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Against consensus: Embracing the disunity of personality theory

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ABSTRACT

Theories of personality traits refer to qualitatively different explanatory mechanisms, limiting prospects for a consensual paradigm. This article presents a trilevel cognitive science analysis that distinguishes multiple, qualitatively different explanations for expressions of personality. Stable individual differences in processes and content associated with traits are distributed within and between levels of explanations. A unitary and coherent account of traits is thus problematic. The Cognitive-Adaptive Theory of Traits (CATT) provides a conceptual framework that inter-relates theories at different levels, and identifies trait coherence with individual differences in strategies for managing adaptive goals. It exemplifies a spirit of explanatory pluralism that accepts disunity in personality theory. That is, it is preferable to work with multiple, conceptually rigorous theories at different levels than to aim for a universal paradigm prematurely.

1. Introduction

Historically, two types of personality trait theory have claimed paradigm status: the psychobiological model exemplified by Eysenck's (1981) theory, and the data-driven Five Factor Model (FFM) supplemented by Five Factor Theory (FFT: McCrae & Costa, 2008). Together, the two classes of theory illustrate two contrasting approaches to paradigm building, loosely corresponding to deductive and inductive reasoning. The former approach specifies a comprehensive theory of brain or mind function, and then identifies major attributes of functioning that show stable and consequential inter-individual variation. Among current psychobiological models, Reinforcement Sensitivity Theory (RST: Corr, 2004; Corr & Krupić, in press) is the clearest exemplar. Specification of brain motivation systems is the first step, which then leads to scales for individual differences and predictions of behavioral outcomes of traits (Corr & Krupić, in press).

The second approach is to define sources of personality data, often but not necessarily self-reports, and to investigate empirically underlying dimensions that explain inter-individual variation. The FFM owes its prominence in part to the consistency with which factor analytic studies revealed five underlying dimensions (Goldberg, 1990; McCrae & Costa, 2008). Following identification of the set of dimensions, including lower-level trait facets, theory-building proceeds by working back from data to determine neural or psychological mechanisms that mediate associations between traits and outcome measures. McCrae and Costa (2008) proposed Five Factor Theory (FFT) as an explanatory theory to complement the FFM descriptive model. They assert that traits are influenced only by biology but they influence behavior via culturally conditioned characteristic adaptations, which appear to include every major mechanism known to psychology. FFT represents a starting point for linking traits to processes but it is not currently specified in detail.

Both recipes for paradigm building have their attractions, as well as mostly enlightening records of scientific success and controversy (Matthews, Deary, & Whiteman, 2009). It is tempting to suppose the path towards a consensual paradigm is more of the same. We can surely hope that rapid advancements in behavioral neuroscience will provide a consensual paradigm for brain functioning – and, in consequence, a consensual personality model. By contrast, advocates of the FFM can point to the ever-richer nomological networks that link the Big Five to numerous process and outcome measures. Prospects for elaborating and refining FFT seem bright. Indeed, theories that explain the Big Five in relation to evolutionary and neuroscience concepts already exist (DeYoung, 2015). Assuming theory- and empirically-driven theories describe the same underlying reality, we might anticipate convergence of the two approaches over time.

This article presents a different view. Current research has good prospects for developing paradigms applying to limited parts of the personality sphere. However, there are serious barriers to developing a universal paradigm for dimensional personality traits that are not adequately appreciated. The most significant of these is that personality traits correlate with constructs that are conceptualized at multiple, incommensurable levels of description (Matthews, 2000), ranging from genetic polymorphisms to self-beliefs shaped by culture and social

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interaction. It is not self-evident that a single paradigm can ever satisfactorily explain trait correlates of highly heterogeneous constructs. This article explores the challenges to developing a consensual paradigm from the standpoint of the multiple levels of explanation specified by cognitive science (Pylyshyn, 1999). Necessarily, I take a critical view of current personality science; this stance is not intended to deny the real and consequential achievements of the theories cited.

2. Definition of personality and major descriptive factors

This article adopts a conventional definition of personality traits as stable, nomothetic, quantitative individual difference constructs that influence experience and behavior, excluding cognitive abilities (Matthews et al., 2009). The reference to "constructs" indicates a focus on source rather than surface traits (Revelle, 2009), i.e., physiological and mental qualities that operate as causal agents, not superficial patterns of behavior. Like any other psychological construct, trait measurements may be validated for explicit research and applied purposes by developing an argument for validity consistent with contemporary test standards. The trait definition covers dimensions assessed objectively, such as implicit traits, as well as familiar self-report constructs. I will assume that sound validity arguments exist for major traits. The definition also excludes, without prejudice, other perspectives on personality, including idiographic, humanistic, and social-constructivist perspectives.

2.1. General and contextualized traits

Here, I accept the utility of the FFM as a broad framework for integrating many areas of personality research (Matthews et al., 2009). It also provides the basis for a hierarchical personality model with primary traits or facets nested within each of the Big Five, although consensus on the optimal set of primary traits is limited. However, the FFM has limitations as a truly universal trait description. The FFM is compared to a periodic table of traits (e.g., Woods & Anderson, 2016), but it is more approximate and contingent than the metaphor suggests (Matthews, 2018). In particular, cross-cultural variation in personality structure, which is non-trivial for non-Western cultures (Church, 2016), calls into question whether any highly precise structural model can be universally defined. Nevertheless, it remains an essential frame of reference for research, just as the magnetic north pole is useful for navigators despite its wandering nature.

General traits such as those of the FFM contrast with contextualized traits, such as test anxiety, driver stress vulnerability, and work self-efficacy (Matthews, in press). Contextualized traits are often more predictive than general traits within the appropriate context (e.g., Zeidner, 1998), but raise difficulties for a consensual paradigm. Social and technological change generate novel traits, such as dislike of robots (Nomura, Suzuki, Kanda, & Kato, 2006). Such traits are neither a direct expression of brain processes nor culturally universal; should a consensual paradigm address them?

2.2. Process and content traits

There is a neglected conceptual distinction between "process" and "content" traits, prefigured by the distinction sometimes made between basic temperament and personality shaped by social and cultural factors. The distinction corresponds to two types of explanation, and hence is important for theory building. As Pylyshyn (1991, p. 241) states, "In cognitive science, as in folk explanations, there appear to be two distinct explanatory principles; one that appeals to intrinsic functional properties or mechanisms, and one that appeals to the content of representations, such as knowledge, beliefs, goals and the like." From a personality standpoint, the former, mechanistic, explanation refers to individual differences parameters that control processing such those for unit connection strengths, decay rates and random noise in a connectionist model (Matthews & Harley, 1993), irrespective of the content of what is being processed. Thus, traits can be operationalized quantitatively as variance in quantitative parameter values associated with computational models of either the virtual cognitive architecture or physical neural networks. In the words of Sun and Wilson (2014, p. 1), "…a cognitive architecture by itself can serve as a generic model of personality, without any significant addition or modification." I will refer to these cognitive and neurological models as Quantitative Architecture Parameter (QAP) traits subsequently.

By contrast, "content traits" refer to long-term memory (whether explicit or implicit) for regularities in the environment, and rules for behaving, feeling and thinking associated with those learned regularities. Traits for political attitudes and ideology would be an example, without precluding an influence from cognitive and neural QAPs. Stable individual differences in content reflect environmental regularities, including the social encounters that shape the self (Robinson & Sedikides, in press), though not necessarily faithfully. We can then conceptualize self-knowledge adaptively. That is, the self includes representations of "knowledge, beliefs, goals and the like" (Pylyshyn, 1991) that allow the person to benefit from the environments to which they are most commonly exposed. Representational explanations of traits refer to individual differences in the content of representations, such as specifications of the threats present in the person's social world. The epistemic rationality of self-knowledge varies; the high threat sensitivity characteristic of anxiety is more or less adaptive depending on the objective level of threat in the environment (Matthews, 2004a). Content also refers to the person's inner mental life. Metacognitive traits, such as beliefs in the importance of attending to images and thoughts, play an important role in negative affectivity (Wells & Matthews, 2015) and resilience to stress (Matthews, Panganiban, Wells, Wohleber, & Reinerman-Jones, 2019).

It is unclear whether a consensual paradigm should focus on process or content or some integration of both. Psychobiological theory highlights process parameters. In RST (Corr & Krupić, in press), traits are, in effect, identified with parameters governing amplitude of brain system response to reinforcers, and can be modeled quantitatively as such (Pickering, 2008). From the FFM perspective, the nature of explanation is ambiguous. The theory identifies the Big Five with brain systems (McCrae & Costa, 2008), but mediating constructs cited in FFT such as the self-concept appear to be infused with content. Indeed, measuring traits via self-report may primarily identify content rather than process (Robinson & Sedikides, in press). A typical personality item such as "Would being in debt worry you?" addresses the respondent's representation of an environmental contingency. The representation may in some way be influenced by neural processes underpinning neuroticism, but it is content that is actually assessed.

3. Multiple levels for processes

3.1. Basic process definition

Minimally, a process is defined by an input, a transformation, and an output. A fourth element may be added – a description of the processor or "processing machinery", whether defined cognitively, such as a memory store, or neurologically, such as a brain region. In personality research, usage of the term depends on the timespan of interest. Over short intervals, where traits are assumed to be fixed, we can use an architecture-modeling approach to test how parameter variation moderates the operation of cognitive or neural processes to generate behavioral expressions of QAP traits (e.g., Matthews & Harley, 1993). Individual differences in content can be similarly accommodated; for example, an implicit test for personality tells us about what representations in memory are associated with the self (De Cuyper et al., 2017). Over intervals of years, process refers to trait change, i.e., how stable parameter values and memory contents are acquired and modified over time. The focus is on learning rather than performance processes. Thus a trait is a causal agent over short timespans (Matthews et al., 2009) and a participant in a more complex dynamic process over longer ones (Roberts et al., 2017).

The trait-state distinction is relevant to short time intervals. Like “trait”, the term “state” is open to different interpretations. Within a computational architecture, some quantities, such as the activation level of a single unit, are constantly changing, and thus represent state variables. However, in personality research, “state” typically refers to a broader construct such as state anxiety. Emotion research (e.g., Scherer, 2009) provides the clearest prototype for states in this sense: emotional states are associated with a coordinated pattern of change in neural activity, cognitive appraisal patterns, information-processing biases, subjective feelings, and action tendencies. (The strength of coupling between different elements is open to debate).

Personality traits may bias onset and persistence of states (Matthews et al., 2009). Thus, one type of explanation for trait effects on behavior is to invoke state mediation, as in Spielberger's (1966) trait-state anxiety theory. Necessarily, but uninterestingly, any trait effect must be associated with individual differences in states (e.g., neural firings or unit activations). Of more relevance is whether trait effects are mediated by theoretically meaningful states such as emotions that can be assessed and conceptualized separately from personality theory. If so, the explanatory questions are pushed along to the state level. Like traits, states may be associated with multiple changes in processing, differing in their impacts on the outcome variable of interest (Matthews, Warm, Reinerman, Langheim, & Saxby, 2010). I will focus primarily on traits in this article but the arguments presented are also applicable to theories of state dimensions.

3.2. Levels of explanation: the trilevel framework

A major theme of this article is that personality theory must refer to multiple, qualitatively different types of process at different levels of abstraction from the neural substrate. Building a consensual paradigm is thus difficult because any such paradigm must refer to processes as low-level as single-neuron firing and as high-level as finding meaning in personal events.

The trilevel explanatory framework of cognitive science provides a starting point for making sense of the multifarious correlates of traits (Matthews, 1997, 2000, 2004b, 2008). Pioneering cognitive scientists including David Marr and Allen Newell proposed that qualitatively different levels of explanation are required to understand information-processing systems (Peebles & Cooper, 2015). Broadly, we can distinguish what problems the system can solve (“design”), the computational algorithm and data used in problem solving (“software language”), and the physical instantiation of computation (“hardware”). Matthews (2008) used terminology modified from Pylyshyn's (1999) version of trilevel theory, characterizing the levels as shown in Fig. 1.

- The *biological level* refers to the physical entities that support or influence information processing. It corresponds to neuroscience, including other relevant influences such as genes and circulating hormones. It is familiar from the standard psychobiological theories of traits.
- The *cognitive architecture* level refers to symbolic information-processing. It includes a description of processing operations (like the instruction set of a computer language) and data representations. It also includes a functional architecture that refers to the processors, memory stores, and communication channels that allow computation to proceed in real-time. Anderson's (2007) ACT-R model exemplifies an architecture that supports a wide range of cognitive functions. There are individual differences in functional architecture elements such as working memory capacity, explored especially in theories of trait anxiety (e.g., Eysenck & Derakshan, 2011). Individual variation in the basic characteristics of the internal programming language(s) seems implausible.
- The *knowledge* level refers to the design of human intelligence to solve the problems of living, shaped by both evolution and sociocultural factors. It overlaps with the self as commonly understood in personality theory, as a representation of personal goals, values, and beliefs about the world and the place of the self within it. It corresponds to a view of the person as a rational if error-prone problem-solver and personality variation as reflecting variation in the motives and beliefs that drive problem-solving.

The trilevel framework elaborates on the QAP/content distinction introduced above. The parametric perspective maps on to the two lower levels, as we can specify and model quantitatively computational and neural architectures. Cognitive neuroscience models potentially integrate the two levels, although the emergent nature of information-processing (Sloman, 2009) mitigates against full integration. Content traits naturally correspond to the knowledge level, given that they refer to goals and beliefs that are contingent on the arbitrary nature of the world. In terms of schema theory (Clark & Beck, 1999), the belief that the world affords no means to realize personal goals contributes to depressive personality even if there is nothing abnormal about the parameters of the architecture.

However, learning also encodes “content” at lower levels of explanation. Computational theories of skill acquisition, notably Anderson's (1987, 2007) ACT-R, assume that expertise in a task domain resides in stable modifications to the computational architecture (the “production system”). Skilled performance remains modeled by a mechanical symbol-manipulation process, but it is one that it is shaped by representations of the world, e.g., a production system for operating a vehicle must encode the different meanings of red and green stop lights. Content traits may be produced by individual differences in learned skills. Wells and Matthews (2015) linked anxiety to acquired production systems that direct attention to threat stimuli and initiate avoidance coping. Similarly, thinking in terms of neural wetware rather than hardware, the individual's conditioning history is represented mechanistically at the biological level, providing yet another theoretical avenue for trait theory.

3.3. Multiple explanatory theories for trait anxiety

Table 1 applies these distinctions to anxiety theory. The knowledge level emphasizes beliefs about personal vulnerability specified in schema theories (Clark & Beck, 1999; Taylor, Bee, & Haddock, 2017). The knowledge level does not distinguish content from quantitative parameters of processes, but stable beliefs can be loosely differentiated from attributes of the dynamic mental models people use to project future outcomes (Endsley, 2000), e.g., anticipating development of a threat over time. Alternatively, we can model individual differences in threat processing computationally within an explicit cognitive architecture. Following Eysenck and Derakshan's (2011) Attentional Control Theory (ACT), anxiety could be linked to a parameter producing weaker inhibitory executive control and distractibility, regardless of stimulus content.

By contrast, a content account of anxiety refers to individual differences in learned procedures for recognizing and handling specific threats (Wells & Matthews, 2015). This perspective gains credibility from clinical observations that specific triggers for anxiety vary across individuals (Wells & Matthews, 2015) and from studies of contextualized traits such as trait anxiety which are linked to strategies for managing the threat of being evaluated (Zeidner, 1998). By contrast with the knowledge-level content, anxiety is related to attributes of the architecture that function mechanistically. For example, in the anxious person the architecture might contain more numerous and more elaborated productions for threat detection, or those productions might fire more readily. At the biological level, we can distinguish parametric reactivity of systems activated by threat and punishment, as in RST (Corr, 2004) and learnt fear responses to specific stimuli supported by

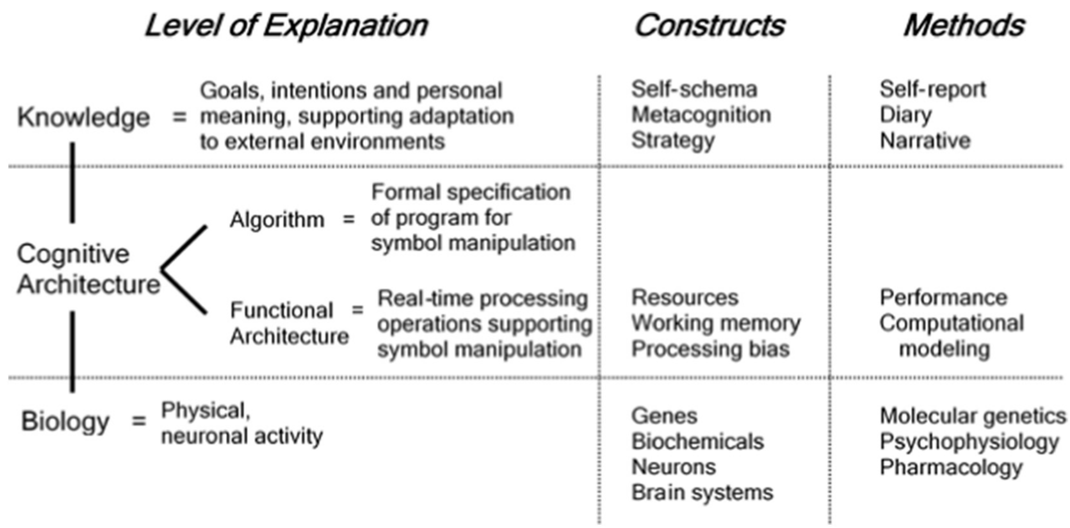

Fig. 1. Three levels of explanation for personality theories, with examples of constructs and methods.

known neural circuits (Lissek, 2012).

Conceptually, we have at least five distinct ways of building a theory of anxiety, some better developed in the literature than others. Any single cell of the figure is too restrictive as a basis for the trait. Processes of different types interact, and contemporary theories duly have elements of multiple cells. For example, Beck's original schema theory has been elaborated to include processing biases and neural correlates of anxiety (Beck & Haigh, 2014). However, simply including multiple theoretical strands is insufficient for unity of theory, unless there is a satisfactory argument reducing phenomena at one level to an explanation at a lower level (not typically the case). Put differently, it is difficult to falsify a successful cognitive-architecture level theory from neurological data alone, although indirect arguments based on neurological plausibility may be advanced.

4. Coherence of distributed traits

The trilevel framework organizes the large and untidy database of empirical findings on trait correlates, but it leaves open the nature of a universal explanatory theory of traits. Another issue is identifying the source of trait coherence, i.e., justifying the legitimacy of treating complex sets of distinct individual differences as unitary traits. The central challenge is that traits appear to be distributed both between and within levels of explanation. Here I summarize the argument made at greater length previously (Matthews, 2000, 2004b, 2008, 2018).

4.1. Traits are distributed between and within levels of explanation

Distribution of traits *between* levels follows straightforwardly from the great diversity of trait correlates, including genetic polymorphisms, information-processing components, and high level social cognition. Important theories have been developed at each level. These include established psychobiological models such as RST (Corr & Krupić, in press), cognitive theories built on constructs such as processing resources (Humphreys & Revelle, 1984) and executive control processes (Eysenck & Derakshan, 2011), and various "high-level" theories referring to self-knowledge (Clark & Beck, 1999), self-regulative processes (Robinson & Sedikides, in press), and motives (Ryan & Deci, 2017). The challenge for a consensual paradigm is that each level of theory is couched in terms of qualitatively different constructs that are not directly commensurate with one another. Some might advocate for a hard neural reductionism (cf., McCauley & Bechtel, 2001). This view is rejected by multi-level cognitive science theory (Cooper & Peebles, 2015), but the limits of reductionism remain to be conclusively established.

Distribution of traits *within* levels is suggested by evidence for multiple attributes controlling any major trait at each level of explanation (Matthews, 2008). Major traits such as extraversion and neuroticism are associated with diverse cognitive functions including perception, attention, memory, decision-making, and rapid response. The complete set of performance characteristics – the "cognitive patterning" of the trait – does not map to any single parameter of the cognitive architecture. Even a broad phenomenon such as the cognitive bias to threat characteristic of trait anxiety may be associated with multiple, distinct processes, including attentional engagement, attentional disengagement, interpretation of text, memory retrieval, expectancy, and more (Matthews, in press; Wells & Matthews, 2015). Each could be identified with a QAP trait. A similar diversity at the biological level is suggested by the role of multiple polymorphisms each playing a small role in trait development (Sallis, Smith, & Munafò, in press), and the variety of brain structures associated with each trait (DeYoung & Blain, in press; Kennis, Rademaker, & Geuze, 2013). High-level social-cognitive correlates of traits are also varied (e.g., Robinson & Sedikides, in press). Identifying a trait with multiple, often small biases in processing suggests a complexity hard to explain on a consensual basis. A further level of complexity is added if we also link traits to individual differences in the wetware or computational procedures reflecting learning.

4.2. The coherence problem

Trait theories are built on qualitatively different constructs that are

Table 1
Different types of explanatory theory for trait anxiety.

Explanatory level	Process parameter	Content
Knowledge	Future anticipation of threat (mental model)	Beliefs in vulnerability to harm
Symbolic processing architecture	Inhibitory executive control strength	Context-bound threat analysis production system
Biological	Reactivity of Behavioral Inhibition System	Conditioned fear response to CS

not obviously commensurable with one another, challenging trait coherence. A trait should have some unitary, defining quality that integrates its multiple expressions. Psychometrically, we expect a trait to be a latent rather than a formative construct, i.e., it can be modeled as a causal agent that influences other measured and latent variables. (The possibility that traits are formative – the outcomes of multiple, unrelated causal factors - is intriguing – but theoretically unsatisfactory.) Conceptually, a trait should correspond to an organized, integrated system of multiple psychological processes. This sense of "coherence" can be distinguished from coherence in behavior and coherence in subjective experience of the self (Cervone & Shoda, 1999), although the three types of coherence may be inter-related.

Traditional psychobiology solves the coherence problem rather neatly, by identifying traits with brain systems whose mechanics and purpose have been determined by evolution. At the other end of the theoretical spectrum, the schema theory of anxiety and depression (Clark & Beck, 1999) provides coherence in content, given that the schema is defined as an organized set of items of self-knowledge. However, the complexity and commensurability issues threaten coherence. If a trait corresponds to a large set of small and weakly-related biases in neural functioning or information-processing, where is the integration of processes? Echoing Cervone and Shoda's (1999) social-cognitive perspective, coherence may exist only at the phenomenological level, as an artifact of self-knowledge indirectly associated with actual brain and cognitive functioning.

4.3. Deductive and inductive pathways to coherence

Dividing trait theories into the "deductive" and the "inductive" offers different paths to "cross-level" coherence. Beginning with a known model of brain functioning, we can try to advance the deductive process up the levels. If individuals differ in punishment sensitivity, how does neurological difference influence individual differences in parameters of information-processing, and how do processing differences in turn influence self-knowledge? This is an entirely reasonable approach, but the evidence to date is that mapping cognitive individual differences to neural ones remains problematic (Matthews, 2016; Matthews & Gilliland, 1999): the challenges posed by complexity and commensurability have yet to be overcome. (This is the "reverse inference" problem of cognitive science: Cooper & Peebles, 2015). Thus, the approach does not yet appear to integrate the multifarious expressions of personality traits coherent, even at a QAP trait level.

The inductive perspective provides a contrasting approach to coherence. The FFM provides coherence in a psychometric sense, but this sense is very limited in the absence of a theory-based explanation for the dimensions, and FFT is vague about processes (Matthews, 2018). There are two possible solutions to the coherence problem. The first is to articulate a detailed, falsifiable theory of attributes of the self-schema supporting the Big Five, e.g., perceptions of vulnerability (neuroticism) and perceptions of social agency and well-being (extraversion). Theory can also accommodate contingent and culture-bound elements of the self-schema. Coherence may emerge from lower-level neural and cognitive processes that are not themselves coherent, supporting a compelling but in a sense illusory unitary self. In the case of anxiety, multiple, independent biases in threat processing might contribute to nudging the self-schema towards a sense of being vulnerable to threat, but they do not necessarily operate as an integrated unit. The same issue may apply to multiple neural mechanisms that collectively influence processing-level constructs such as working memory and vigilance (cf., Langner & Eickhoff, 2013).

Proponents of the FFM are unlikely to accept this solution because of its strong assumption that the Big Five are exclusively biological constructs (McCrae & Costa, 2008). In addition, the knowledge level represents a rather weak level of explanation due its detachment from causal mechanisms (Pylyshyn, 1999). Coherent process-based Big Five traits could perhaps be inferred from content-based questionnaires, but issues of emergence and the limits of introspection make the inductive process problematic. One strategy is to use questionnaire data as a source of hypotheses that can be more rigorously tested using a deductive approach. For example, we could identify core beliefs that are central to trait anxiety, hypothesize an organized set of computational processes congruent with those beliefs, and conduct studies to determine if variance in that coherent process set, objectively assessed, actually influences the self-schema. Current cognitive science addresses how theories based on computational models and on rational, knowledge-level principles may constrain one another (see Cooper & Peebles, 2015), but the issue is beyond the present scope.

Overall, there is thus a tension between coherence and universality. We can have a coherent account of a limited part of the personality universe, but coherence is lost as the scope of theory is increased to include a greater range of phenomena, mitigating against a general consensual paradigm. In the next section, I consider a possible solution to the problem, which offers a novel solution to the coherence issue.

5. A cognitive-adaptive framework for theory integration

5.1. The case for explanatory pluralism

To summarize, a consensual paradigm faces the following challenges that may require continued acceptance of diversity in theories of traits:

- *Content and process*. Standard trait assessments assess both fundamental parameters of cognitive and neural processes (QAPs) and acquired declarative and procedural knowledge, in unknown admixtures. Process and content models imply different types of explanatory construct.
- *Adaptation to the environment*. Personality in part reflects internalized regularities of the environments experienced by the person and the skills acquired to manage those environments adaptively. The contingency of these skills on the sociocultural environment precludes the existence of a universal periodic table of traits – unless those traits are strictly process-based and content-free.
- *Complexity of trait expressions*. Major traits are associated with a multitude of neurological, cognitive, social and wellbeing correlates. Even within a single level of explanation in the trilevel framework, this level of complexity makes it hard to identify a set of processes that mediate associations between the trait and its various expressions. Complexity may doom the search for "master-processes" such as arousability or reinforcement sensitivity.
- *Commensurability of explanatory constructs*. Traits are distributed between as well as within levels of explanation. The constructs used by neurological and cognitive theories do not map into each other in any simple way, limiting any possible universal theory. There is scope for theory development that crosses explanatory boundaries but there are few exemplars for personality research.
- *Coherence*. The distributed nature of traits threatens the core assumption that traits are integrated neuropsychic entities. If a trait constitutes multiple, largely unrelated biases in diverse elements of processing, the whole is not in fact greater than the parts. Paradigms are necessarily limited to important but limited domains of personality such as aspects of neural functioning, and the self-schema.

5.2. The cognitive-adaptive theory of traits

Pragmatically, there is little immediate prospect for abandoning current lines of research in favor of a notional consensual paradigm. Multiple, parallel theories at different levels of explanation will be needed for some time to come. That is, personality research should accept explanatory pluralism, which promotes multi-theoretical approaches (McCauley & Bechtel, 2001). Whether a unitary theory is ever possible is essentially a question about reductionism, pitting hardline neurological theorists against those who point to the barrier to reductionism thrown up by the emergent properties of complex systems. Explanatory pluralism proposes that for some but not all research issues, concepts from different levels of theory can be satisfactorily mapped allowing limited, local theory integration and reduction (McCauley & Bechtel, 2001). For example, connectionist models might support an integrated specification of neural and cognitive architectures (Matthews, 2008; Matthews & Harley, 1993).

Accepting explanatory pluralism, the Cognitive-Adaptive Theory of Traits (CATT: Matthews, 2008, 2016, 2018) provides a conceptual framework that inter-relates multiple, incommensurate theories and defines coherence for distributed traits. Typically, personality theories identify coherence on a *structural* basis, by identifying traits with specific organized systems, whether brain systems for arousal and motivations, or self-knowledge organized as a schema. CATT identifies coherence with *function* not structure. That is, traits are associated with a set of processing characteristics, which may be unrelated to one another, but support a common, broad, adaptive goal.

For example, the anxiety/neuroticism dimension represents contrasting strategies for threat management. High scores favor early detection, anticipation, and avoidance of social threat, whereas low scorers prefer direct response to salient threats only (Matthews, 2004a). The adaptive goal of anxious individuals is supported by processes defined at different levels of explanation: neurally-based sensitivity to punishment signals, selective attention to threat, and a self-schema representing vulnerability and avoidance motives. Multiple processes at the same level of explanation are accommodated. Multiple, distinct threat biases support the common early threat-detection goal. Adaptation is also supported by content: selective attention to threat reflects learned, proceduralized skills, as well as processing-level biases (Matthews, 2008; Wells & Matthews, 2015). Other FFM traits can be related to strategies for handling demanding social situations (extraversion-introversion), cooperation vs. competition (agreeableness), sustained effort vs. opportunism (conscientiousness), and reliance on intellect over received wisdom (openness) (Matthews, 2008).

5.2.1. *The adaptive triangle*

CATT also adopts a dynamic view of person-situation interaction. Central to the theory is the adaptive triangle linking skill, self-knowledge and behavior, illustrated for anxiety/neuroticism in Fig. 2. Stable parametric characteristics of the neural and cognitive architectures (QAPs) bias acquisition of contextualized procedural and declarative skills congruent with the adaptive goals associated with the trait. In CATT, skills are a more direct influence on adaptive outcomes than basic processing parameters (Matthews, 1999). Skills are reciprocally related to elements of self-knowledge congruent with the skill. For example, one attribute of anxiety is rejection sensitivity. Some individuals are especially aware of cues to social rejection by significant others (Berenson et al., 2009), conceptualized here as a skill promoted by selective attention to social threat. These people experience a social world where even close friends can seem critical and hostile. This experience will in turn shape elements of self-knowledge, such as beliefs that one deserves rejection, negative beliefs about others, and motives to avoid being exposed to rejection. Negative emotions are seen here as primarily driven by self-knowledge, consistent with transactional theory (Lazarus, 1999). Self-knowledge may feed back to influence further skill acquisition; the person may be motivated to actively search for rejection cues. Note that "skill" here simply refers to the computational machinery, which may or may not deliver accurate and adaptive outcomes. Note too that accuracy and adaptiveness may diverge; there may be benefits to neglecting occasional, low-magnitude rejection cues from significant others. In severe cases, such as in avoidant and borderline disorders (Berenson et al., 2009), therapy could be directed towards interrupting the positive feedback cycle.

5.2.2. *Cognitive-adaptive perspectives on diversity in personality theory*

Importantly, CATT is a framework that accommodates multiple theoretical perspectives and it is not claimed to be a possible consensual paradigm. However, it does address the five issues identified above as problematic for theoretical consensus, as follows:

- *Content and process*. CATT acknowledges that traits have both process and content elements. In the case of anxiety, these include multiple neurological and cognitive QAPs that enhance threat sensitivity, as well as proceduralized skills and relevant elements of the self-schema. Threat management is a universal and important human challenge, so anxiety dimensions will always be obtained in studies of dimensional structure. However, cultural variation in social threat ensures that anxiety dimensions found in different populations do not necessarily align exactly, i.e., meeting strict measurement invariance criteria (Church, 2016).
- *Adaptation to the environment*. CATT highlights that the correspondence of the content elements of personality with the person's model for their relationship with the world, and with skills for managing real-world challenges. Major traits thus correspond to strategic variation in handling challenges common to all modern cultures associated with Power, Love, Work, Affect, and Intellect (Goldberg, 1990). The specific functional goals linked to each trait match the environments within which those goals can be accomplished. Contexualized traits are linked to more specialized challenges. Thus, matching content traits to environmental adaptations is critical for theory.
- *Complexity of trait expressions*. CATT was designed to accommodate complexity, given that traits are identified with sets of processes of various types, rather than with any single process.
- *Commensurability of explanatory constructs*. Adaptation depends on processes at multiple levels of explanation. An effective early warning "radar" for threat capitalizes on innate brain systems, symbolic information-processing, and schema-driven search and analysis simultaneously. Different threat detection mechanisms may require different levels of theorizing but they serve a common adaptive goal. Thus, CATT provides a means for integrating functionally correspondent processes in the (current) absence of an integrated process-level theory.
- *Coherence*. The functional perspective of CATT identifies the source of trait coherence as the overarching adaptive goal of the trait, and associated strategies for goal attainment, not as any structural system of the brain or mind.

6. Existing theories from the CATT perspective

CATT suggests how the scope of leading theories might be more clearly demarcated. Psychobiological theories already investigate stable individual differences in parameters of neural functioning (Pickering, 2008). CATT emphasizes the need to complement the basic neuroscience with deeper investigation of the consequences of those individual differences for content traits and adaptation to the external environment. Assuming we can measure stable individual differences in punishment sensitivity, how does that trait basis acquisition of context-sensitive skills for managing threat and harm? Are some skills or environmental challenges especially dependent on punishment sensitivity? How does the biological attribute shape higher-level self-knowledge? CATT also calls into question the utility of questionnaire assessment of parameter traits. If questionnaires typically assess content more than process, then utilizing questionnaires to predict content-related outcome measures risks criterion contamination. A priority for this approach should be the development of objective trait scales based on neurological assessments.

A similar argument can be applied to stable individual differences in processing parameters (QAPs), such as the attentional correlates of trait anxiety (Wells & Matthews, 2015). Relevant theories such as ACT

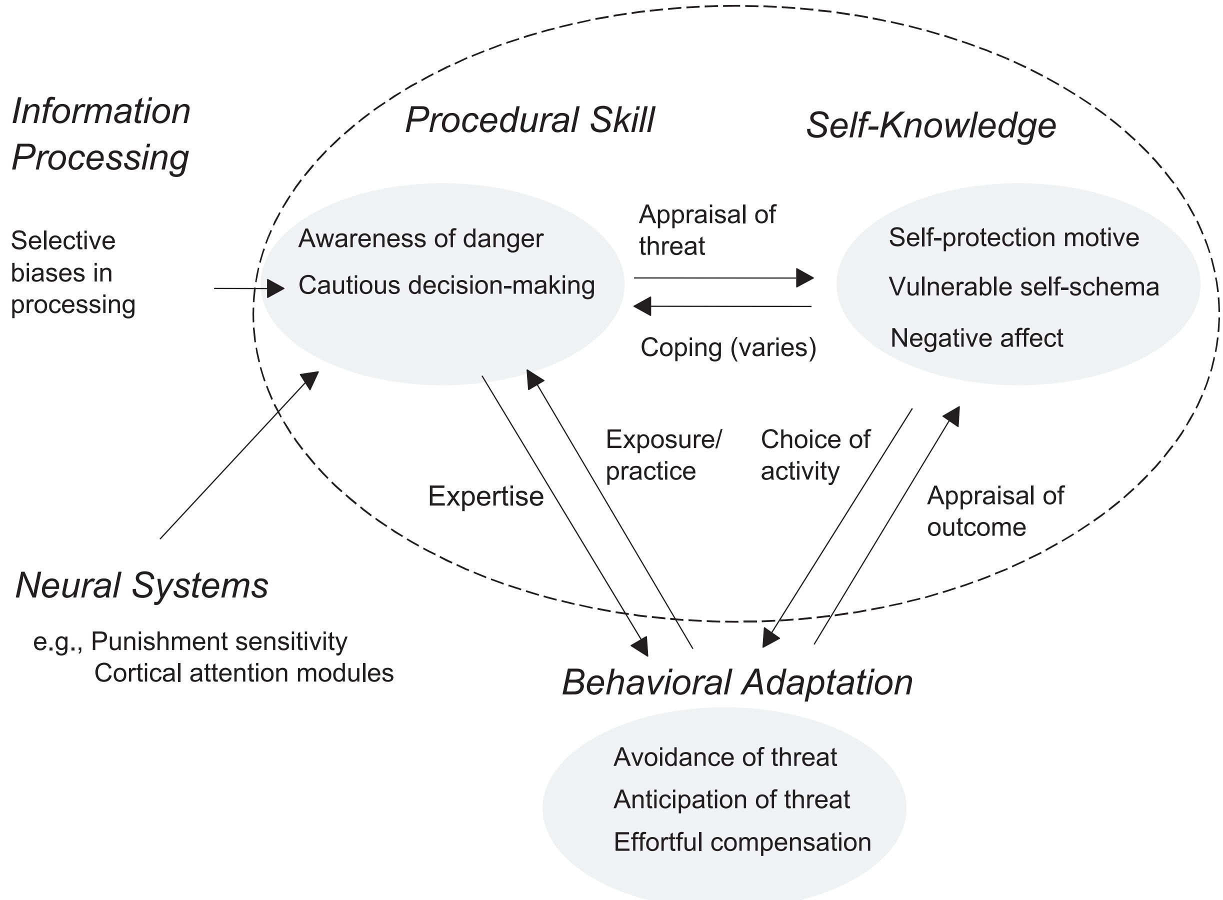

Fig. 2. A cognitive-adaptive model for neuroticism/trait anxiety.

(Eysenck & Derakshan, 2011) have an inductive, working-backwards flavor. Research begins with trait measurement and then seeks correlated processes on the basis of a loose equivalence between trait and process definitions, i.e., both appear to involve threat-sensitivity. CATT suggests the value of investigating feeds bias in QAPs might feed forward into the elements of the adaptive triangle, i.e., actual skills and competencies, self-knowledge, and contextual behaviors. That is, a developmental perspective on the consequences of individual differences in bias over time would be valuable. Evidence for changes in trait anxiety and allied dimensions following training on selective attention tasks points towards the direct role of processing bias in the trait (Grafton et al., 2017). By rough analogy with the use of polygenic scores to assess contributions to intelligence from multiple genes (Plomin & Deary, 2015), work on consequences of information-processing differences could be based on an aggregate measure of threat-processing bias, irrespective of correlation between individual processing measures.

CATT also suggests research strategies for investigating processing bases for established traits such as the FFM. Such traits are unlikely to be isomorphic to brain systems because they are assessed via content-laden self-reports. A deeper understanding of the FFM might start with treating the Big Five as knowledge-level constructs, and investigate them as aspects of the self-schema, systematically distinguishing beliefs, attitudes, motives, values, and self-regulatory strategies. Further work to complement representational with mechanistic explanations, in Pylyshyn's (1991) terms, would require efforts at integration of knowledge and computational constructs. General traits correspond to broad-based skills that are deployed in multiple though not all contexts, such as getting to know a stranger, making decisions under time pressure, or regulating one's negative emotions. Quite how such generic skills should be defined remains an open question; Scherer's (2007) notion of competencies as intermediate to abilities and specialized skills provides a starting point. Anderson's (1987) cognitive skill theory defines weak-method problem solutions as generalizable strategies that require integration with domain-specific knowledge to be effective. A trait-anxious person might possess a general competency or production system for parsing speech for subtle indicators of hostility. The adaptive value of this competency would depend on its accuracy of tuning to different social environments, and its behavioral outputs.

Thus, CATT takes no position on central planks of existing theory, e.g., whether extraversion reflects arousability or reward sensitivity. It does clarify which phenomena any given theory should seek to explain, and it suggests that the role in personality of broad-based skills and the environments has been neglected.

7. Advantages and limitations of the cognitive-adaptive perspective

The principal advantages of CATT are that it provides a framework for inter-relating multiple qualitatively different personality theories and a novel, functional perspective on trait coherence, as already discussed. It also illuminates theoretical directions that have been neglected including the influence of traits on acquisition of important life skills and the matching of traits to adaptive challenges. It may also help avoidance of category errors in theory development such as inappropriate matching of trait constructs to process (Matthews, 2016) or confusing content with process. One such error is assuming trait and state structures are directly correspondent. Traits and states cohere around different sets of adaptive challenges and thus factor structures differ qualitatively (Matthews & Zeidner, 2004).

CATT also resolves the causal status of traits (Matthews et al., 2009). In some instances, behavioral expression of traits is a direct consequence of the functional attributes of the trait concerned. For example, extraversion can be seen as a causal influence on talkativeness in a gathering of strangers, even though the extraversion – verbal behavior may be mediated by multiple processes (Matthews, 2008). In other cases, behavioral correlates may be a side-effect of a specific parameter contributing to the trait rather than a direct functional expression, and causality should be attributed to the specific process rather than to the trait itself. Semantic priming effects associated with extraversion are an example (Matthews & Harley, 1993). CATT also suggests a more theory-driven approach to applications of personality research. For example, metacognitive theory for emotional disorder is based on a model of the cognitive architecture that specifies the role of metacognitive processes in maintaining negative emotion and worry (Wells & Matthews, 2015). Finally, CATT is compatible with recent evidence that traits are more malleable over the lifespan than generally appreciated (Roberts et al., 2017). Trait change may be associated in part with changes in skill prompted by environmental change, and changes in exposure to environments requiring relevant skills, as well as maturational changes at the QAP level.

A limitation of CATT is that it does not yet provide an integration of theories at different levels of explanation. It does point towards issues for which integration would be especially valuable. For example, it is assumed that neurological individual differences influence cognitive architectures for skill, calling for network models that are both neurologically informed and capable of generating computational-level constructs (Scherer, 2009). Similarly, the interplay between skill and self-knowledge of the adaptive triangle calls for integration of computational and knowledge level constructs (see Cooper & Peebles, 2015). Another limitation is that methods for determining the adaptive core of traits are limited. CATT was inspired in part by Lazarus' (1999) transactional emotion theory, in which basic emotions are identified with a core relational theme that defines the relationship between the person and the environment. For example, anxiety is "facing uncertain, existential threat". However, neither core relational themes nor broad adaptive goals and strategies are readily measurable, and some methodological innovation and deeper investigation of motivational factors in personality may be necessary.

8. Conclusion

It is premature to consider a consensual paradigm for all personality trait research so long as major theories utilize constructs at different levels of explanation. The prospects for an integrated theory depend on the scope for integrating constructs across and within levels, and those prospects are difficult to anticipate. In the meantime, CATT provides a framework for co-existence of multiple theories, for optimizing theories at different levels, and for CATT also sets priorities for integrating theories across levels. For example, parametric theories should be true to their "deductive" nature by measuring traits as quantitative parameter sets using objective data. Content theories should acknowledge that trait constructs are not direct assessments of process parameters and focus on the longer-term mechanisms through which processing variation builds differing content at multiple levels. Echoing Fodor's (1974) advocacy of disunity in science, it is concluded that a diversity of rigorous theories is preferable to premature consensus.

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