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Cognition and personality: an analysis of an emerging field

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It is now well established that individuals can differ consistently in their average levels of behaviour across different contexts. There have recently been calls to apply the same adaptive framework to interindividual differences in cognition. These calls have culminated in the suggestion that variation in personality and cognition should correlate. We suggest that both these appealing notions are conceptually and logistically problematic. We identify the first crucial step for establishing any cognition–personality relationship. This is to determine the degree to which cognitive abilities yield consistent task performance. We then suggest how to establish whether such consistency exists. Finally, we discuss why formulating predictions about how cognition might be related to personality is much more difficult than is currently realised.

Relating cognition to personality: an introduction to the problem

There has been a recent explosion of interest in quantifying consistent individual differences in behaviour (see Glossary), exploring their adaptive significance, and describing the mechanisms responsible for their maintenance [1–6]. As a result it is now well established that a broad range of species show consistent within-species interindividual variation in a range of behaviours such as aggressiveness, boldness, exploration, activity, and sociability [7–12]. By contrast, there has been much less work to establish whether species show consistent within-species between-individual variation in cognitive abilities such as attention, learning, and memory. Nevertheless, researchers are now attempting to relate consistent individual differences in personality to individual differences in cognition, both theoretically (e.g., [7–9]) and empirically [13–22]. As potential key determinants of interindividual variation in behaviour and its associated evolutionary and ecological consequences, we consider the investigation of the possible relationships between cognition and personality to be an important research endeavour.

Although a relationship of some type between personality and cognition is intuitively appealing, we are concerned, however, that because cognitive ability of one kind

Glossary

Animal personality: defined as differences between individuals' average level of behaviour that are repeatable across time and/or contexts [6]. Defined statistically as variation between individuals in the intercept of their behavioural reaction norm [42] or the existence of between-individual (co)variance in behaviour [44].
Appetitive conditioning task: a Pavlovian conditioning task in which one cue is associated with a second, desirable cue (e.g., food).
Aversive conditioning task: a Pavlovian conditioning task in which one cue is associated with a second, undesirable cue (e.g., mild foot-shock).
Behaviour: the motor actions performed by an animal. Changes in behaviour are the phenotypic representation of cognition.
Behavioural reaction norm: the function describing the relationship between the behavioural phenotype and environmental gradient within the same individual. We focus here on within-individual reaction norms [42]. Within this context, cognition (e.g., learning) is one source of behavioural change.
Between-individual correlation: phenotypic correlation at the between-individual level where the individual average phenotypic responses of two traits are correlated [44]; also known as a behavioural syndrome [61].
Cognition: the mechanisms that enable the acquisition, processing, storage and use of information, which include perception, learning, memory, and decision making [23].
Cognitive performance: a quantitative measure of continuous variation in a dependent behavioural variable, which can be used to quantify a cognitive trait. For example, the number of trials an animal takes to reach the criterion level of performance on a task where the animal has to remember the distinctive features of an object.
Context: refers to the functional domain in which a test is conducted. Examples include contexts related to food, threat, and reproduction, but can also include stimulus dimensions such as social, novelty, and space.
Instrumental conditioning: a form of associative learning in which an animal learns the association between one of its behaviours (e.g., approaching a conspecific) and its consequence (being attacked).
Pavlovian conditioning: a form of associative learning in which an animal learns the association between two cues.
Personality type: used here to refer to the various degrees of a personality trait (e.g., bold vs shy). Also known as a behavioural type [61] or a temperament phenotype [6].
Plasticity: change in the behaviour of an individual as a function of changing environmental conditions; also defined as the slope of the behavioural reaction norm [44]. Cognition is one mechanism underpinning plasticity.
Repeatability: the proportion of phenotypic variance explained by differences among individuals [42]. If repeatability is >0, a behavioural trait is considered to show some degree of consistency.
Reversal learning: the ability to change behaviour when the environment changes. Its constituents are both the ability to inhibit a previously successful behaviour and the ability to produce a second behaviour to the same stimulus.
Training to criterion: the training on a learning task that an experimental subject receives before that subject reaches a pre-established criterion of performance, at which point it is considered to have learned the task. For example, when on 8 of 10 successive trials the animal selects the correct cue or the correct location in space.
Trait: we define a 'trait' here as the material on which natural selection can act. For a cognitive trait to be favoured it must cause an animal to change its behaviour in such a way that the fitness of the animal is enhanced.
Trial: one experience of a learning event. Examples would be: one pairing of two cues; one pairing of a cue and a consequence; one encounter of food in a given location.
Within-individual variance: amount of phenotypic variance attributable to differences in phenotype among measurements of the same individual [44].

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and/or another underpins most, if not all, behaviours, investigating this notion is a more conceptually and practically difficult task than is currently realised. The first and major challenge lies in establishing which cognitive ability underpins the performance of an animal on a task or a change in its behaviour. Only then can we begin to establish whether that performance or change, for example in the ability of an animal to learn the location of food, is repeatable. We suggest how one might approach this issue because, without first addressing it, describing what it means in practice to say that personality is related to cognition will not be possible. Lastly, we identify two factors, one of which is logistical and the other terminological, which we consider restrain progress in this endeavour.

Cognition

Cognition can be defined as the acquisition, processing, storage and use of information [23]. It encompasses a large variety of abilities, including attention, categorisation, rule learning, associative learning, behavioural inhibition, language, self recognition, and social learning, to name only a few [23,24], some of which may themselves be divisible into further subcategories.

Because cognitive abilities are not directly manifested phenotypically, their measurement is achieved through the quantification of a change in behaviour. Thus far, most animal cognition researchers have been interested in identifying and quantifying what cognitive ability(ies) cause observable changes in behaviour (i.e., the mechanistic basis of variation in behaviour). This contrasts with the aim of behavioural ecologists, who are interested in determining the adaptive significance of a trait (i.e., the functional basis for variation in behaviour). For example, the behavioural ecologist would employ a cost/benefit analysis to determine whether the optimal load size that parents deliver to their nest when provisioning their offspring varies as a function of the distance travelled to find food, whereas the animal cognition researcher would want to determine the cognitive abilities parents use to relocate their nest. Evidence for a specific cognitive ability is gathered by using experimental designs that disentangle behavioural responses attributable to, for example, computation of travel distance and direction from their point of departure, an ability known as path integration, from those behavioural responses that are attributable to other underlying cognitive mechanisms (e.g., landmark learning).

Consistent individual differences in cognition

Before we can determine whether there is a relationship between the personality of an individual and its cognitive abilities we need to identify the relevant cognitive abilities and then to confirm that those cognitive abilities cause repeatable behavioural effects. Identification of relevant cognitive abilities and problems therein has been recently discussed elsewhere, however, and we will therefore not elaborate on that issue here [25]. It may seem surprising, then, that consistency in cognitive abilities in nonhuman animals seems to have received very little attention thus far (but see [26,27]). Much of the existing work on individual differences in cognition is to be found within the biomedical sciences, the focus of which has been primarily directed at quantifying variation between genetic strains of rodents, with the view to using them as a human model [28–33].

For most other researchers investigating animal cognition, both within- and among-individual variation are considered sources of undesirable variability that contribute to masking between-group treatment effects. Indeed, considerable effort is made to reduce among-individual variation by incorporating procedures such as routine handling, habituation to test environments, and/or implementing standardised food-deprivation schedules [34].

Nonetheless, the lack of interest in variation in cognitive performance in other nonhuman animals is surprising for two reasons: (i) there is a vast body of work on repeatability in cognition in humans (e.g., [35,36] and references therein), which one might have thought would have lead to the development of nonhuman animal models to investigate the behavioural and neural sources of consistent interindividual differences; and (ii) cognition is a major source of phenotypic plasticity [37–40], and therefore interindividual differences in cognition should play an important part of any discussion of individual variation in plasticity and its adaptive nature [41–43].

Demonstrating consistent individual differences in cognition relies on researchers using the same logic used for demonstrating consistent individual differences in personality, a key feature of which is that individual differences in a given trait are repeatable across time and contexts [5,6]. For example, boldness (e.g., latency to leave shelter) is measured in the same context across two or more timepoints or in two different contexts, such as the latency of an individual to leave shelter when alone and then again when the individual is in a social group.

Similarly, showing that individual differences in cognition are repeatable requires demonstrating consistency in cognitive abilities across time and contexts. Cross-contextual consistency will require demonstrating that an individual performs similarly on two different types of task, such as reaching a given learning criterion faster (than another individual) on both an appetitive conditioning and an aversive conditioning task, on an instrumental conditioning and a spatial learning task, or on a discrimination task across two domains (e.g., auditory and visual [13]; Table 1).

In contrast to personality tests, however, whereby individuals might habituate across repeated tests (e.g., decreased exploration or decreased neophobia), when tested on a learning task individuals might reach criterion increasingly quickly across tests because they either become more experienced at solving the task or they become more motivated to gain reward across successive tests. It is important to note that it is typical when training animals how to perform on a cognitive test that all individuals are trained until they reach the same level of performance (criterion training). Demonstration of between-individual consistency in a cognitive ability requires that the rank order of the performance scores (e.g., the number of trials to criterion) remains the same across successive tests, that is, each time the animals are trained to criterion on a given task.