Chapter 4
General Models of Individual Differences in Cognition: The Commentaries

Philip Corr, William Revelle, Joshua Wilt, and Allen Rosenthal

1. Which brain systems are critical for understanding systematic individual differences in cognition?

Philip Corr

The answer to this question depends upon one's theoretical orientation. I favour a broad-brush approach in the tradition promulgated by Hans Eysenck and others which lays stress on thinking of personality not as yet another separate faculty of mind but rather as the outcome of the functioning of crucial brain–behavioural processes/systems, with individual differences in the operating parameters of these processes/systems giving rise to what we call "personality" – the grand learning theorist, Hull, made essentially the same point many years ago (his approach stimulated Eysenck to develop his first causal theory of personality in 1957). This perspective sees "personality" as the flip-side of the brain–behavioural coin, including its cognitive components. Which brain–behavioural systems are crucial to individual differences in cognition? According to Corr (2007), crucial systems for personality show the following characteristics: (1) they exert pervasive and significant influences on psychological functions; and (2) they serve to differentiate people in terms of habitual forms of behaviour. In addition, the systems involved in systematic variations in behaviour, emotion and cognition that correspond to crucial underlying brain–behavioural systems must also show: (1) significant polymorphic variation in the population; and (2) stability over time.

As so many systems are now suspected of having a polygenic basis, the door is left wide open for many brain–behavioural systems to contribute to systematic variation in personality; however, there are some major systems that should attract our attention when trying to construct the foundation for a comprehensive causal model of personality, including its cognitive parts. A good example of this approach is seen in the postulation of three neuropsychological systems, related to emotion, motivation and learning, namely, Jeffrey Gray's reinforcement sensitivity theory (RST), which argues that it is individual differences in the operating parameters of these basic and necessary systems that gives rise to the foundations of personality, both human and non-human, healthy and abnormal (Corr, 2008). At this level of analysis, appraisal (primary and secondary) processes of motivationally significant stimuli are crucial, as seen in the effectiveness of cognitive behavioural therapy to restructure interpretation of events. Built upon this basic cognitive–behavioural architecture is the panoply of related cognitive processes involved in decision-making, categorisation, semantic processing, inhibitory processing, etc., as well as the cognitive processes involved in the generation and processing of the contents of consciousness.

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The above answer points not just to specific cognitive systems – which, in the normal course of events, will only ever be exposed fully by careful research – but to where such research should be focused. This theoretical disposition helps render viable the possibility of unifying the two major schools of psychology, showing that the experimental approach and the differential approach are mutually compatible and, indeed, complementary ways of viewing the flip side of the same brain–behavioural processes/systems, including the full array of cognitive components involved in personality and individual differences.

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Although we prefer to leave this discussion to others, it is worth mentioning the important data of Aljoscha Neubauer (this volume, see also Neubauer & Fink, 2009) and others who have shown that levels of brain activation should not necessarily be considered direct measures of cognitive functioning, as high ability is associated with *less* activation of specific cortical regions than is lower ability. In addition, the broad pattern of activation seen when doing complex cognitive tasks thought to involve working memory might be associated with the increased effort involved, rather than specific increases in the functioning of memory systems.

2. What is the proper direction of causation: do individual differences in traits (personality and ability) influence cognitive processes or do variations in cognition determine traits?
and
3. To what extent can cognition (as a common ground) constitute a missing link between temperamental and abilities facets of "personality" as broadly understood?

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The framing of this question encourages a form of perspective bias, and begs the question as to what is meant by "personality", especially the meaning of a personality *trait* and the implication that a trait may be separated from cognition in some meaningful way. Framed thus, this may not be the most helpful way to try to understand the relationship between personality (or ability) and cognition.

Systematic individual differences in important brain–behavioural systems, including those of the "cognitive" variety, most likely reflect a complex hierarchical arrangement, with basic defensive and approach systems at the bottom, and more cognitive systems towards the top. The distinction between automatic and controlled processes may be especially significant here. Assuming that we have solved the problem of how off-line (controlled) and on-line (automatic) processes interface – and this assumption might be no more than a promissory note written on a bank with an empty safe – it is probable that environmental factors determine whether traits influence cognitive processes or cognition influence traits. To answer this question properly would require the formulation of a model of personality–cognition–behaviour, and then fair and adequate tests of it. I doubt whether once we have achieved this level of theoretical sophistication, we would continue to ask questions about how "individual differences in traits (personality and ability) influence cognitive processes?" – for how do we know that cognitive processes are not part and parcel of these traits – or how "variations in cognition determine traits?" We might, instead, want to talk about how fundamental brain–behavioural systems interact in the production of specific forms of emotion, cognition and behaviour under specific ecological conditions (e.g., dealing with an aggressive predator vs. playing chess). Seeing nomothetic processes/systems and individual differences as flip sides of the same coin negates this question – at least, in the specific form it is expressed – and may point to the true nature of traits and cognition as one integrated psychological package (see McNaughton & Corr, 2008a, b).

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The direction of causation is between the basal (trait) level and the momentary state. A useful distinction to make is between traits (characteristics of individuals over time) and states (characteristics of individuals at a particular moment). Traits may be conceived: (1) as rates of change in states as a function of situations; or (2) as probabilities of being in a particular state in a particular situation. State levels vary from moment to moment and from situation to situation and are positively correlated with trait level. For example, the trait of anxiety is seen in a rapid increase in state anxiety when in a threatening situation; the trait of cognitive ability is a rapid movement through a problem space when confronted with a cognitive task; the trait of extraversion reflects a more rapid attainment of a sociable state when presented with social cues. Cognitive processes are not uniform but rather vary as a function of the current level, availability, and allocation of cognitive resources. That is to say, they are state variables. Pure measures of latent ability are impossible to attain for the observed output reflects ability as well as resource availability and allocation which in turn reflect individual differences in cognitive ability as well as such non-cognitive personality variables as impulsivity or anxiety. For instance, although chiefly a function of cognitive ability, complex cognitive performance on tasks similar to Graduate Record Exams show systematic and replicable patterns of interactions between trait levels of impulsivity, time of day, and levels of caffeine induced arousal (Revelle, 1993; Revelle, Amaral, & Turriff, 1976; Revelle, Humphreys, Simon, & Gilliland, 1980). Trait anxiety interacts with time pressure and task components (affecting both attentional and memory load) to affect problem solving on complex geometric analogies (Leon & Revelle, 1985). Cognitive resources may be depleted through sleep deprivation (Broadbent, 1971), time of day (Revelle et al., 1980), or through social interaction (Richeson & Trawalter, 2005). Our model of how energetic and directional components of motivation affect short term memory and sustained information transfer (attentional) aspects of cognitive processing (Humphreys & Revelle, 1984, Revelle, 1993), although complex, probably underestimates the complexity of the personality–motivation–cognition relationship.

Traits and their corresponding states are encompassed in our definition of personality writ large. In our chapter and elsewhere (Ortony, Norman, & Revelle, 2005; Revelle, 2007; Wilt & Revelle, 2009); we define personality as the coherent patterning of affect, behaviour, cognition and desire (ABCDs) over time and space. Both temperamental (e.g., extraversion) and ability (e.g., intelligence) traits are thus conceptualised as being composed of different ABCD components – the example of extraversion's ABCD components is elaborated in our chapter. From this view, it is possible that shared cognitive components – in addition to affective, behavioural, or motivational components – account for the overlap and thereby forge a common ground between temperamental and ability traits. Unfortunately, theoretical and empirical scrutiny of the cognitive processes included in non-cognitive traits is uncommon. We are thus heartened by the efforts of Kaczmarek, Strelau, & Miklewska (this volume) to discuss how temperament and ability traits relate to cognitive processes. We are especially intrigued by the idea that the overlap among temperament and ability traits may be accounted for by shared cognitive processes. This theoretical position may be especially helpful in unpacking the relationship between the personality trait of openness (or intellect) and the ability trait of general intelligence (Revelle, Wilt, & Rosenthal, this volume). Borrowing from Kaczmarek and colleagues' reasoning about why the Pavlovian trait of mobility should be related to intelligence, we hypothesize that openness/intellect and intelligence are both related to speed of processing as well as working memory capacity. Open and intellectual individuals' enjoyment of complex cognitive tasks (Costa & McCrae, 1992; Goldberg, 1990) suggests that openness may comprise superior cognitive resources. We encourage further investigations into this hypothesis specifically, and we also call for the more general application of Kaczmarek and colleagues' framework for thinking about traits and cognitive processes.

4. How do individual differences in trait variables compare with individual differences in state variables as predictors of cognitive performance?

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Traits typically refer to the distal *potential* for activation and behavioural output (e.g., emotion, cognition or behaviour); in contrast states typically refer to proximal *output*, reflecting the interplay of trait potential and environmental demands, as well as being influenced by the moment-by-moment temporary fluctuations of the neuroendocrine system. It would be tempting to say that traits refer to more basic (relatively automatic) reactions, while states reflect the complexity of trait x situation interactions, and they may well be some value in making this distinction. However, traits reflect operations at all levels of the brain–behavioural control hierarchy, from basic automatic reflexes to controlled and conscious processes. In complex, unfamiliar, or otherwise problematic environments, flexibility, deliberation and control of behaviour is necessary and here we see the evocation of higher-level cognition, which in its grandest form is experienced in the medium of conscious awareness. In terms of this perspective, states relate to outputs, where simple or complex, singularly or multifactorially determined.

There is a potential problem with the definition and operationalism of state *measures*, which are found often to relate best to cognitive processes and performance, and, arguably, often for a rather trivial reason: the proximal (theoretical and temporal) association of the two sets of variables (state predictors and performance outcomes). For example, a close association of states and cognitive performance is seen when state measures are specifically designed to measure the very cognitive processes they purport to "predict". For example, it should come as little surprise that state measures of worry "predict" interference in cognitive processing, or that negative self-schema "predict" cognitive performance on a semantic decision task with self-referential words. State measures can be useful in delineating and describing the component processes involved in cognitive performance, but often their causal status is confused, or at least ambiguous.

The primary function of personality is to predict future behaviour (and its related components) on the basis of variation in major brain–behavioural systems; the more pervasive the power of prediction, the more impressive the system (or "trait") – when these traits (e.g., anxiety) predict, and help to explain, the genesis of major psychological phenomena (e.g., clinical anxiety) then the trait may, with sufficient justification, may be awarded a rare status. Importantly, it is necessary for theory to state *how* and *why* the trait leads to the psychological outcome – the RST of personality (Corr, 2008), is one example of this desideratum.

Trait variables are usually, indeed, intentionally so, more broad-based than state measures – this latter feature reflects their temporal and theoretical proximity to target performances indicators – designed to predict a wider range of behaviour. However, the price paid for this wide-frame angle is less specificity and more statistical error. The empirical trick is to achieve a balance between trait generality and state specificity, not losing sight of the requirement that traits predict behaviour in ways that go beyond mere proximal homology. Trait theory also needs to show how trait *potential* is expressed in *state* activation; that is, a theory of *process*.

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Strong prediction marries the breadth of the predictor with the breadth of the criterion. The broader the criterion measure, the broader the predictor variable needs to be (Wittmann, 1990). Trait variables are distal predictors while state variables are proximal. That is, even the most able person, when sleep deprived or distracted by emotionally salient cues, will show decrements in cognitive functioning. To predict cognitive performance in a particular situation (say a brief cognitive task in a lab), we need to know the trait levels of ability (e.g., working memory capacity, the content of procedural and semantic memories), impulsivity and anxiety, but more importantly, state levels of energetic and tense arousal, task engagement, and potential distractors. As we predict broader performance (e.g., class room performance in physics over the year), the state variables become less important and higher level ability factors (spatial reasoning, working memory capacity) become more important. But to predict the cumulative performance over several years, we also need to know the non-cognitive variables of consciousness and typical intellectual engagement as well as openness (Ackerman & Heggestad, 1997; Revelle, 1987; Roberts, Kuncel, Shiner, Caspi, & Goldberg, 2007).

5. Should the models of individual differences in cognition differ for conscious and unconscious information processing?

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Information processing models of cognition have tended to eliminate consciousness by ignoring the subjective nature of much of psychological phenomena. In one sense, this has had a major benefit, namely, the formulation of formal models that have not get lost in the theoretical fog surrounding issues of consciousness. In another sense, this widespread disinterest in conscious awareness and experience has resulted in cognitive models that do not tally well with the psychological phenomena of conscious experience that simply no one would deny are important in their own life! (Often, though, these same people consider that it is not terribly important in the lives of their experimental subjects, at least as it pertains to the theoretical models they are testing.)

The gulf between models that lay different emphasis upon the importance of conscious experience is seen in two, hitherto separate, cognitive domains: cognitive psychology and cognitive therapy. Cognitive psychology tends to focus on processes, often described in some form of boxology or consciousness-free zone of associative networks; in contrast, cognitive therapy focuses on the subjective nature of depression, anxiety, etc., specifically its meaning to patients, and the underlying cognitive processes that are, at least in principle, amenable to conscious processing and self-report. (Recent years has seen a productive rapprochement of these two approaches.)

The fact that the *output* of conscious processing is open to introspection and self-report is itself first-person datum; this datum is of a very different quality to the third-person datum of standard cognitive processing models. However, underlying conscious and unconsciousness information processing may not be different, and we should expect that it uses the same neural "code". The problem is how do we index the two systems, something which is not so easily achieved in the case of unconscious processing – although the latter may be indexed by consciously performed tasks (e.g., the Jacoby exclusion task). One major obstacle to the construction of information processing models is the ever-presence of rarifying consciousness, by giving it privileged status beyond its causal importance. As seen in the Corr chapter, what we experience consciously (i.e., contents of consciousness) is only one part of ongoing processing, and then only a partially accurate representation of prior (~100 ms) neural activation (different neural activation is, of course necessary to instantiate the medium of conscious awareness in the first place). Specifically, all conscious processing is prepared and initiated entirely unconsciously – including that involved in generating conscious awareness itself – so what we experience in the medium of conscious awareness is not veridical of the world (but there is usually a good enough physical–psychological correspondence for this discrepancy not to matter too much for everyday concerns – although this illusion is of great import to the scientist).

When constructing causal models of brain–cognitive processes, the lateness and partiality of conscious awareness needs to be fully respected and incorporated into any model that purports to capture the essential features of conscious experience on which so much of personality data rests. However, it should be doubted whether the nature of information processing is fundamentally different in unconscious and conscious processing – at least this is a sensible starting point. (However, it has to be freely admitted that our ignorance of the neural and cognitive processes involved in the generation of conscious awareness is so great that we should be at liberty to entertain other accounts of conscious information processing, including more exotic accounts such as those related to quantum physics; see Gray, 2004.) No theoretical doors need to be closed; and certainly none securely bolted.

A useful way to start to approach the problem of conscious vs. unconscious processing is to think in terms of a hierarchically arranged set of brain–behavioural modules, that takes into account both the first-person (experienced and self-reportable) and third-person (experimental data) perspectives in ways that achieve some harmony between these respective accounts. In a fundamental sense, the *process* of cognition (both unconscious and conscious), and individual differences therein, must be separate from the *output-content* of cognition which contains the *qualia* of experience divorced from the necessary prior processing; and, furthermore, this differentiation needs to be separated from the cognitive processing involved in the generation of the medium of conscious awareness itself.

Although it is not possible at this stage to state, with any degree of confidence, the nature of unconscious vs. conscious information processing, it is time to take seriously the data we also have in our possession concerning the lateness of conscious experience and other issues surround the experience of consciousness. Only once we have a firm grasp on the problems at hand will we be in a position to start providing psychologically valid models of information processing.

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Corr's theory of the functional relationships between unconscious and conscious processing (this volume) may be useful in clearing up the current debate over whether and when individual differences in unconscious and conscious processes are related to each other (Fazio & Olson, 2003). Corr draws from Jeffrey Gray (1982) in proposing that unconscious or on-line processes govern information processing until a comparator detects a discrepancy between actual stimuli encountered in the world and expected stimuli. The comparator registers the discrepancy as an error and engages conscious processes, which subsequently work to modify the error and thus adjust on-line processing. As such, this model predicts that unconscious and conscious information processing should be more closely related in particular domains in which conscious processes are frequently engaged and thus have had more opportunities to modify unconscious processes. This prediction fits well with empirical evidence suggesting that (a) implicit and explicit attitudes are more closely aligned when individuals have more experience with targets of evaluation (Nosek, 2005), and (b) implicit and explicit anxiety biases are more closely related in more anxious individuals (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Ijzendoorn, 2007).

Corr goes on to offer the example of how neurobehavioral systems related to RST might work in concert to bring about conscious processing as just one of the many possible ways that conscious and unconscious processes interact. We offer a more general metaphor for such interactions by considering the graphical user interface (GUI, e.g., desktop screen) of a computer as akin to conscious information processing and the software running on the computer as unconscious information processing. The GUI represents the applications that are currently available for direct usage in a similar way to how people represent stimuli that are currently available to consciousness. The processes of the computer software cannot be perceived by interacting with the GUI and continue uninterrupted until an error is detected. At this point, the error may be displayed on the GUI, similar to how an error-detection mechanism engages consciousness.

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