Designing Personality: Cognitive Architectures and Beyond

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Abstract

Modeling personality is important both for understanding human traits, and for designing artificial systems. Both aims are challenging. Studies of human personality suggest that personality traits such as extraversion and neuroticism have multiple correlates relating to many qualitatively different aspects of neural and cognitive functioning. The tri-level explanatory framework of cognitive science provides a basis for personality description. Traits are expressed as biases in neural functioning, in the functional architecture supporting symbolic processing, and in high-level self-knowledge and motivation. Furthermore, traits relate to multiple biases of each type, so that traits are distributed across and within levels. Such a description supports fine-grained modeling of personality. A similar approach may be applied to modeling transient states such as emotions. However, the descriptive picture is incomplete. Personality also has a dynamic, adaptive aspect, as the system learns to fulfill its goals by acquiring contextualized skills appropriate to the external environment. Thus, in humans, observed differences in architectural parameters must be interpreted adaptively. In designing artifacts, there may be advantages to allowing personality to emerge in part from interactions between the artifact and the environments within which it is intended to function.

Personality and Cognitive Architecture

Personality theory needs cognitive architecture – and studies of cognitive architecture need personality. Traditionally, the theory of stable personality traits has been derived from biological psychology. Theorists such as Eysenck (1967) and Gray (1991) have proposed that individual differences in brain function generate expressions of personality ranging from psychophysiological response to social learning. For several decades, the search has been on for key brain systems, controlling arousal or motivation, that are the locus for the major personality traits such as extraversion and neuroticism. It is now beyond dispute that such traits do indeed have biological bases, as evidenced by their partial heritability, their sensitivity to brain lesions, and psychophysiological correlates of traits (Zuckerman, 1991).

However, cognitive psychological studies show the weaknesses of the traditional biological models in explaining the behavioral correlates of traits. Experimental tests of predictions derived from the Eysenck and Gray models have met with limited success. Even when predictions are confirmed, effect sizes are normally modest, and indices of psychophysiological change fail to mediate effects of personality on performance (Matthews & Amelang, 1993). By contrast, effects of personality are often predictably moderated by the information processing demands of the task. Task factors well-known to cognitive psychologists such as working memory load, stimulus onset asynchronies in priming, and demands on attention influence the direction and magnitude and of trait effects (Matthews, 1997a). The behavioral consequences of personality cannot be explained adequately in terms of gross qualities such as arousability and conditionability. Instead, a more fine-grained analysis of the effects of personality on information-processing is required. In consequence, linking personality to individual differences in parameters of the cognitive architecture is critical.

The argument that the study of cognitive architectures requires attention to personality factors is less well-known. Recent interest in personality in artificial intelligence derives in part from issues raised by the design of emotionally intelligent artifacts. The display of emotionally appropriate responses to user input may be an important design feature of such systems, facilitating naturalistic communication. For example, Ball (2003) describes an outline architecture for a conversational interface that might be applied, initially, to domain limited applications such as buying a travel ticket from an artificial travel agent. The architecture includes modules that assess emotion and personality from the sensory cues provided by the user. A 'policy module' uses this information to judge an appropriate emotional response, which influences the behavior of the agent via a Bayesian network.

Ortony (2003) views personality as a potential driver of behavior in affective artifacts. The design of believable artifacts requires stability and coherence in behavior, which requires that personality traits should be built into the architecture. Ortony suggests that a principled approach to the design issues may be derived from standard trait models, such as the Five Factor Model

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(FFM: Costa & McCrae, 1992). Each trait may be linked to a set of key parameters able to generate (in interaction with environmental input) a range of trait-characteristic states and behaviors. Thus, to build an artifact that is friendly, those behaviors it produces that convey friendliness should be generated by biases in some rational system for handling emotion. For example, the system could be biased to appraise the human user as well-intentioned, to follow goals of increasing user comfort, and to prioritize inputs indicating discomfort. Such 'motivated' friendliness is likely to be more believable, and hence more effective, than simply having the system emit more frequent 'friendly' responses irrespective of context.

In this article, I will summarize what can be learnt from human experimental studies of personality, affect and performance that may facilitate designing personality into cognitive architectures. I will focus primarily on the use of architectures to simulate human behavior, but I will also refer to implications for design of artifacts. Next, I will outline the key trait and state constructs that are open to modeling. I will go on to argue that modeling individual differences in parameters of the architecture is necessary but not sufficient. Traits and states have important effects on neural functioning and intention, as well as on computation, that call for a multi-level approach. Pylyshyn's (1984, 1999) tri-level cognitive science framework provides a systematic approach to mapping the various attributes of traits and states. I will argue that these attributes are distributed both within and across levels of explanation. Traits are supported by a multitude of typically small biases at various levels of abstraction from the neural substrate. Finally, I will argue that fine-grained descriptive accounts should be integrated with a dynamic perspective that relates traits to individual differences in adaptation. Traits may correspond to environmental affordances, that, over time, build congruence between basic parameters of the architecture, acquired skills and ongoing interaction with environmental demands and opportunities.

Key Constructs: Traits and States

There is a plethora of dispositional traits and transient states that may be related to properties of the cognitive architecture. Although traits are defined in terms of temporal stability, personality changes over time, and the roles of maturation and learning in personality change are important topics of study. Here, I will focus primarily on short-term behavioral change, so that traits may be treated as 'fixed'. One of the most useful trait frameworks has proved to be the FFM. Each of the five traits represents a continuum contrasting qualities that are polar opposites, as shown simplistically in Table 1 (see Matthews, Deary & Whiteman, 2003, for a review). Also important are more narrowly-defined traits, that sit beneath the Big Five in hierarchical models of personality, such as impulsivity, sensation-seeking, optimism-pessimism and many others. Typically, researchers are concerned with modeling a single trait only, but, as many behaviors are influenced by multiple traits, multiple-trait modeling may become increasingly important.

Table 1. Examples of qualities defining the high and low poles of the 'Big Five' traits.

Trait	*High Pole*	*Low Pole*
Extraversion	Sociable	Withdrawn
Neuroticism	Vulnerable to Stress	Emotionally stable
Conscientiousness	Hardworking	Careless
Agreeableness	Sympathetic	Uncaring
Openness	Imaginative	Practical

In each case, we may seek to relate the trait to fundamental parameters of the cognitive architecture, such as memory spaces, connection strengths, and speed of processes, representing the trait as a collection of structurally independent biases. However, traits also bias the acquisition of skills and knowledge, so that, for example, the content of memory as well as its formal operating parameters may vary according to personality.

By contrast with traits, research on transient states offers a hazier picture of dimensionality of constructs, but more sophisticated cognitive models that draw on emotion theory. I will confine discussion here to subjective states, including not just affective states such as moods and emotions, but also cognitive states, such as worry, and motivational states such as apathy. Most of the psychometric work has been conducted on mood states or basic affects, with reasonable agreement in favor of either two dimensions of positive and negative affect, or three dimensions of energy, tension and pleasure (Schimmack & Grob, 2000). In recent work, my colleagues and I (Matthews, Campbell et al., 2002) have discriminated three state dimensions that integrate affect with cognition and emotion: task engagement (energy, motivation and concentration), distress (tension, displeasure, low confidence) and worry (self-focus, intrusive thoughts, low self-esteem).

The main areas of research that relate states to performance and information-processing center on state anxiety, overall mood (often related to cognitive bias) and fatigue. As with traits, states have complex effects dependent on a host of moderating factors. Several rather different types of explanation for associations between states and performance have been advanced (Matthews, Zeidner & Roberts, 2002):

- States may be associated with temporary changes in parameters of the architecture. Such changes may be described as specific local effects, such as prioritization of threat processing in anxiety, or as a system-wide reconfiguration geared to the motivational context

(Oatley & Johnson-Laird, 1996), so that changes in operational parameters are functionally linked.

- States may relate to changes in strategy, for example, in voluntary allocation of effort. In this case, the parameters of the architecture may remain the same, but the usage of the functionality the architecture provides is different.
- States may operate through representation rather than computation (cf., the idea of 'emotion-as- information'). In Bower's (1981) classic semantic network model, states are represented as network nodes whose activation follows the same rules as the nodes for other types of concept. States may influence the contents of memory; for example, effects of worry on performance appears to reflect the intrusion into working memory of self-referent cognitions.
- States may represent targets for self-regulation; i.e., as drivers of voluntary attempts at mood-regulation (cf. the idea of 'emotion-as-motivation') . People differ in their metacognitions of the importance of changing moods and cognitive states, and in their strategy preferences.

Some trait and state effects may be inter-related, whereas others are separate. Often, effects of traits are said to be mediated by states. Typically, extraversion is linked to positive affect, whereas neuroticism is related to negative affect (Watson, 2000). Thus, extraverts and introverts may differ in how they process information because the trait predisposes differing affective states, which are the more proximal influence on processing. However, trait effects can also be demonstrated with state factors statistically controlled, indicating that some trait effects are not mediated by individual differences in states (Matthews & Harley, 1993). Such 'direct' effects may indicate that traits influence parameters of the architecture that are insensitive to state effects. These effects may be a consequence of learning processes operating over many years.

Architecture and Beyond: A Multi-Level Explanatory Framework

Cognitive Architectures and Their Limitations

Extensive empirical research indicates that, typically, any given trait or state (or trait × state interaction) correlates with multiple attributes of performance (Matthews et al., 2003). By analogy with cognitive stress research (Hockey, 1984), effects of trait and state factors on performance may be described by a cognitive patterning, which describes how the factor influences a set of performance indicators chosen to reflect key processing functions, such as attentional selectivity and working memory capacity. Such a description leaves open the issue of how each empirical effect of the factor may explained. Certainly, it can be shown that some effects can be modeled computationally, thereby relating the trait to individual differences in parameters of the architecture (e.g., Matthews & Harley, 1993).

However, a purely architecture-based approach also has limitations of its own. First, effects on performance may be either 'structural', changing the operation of some basic processing function, or 'strategic', changing the person's voluntary choice of task goals and subgoals (Hockey, 1984). For example, anxiety is associated with increased attentional selectivity, but it is unclear whether the effect relates to some 'automatic' narrowing of an attentional spotlight, or to a voluntary decision to concentrate attention on salient, potentially threatening stimuli (see Eysenck, 1992). Second, while effects of personality and emotion on strategy may be mapped descriptively, it remains unclear why there are individual differences in task- and self-referent goals. Third, the cognitive patterning approach risks losing sight of the core attributes of personality traits. For example, it is unclear how biases in information-processing generate the attributes such as sociability, impulsivity and assertiveness that are central to extraversion. Fourth – in line with both interactionist theories of personality and situated approaches to emotion – a description of architecture that neglects its functionality within some external environment cannot capture individual differences in dynamic person-situation interaction.

The Tri-level Explanatory Framework

One solution to these difficulties is to develop multi-leveled conceptions of traits and emotions. According to the 'classical theory' of cognitive science (Newell, 1982; Pylyshyn, 1984, 1999), cognitive phenomena are open to three complementary, types of explanation[1]. The first is the biological level, which refers to the neural 'hardware' supporting processing. Individual differences in performance might reflect variation in brain functioning, as proposed by biological personality theories. The second level of explanation is described by Pylyshyn (1984) as the symbolic level, referring to the formalized computational operations which constitute the 'software' of the mind, and the software facilities such as memory space and communication channels which support processing. I have suggested elsewhere (Matthews, 1997b, 2000) that in personality research this level of explanation might be reconceptualized as a cognitive-architectural level, in order to accommodate sub-symbolic, connectionist models. As in the typical cognitive-psychological model, the aim is to identify the specific processing components which mediate personality effects.

The third level of explanation is labeled the semantic level by Pylyshyn (1984), in that it refers to the personal meaning of the otherwise arbitrary processing codes, and the knowledge level by Newell (1982), because it refers to the person's knowledge of how to obtain personal goals. More generally, it explains behavior on the basis of

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[1] I will leave aside the issue of whether higher levels are ultimately reducible to the biological level (see Matthews, 2000)

intentions, motivations and personal meaning. It is compatible with cognitive stress models, which attribute stress symptoms to the status of self-regulative plans for goal-satisfaction (Wells & Matthews, 1994).

Thus, accounts of personality and emotion expressed in terms of the cognitive architecture are necessary but not sufficient. We need to look downwards from the cognitive architecture to its neural foundations, the appropriate level for explaining responses closely coupled with the neural substrate. We also need to look upwards to the knowledge level to understand why personality and affect may be correlated with personal goals and strategy choice.

Personality Traits as Distributed Constructs

Extraversion and Neuroticism

How can the multi-level approach be realized in practice? Table 2 illustrates some of the correlates of extraversion-introversion, allocating each of several of the more robust empirical findings to one of the three levels (see Matthews, 1997a, for a more detailed review). These allocations are tentative because researchers often neglect to probe mechanisms in detail, but some modeling studies are at least suggestive of where specific effects should be placed (e.g., Matthews & Harley, 1993).

The key feature of the table is that personality effects are distributed at every level. At the biological level, Zuckerman (1991) emphasizes that there is no isomorphism between traits and specific brain systems; instead, multiple systems may underpin each trait. Consistent with this principle, a review of psychophysiological studies (Matthews & Gilliland, 1999) concluded that there are at least two reliable sets of correlations of extraversion: one set relating to corticoreticular arousability, and a second set associated with dopaminergic reward systems and motor responsivity. Effect sizes for these correlations are typically modest.

Table 2. Differing explanations for empirical correlates of extraversion: some examples.

Level of explanation	*Empirical correlates*
Biological	- Conditioning to reward
	- Low cortical arousability
	- Motoneuronal excitability (low)
Cognitive-architectural	- Verbal divided attention
	- Sustained attention (poor)
	- Fluency of speech production
Knowledge	- Social motivations and interests
	- Appraisal of events as challenging
	- Coping using task-focused strategies

At the level of cognitive architecture (and admitting that some effects may in fact be strategic), extraverts process information more efficiently when the task involves multiple channels of information (especially verbal information), such as dual-task performance and resisting distraction. Extraverts also exhibit superior speech production abilities and faster memory retrieval. Introverts, however, are superior at sustaining attention over time in simple vigilance paradigms. At the knowledge level are performance effects associated with strategy change such as setting a response criterion and maintaining focus during reflective problem-solving: extraverts tend to be more impulsive. More generally, extraverts and introverts differ in the meanings they assign to events, and the goals and coping strategies they adopt in challenging situations.

Table 3 shows a comparable analysis of correlates of neuroticism and trait anxiety (Matthews, Derryberry & Siegle, 2000). Like extraversion, neuroticism is distributed across neural processes (e.g. sensitivity to punishment signals), basic information-processing operations (e.g., disengagement of attention from sources of threat) and high-level self-regulation and motives (e.g., biases towards threat appraisal and emotion-focus coping). In principle, multi-level analyses could be applied to other Big Five Traits. Future research might relate conscientiousness to processes governing effort and task commitment, agreeableness to social cognitions, and openness to the intellect (Matthews et al., 2003).

Table 3. Differing explanations for empirical correlates of neuroticism: some examples.

Level of explanation	*Empirical correlates*
Biological	- Conditioning to punishment
	- Immune response (weak)
	- Startle response to fear stimuli
Cognitive-architectural	- Attentional bias to threat
	- Selective memory for negative events
	- Negative bias in judgement
Knowledge	- Self-protective motives
	- Appraisal of events as threatening
	- Coping using emotion-focused strategies

Levels of Affective Functioning

How does affect fit into the multi-leveled picture? There are two issues here: why emotions (and other states) influence cognition and performance, and why personality relates to individual differences in emotions.

As with personality, it is likely that emotion operates at all three levels of the cognitive science framework (Matthews et al., 2000). The neurological foundations of emotion are well-known, although it is regrettable that neuroscientists have tended to neglect relationships between individual differences in brain systems and in performance. Fear-conditioning might be a good example of a process best understood neurologically, although it is likely that expectancies and higher-level cognitive processing also play a role. As previously noted, emotions may also be associated with specific changes in the architecture, and with information content. The knowledge-based perspective on emotion is also familiar from studies of strategy change in emotional states, and from cognitive models of stress and self-regulation.

I will set aside the biological level here, so as to provide two brief examples of how research may draw on explanations based on both cognitive architecture and on self-knowledge. The first example concerns the robust association found between energetic arousal and efficiency of performance of attentionally demanding tasks, such as signal detection and controlled visual search tasks (reviewed by Matthews, 1997a). Effects of energetic arousal are reliably moderated by a variety of task demand factors, such that energy is related only to attentionally-demanding tasks. Hence, energetic mood may index attentional resource availability. Although energy primarily appears as an index of the cognitive architecture, it also correlates with task motivation, effort, challenge appraisal and task-focused coping (Matthews, Campbell et al., 2002). This broader syndrome of task engagement may be understood at the knowledge level as relating to the person's understanding of the environment as calling for the application of systematic, goal-directed effort.

Another example concerns anxiety and negative affect. Wells and Matthews (1994) proposed that such states are often generated by dysfunctional self-referent executive processing, associated with exaggerated attention to self-discrepancies and intrusive thoughts. This account of anxiety and depression proposes an architecture, but explains their behavioral consequences primarily in terms of how the anxious person deploys the architecture, rather than in terms of changes in parameters of the architecture (although these may occur simultaneously). For example, although threat-sensitivity in anxiety is often considered to operate 'automatically', data suggest that attentional bias is sensitive to expectancies and strategy. Such bias may in fact be a consequence of a strategy for handling threat by 'hypervigilance' for potential dangers. Matthews and Harley (1996) modeled attentional bias by relating anxiety to activation of 'task-demand' units that modulate the operation of a parallel distributed processing (PDP) network. The model provides an architecture-level description of the effect, but explaining why anxiety relates to variation in task-demand activation requires the knowledge level. Anxious individuals interpret the world and their own place in it differently to those low in anxiety, emphasizing the likelihood of personal danger (social or physical), and the utility of hypervigilance as a means of coping.

The second issue is the relationship between personality and affect. Extraverts' tendencies to positive affect are often attributed to a brain reward system, whereas the association between neuroticism and negative affect is said to be mediated by a punishment system (e.g., Watson, 2000). However, there is rather little evidence linking personality-mood covariation directly to neural bases (Matthews & Gilliland, 1999). My suggestion is that multiple mechanisms may support the associations. For example, in neuroticism and anxiety, information-processing biases that increase the salience of threat may contribute to higher levels of negative affect. So too may biases in self-knowledge, appraisal and coping, as shown directly in studies of task-induced stress (Matthews, Campbell et al., 2002).

These constellations of change in neural, computational and self-regulative processes associated with transient states may partly mediate the effects of personality traits on cognition and performance. For example, the role of state anxiety in mediating effects of trait anxiety is well-known. However, some effects appear to be unique to traits. Because of the stability of traits they become associated over time with individual differences in acquired skills, such as social skills in the case of extraverts, and skills for early recognition of danger in the case of neurotics (Matthews et al., 2003). Skill differences may influence behavior irrespective of temporary state. Conversely, if we look at true state measures, rather than aggregated 'typical mood' measures, much of the variance in states is not predictable from traits (instead reflecting situational factors). Thus, we cannot use traits as proxies for states in research.

The Role of the Environment: Adaptation and Design

Traits, Processing Bias and Environmental Choice

The material I have covered so far provides the basis for a painstaking, piece-by-piece dissection of the biological and cognitive attributes of traits. This enterprise is essential for simulating traits as being distributed across many subcomponents of the cognitive architecture, giving us a picture of the trait as a collection of many small biases, rather than being an attribute of a single component or subsystem. This approach provides some purchase on design issues, to the extent that we program the various biases into a simulation, and observe how the system behaves at a macro level.

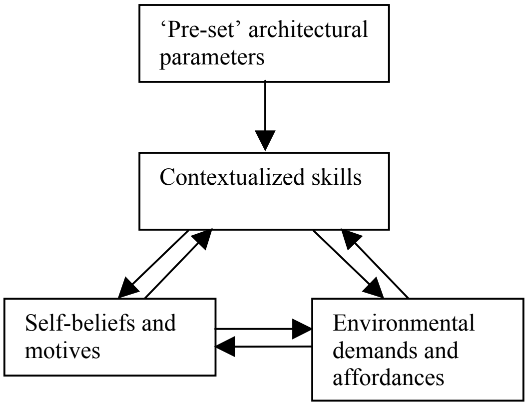
However, focusing only on description of processing biases neglects two key issues. First, in both human and machine contexts, showing that a given architecture produces some set of stimulus-response mappings tell us little about whether such behavior patterns are adaptive or maladaptive in a given environment. Second, in the context of understanding human personality, it is unclear why multiple component biases should be collectively linked to specific traits.

Previously, I have argued that the various correlates of personality traits – at all three levels of explanation – are linked functionally, not architecturally (Matthews, 1999; Matthews, Zeidner et al., 2002). Thus, the multifaceted attributes of extraversion help the person to function effectively as an extravert, i.e., to obtain more gains than losses from sociable, assertive and impulsive behaviors. For example, biological sensitivity to reward signals helps to maintain engagement with challenging, potentially harmful social situations. Information-processing qualities such as rapid speech production, and good concentration on multiple verbal messages, facilitate social skills. Knowledge-level attributes of extraversion such as high self-efficacy and preference for task-focused coping strategies fulfill a similar function. Conversely, introverts may be adapted for environments that offer infrequent stimulation, as indicated by their better performance at vigilance and reflective problem-solving tasks. A similar analysis may be conducted for other traits. For example, neuroticism may be associated with individual differences in two broad strategies for handling threat: anticipating and avoiding threat (high neuroticism) or waiting until the threat may be confronted directly (low neuroticism).

This cognitive-adaptive perspective has two corollaries. First, personality must be situated in an environmental context; whether trait characteristics are advantageous or disadvantageous depends on the challenges of the social and physical environment. Indeed, personality traits may correspond to the major adaptive challenges posed by human environments; in a sense, traits mirror key environmental challenges. Second, learned skills play a key role in mediating adaptation. Basic processing components such as those controlling reaction time may sometimes have adaptive consequences but the availability of learned skills tuned to specific environments is more important. For example, culturally-appropriate social skills for managing a conversation are more adaptive than the processing components that provide the platform for skill acquisition.

Next, I will describe further how the multiple architectural features of traits are situated within dynamic interaction with the environment. Figure 1 shows the dynamic adaptive process in simplified form (see Matthews, 1999; Matthews, Zeidner et al., 2002, for more detail). Individual differences in parameterization of the cognitive architecture vary in temporal stability. Parameters of simple processing components, such as attentional and memory capacities, are typically 'pre-set' early in development through the interaction of genetic and environmental factors. Parameters are not necessarily rigidly fixed, but it is convenient to treat them as stable throughout early adulthood, in line with the stability of cognitive abilities. Key parameters of the neural architecture may show similar stability, as suggested by the continuity into adulthood of childhood emotional temperament (see Zeidner, Matthews, Roberts & MacCann, 2003).

Figure 1. A simplified view of the dynamic perspective on personality and adaptation.



In addition, the cognitive architecture changes, relatively rapidly, with learning and skill acquisition, through dynamic interaction with the environment. However, this interaction may be influenced by the component process biases I have linked to traits. In the case of introverted personality, a child whose attention to speech is poor is liable to find it more difficult to acquire conversational skills, compared with a child with more efficient speech processing. Similar difficulties may arise independently if the child is neurologically ill-equipped for social interaction; for example, if encounters with strangers elicit excessive stress responses. An introverted temperament then manifests initially as a collection of component process biases. Over time, these biases contribute to shaping the architecture dynamically as the child acquires skills congruent with temperament. Thus, in the older child and adult, we can observe both individual differences in the architecture supporting skilled performance, and, independently, individual differences in the component processes that biased skill acquisition during development.

However, it is not just the cognitive architecture that changes. Skill acquisition typically promotes congruent self-beliefs such as self-efficacy; the extravert acquires social self-confidence together with behavioral skill. Such constructs can be represented within cognitive architectures, but as described previously, understanding individual differences in the personal meaning of situations requires a knowledge level analysis.

Furthermore, skills and self-beliefs influence exposure to the environments that afford exercise of the skill. The socially-skilled, self-confident extravert is likely to seek out socially challenging situations that provide further opportunity for refining skills and building confidence. In the prototypical case, there is positive feedback between skills (as controlled by the cognitive architecture), self-beliefs and environmental exposure, a synergy that may contribute to personality stability over and above stability conferred by its bedrock 'preset' components. The coupling between the systems shown in Figure 1 should not be over-stated. Skills and self-beliefs may dissociate;

for example, extraverts of the saloon-bar bore variety may have more self-confidence than actual skill. External circumstances, including the social-cultural background, may also limit or enhance environmental exposure. Events may also perturb the feedback cycle. For example, a traumatic event (environmental exposure) might lead to loss of self-confidence, avoidance of feared environments, and skill degradation. However, as research shows (e.g., Magnus, Diener, Pavot & Fujita, 1993), events themselves are influenced by personality, as a consequence of the dynamic adaptive process.

States and Short-term Adaptation

If traits index long-term adaptation, states (including emotions) may relate to short-term adaptive status: an idea familiar from the hypothesis that emotions relate to control signals generated by ongoing plans (Oatley & Johnson-Laird, 1996). Emotions, cognitions and motivations cohere around the self-regulative goals activated by the surrounding context. Work based on the three-factor model of states (Matthews, Campbell et al., 2002), summarized in Table 4, suggests that task engagement (e.g., energy, motivation) relates to commitment to apply effort, distress (e.g., negative affect, low confidence) signals uncontrollable overload, and worry (e.g., self-focused attention, intrusive thoughts) is associated with re-allocating attention onto personal concerns.

Table 4. A cognitive-adaptive perspective on three dimensions of state.

	Task Engagement	*Distress*	*Worry*
Appraisals	High demands Challenge	High workload Threat Failure to attain goals	-
Coping	Task-focus Low avoidance	Emotion-focus	Emotion-focus Avoidance
Performance	More resources for attention	Impairs multi-tasking and executive control	Interferes with verbal processing
Adaptation	Maintaining effort and focused attention	Mitigating overload	Re-evaluating personal relevance of task

The exquisite sensitivity of states to feedback from the situation functions to keep the various layers of adaptation attuned to changing environmental contingencies. The person's adaptive choices, as reflected in state response, may be biased by personality, but are more strongly governed by situational constraints and situation-specific appraisals. I will mention briefly that there is an important dynamic interplay between traits and states associated with prolonged patterns of person-situation interaction. For example, in anxiety patients, the states of high worry and negative affect elicited by demanding situations dispose the person to rumination and strengthening of maladaptive cognitive biases, so maintaining the anxious personality (Wells & Matthews, 1994).

Thus, a complete account of human personality and affect requires an adaptive perspective, in addition to the fine-grained investigation of neural and cognitive architectures. Depending on personality, the individual is designed to handle somewhat different environmental challenges. The package of biases in the functioning of the architecture provided by the interaction of genes and early learning provides a predisposition to prosper in some environments and struggle in others. Typically, there is a developmental trajectory towards acquisition of contextualized skills congruent with the predisposition, leading to reconfiguration of the architecture, and to individual differences in the content of knowledge and environmental exposure. The implication is that a human-like personality may be difficult to program into the architecture ab initio. Perhaps, personality must mature over time through interaction with the outside world.

Individual differences in emotional response are primarily shaped by immediate situational pressures and their adaptive significance. Emotions accompany rapid system reconfiguration, within the design constraints set by personality. Traits bias state responses through multiple mechanisms, i.e., individual differences in neural processes, in computation of the valence and other attributes of the stimulus, and in assignation of personal meaning.

Conclusion

Designing an adaptive system involves a multitude of independent processes, at different levels of abstraction. However, despite the distributed nature of adaptive processing, individual differences are given coherence by self-regulation. Traits represent adaptations to the major challenges of human life that constrain long-term self-regulation, supported by self-knowledge and acquired skills as well as individual differences in neural and cognitive architectures set early in development. Thus, we see traits most clearly through their 'macro', adaptive features, that are apparent even to the lay observer. Paradoxically, as we try to focus ever more finely on the 'micro' biases that underpin the trait, personality becomes ever more elusive. By contrast, transient states, including affective states, map onto the mode of self-regulation required to solve some immediate adaptive problem, whose terms are often outside of personal control. The state is associated with both biological and cognitive changes that support common adaptive goals such as succeeding through commitment of effort or mitigating the effects of unavoidable overload.

Conventional modeling of human personality and affect is based on biasing parameters of the cognitive architecture. This is an appropriate method for simulating specific functions, and the growing trend towards distributing personality across multiple biases within dynamic architectures (e.g., Hudlicka, 2002) is to be applauded. However, for a deeper understanding of personality as situated within specific environments, more effort needs to be applied to modeling developmental processes. The cognitive-adaptive model sketched out here provides one approach of this kind: it relates change in architecture to change in self-knowledge and in interaction with the environment. In addition, recent interest in modeling autonomous agents with personality and emotion (see Trappl et al., 2003) may provide powerful new simulation techniques for studying personality development. The present analysis also suggests that there may be more to the design of personality in artifacts than simply programming in appropriate biases (even multiple biases in learning processes). Human-like personality may require the artifact to possess a developmental history of interaction with an outside world that generates congruence between its initial processing biases, learning and style of self-monitoring and self-regulation.

References

Ball, E. 2003. A Bayesian Heart: Computer Recognition And Simulation Of Emotions. In R. Trappl, P., Petta, and S. Peyr, eds., *Emotions in Humans and Artifacts*, 303-332. Cambridge, Mass: MIT Press.

Bower, G.H. 1981. Mood and Memory. *American Psychologist* 36: 129-148.

Costa, P.T., Jr. and McCrae, R.R. 1992. Four Ways Five Factors are Basic. *Personality and Individual Differences* 13: 653-665.

Eysenck, H.J. 1967. The *Biological Basis of Personality*. Springfield, Ill.: Thomas.

Eysenck, M.W. 1992. *Anxiety: The Cognitive Perspective.* Hove, UK: Lawrence Erlbaum Associates.

Gray, J. A. 1991. Neural Systems, Emotion and Personality. In J. Madden IV, ed., *Neurobiology of Learning, Emotion and Affect*, 273-306. New York: Raven Press.

Hockey, G.R.J. 1984. Varieties of Attentional State: The Effects of the Environment. In R. Parasuraman and D.R. Davies, eds., *Varieties of Attention*, 449-483. New York: Academic Press.

Hudlicka, E. 2002. This Time with Feeling: Integrated Model of Trait and State Effects on Cognition and Behavior. *Applied Artificial Intelligence* 16: 1-31.

Magnus, K., Diener, E., Fujita, F., and Pavot, W. 1993. Extraversion and Neuroticism as Predictors of Objective Life Events: A Longitudinal Analysis. *Journal of Personality and Social Psychology* 65: 1046-1053.

Matthews, G. 1997a. Extraversion, Emotion and Performance: A Cognitive-Adaptive Model. In G. Matthews, ed., *Cognitive Science Perspectives on Personality and Emotion*, 339-442. Amsterdam: Elsevier.

Matthews, G. 1997b. An Introduction to the Cognitive Science of Personality and Emotion. In G. Matthews, ed., *Cognitive Science Perspectives on Personality and Emotion*, 3-30. Amsterdam: Elsevier.

Matthews, G. 1999. Personality and Skill: A Cognitive-Adaptive Framework. In P.L. Ackerman, P.C. Kyllonen and R.D. Roberts, eds., *The Future of Learning and Individual Differences Research: Processes, Traits, and Content*, 251-270. Washington, DC: American Psychological Association.

Matthews, G. 2000. A Cognitive Science Critique of Biological Theories of Personality Traits. *History and Philosophy of Psychology* 2: 1-17.

Matthews, G., and Amelang, M. 1993. Extraversion, Arousal Theory and Performance: A Study of Individual Differences in the EEG. *Personality and Individual Differences* 14: 347-364.

Matthews, G., Campbell, S.E., Falconer, S., Joyner, L., Huggins, J., Gilliland, K., Grier, R., and Warm, J.S. 2002. Fundamental Dimensions of Subjective State in Performance Settings: Task Engagement, Distress and Worry. *Emotion* 2: 315-340.

Matthews, G., Deary, I.J., and Whiteman, M.C. 2003. *Personality Traits,* 2nd ed.. Cambridge, UK: Cambridge University Press.

Matthews, G., Davies, D.R., Westerman, S.J., and Stammers, R.B. 2000. *Human Performance*: *Cognition, Stress and Individual Differences*. London: Psychology Press.

Matthews, G., Derryberry, D., and Siegle, G.J. 2000. Personality and Emotion: Cognitive Science Perspectives. In S.E. Hampson, ed., *Advances in Personality Psychology*, vol. 1, 199-237. London: Routledge.

Matthews, G., and Gilliland, K. 1999. The Personality Theories of H.J. Eysenck and J.A. Gray: A Comparative Review. *Personality and Individual Differences* 26: 583-626.

Matthews, G., and Harley, T.A. 1993. Effects of Extraversion and Self-Report Arousal on Semantic Priming: A Connectionist Approach. *Journal of Personality and Social Psychology* 65: 735-756.

Matthews, G., and Harley, T.A. 1996. Connectionist Models of Emotional Distress and Attentional Bias. *Cognition and Emotion* 10: 561-600.

Matthews, G., Zeidner, M., and Roberts, R. 2002. *Emotional Intelligence: Science and Myth.* Cambridge, Mass*:* MIT Press.

Newell, A. 1982. The Knowledge Level. *Artificial Intelligence* 18: 87-127.

Oatley, K., and Johnson-Laird, P.N. 1996. The Communicative Theory of Emotions: Empirical Tests, Mental Models, and Implications for Social Interaction. In L.L. Martin and A. Tesser, eds., *Striving and Feeling: Interactions Among Goals, Affect, and Self-Regulation*, 363-393. Hillsdale, NJ: Lawrence Erlbaum.

Ortony, A. 2003. On making believable emotional agents In R. Trappl, P., Petta, and S. Peyr, eds. *Emotions in Humans and Artifacts,* 189-211. Cambridge, Mass: MIT Press.

Pylyshyn, Z.W. 1984. *Computation and Cognition: Toward a Foundation for Cognitive Science*. Cambridge, Mass: MIT Press.

Pylyshyn, Z.W. 1999. What's in Your Mind? In E. Lepore and Z.W. Pylyshyn, eds., *What is Cognitive Science?*, 1-24. Malden, Mass: Blackwell.

Schimmack, U., and Grob, A. 2000. Dimensional Models of Core Affect: A Quantitative Comparison by Means of Structural Equation Modeling. *European Journal of Personality* 14: 325-345.

Trappl, R., Petta, P., and Peyr, S. eds. 2003. *Emotions in Humans and Artifacts*. Cambridge, Mass: MIT Press.

Watson, D. 2000. *Mood and Temperament*. New York: Guilford Press.

Wells, A., and Matthews, G. 1994. *Attention and Emotion: A Clinical Perspective*. Hove, UK: Lawrence Erlbaum Associates.

Zeidner, M., Matthews, G., Roberts, R.D., & McCann, C. (2003). Development of Emotional Intelligence: Towards a Multi-Level Investment Model. *Human Development* 46: 69-96.

Zuckerman, M. 1991. *Psychobiology of Personality*. New York: Cambridge University Press.