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Personality, Stress and Resilience: A Multifactorial Cognitive Science Perspective

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Abstract

Personality traits are consistently correlated with various indices of acute psychological stress response, including negative emotions and performance impairment. However, resilience is a complex personal characteristic with multiple neural and psychological roots. This article advocates a multifactorial approach to understanding resilience that recognizes the complexity of the topic both empirically and theoretically. The Trait-Stressor-Outcome (TSO) framework for organizing empirical data recognizes the multiplicity of traits, stressors and outcome metrics that may moderate stress response. Research requires a fine-grained data collection approach that discriminates multiple stress factors. Also, multiple layers of theory are necessary to explain individual differences in stress response, including biases in neural functioning, attentional processing, as well as styles of coping and emotion-regulation. Cognitive science differentiates multiple levels of explanation and allows for the integration of mechanisms at multiple levels of abstraction from the neural substrate. We illustrate the application of the multifactorial approach to collecting interpreting data on operator stress resulting from interaction with technology.

Keywords: resilience, personality, stress, performance, unmanned vehicles, cognitive science, transactional model

Personality traits such as emotional stability, positive emotionality, hardiness, and emotional intelligence have all been linked to superior adaptation to life stressors (Matthews, Deary, & Whiteman, 2009). That is, personality characteristics confer resilience on the individual, over and above other stress-buffering factors such as social support and specific coping skills (e.g., Edward & Warelow, 2005). Traits for resilience include both broad personality factors such as neuroticism and more narrowly-defined traits such as hardiness, grit, and mental toughness (Pangallo, Zibarras, Lewis, & Flaxman, 2015).

Two major challenges to understanding resilient personality remain. First, it may be simplistic to locate individuals along a single, unitary dimension contrasting

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resilience with stress vulnerability. We will make a case for a multivariate understanding of individual differences that recognizes the diversity of relevant traits, external stressors, and outcomes. Second, the processes that underpin individual differences may also be multifaceted. Psychobiological models have traditionally dominated theoretical accounts of individual differences in stress response, but cognitive processes are also critical (Matthews, 2008). A satisfactory theoretical account of resilient personality requires a cognitive science perspective to accommodate the different ways in which traits may influence and shape the stress process.

Some process-based accounts of resilience (Masten & Wright, 2009) focus on lifespan development. Over extended durations, adaptation to stress may be both a cause and a consequence of personality. By contrast, we focus on short-term adaptation to the demands of task performance environments. Traits function as fixed influences that interact with acute situational demands such as overload, time pressure, and failure, to affect neural and cognitive stress processes, and subjective and objective outcomes.

The article is structured as follows. First, we make the case for a multivariate perspective on resilience. Personality traits, stressors and outcomes are all diverse, and none can be reduced to a general "stress" factor. Next, we introduce the Trait-Stressor-Outcome (TSO) framework for organizing empirical findings on personality and resilience, in the context of acute stressful encounters, such as vehicle driving. We also describe a TSO perspective on the emerging field of resilience in managing automated technology. The TSO framework is not itself a theory of individual differences in resilience. We address the need for theory by identifying multiple levels of explanation for personality effects that can be accommodated within a multi-level cognitive science model. Traits are distributed across multiple types of process whose salience may vary across different stressors and outcomes.

Personality and Resilience: Multifactorial Perspectives

In the tradition of Selye's (1956) General Adaptation System, researchers remain prone to think of stress in unitary terms, such that various external stressors elicit a common psychophysiological stress response. Similarly, a general resilience trait might attenuate the stress response across different forms of challenge. However, the unitary perspective appears increasingly untenable (Matthews, 2016a). Next, we will make the case that resilience, external stressors, and response modalities should all be considered multifactorial.

Traits for Resilience

Davydoff et al.'s (Davydov, Stewart, Ritchie, & Chaudieu, 2010) review of the resilience construct pointed out that "mental health research is currently hindered by the lack of a unified methodology and poor concept definition." Difficulties partly reflect the tension between viewing resilience as a stable trait versus a dynamic adaptive process. However, even trait definitions vary and numerous personality scales are used for assessment:

- *General negative affectivity scales.* The broad trait of neuroticism is associated with stress vulnerability and maladaptive coping (Carver & Connor-Smith, 2010); resilience can be identified with low neuroticism or emotional stability. High neuroticism is linked to numerous adverse health and wellbeing outcomes (Lahey, 2009; Matthews et al., 2009). However, an exclusive focus on negative affectivity may fail to capture elements of personality associated with personal growth following stressful events (e.g., Fredrickson, 2004). Over longer timespans, changes in neuroticism may result from exposure to life events (Sarubin et al., 2015).

- *Specialized resilience scales.* Following Kobasa, Maddi and Kahn's (1982) pioneering studies on hardiness, traits specifically associated with resistance to stress have been described. For example, the Connor and Davidson (2003) resilience scale includes items that ask the respondent to rate their ability to adapt to change and to bounce back after illness or hardship. These measures rely in part on the respondent's retrospective reports of success in overcoming stressful events (Davydoff et al., 2010). Similarly, within the Five Factor Model (FFM: McCrae & Costa, 2008), vulnerability (to stress) is one of several facets of neuroticism. A limitation is that such scales may reflect biases in retrospective appraisals of life events.

- *Determinants of resilience*. Numerous scales assess qualities believed to contribute to resilient personality, such as personal competence and acceptance of self and life (Ahern, Kiehl, Lou Sole, & Byers, 2006). In practice, resilience scales may incorporate ratings of such qualities along with retrospective stress reports (Davydoff et al., 2010). For example, facets of hardiness (Kobasa et al., 1982) include commitment to self and life domains, perceived control, and appraisal of stressful events as potentially beneficial challenges. Commitment, control and challenge may be important for personality even in the absence of stress. From the perspective of Five Factor Trait (FFT) theory (McCrae & Costa, 2008), such constructs are seen as characteristic adaptations acquired through developmental processes, which may mediate the influence of biologically-based broad traits on stress response. In addition to personality, cognitive factors such as efficiency of executive processing may contribute to resilience (Panganiban & Matthews, 2014).

This brief survey of traits for resilience suggests that finding the appropriate level of granularity for assessment within a specific context is essential. Neuroticism is important as a broad trait whose influence on affect generalizes across multiple contexts, but it is unlikely that individual differences in resilience can be reduced to this single trait. Traits such as hardiness (Maddi, 2016), emotional intelligence (Mikolajczak, Roy, Luminet, Fillée, & de Timary, 2007), and adaptive time perspective (Stolarski & Matthews, 2016) overlap with low neuroticism but also predict stress outcomes incrementally, with neuroticism controlled. Sometimes, working with contextualized traits is preferable. For example, a focus on test anxiety rather than neuroticism provides more insight into stress vulnerability in the classroom. However, if individual differences reflect numerous, separable influences, it may threaten the integrity of resilience as a unitary construct. At the extreme, it suggests resilience may be a formative construct – one in which multiple indicators influence the construct (Edwards & Bagozzi, 2000) - rather than a well-defined element of personality.

Diversity of Stressors

Much of the literature on resilience and personality assumes that "stress" is a unitary construct, i.e., that resilient individuals cope effectively with diverse external stress factors ("stressors"). This assumption is crystallized in the psychobiological theory of neuroticism (Corr, 2009), in which stressors operate via a common pathway of activating brain punishment systems. However, research on human performance paints a very different picture of stressors. Effects of stressors such as loud noise, heat, time pressure, and negative feedback differ from one another in their impacts on information-processing (Matthews, Davies, Stammers, & Westerman, 2000). Hockey (1985) identified individual stressors with distinctive cognitive patternings, reflecting diverse effects on key cognitive constructs such as attentional selectivity and short-term memory. Thus, individual stressors have various and unique physiological and psychological impacts.

The moderator role of personality traits may vary across stressors also. For example, traits helpful in handling time pressure may not be relevant to dealing with social stress. The stressor-specificity approach was recognized best in Endler's multidimensional anxiety model (e.g., Endler, Parker, Bagby, & Cox, 1991). The model distinguishes separate dimensions of trait anxiety linked to four types of situations: social evaluation, physical danger, ambiguous situations, and daily routines. Correlations between scales for the four traits ranged from -.08 - .43 in Endler et al.'s (1991) data, confirming that resilience in one situation does not necessarily imply resilience in others. Such approaches are rather neglected in contemporary resilience research, although anxiety research recognizes different forms of evaluative threat, such as computer, sports and social anxiety (e.g., Zeidner & Matthews, 2005).

Diversity of Stress Outcomes

Acute and longer-term outcomes investigated in resilience research are also multifarious. Contributing to the lack of concept definition, research has been conducted in very diverse domains (see Reich, Zautra, & Hall, 2010) including child development, life stressors, traumatic stress, emotional disorder, and acute response to laboratory stressors. Each domain has its own outcome criteria. In the human performance context, outcomes may include psychophysiological stress response, subjective stress and fatigue, workload, task motivation, response speed, response accuracy, and task persistence (Matthews et al., 2000). These broad categories may be further subdivided; subjective stress can be assessed in terms of near-independent dimensions of distress, task disengagement, and worry (Matthews, 2016a).

The adaptive significance of this multiplicity of outcomes can be hard to gauge (Matthews, Zeidner, & Roberts, 2002). The discomforts of stress, such as experiencing negative emotions, may be adaptive if the person regulates the emotion effectively in the short term, or grows from the experience in the longer term. Assessing multiple outcomes affords a more detailed picture of response patterns, and how they vary in individuals (Matthews, 2016a).

The multiplicity of outcome measures is also problematic for the modern conception of validity enshrined in the AERA/APA/NCME (1999) standards. Traditionally, validity was conceptualized as a static property of the test itself, without reference to the context for assessment (Goodwin & Leech, 2003). By contrast, the modern interpretation is that validity reflects an evaluation of the evidence of a proposed interpretation of a test score, in relation to some intended use of the test. Given the diversity of usages of resilience assessments, a given scale may be valid in some contexts but not others. For example, a scale might be valid for predicting performance failure under stress, but not for predicting mental health issues.

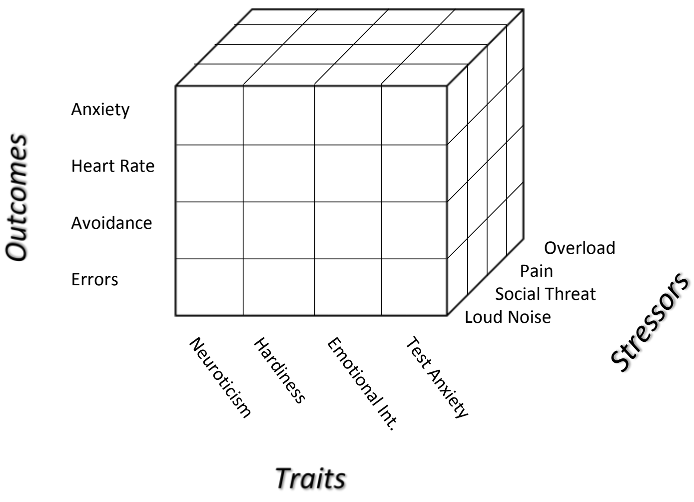
Validation requires a theoretical argument to support test score interpretation: e.g., use of scales to predict performance under stress should refer to information-processing theory. There is an important role for cognitive neuroscience, but a purely neurological approach fails to capture the acquired self-knowledge and contextualized skills that also shape individual differences in adaptation to stress (Wells & Matthews, 2015). We will return to the issue of how best to capture multiple levels of theory after first addressing the diversity of relevant stress factors.

The Trait-Stressor-Outcome (TSO) Model for Resilience

Theories cannot be adequately built and tested without a systematic understanding of the relevant empirical data. A basis for resilience theory is the Trait-Stressor-Outcome (TSO) model illustrated in Figure 1. It recognizes that individual differences in stress vulnerability reflect multiple types of trait including broad superfactors (e.g., neuroticism), specialized general resilience traits (e.g., hardiness), emotion-regulation traits (e.g., emotional intelligence), and contextualized traits (e.g., test anxiety). These traits moderate the impact on the stress process of multiple external stressors, such as environmental stressors (e.g., loud noise), social stressors (e.g., loss of social role), somatic stressors (e.g., pain), cognitive stressors (e.g., high workload), and self-regulative stressors (e.g., self-criticism). Finally, outcomes, over short durations, include subjective stress (e.g., anxiety), physiological response (e.g., cardiac acceleration), behavioral coping (e.g., avoiding a feared situation), social behaviors (e.g., seeking help), and performance changes (e.g., increased error rate). The figure emphasizes the challenge of mapping the space that defines resilience, especially as categories may be further subdivided. Each "mini-cube" defined by a specific trait, stressor, and outcome might be set to zero (no effect on the outcome) or to a value representing a change in the outcome variable associated with a trait × stressor interaction. Different configurations are possible. For example, if neuroticism is truly a master trait for resilience, we would see a mostly active slice through the TSO space, indicating that neuroticism moderates the impact of most stressors on most outcomes. Conversely, if resilience effects are highly specific, we would see an irregular sprinkling of small activated volumes throughout the larger space.

We could expand the model to four dimensions –Time-Trait-Stress-Outcome (T^2SO) – to accommodate the temporal dynamics of individual differences. For example, work activities that impose excessive cognitive demand might elicit acute emotional distress, but burnout in the long term, with different traits predicting the different outcomes. Here, we keep the primary focus on individual differences in acute stress response.

Figure 1. *Illustration of the TSO Framework*



Application to Driver Stress Vulnerability

Studies of vulnerability and resilience to the demands of vehicle driving (Matthews, 2001) illustrate the TSO perspective. Driving is frequently stressful, and outcomes include increased accident risk. However, "driver stress" covers various interactions between the driver and the traffic environment. Drivers vary in what events elicit stress, and stress reactions take a wide variety of forms ranging from subjective anxiety to objective behaviors such as aggressive driving.

Psychometric studies discriminate multiple distinct traits that moderate the stress process. The Driver Stress Inventory (DSI: Matthews, Desmond, Joyner, & Carcary, 1997) assesses dimensions of dislike of driving, aggression, hazard-monitoring, sensation-seeking, and fatigue-proneness. These traits correlate moderately with the FFM, but are more predictive of driving-related outcomes (Matthews, 2002). Validation efforts have centered on prediction of subjective stress, performance measured in simulator driving, and real-world criteria including crash involvement and convictions (Matthews, Tsuda, Xin, & Ozeki, 1999).

Associations between traits and outcomes are moderated by situational factors. That is, individuals possessing different traits are reactive to different types of driving encounter. For example, people high in dislike of driving respond strongly to disruption of vehicle control, fatigue-proneness moderates responses to long-duration driving, and aggressive drivers react adversely to being impeded by other drivers (Matthews, 2001). Thus, loss of safety may result from congruence between personality and stressors, as in the anxious (high dislike) driver who becomes distracted on an icy road, or the aggressive driver who responds to a driving cutting in front by tailgating.

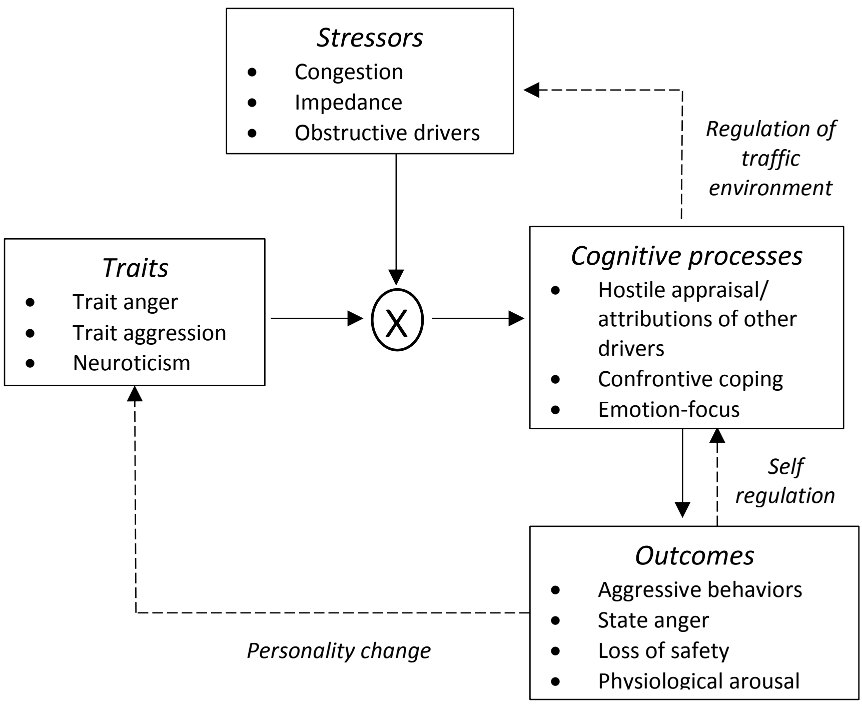
Driver stress is also expressed through multiple outcome variables. Drivers experience different forms of subjective stress according to their personality. Dislike of driving promotes distress and worry, aggression leads to anger, and fatigue-proneness is associated with task disengagement (Matthews, 2002), although dislike and aggression sometimes relate to multiple dimensions (Emo, Matthews, & Funke, 2016). Similarly, simulator studies link certain DSI traits to characteristic styles of driving under stress (Matthews, 2002). Dislike is associated with impairments in attention and vehicle control, which may reflect the impact of worrying when stressed. Aggression is associated with faster driving only in the presence of other traffic.

The TSO framework emphasizes the multiplicity of constructs that must be accommodated within an account of driver resilience. Various traits may confer resilience but their relevance depends on which stressors are present, and they may differ in the outcomes they impact. The TSO framework organizes empirical data on individual differences in stress response, but it is not a theory of individual differences in the stress process. Figure 2 shows the TSO perspective on driver aggression (Emo et al., 2016). The transactional theory of driver stress (Matthews,

2002) proposes that cognitive processes intervene between traits, stressors and outcomes, as in Lazarus' (1999) theory of stress and emotion. Traits and stressors interact to bias appraisals of traffic events and choice of coping strategies. Thus, aggressive drivers are prone to appraise the actions of other drivers as hostile. They choose confrontive strategies to cope with this essentially social stressor such as gesturing, honking the horn, and tailgating. They may also brood on thoughts of retribution and justice (Roseborough & Wiesenthal, 2014). This constellation of biased cognitive processes potentially elicits a variety of outcomes, depending on context, including subjective anger and other expressions of stress, and dangerous behaviors that may increase crash risk.

The T^{2}SO perspective additionally recognizes the differing timecourses of stress processes and outcomes, consistent with the dynamic conceptualization of stress in the transactional model (Lazarus, 1999). The broken lines in Figure 2 indicate feedback processes that may operate over different durations. Over periods of seconds, the person may recognize their own anger and self-regulate, for example, to make a deliberate attempt to cool down. Over multiple trips, the driver may regulate the external environment to mitigate aggression, for example, by avoiding congested routes. Over years, personality itself may change, shaped by the accumulation of events. Perhaps living in New York raises aggressiveness to match the habitually confrontive nature of driving in the metropolis.

Figure 2. *Driving Aggression and Stress within the TSO Framework*



Resilience in Unmanned Vehicle Operation

Resilience traits may be expressed within the broad domain of interaction with information technology. Working with computers, robots and software agents may be stressful for various reasons, including the cognitive challenge of understanding the system, concerns about personal competence and performance effectiveness, and the frustrations of using poorly-designed interfaces (Klein, Moon, & Picard, 2002; Powell, 2013). The technology domain also illustrates how stress can be a moving target for research, given that demands on the operator are rapidly changing as hardware and software become more sophisticated. Advances in sensor engineering and artificial intelligence will increasingly require the human to interact with autonomous machines, challenging the operator's ability to understand machine functioning, to assign trust appropriately, and to handle intelligent feedback from the machine (Matthews et al., 2016).

The TSO framework suggests ways of identifying key factors for resilience within this context. Table 1 lists some of the traits, stressors and responses that may be critical for human-machine interaction. Some of these factors are general in nature, applying to various domains. These include broad resilience and vulnerability traits such as hardiness and neuroticism, as well as stressors such as cognitive overload. On the outcome side, standard subjective and physiological response metrics can be secured as in other contexts.

Table 1. *Multiple Stress Factors for Human-Machine Interaction within the TSO Framework*

Traits	Stressors	Outcomes
General factors		
Neuroticism Hardiness	Cognitive overload Time pressure Perceived failure	Subjective stress Physiological response
Contextual factors		
Computer anxiety Computer skills and experience Trust in machines	Interface design Machine malfunction	Slow performance Suboptimal reliance on machine Neglect of task Errors

Domain-specific traits are also important in human-computer interaction. Resilient individuals may be low in computer anxiety, as well as possessing high levels of skills and experience that support more effective coping with challenges. Trust in machine functioning may mitigate concerns about technology (Schaefer & Scribner, 2015). Both excessive and insufficient trust may be maladaptive. Excessive trust may be stress-reducing in the short-term, but liable to elicit stress response after a time delay, as the consequences of undetected machine failures become apparent (an example of the T^2SO perspective). Similarly, interface features such as displays that are hard to interpret, unresponsive controls, and lack of critical information are domain-specific stressors (e.g., Guznov, Matthews, Funke, & Dukes, 2011).

Assessment of behavioral outcomes of stress, broadly reflecting impaired performance in operating the machine, requires task-specific metrics such as speed and error measures. More subtly, stress response may take the form of neglect of sub-tasks or activities, which may accompany fatigue. Where the computer system includes automation, stress may be reflected in over- or under-reliance on the computer. For example, a factor in the 2009 Air France 447 crash into the Atlantic Ocean was the pilots' failure to react appropriately to repeated stall warnings from the autopilot. The exact causes of the pilot error are unknown but the voice recorder indicated escalating stress and panic as the operational situation deteriorated (Bureau d'Enquêtes d'Analyses, 2011).

Multi-UAV Operation: Predictors of Subjective and Physiological Stress Response

Wohleber, Matthews, Reinerman-Jones, Panganiban, and Scribner (2015) incorporated TSO principles into a study of resilience during a simulated Unmanned Aerial Vehicle (UAV) task. Participants (N=70) directed multiple UAVs to target locations shown on a map display, and monitored their status. The study investigated predictors of subjective and objective stress response during performance, in two different stressful conditions. Multiple constructs for each type of factor were as follows:

- *Traits*. *Hardiness* was assessed using Bartone's (2006) scale, which assesses overall hardiness and three sub-scales of commitment, challenge, and control. Importantly, hardiness appears to be distinct from low neuroticism: a meta-analysis (Eschleman, Bowling, & Alarcon, 2010) estimated the population correlation between hardiness and neuroticism to be -.44. *Grit* was measured using Duckworth and Quinn's (2009) scale which includes items on participants' capacity to sustain both effort and interest in demanding activities. Stress vulnerability was measured using the *Anxious Thoughts Inventory (AnTI*: Wells, 2008*)*, which includes subscales for social worry, health worry, and meta-worry. The AnTI is unique among trait anxiety scales because it assesses metacognitions of worry, such as being prone to worry about one's own negative thoughts. Metacognitions may be especially influential in promoting and maintaining clinical anxiety (Wells, 2008).
- *Stress*. Two stressors known to elevate subjective distress (Panganiban & Matthews, 2014) were manipulated independently, within-subjects. One was cognitive overload, induced by increasing task difficulty (e.g., number of UAVs controlled). The second was non-contingent negative feedback: messages in a chat window stated that the person was performing badly

(irrespective of actual performance). Each stressful task run was preceded by a control run with no stressor.

- *Outcomes*. Subjective stress state was assessed with the short version of the *Dundee Stress State Questionnaire* (DSSQ: Matthews, 2016a; Matthews, Szalma, Panganiban, Neubauer, & Warm, 2013) which measures task engagement, distress, and worry. In addition, a battery of psychophysiological measures was recorded, including the electroencephalogram (EEG), electrocardiogram (ECG), cerebral bloodflow velocity (CBFV), and regional blood oxygenation saturation (rSO^2) in the forebrain. These measures (see Matthews, Reinerman-Jones, Barber, & Abich, 2015), are sensitive to several factors influencing task demands, including multi-tasking, signal discriminability, and time pressure.

We focused on stress reactivity, i.e., subjective and objective responses to the two stress manipulations. At the physiological level, both manipulations elicited increased spectral power density in high-frequency EEG bands (beta and gamma), together with changes in heart rate variability (HRV). This response pattern suggested induction of "cognitive" stress rather than autonomic arousal, perhaps reflecting concerns about performance. The two manipulations were distinguished by subjective state data. Both elevated distress, but negative feedback also lowered task engagement, suggesting that the failure messages were demotivating.

The resilience traits were generally stressor-specific in their predictive validity, with the exception of grit which predicted a reduced distress response to both stressors. The hardiness scales dissociated across stressors. Challenge predicted higher task engagement and lower distress in response to overload, but was unrelated to response to negative feedback. Task engagement was generally higher during overload than during negative feedback, suggesting that the former stressor was more likely to provoke individual differences in interpreting the stressor as a challenge to be confronted through effort and task-focus. By contrast, control was related to responsivity to negative feedback but not overload; high control was associated with lower distress and worry. The third hardiness factor, commitment, tended to be more strongly associated with overall subjective state – higher engagement and lower distress and worry – than with responsivity to the stressors.

The stress vulnerability traits assessed by the AnTI (Wells, 1994) were also specific to negative feedback, consistent with their link to self-regulative processing. The AnTI traits predicted the worry but not the distress response, showing selectivity of outcome. The AnTI traits also predicted EEG response to negative feedback, tending to be associated with lower theta and higher gamma power. This response pattern may reflect poorer emotion-regulation (Tolegenova, Kustubayeva, & Matthews, 2014).

In sum, the study shows the limits of treating resilience as a unitary personality trait. Each resilience trait broadly correlated with lower "stress", but they appeared to play somewhat different roles in the stress process, depending on the stressor and the outcome measure.

Multi-UAV Operation: Performance Outcomes

Using a different simulation, Lin et al. (2015) investigated predictors of subjective stress and performance when multiple UAV operation was supported by automation of several operator functions, including routing the UAV to a target location, and discriminating ground targets from non-targets. A TSO perspective groups stressor factors thus:

- *Traits*. Saucier's (2002) adjectival markers for the FFM assessed general personality. In performance studies, neuroticism typically correlates with DSSQ distress and worry, whereas conscientiousness and agreeableness predict higher task engagement (depending on task demands). We also measured relevant computer skills and interest, interest and participation in leisure video gaming. Previous studies (e.g., Cummings, Clare, & Hart, 2010) suggest video gaming expertise may transfer to UAV operation.
- *Stressor*. Only a single stressor was manipulated, between-subjects; cognitive demands. The simulation includes nine sub-tasks. Event rates on five of these were manipulated to create higher and lower levels of demand. The demands of two surveillance sub-tasks were held constant to provide performance metrics. Here, we focus on the more demanding of the two sub-tasks which required the participant to discriminate degraded images of friendly and hostile tanks, which differed slightly in their appearance. An automated targeting decision aid highlighted likely hostile tanks, but the participant could over-ride the automation's recommendation. (The study also manipulated level of automation /LOA/, but this factor was not conceptualized as a stressor).
- *Outcomes*. As in Wohleber et al. (2015), the DSSQ assessed multiple subjective dimensions, though psychophysiological measures were beyond the scope of the study. In addition, several performance measures were secured from the surveillance subtasks, including overall accuracy in identifying targets, neglect of the task (failure to initiate target search), and reliance on automation. Reliance reflected the percentage of trials on which the participant followed the recommendation from the automated aid, as opposed to over-riding it to make a different decision. Optimal reliance would follow the reliability of the automation, which was set to 80%.

The cognitive demand manipulation was successful in increasing distress, without lowering task engagement, as well as in impairing performance. Table 2 shows selected correlations between trait measures and post-task DSSQ scores, based on a re-analysis of Lin et al.'s (2015) data. As in Wohleber et al.'s (2015) study, none of the traits for resilience predicted all subjective stress outcomes in all conditions. Some traits predicted state irrespective of cognitive demand. Individuals higher in neuroticism and lower in agreeableness and conscientiousness tended to be higher in distress, consistent with previous findings (Matthews et al., 2013). Individuals with greater experience of video gaming, and higher self-rated expertise, were more engaged with the task. Correlations were highest for involvement in first person shooter (FPS) games such as *Call of Duty*. In addition, complacency about automated technology was associated with resilience as expressed in lower distress and worry.

Table 2. *Trait-Outcome Correlations in a Multi-UAV Simulation Study (Lin et al., 2015)*

Correlation Consistent Across Experimental Conditions		
Variable pair	r (N=101)	
Neuroticism – Distress	.21*	
Agreeableness – Distress	-.24*	
Conscientiousness – Distress	-.27**	
Complacency – Distress	-.31**	
FPS gaming expertise – Task engagement	.23*	
FPS gaming experience – Task engagement	.23*	
Complacency – Worry	-.25*	
Correlation Varying Across Experimental Conditions		
Variable pair	Lower demand	Higher demand
	r (N=50)	r (N=51)
Conscientiousness – Task engagement	-.07	.43**
Neuroticism – Worry	.32*	.07

$^{*}p$<.05; $^{**}p$<.01.

By contrast, additional roles for FFM traits were shown when data were analyzed separately for the two cognitive demand conditions. Conscientiousness was associated with task engagement only under higher demand conditions, consistent with the view that traits for determined effort may come to the fore when the going gets tough (Duckworth & Quinn, 2009). Neuroticism correlated with worry only in the lower demand condition. This finding may reflect the tendency for higher cognitive demands to suppress worry as attention is forced outwards towards task stimuli (Matthews et al., 2002). A similar moderating role for task demands was found in driver stress (Matthews, 2002).

The other class of outcome was performance data (Lin et al., 2015). Video gaming expertise and experience were generally associated with superior performance (with minor variation across the two conditions). In the whole sample FPS gaming expertise correlated with greater accuracy (r=.32, p<.01), less neglect (r=-.25, p<.05), and greater reliance on automation (r=.26, p<.05). These associations might reflect transfer of cognitive skills from gaming to the UAV simulation, rather than resilience per se, although additional correlational analyses confirmed that higher DSSQ engagement and lower distress were associated with superior performance. These stress state factors are related to attentional resources and multi-tasking respectively (Matthews, 2016a; Matthews et al., 2013), suggesting mediating mechanisms for the impact of resilience factors on performance.

Analyses of the FFM showed a moderator effect of the cognitive demand manipulation. In the high task load condition only, conscientiousness was significantly negatively correlated with neglect (r=-.29, p<.05), commensurate with the positive association between conscientiousness and task engagement in this condition. Agreeableness was also associated with lower neglect under high task load (r=-.30, p<.05). The FFM were also associated with reliance on automation only under high task demands. Conscientiousness (r=-.37, p<.01), agreeableness (r=-.35, p<.05), and extraversion (r=-.35, p<.05) all correlated with lower reliance. These findings are somewhat paradoxical, because under high demands it is adaptive to increase reliance on automation that was quite reliable (80%). Possibly, under high stress from cognitive demands, certain individuals prefer taking charge of the situation personally, rather than cede decision-making authority to the automation. The "take charge" response may often be adaptive, but it is counter-productive when automation can actually do the job more effectively.

Thus, Lin et al.'s (2015) data did not substantiate any general resilience factor; instead, different traits predicted different outcome patterns, depending, in some instances, on level of cognitive demand. In particular, while neuroticism predicted higher distress, to a modest degree, this supposedly general stress vulnerability trait did not predict task engagement, or any of the objective measures. An assessment of neuroticism could not adequately gauge UAV operator resilience. As in Wohleber et al.'s (2015) study, multivariate assessment of resilience traits appears to be essential.

Theory: A Cognitive Science Framework

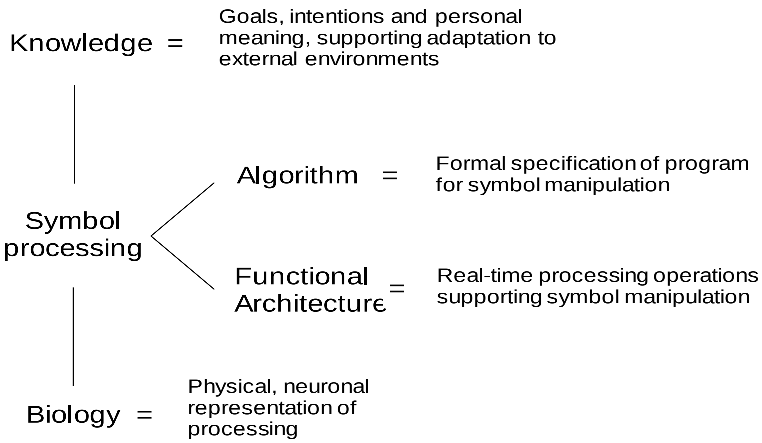
The TSO model provides a framework for organizing research findings on individual differences in resilience, but it is not itself a theory of how resilience emerges from variation in the stress process. We have touched on mechanisms such as biases in appraisal and coping (Matthews, 2001), emotion-regulation (Wohleber et al., 2015), and attentional resource utilization (Lin et al., 2015). In this section, we provide a more systematic framework that differentiates the multiple processes mediating the impact of resilience factors on stress outcomes.

The challenge is that personality theory frequently raises more questions than answers. Traits correlate with a multitude of processes implicated in stress, at a variety of levels of abstraction from the brain. The spectrum of trait correlates runs from genetic polymorphisms through neural activity to high-level self-regulation, beliefs and values (Matthews, 2008). The higher-level cognitive correlates of traits are not readily reducible to neural processes (Matthews, 2008, 2016b). To explain a stress vulnerability trait such as neuroticism, the trait researcher could equally well point to sensitivity of brain punishment systems (Corr, 2009), to biased processing of threat stimuli (Eysenck & Derakshan, 2011), or to self-beliefs emphasizing personal vulnerability and lack of competence in coping (Wells & Matthews, 2015).

Three Levels of Explanation in Cognitive Science

Cognitive science provides an explanatory framework for understanding the various, qualitatively different processes that contribute to individual differences in resilience and vulnerability. Specifically, Pylyshyn (1984) distinguished three levels of explanation, each of which is applicable to understanding personality and stress (see Figure 3). The lowest level is that of physical, biological processes. Resilience can in part be attributed to the well-known physiological systems that control stress response such as the hypothalamic-pituitary-adrenocortical (HPA) axis (Ulrich-Lai & Herman, 2009), and, more distally, to inter-individual variability in the relevant genes. Traditionally, traits such as the FFM have been mapped to major brain systems such as those controlling arousal and reward sensitivity (Corr, 2009).

Figure 3. *Trilevel Explanatory Framework for Cognitive Science*



The second level concerns the symbol processing that provides a software-level description of brain functioning, such as rules of grammar in linguistics. The formal processing rules described by Pylyshyn (1984) are a human universal, but people may vary in the "functional architecture" that implements rule-based processing in real time. Traits may be linked to attentional resource availability, working memory capacity, executive processing speed, and other parameters of key cognitive processes (Matthews, 2008). Stress vulnerability might be associated with overload of the processing architecture, impairing coping abilities, as well as over-sensitivity to threat. In the longer term, processing limitations may constrain the person's ability to acquire the skills for handling task demands effectively (Matthews, 1999). Resilience is then primarily cognitive, reflecting more efficient processing of threatening events, and the skills supported by that processing.

The third level is called the knowledge level by Pylyshyn (1984) because it refers to the person's understanding of how to accomplish their personal goals. In personality research, theories of the self draw upon this perspective, referring to both processes such as self-verification, and the content of personal beliefs, including the self-schema. Similarly, the transactional theory of stress and emotion (Lazarus, 1999) puts personal meaning at the core of the stress process. Personality may be associated with variation in the meanings attributed to challenging events. The resilient individual appraises demanding events constructively, leading to feasible and effective coping strategies (Matthews et al., 2002).

Thus, from the cognitive science perspective, resilience resides in multiple personal processing attributes that may coincide or diverge within the individual. These attributes are distributed within as well as across levels of explanation. That is, a given resilience trait may relate to multiple, separable parameters of neural functioning, information-processing, and self-knowledge.

Trilevel Perspective on Neuroticism and Stress

The cognitive science framework provides a novel perspective on neuroticism, as an example of a trait for stress vulnerability vs. resilience. In the Cognitive-Adaptive Theory of personality (Matthews, 2008, 2016b; submitted), the expression of traits in behavior and emotional response reflects multiple, independent processes that serve the adaptive goal associated with the trait, rather than any single master process. That is, the coherence of traits is functional, not structural. Brain-based punishment sensitivity (Corr, 2009) cannot explain all the stress outcomes associated with neuroticism (Matthews, 2004). Individual differences in cognitive process and content that support the goals of self-preservation and anticipation of social threats must also be considered. The various neural and cognitive attributes of the high-neuroticism individual support an overarching goal of pre-empting threat through early awareness and avoidance. By contrast, the resilient individual is geared more towards direct management of threat as it becomes concrete (Matthews, 2004). Within this general account, neuroticism is associated (often modestly) with a variety of biases in threat processing at each level of explanation.

Biological processes. Neuroticism is identified with brain systems sensitive to punishment (Corr, 2009), centered on the amygdala and other limbic system areas associated with negative emotion. If this is true, then stressors of all types would tend to active punishment areas more strongly in high neuroticism individuals. The primary response outcomes would be psychophysiological, including outputs from sympathetic arousal and HPA activation. In fact, the neurobiology of neuroticism appears to be more complex than this simple account of stress sensitivity; neuroticism does not always moderate physiological stress response as expected (Matthews & Gilliland, 1999).

A recent review (Ormel et al., 2013) provides a more nuanced account of correlates of neuroticism that may be relevant to lowered resilience. Notably, neuroticism is not consistently associated with classical stress responses including general arousability, autonomic reactivity, and HPA reactivity and regulation. Consistent with the TSO perspective, positive results are obtained in some studies, but the experimental conditions required to elicit heightened stress response in high neuroticism individuals remain elusive. The reviews of Ormel et al. (2013) and others (Kennis, Rademaker, & Geuze, 2013; Servaas et al., 2013) find greater support for biological bases for neuroticism from functional neuroimaging studies showing heightened response to negative stimuli in various brain areas (Servaas et al., 2013). Possible candidate mechanisms for greater resilience in low neuroticism individuals include enhanced functional connectivity supporting cognitive control over negative stimuli (Ormel et al., 2013), lower reactivity of the amygdala to punishment signals (Kennis et al., 2013), and reduced fear learning and anticipation of aversive stimuli (Servaas et al., 2013).

Information processing. Two broad characteristics of information-processing may limit effective coping with stress in high neuroticism individuals: overall attentional efficiency and selective cognitive bias (Eysenck & Deraskhan, 2011; Wells & Matthews, 2015). First, they may lack attentional capacity or working memory, a deficiency especially detrimental in task performance environments. Second, neuroticism and allied traits such as anxiety bias selective processing of threat stimuli, which may lead to overestimation of threat and maladaptive coping. Evidence for the causal role of amplifying negative affect comes from training studies in which participants practice orienting attention towards or away from threat stimuli. Attentional training produces congruent changes in emotional functioning (MacLeod & Mathews, 2012).

However, similar to neuroscience studies, studies that seek to identify the key parameters controlling differential response to threat provide a more complex picture of individual differences (see Cisler & Koster, 2010; Matthews, 2004, 2008, for reviews). Eysenck and Derakshan (2011) differentiated multiple executive functions supporting cognitive control of attention, and concluded that inhibition of task-irrelevant stimuli may be the most sensitive to anxiety, and working memory updating the least. Cognitive bias may be supported by multiple mechanisms including impaired disengagement from sources of threat and semantic interpretive bias. Both automation and controlled processing mechanisms may be implicated (Cisler & Koster, 2010). That is, if insensitivity to threat promotes resilience, multiple parameters of the cognitive architecture may play a role.

Self-knowledge. Stress vulnerability may reflect individual differences in the meaning that individuals attribute to events and their personal relevance. Neurotic individuals may be stress-vulnerable because they read threat into innocuous events and they perceive themselves as ineffective in coping (Wells & Matthews, 2015). Processing biases are likely to shape self-knowledge but self-beliefs cannot be directly reduced to parameters of the cognitive architecture.

As always, multiple mechanisms appear to be implicated. There may be biases in both high-level appraisals such as judgments of personal vulnerability, and in preferences for coping through strategies such as self-blame and avoidance of feared situations (Matthews, 2004). A key role is played by metacognitions: the meanings the person attributes to their own interior mental life. For example, appraising negative thoughts and imagery as directly harmful and/or beyond personal control contributes to anxiety (Wells & Matthews, 2015). In the UAV context, Wohleber et al. (2015) confirmed the importance of metacognitive traits in predicting stress response to negative feedback. By contrast, the resilient individual is not overly concerned by negative thoughts, facilitating effective emotion-regulation.

Integration of multiple explanations. The cognitive science perspective thus suggests that the emotionally stable (low neuroticism) individual may draw mental strength from multiple sources, ranging from reduced neural response to threat to constructive appraisal and adaptive coping. In terms of the TSO framework, different traits may correspond to different admixtures of the various sources of resilience. However, the framework also reminds us of the importance of context; individual differences may be stressor-specific. High neuroticism individuals may be especially vulnerable to social threat. For example, in the performance context, Guznov, Matthews, and Warm (2010) found that neuroticism was most strongly linked to emotional stress when the person was placed in a supervisory role requiring effective direction of a team member. Explanatory mechanisms become more contextualized at higher levels of explanation. Self-knowledge typically refers to beliefs about personal efficacy within a particular context (Bandura, 1994). Thus, a UAV operator might be confident in her competence to respond appropriately to enemy units, but lack confidence in dealing with an uncooperative team-mate.

A final issue is the emphasis of cognitive-adaptive theory on contextualized skills in managing stressors (Matthews, 1999). Neurological threat insensitivity, effective cognitive control of attention, and positive self-beliefs may all promote resilience in the UAV operator. However, the more proximal influences will be skills for handling potential stressors, such as knowing how to route the vehicle away from danger, or how to elicit cooperation from an obstructive team-mate. The processing attributes of traits operate indirectly, through enhancing or limiting acquisition of the contextualized skills necessary to succeed in the environments to which the trait is relevant.

Conclusions

Resilience is a critical but misunderstood element of personality. It is tempting but wrong to think of individuals as varying along a single continuum contrasting resilience with stress vulnerability. We have discussed two failings of a unitary conception of personal resilience. First, traits for resilience, stressors, and outcomes are all multifaceted, requiring a more fine-grained account of research findings. The TSO framework systematically maps the role of resilience traits across multiple domains and contexts. Second, multiple mechanisms mediate the impacts of traits on stress response. Within cognitive-adaptive theory (Matthews, 2008), trait effects are distributed across individual differences in neural functioning, information-processing parameters, and high-level self-knowledge. Understanding resilience requires identification of the processes and skills critical for adaptation within specific contexts.

The challenge of working with new technologies illustrate the need to consider resilience traits contextually. Task such as operating unmanned vehicles introduce some stressors that are common to multiple contexts, such as coping with negative feedback, and some that are more specific, such as managing imperfect automated targeting. Evaluating adaptation to stressors requires attention to multiple outcomes, including subjective and objective stress response metrics, performance accuracy, and reliance on automation. Consistent with the TSO framework, we saw from empirical studies (Lin et al., 2015; Wohleber et al., 2015) that multiple factors are important for predicting response, depending on the stressor and outcome measure. Predictors included FFM dimensions, more narrowly-defined resilience and vulnerability traits, and characteristics specific to technology, such as automation complacency and video gaming experience.

Significant issues remain for developing a fully multivariate understanding of resilient personality. One is simply the complexity associated with the multiplicity of relevant traits, stressors and outcomes, even with a limited domain. As in stress research generally (Matthews, 2001) a focus on underlying mechanisms that generalize across traits and stressors is necessary to build a manageable science of the area. A second issue is that investigating each level of mechanism specified by cognitive science has its own methodological challenges. Neuroscience studies are often limited by small *Ns*, heterogeneity in samples, and large variations in methods (Ormel et al., 2013), whereas studies of self-knowledge tend to be over-reliant on self-report and vulnerable to proliferation of poorly differentiated constructs (Matthews et al., 2009). A final issue is the dynamic nature of the transactional model of stress (Lazarus, 1999; Matthews, 2001). The T^2SO perspective accommodates time and the interplay between stress processes in understanding resilience.

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Personalidad, estrés y resiliencia: Perspectiva multifactorial de la ciencia cognitiva

Resumen

Rasgos de la personalidad están correlacionados coherente con varios índices de la repuesta psicológica al estrés agudo, incluidas las emociones negativas y el deterioro del rendimiento. Sin embargo, resiliencia es una característica personal compleja con múltiples raíces neurales y psicológicas. Para entender resiliencia, este artículo aboga por el enfoque multifactorial que entiende su complejidad tanto empírica como teórica. El marco rasgo-estresor-resultado (RES) para organizar datos empíricos reconoce la multiplicidad de métricas de rasgos, estresores y resultados que podrían moderar respuesta al estrés. La investigación requiere un enfoque de recolección de datos finamente elaborados que distingue factores múltiples de estrés. Además, son necesarios niveles múltiples de teoría para explicar diferencias individuales en la respuesta al estrés, incluidos los sesgos en el funcionamiento neural, procesos de atención, tanto como los estilos de afrontamiento y regulación de emociones. Ciencia cognitiva diferencia niveles múltiples de explicación y permite la integración de mecanismos a niveles múltiples de abstracción del sustrato neural. Demostramos la aplicación del enfoque multifactorial para la recolección de datos interpretativos sobre el estrés laboral que proviene de la interacción con la tecnología.

Palabras claves: resiliencia, personalidad, estrés, actuación, vehículos no tripulados, ciencia cognitiva, modelo transaccional

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