other, exactly is one of the intentions of PASTOR.

We are therefore confident that combining a functional analysis based on an appraisal framework with cognitive-algorithmic and neural-level analysis will much advance resilience research. It will be exciting in the coming years to explore the appraisal functions and resilience effects of cortical excitability and homeostatic plasticity mechanisms (**Schutter et al.**), of features of neural network architecture (**Levit-Binnun & Golland**), of their experience-dependent shaping and reorganization during resting states (**Murray et al.**), of the relation of these processes to stress aftereffects (**Walter et al.**), and of the interplay of limbic and prefrontal functions (**Beer & Flagan**; **Hermans & Fernández**; **Quirin et al.**; Walter et al.).

R6. Need for empirical research based on an atheoretical definition of resilience

Our discussion in section R1– about whether the positive effects that a reduced stressor exposure has on mental health can truly count as effects on resilience R, or whether, alternatively, an increase in resilience should be stated only if good mental health outcomes cannot merely be explained by reduced stressor exposure – may appear unnecessarily academic, given the unquestionable link between stressor exposure and mental health. There is, however, an important practical advantage in providing a comparatively clear and unambiguous mathematical formalization of the construct one tries to measure (such as in our equation in sect. 3.1 of the target article), and in sticking to it. The advantage is that it enormously facilitates empirical research: For the individual researcher, it can provide guidance on how to analyze data and report results; and for the research community, it permits easier comparison of findings and reduces discursive ambiguity.

Ambiguity is an issue when one researcher defines resilience based on the Connor-Davidson Resilience Scale (CD-RISC; Connor & Davidson 2003; see **Kimbrel & Beckham**), one based on the ego resiliency scale (ER 89; Block & Kremen 1996), another one based on the Resilience Scale for Adults (RSA; Friborg et al. 2003), and so forth. (See Windle et al. [2011] for a summary of the 15 most used questionnaires in the field.) Ambiguity also is not resolved by general definitions that do not include guides toward operationalization. Examples of such definitions provided by the commentators include

"the process of effectively negotiating, adapting to, or managing significant sources of stress or trauma" (Windle 2011, in Kimbrel & Beckham);

"the ability to bounce back from negative emotional experiences by flexible adaptation to the changing demands of stressful experiences" (Tugade & Fredrickson 2004, in **Soenke et al.**), a definition that includes "mechanisms such as the experience of positive affect, nurturing social interactions, creativity, a focus on positive memories, and even physical health," according to these commentators, for whom resilient individuals are those "who are flourishing rather than struggling";

or "the capacity to absorb disturbance; to undergo change and still retain essentially the same function, structure and feedbacks, without crossing a threshold to a different system regime" (Walker & Salt 2006, in **Southwick et al.**).

Even if the community could agree on just one of these scales or definitions, an additional and perhaps even more serious problem would be that they all include implicit or explicit theoretical assumptions on how good mental health outcomes are achieved, whether through a combination of five specific factors (personal competence, trust/tolerance/strengthening effects of stress, acceptance of change and secure relationships, control, spiritual influences), as in the CD-RISC; through a specific personality construct, as in the ER 89; through a series of intrapersonal and interpersonal protective factors (family support and cohesion, external support systems, dispositional attitudes and behaviors), as in the RSA (descriptions as in Windle et al. 2011); or through any of the abilities or mechanisms in the above general definitions. Hence, all of these approaches to resilience already anticipate resilience factors and mechanisms, the identification of which should be the goal of empirical resilience research. By contrast, an explicitly atheoretical definition of resilience that is based purely on mental health status and stressor exposure is agnostic as to what a study might find and can therefore be used by researchers from different theoretical backgrounds to test their predictions.

In our ambition to propose a pragmatic operationalization of resilience that constitutes some sort of lowest common denominator and could find acceptance across schools of thinking as a common ground for model testing and comparison, we also have based our definition of resilience exclusively on the presence of mental problems or dysfunctions (as rightly noted by **Kimbrel & Beckham**). By contrast, we have refrained from including in our definition aspects of positive psychology such as "life-insight" (in **Freund & Staudinger**); "appreciation of life," "more intimate social relationships," "personal strength," "engagement," or "wisdom" (in **Jayawickreme, Forgeard, & Blackie** [**Jayawickreme et al.**]); "positive affect," "creativity," "well-being," or "flourishing" (in **Soenke et al.**); or "capacities," "benefits," "autonomy," "self-acceptance," or "sense of control" (in **Vázquez**).

We completely agree with the commentators that those are highly interesting topics and worthy of investigation. Also, as we noted in section R3, we believe that non-hedonistic valuations contribute to a positive appraisal style and thereby benefit mental health. So, wisdom or self-acceptance, or being engaged in meaningful activities, may increase resilience through the proximal mechanism of

positive appraisal. Nevertheless, basing a definition of resilience on any of these terms simply would overburden resilience research with complex semantic debates about the nature of these constructs and enormous problems of operationalization. In this context, it also may be worth remembering that Foucault's (2006) criticism of how psychiatry defines mental illness already is difficult enough to counter. Defining what is wisdom, well-being, or strength, or even happiness or fulfilment (Seligman et al. 2006) and making them goals for mental health research is not only ambitious but also associated with significant ethical and political implications (e.g., Antonovsky 1995).

An exception may be the concept of *growth* (or "posttraumatic growth"; see **Freund & Staudinger**; **Jayawickreme et al.**; **Vázquez**), which refers to the observation that some people appear to develop a more mature or positive personality when experiencing hard times (Joseph & Linley 2006; Tedeschi & Calhoun 2004). In our framework, psychological growth could be framed atheoretically and without reference to constructs from positive psychology simply as a decrease in mental problems during/after adversity (negative ΔΣP; see the lowest of the three mental-problem trajectories in Figure 1 of the target article). Growth then would be a highly resilient outcome (high R). From Jayawickreme et al. we learn that there is an ongoing debate as to the exact nature of posttraumatic growth, and perhaps investigating what brings about improvements in mental health could contribute to clarifying the construct.

To sum up this discussion, our focus is entirely on making *empirical* research on resilience possible, not excluding that this research also may yield results that are of relevance to other, related research fields. In the same vein, we have proposed PASTOR only to generate testable experimental hypotheses. If empirical resilience research were to result in falsification of PASTOR and to find better explanations in **Ungar**'s social ecological model, or **Carver & Scheier**'s and **Sachser & Richter**'s optimism-based accounts, or models that invoke a wider range of emotion generation and regulation processes (**Egloff**; **Juslin**; **Koole et al.**; **Luyten et al.**; **Quirin et al.**; **Troy**; **Vázquez**), or pronounced (neuro)biological formulations (e.g., **Hermans & Fernández**; **Levit-Binnun & Golland**; **Schutter et al.**; **Walter et al.**) – to name but a few proposals made by the commentators – then our initiative would have served its purpose.

R7. Toward a concerted international research effort

In our attempt to advance empirical resilience research, we felt very much encouraged by **Chang et al.** and **Kleim & Galatzer-Levy**, whose commentaries we understand as calls for a concerted international and interdisciplinary research effort that must aim at conducting extensive large-scale longitudinal studies in humans. We wholeheartedly agree with these commentators when they point out that resilience research needs large sample sizes and high sampling frequencies for stressor events and resilience outcomes in order to be able to address problems such as a low base rate of stressor events, a low rate of nonresilient outcomes (see also **Boden & McLeod**), heterogeneous distributions, and variable temporal outcome trajectories, all of which are inherent to resilience research and make

studying resilience particularly challenging. We also agree that recent advances in data collection and data analysis should be exploited for this purpose.

These and other commentators have made a range of suggestions about what an optimal study design and a data-analytical strategy should look like. Suggestions include also taking into account vulnerability factors (**Boden & McLeod**; **Luyten et al.**), which precisely may put people at risk for psychopathology because they compromise the working of resilience mechanisms (Boden & McLeod); incorporating self-report measures into laboratory paradigms in order to get access to subjects' experience (Luyten et al.); analyzing also factors or mechanisms that protect against specific dysfunctions, instead of exclusively focusing on general resilience mechanisms (Luyten et al.; **Southwick et al.**); assessing outcome (mental health ΣP) not just at two, but at several time points TX (**Chang et al.**; **Vázquez**) (a clear methodological desideratum only briefly mentioned in sects. 4.2.4.3, 4.3.5, and 5.2); and employing functional methods (Chang et al.) or latent-growth mixture modeling and machine learning approaches for data analysis (**Kleim & Galatzer-Levy**). Naturally, there is also variation in how our commentators appraise the value of laboratory experiments (our sect. 4.3), some of them arguing that these experiments are unlikely to achieve stress levels that would engage resilience processes in normal, healthy individuals (Boden & McLeod), others that they may not tell us much about non-hedonic needs or goals or the underlying value systems (**Vázquez**).

It is beyond the scope of this paper to address all these points in detail. We believe that the wide interest our target article has aroused and the many valuable and constructive suggestions made by the commentators show that this is a good time to act and to forge a global alliance for large-scale multicenter longitudinal studies that take human resilience research to the same level as contemporaneous pathophysiological research. These studies could provide an opportunity for evaluating different resilience theories and for better elucidating how socioenvironmental (**Bennett & Windle**; **Chang et al.**; **IJzerman & Lindenberg**; **Kimbrel & Beckham**; **Southwick et al.**; **Ungar**; **Washington**) or developmental (IJzerman & Lindenberg; **Nederhof**; **Sachser & Richter**) factors shape resilience. They could allow for comparing resilience factors and mechanisms in different age groups (Bennett & Windle). They could help the community develop better tools for measuring stressor exposure (Kimbrel & Beckham). They could be a basis for designing dedicated experimental interventions that test the causality of an identified mechanism (**Brummelman & Walton**; **Jayawickreme et al.**; Southwick et al.). We would hope they would lead to new prevention programs (whether these consist of social-psychological interventions, as in the elegant examples provided by Brummelman & Walton, or in cognitive-skills trainings or in neuroscientific interventions). Human research must be closely interlinked with animal research (Sachser & Richter; **Shumyatsky et al.**) in the elucidation of mechanisms and development of interventions. Such a resilience research initiative would not replace, but complement, psychopathological research initiatives.

By providing a "mathematical formulation of the resilience phenomenology" (**Shumyatsky et al.**) and

attempting to find a possible mechanistic explanation for the many disparate findings in the literature, it was our intention to offer the community "a guiding framework in which to organize the variables used in the study of resilience" (Shumyatsky et al.). Regardless of whether our ideas survive the test of time, we think that common action is urgently needed to advance mental health research in the twenty-first century.

NOTES

1. Put succinctly and a bit provocatively, we believe that countries or societies where living is surviving need not psychobiological research but more resources and better politics. Some of our commentators criticizing us (wrongly, we think) for not sufficiently acknowledging socioenvironmental factors (see sect. R1) may have had those more disadvantaged societies in mind. This is not to say that resilience research may not be inspired from the analysis of cases of extreme resilience (resilience to extreme stressors) that can sometimes be found in those societies (Crombach & Elbert 2014).

2. We permit ourselves here to note with some satisfaction that a distinguished neurobiologist and animal researcher with declared skepticism toward psychological explanations recently has acknowledged that "Pavlovian aversive conditioning [is] appropriately conceived of as involving a process in which the meaning of the CS has been changed" (LeDoux 2014), which is an appraisal-theoretic statement *par excellence*.

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[The letters "a" and "r" before author's initials stand for target article and response references, respectively]

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