



## Personality predicts cognitive bias in captive psittacines, *Amazona amazonica*



Victoria A. Cussen<sup>a,b</sup>, Joy A. Mench<sup>b,c,\*</sup>

<sup>a</sup> Animal Biology Graduate Group, University of California, Davis, CA, U.S.A.

<sup>b</sup> Center for Animal Welfare, University of California, Davis, CA, U.S.A.

<sup>c</sup> Department of Animal Science, University of California, Davis, CA, U.S.A.

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The prevalence of stable behavioural differences between individuals of a species (i.e. personality) is puzzling because it indicates that there are limits on animals' behavioural plasticity and, therefore, optimality of behaviour. Personality may result from individual state characteristics (e.g. morphology or physiology). In turn, these characteristics can lead to differential fitness outcomes for individuals. Cognitive processing of environmental information may be such a characteristic. We developed a subjective personality assessment for *Amazona amazonica*. We then assessed whether personality predicted a cognitive state difference in attention bias, as measured by the proportion of barks and errors when performing a spatial foraging task in the presence of a passive human observer. Attention biases occur either because individuals attend more quickly to certain environmental stimuli, or because they cannot disengage their attention from such stimuli. Two factors, 'neuroticism' and 'extraversion', accounted for 66% of the total variance in personality. There was individual variation between parrots' scores on both personality factors and both factors were temporally consistent over 1 year. There was a significant correlation between neuroticism and attention bias. Evolutionarily, attention biases are selected for because the fitness cost of failing to attend to potential threats is much greater than the cost of expending energy attending to benign stimuli. Therefore, cognitive biases such as attention bias are logical candidate cognitive states driving stable personality differences. Our findings show that differences in personality in *A. amazonica* are correlated with attention bias, a biologically relevant difference in cognition.

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Research efforts across a range of scientific fields are investigating the evolution (e.g. Dingemanse & Wolf, 2013; Foster, 2013), fitness effects (e.g. Dingemanse & Réale, 2005; Smith & Blumstein, 2008), genetics (e.g. van Oers, de Jong, van Noordwijk, Kempenaers, & Drent, 2005) and practical implications (e.g. Carere, Caramaschi, & Fawcett, 2010; Ijichi, Collins, & Elwood, 2013; Schuett, Dall, & Royle, 2011; Weinstein & Capitanio, 2008) of intraspecific differences in behaviour that are stable across multiple contexts (Gosling & Vazire, 2002). Such differences are referred to as 'personality' in the comparative personality literature (Gosling, 2001) and 'behavioural syndromes' in the behavioural ecology literature (Sih, Bell, & Johnson, 2004). Individual personality traits can be grouped together based on the latent variables (dimensions) they reflect. Human personality traits are often explained by five dimensions, referred to as the 'big five' (Digman, 1990; McCrae & John, 1992).

Comparative personality research has identified three of these big five dimensions in animals (Gosling & John, 1999). Behavioural syndromes in animals also consist of correlated suites of behaviours (Dingemanse & Wolf, 2010). These may similarly reflect underlying behavioural organization (Wolf, van Doorn, & Weissing, 2008) akin to personality dimensions and, like personality dimensions, be generalizable across taxa (Groothuis & Carere, 2005).

The prevalence of personality/behavioural syndromes is puzzling because it indicates that there are limits on animals' behavioural plasticity and, therefore, optimality of behaviour (DeWitt, Sih, & Wilson, 1988; Sih et al., 2004; Wolf & Weissing, 2010). Our understanding of why personality types evolve and vary among individuals within a species is still limited (Wolf et al., 2008). Theoretical models suggest that between-individual state differences lead to consistent behavioural differences across time and contexts because animals adopt different behavioural strategies on the basis of their initial starting point for a particular state (Dingemanse & Wolf, 2010; Nettle, 2006). State differences can be morphological, physiological or neurobiological (Dingemanse & Wolf, 2010); examples include body size (e.g. McElreath &

\* Correspondence: J. A. Mench, Department of Animal Science, University of California, One Shields Avenue, Davis, CA 95616, U.S.A.

E-mail address: [jamench@ucdavis.edu](mailto:jamench@ucdavis.edu) (J. A. Mench).

Strimling, 2006) and growth rate (e.g. Stamps, 2007). The resultant behavioural strategies could increase fitness through increased reproductive success and/or increased survivability (Both, Dingemanse, Drent, & Tinbergen, 2005; Dingemanse, Both, Drent, & Tinbergen, 2004; Smith & Blumstein, 2008). These models generate testable hypotheses about the effect of state differences on behavioural types. For example, if a difference in body size underlies a behavioural difference (e.g. shy versus bold), then altering relative body size should also alter the animals' behavioural type.

Cognition is another putative state underpinning personality differences in animals, but this has yet to be experimentally evaluated (Dingemanse & Wolf, 2010). Because cognition is a broad term, this evaluation would require hypotheses about how specific cognitive state differences drive differences in personality. In humans, certain personality traits (i.e. anxiety) are known to correlate with altered cognitive processing of environmental stimuli, known as attention biases (Mathews, Mackintosh, & Fulcher, 1997). It is thought that this relationship is bidirectional: personality renders certain individuals more susceptible to developing attention biases during periods of stress, and such biases can then have a positive feedback on personality traits such as anxiety (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). Attention biases occur either because individuals more quickly attend to environmental stimuli, or because they cannot disengage their attention from such stimuli, or both (Cisler, Bacon, & Williams, 2009). Evolutionarily, such biases are selected for because the fitness cost of failing to attend to potentially important environmental stimuli is much greater than the cost of expending energy attending to benign stimuli (Haselton & Nettle, 2006). Therefore, cognitive biases such as attention bias for environmental stimuli are logical candidate cognitive states driving stable personality differences.

We integrated predictions generated from theoretical models with the methodology of comparative personality in order to assess the relationship between cognitive state differences and personality in *Amazona amazonica*. Psittacines are an ideal system for this question because they possess complex cognition (e.g. Emery, 2006; Huber & Gajdon, 2006; Pepperberg, Koenke, Livingston, Girard, & Hartsfield, 2013) and display consistent variability in behaviour between individuals (Mettke-Hoffman, Winkler, & Leisler, 2002), and because their longevity allows temporal stability of personality to be assessed over long periods. We developed a multidimensional personality assessment for *A. amazonica* using subjective ratings, and then experimentally tested our prediction that a state difference in cognition would correlate with personality differences. For our cognitive measure we chose to evaluate differences in attention bias during a foraging task, because this has potential implications for fitness and such biases are related to personality in humans.

## METHODS

### *Subjects and Housing*

All animal care and experimental procedures were approved by the University of California, Davis Institutional Animal Care and Use Committee (protocol numbers 15046 and 17002). We hatched 20 parrots (11 female, 9 male) from an established breeding colony of *A. amazonica*. Chicks were parent-reared with human interaction until fledging at approximately 60 days post hatch. They were then removed from the breeding colony and individually housed in wire cages (91.4 × 91.4 × 121.9 cm) in visual and auditory contact with their cohort members. Cages contained multiple perches: one softwood; one Manzanita; one concrete; one grape vine. A softwood cube for chewing and a plastic dish with water (changed

daily) for soaking food were also provided. We fed the parrots an extruded complete ration (Roudybush Lowfat Maintenance Pellets, Roudybush Inc., Woodland, CA, U.S.A.) and provided drinking water via water lines with nipple drinkers, both ad libitum.

We socialized the chicks to human contact for 15 min per day, 6 days per week. Socialization consisted of positive human–parrot interactions (e.g. feeding treats, time outside of home cage, allowing flight around the room, etc.). All chicks had additional foraging devices or toys in their cage during these socialization sessions. The socializers were the first author, another graduate student, and approximately 20 undergraduate students, and all of the parrots were exposed to all of the socializers. In addition to the unstructured socialization, we used a positive reinforcement protocol to train the parrots to respond to verbal commands, such as to move to a particular cage location. These training sessions lasted 5–10 min per bird, 3 days per week. The first author and two of the socializers conducted the training. Training lasted a minimum of 2 months, while socialization occurred throughout the study period.

### *Personality Instrument and Assessment*

The personality inventory was adapted from one developed by Gosling (1998) for spotted hyaenas, *Crocuta crocuta*. That inventory was sent to four psittacine experts and, based on the input received from three of the experts, the trait definitions were revised to be unambiguous and appropriate for parrots. The revised inventory consisted of 36 personality traits and four physical traits (see Results, Table 1) that were scored from 0 (complete absence of the trait) to 7 (extreme amount of the trait).

Two raters, the first author and one of the trainers, each completed the personality inventory twice for each bird: an initial rating and a second rating 1 week later. These ratings were carried out independently, and the raters did not discuss their ratings with one another. Ratings were based on the raters' aggregate experiences with the parrots from both the structured training and free-form socialization sessions. Raters were required to wait at least 24 h after interacting with a parrot before completing the inventory for that parrot to minimize the chance that they were biased by contextual cues or interactions that occurred shortly before they rated the parrots. The second rating allowed an assessment of intra-rater reliability. The parrots hatched over the course of three breeding cycles (Winter 2008/2009, Winter 2009/2010 and Winter 2010/2011). All initial personality assessments occurred during the autumn of 2011, so the parrots were juveniles (12–32 months of age) at the time of initial personality assessment, depending on the breeding cycle of hatch. Raters varied in the length of time they were acquainted with the parrots, but all raters had socialized and trained the parrots for at least 2 months. Ratings were absolute (i.e. parrots were not rated in relation to the other individuals in their cohort), and raters were encouraged to use the entire scale from 0 to 7 as necessary (Capitanio, 1999). For each rater, the initial and 1-week rerate scores were averaged; these scores were then averaged across raters, resulting in a composite average personality trait score for each trait for each bird, which was then used in the factor analysis. Such composite scores help to minimize measurement error (J. Capitanio, personal communication).

### *Reliability and Agreement*

For each trait on the inventory, we assessed intra-rater reliability using Spearman rank correlations comparing the results of the 1-week rerate with the initial rating. Because we used a composite trait score, inter-rater reliability for each trait on the inventory was calculated using the Spearman–Brown prophecy formula (Capitanio, 1999). In addition to assessing inter-rater

reliability, inter-rater agreement (similarity in scores between raters) was calculated using the chi-square agreement formula described in [Tinsley and Weiss \(1975\)](#).

#### *Factor Analysis and Scale Development*

We retained traits that had significant inter-rater reliability (Spearman–Brown prophecy of  $>0.5$ ) and significant inter-rater agreement (chi-square:  $P < 0.05$ ) for factor analysis. The number of factors chosen was based on examination of the scree-plot and factor loadings for the promax-rotated factor solution. Once the factor structure was determined, we calculated Cronbach's alpha for each factor to determine whether any traits should be excluded. Traits were excluded from the final scale if doing so increased the overall scale alpha, or if that trait loaded heavily on another factor. Scale scores for individuals were then calculated by summing the trait scores for a given scale.

#### *Temporal Stability*

Approximately 1 year after the initial rating, the parrots' personalities were rerated (by the first author) using the same methods described above. The average score of a single rater was used for the temporal stability assessment, due to the long interval between ratings. We used two measures of temporal stability for each scale that resulted from the factor analysis. For each personality scale, Spearman rank correlation coefficients were calculated to assess the consistency of each parrot's relative position within the flock ([Roberts & DelVecchio, 2000](#)), and Wilcoxon signed-ranks tests were used to assess the stability of the overall scale.

#### *Attention Bias Assessment*

We had previously trained 13 (5 male, 8 female) of the 20 parrots on a standardized operant task, the Hamilton search task ([Ha, Mandell, & Gray, 2011](#)); 12 (4 males and 8 females) of the 13 reached the criterion of 13/15 trials completed on two consecutive days. This task is described in detail elsewhere ([Cussen & Mench, 2013](#)). Briefly, the parrots were trained to choose one of four identical opaque containers to obtain a highly valued food reward (almond sliver). The location of the reward was randomized across trials, such that the parrots could not predict which container contained the reward on any given trial. During a single trial, the parrot could make multiple choices until either the correct container was selected or until 120 s had elapsed. We shaped the parrots to touch the container lid with their beaks to indicate their selection. Incorrect choices were followed by a 'no' response from the tester, while a 'yes' response and opening of the container followed correct choices. Of the 13 parrots, 12 (4 male, 8 female, 92%) had reached criterion on the task ([Cussen & Mench, 2013](#)). Each test session comprised 15 trials per bird. Testing was conducted in the parrots' home cages.

Intertrial interval and latency to reward were recorded using a stopwatch. The intertrial interval depended upon the time it took the parrot to consume the almond sliver and reposition to its test position. Latency to reward was the time from the initial choice until the reward was found. The number of choices was also recorded, allowing us to calculate the number of choices per second. If the parrot failed to make a choice during the 120 s trial period, the trial was considered a 'balk' trial. If the parrot made at least one choice but failed to choose the correct container during the 120 s trial period, the trial was scored as 'error'.

The parrots were tested in two testing conditions, on separate days: one condition with only the tester in the room

(baseline) and another condition where an additional, unfamiliar, human observer was present (observer present). The observer stood approximately 0.3 m behind the parrot's home cage, at a 45° angle to the rear left corner of the cage, in a passive position with gaze directed away from the parrot. The unfamiliar observer was the same individual for all of the parrots. The first author was the tester for all of the parrots in both conditions, and stood approximately 0.3 m in front of the cage. Testing occurred on two consecutive days. Half of the parrots were tested in each condition each day, and the baseline testing was conducted prior to the observed condition. Test condition order was randomized across the parrots.

For each parrot, mean intertrial interval, latency to reward and choices per second were calculated for both test conditions. Balk and error trials for each condition were summed and calculated as a proportion of total trials. Wilcoxon signed-ranks tests were performed on the intertrial interval, latency to reward, choices per second and balks and errors, for baseline and observer-present conditions. Spearman rank correlations were used to assess the relationship between personality score for 'neuroticism' and intertrial interval, latency to reward and balks and errors as well as the relationship of a single trait ('fearful') to balks and errors during the observer-present condition.

#### *Statistical Tests*

The sample size was 20 parrots for personality assessment and 12 for cognitive tests. We used the statistical package R (version 2.15.2) for all data analyses.

## RESULTS

#### *Reliability and Agreement*

Intra-rater reliability was high for all but four of the forty traits rated ([Table 1](#)). The trait 'deceitful' was consistently scored as 'not enough information to rate' by rater 1. Only three other traits failed to reach significance on intra-rater reliability: impulsive (Spearman rank correlation:  $r_s = 0.39$ ,  $P = 0.09$ ), jealous ( $r_s = 0.66$ ,  $P = 0.108$ ) and lazy ( $r_s = 0.32$ ,  $P = 0.167$ ). For the remaining traits, there was significant intra-rater reliability between the initial rating and the 1-week rerate.

Inter-rater reliabilities (Spearman–Brown prophecy) ranged from 0.54 to 0.93, and the amount of inter-rater agreement was significantly greater than chance, with chi-square  $P$  values ranging from 0.025 to  $<0.001$  across traits. Of the 40 traits measured, 19 were retained for further analysis based on reliability criteria ([Table 2](#)).

#### *Factor Analysis*

Exploratory factor analysis was used to examine the dimensions underlying the 19 retained personality traits. The scree-plot indicated either a two- or a three-factor solution. However, the three-factor promax rotated solution contained one factor with only a single trait loading onto it ('eccentric'), so we chose to use a two-factor solution ([Table 3](#)). The two-factor solution accounted for 66% of the total variance; the factor correlation was 0.54. [Table 3](#) lists the retained traits and promax-rotated factor loadings, and [Table 4](#) shows the two resulting scales, 'neuroticism' and 'extra-version', and their Chronbach's alpha scale reliability scores (0.95 and 0.93, respectively). Both factors had several uniquely loading traits, and few traits loaded heavily on both factors ([Table 3](#)).

There was a large degree of between-individual variation on each of the two scales ([Fig. 1](#)). Individual scores for neuroticism

**Table 1**  
Intra-rater reliabilities of two raters (rater 1 and 2) for 40 traits of *A. amazonica*

Trait	Rater 1	Rater 2
	$r_s$	$r_s$
Active, energetic	0.62	0.76
Affiliative, companionable	0.94	0.85
Aggressive	0.86	0.74
Bold, brave, not shy	0.84	0.90
Bullying	0.75	0.96
Calm, equable	0.73	0.85
Cautious	0.78	0.80
Confident, not insecure	0.78	0.82
Curious	0.77	0.78
Deceitful	NE	0.85
Eccentric	0.84	0.49
Excitable	0.86	0.65
Fearful	0.73	0.88
Flexible, not rigid	0.48	0.77
Friendly	0.87	0.71
Greedy	0.73	0.83
High strung, tense	0.67	0.74
Imaginative, creative	0.64	0.90
Impulsive	0.39	0.62
Intelligent	0.88	0.77
Irritable, not tolerant	0.74	0.70
Jealous	0.65	0.75
Lazy	0.55	0.32
Nervous, anxious, not calm	0.60	0.61
Obedient, cooperative	0.64	0.83
Opportunistic	0.79	0.83
Persistent	0.52	0.85
Playful	0.82	0.87
Slow	0.74	0.81
Sociable, not solitary	0.90	0.71
Tame	0.88	0.70
Timid, shy	0.86	0.85
Vigilant, alert	0.79	0.50
Vocal, alarm calls, not quiet	0.64	0.46
Vocal, mimicking	0.79	0.48
Warm, affectionate	0.76	0.81
Attractive	0.91	0.87
Clean	0.77	0.49
Scruffy	0.84	0.78
Feather picked	0.94	0.91

Only 'deceitful', 'impulsive', 'jealous' and 'lazy' failed to show significant intra-rater reliability ( $P > 0.05$ ).

**Table 2**  
Inter-rater reliability (Spearman–Brown prophecy) and inter-rater agreement (chi-square) results for the 19 personality traits of *A. amazonica* retained for factor analysis

Trait	Spearman–Brown	Chi-square
Active	0.65	10.94***
Affiliative	0.77	5.77*
Aggressive	0.54	5.77*
Bold	0.82	5.77*
Cautious	0.82	10.94***
Confident	0.88	14.16***
Eccentric	0.76	14.16***
Excitable	0.70	10.94***
Fearful	0.93	14.16***
Flexible	0.59	10.95***
High strung	0.69	8.15**
Impulsive	0.67	14.16***
Intelligent	0.76	14.16***
Lazy	0.72	14.16***
Cooperative	0.63	8.15**
Persistent	0.66	14.16***
Sociable	0.83	8.15**
Tame	0.87	14.16***
Shy	0.90	10.95***

\* $P = 0.025$ ; \*\* $P < 0.005$ ; \*\*\* $P < 0.001$ .

**Table 3**  
Promax-rotated factor loadings of 19 retained personality traits of *Amazona amazonica*, using a two-factor solution

Trait	Factor 1	Factor 2
Excitable	1.01	
High strung	1.01	
Fearful	0.81	
Eccentric	0.71	0.36
Shy	0.63	-0.4
Aggressive	0.54	
Cautious	0.47	-0.58
Intelligent	-0.45	0.55
Bold	-0.53	0.57
Confident	-0.59	0.54
Flexible	-0.61	0.3
Affiliative	-0.64	0.37
Sociable	-0.7	
Tame	-0.72	
Active		1.08
Impulsive		0.8
Lazy		-0.9
Cooperative		0.41
Persistent		0.89

ranged from -10 to 22.25, with a positive score indicating a larger amount of the latent variable; extraversion scores ranged from 9.25 to 27.5.

#### Temporal Stability

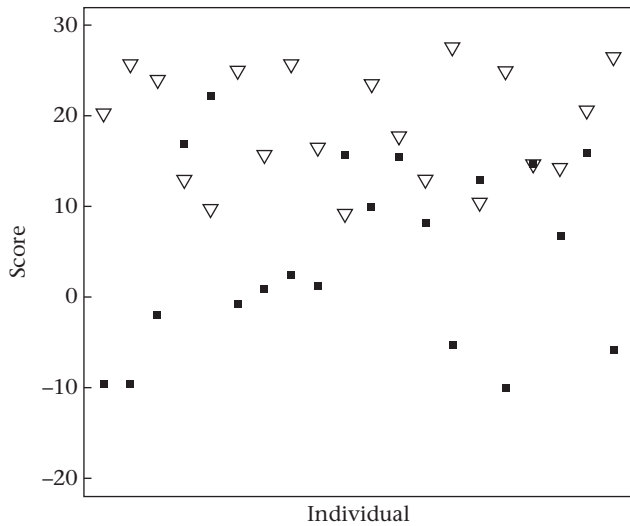
Both extraversion and neuroticism were temporally consistent across individuals (Spearman rank correlation: neuroticism:  $r_s = 0.82$ ,  $N = 20$ ,  $P < 0.00001$ ; extraversion:  $r_s = 0.88$ ,  $N = 20$ ,  $P < 0.00001$ ; Fig. 2). The scale mean was also temporally stable for extraversion (initial mean = 17.5, retest mean = 18.8; Wilcoxon signed-ranks test:  $T = 75$ ,  $P = 0.27$ ), but not for neuroticism (initial mean = 8.3, retest mean = 5.3;  $T = 170$ ,  $P = 0.016$ ).

#### Attention Bias

Baseline and observer-present conditions differed significantly for latency to reward (Wilcoxon signed-ranks test:  $T = 8$ ,  $N = 12$ ,  $P = 0.01$ ), choices per second per trial ( $T = 68$ ,  $N = 12$ ,  $P = 0.02$ ) and balks and errors ( $T = 1$ ,  $N = 12$ ,  $P = 0.03$ ) but not for intertrial interval ( $T = 19$ ,  $N = 12$ ,  $P = 0.13$ ; Fig. 3). Neuroticism was not significantly related to intertrial interval during the observer-present condition (Spearman rank correlation:  $r_s = 0.28$ ,  $N = 12$ ,  $P = 0.38$ ; Fig. 4), but there was a significant correlation between neuroticism score and attention bias, such that parrots with a higher neuroticism score also showed poorer performance during the observer-present condition, as measured by latency to reward ( $r_s = 0.61$ ,  $N = 12$ ,  $P = 0.04$ ) and proportion of trials with balks and

**Table 4**  
Personality scales identified for *A. amazonica*

Neuroticism	Extraversion
Not affiliative	Active
Aggressive	Bold
Not confident	Not cautious
Eccentric	Impulsive
Excitable	Intelligent
Fearful	Not lazy
Not flexible	Cooperative
High strung	Persistent
Not sociable	
Not tame	
Shy	

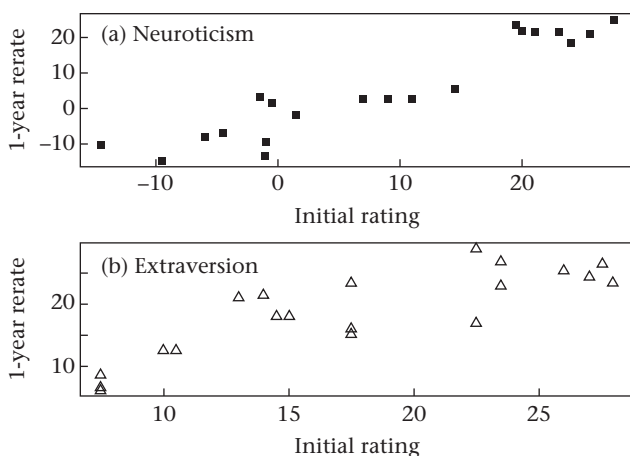


**Figure 1.** Individual scores for *A. amazonica* on the neuroticism scale (solid squares) and the extraversion scale (open triangles).

errors ( $r_s = 0.58$ ,  $N = 12$ ,  $P = 0.047$ ; Fig. 4). The single trait ‘fearful’ was not significantly correlated with either latency to reward ( $r_s = 0.43$ ,  $N = 12$ ,  $P = 0.16$ ) or proportion of trials with balks and errors ( $r_s = 0.53$ ,  $N = 12$ ,  $P = 0.07$ ).

## DISCUSSION

Our results provide experimental support for a postulated (e.g. McElreath & Strimling, 2006; Nettle, 2006; Wolf et al., 2008) relationship between cognition and personality. We found that more neurotic parrots showed a greater attention bias for environmental stimuli. Monitoring of environmental stimuli is important for fitness, but prolonged environmental assessment is costly because energy is diverted away from other activities such as foraging (Wolf et al., 2008). We saw a negative relationship between attention bias and performance on the foraging task, although because our parrots were not experiencing direct fitness costs we cannot draw conclusions about the fitness implications of this poorer performance. Because of such hypothesized costs, cognitive biases and extreme neuroticism may be beneficial only under certain



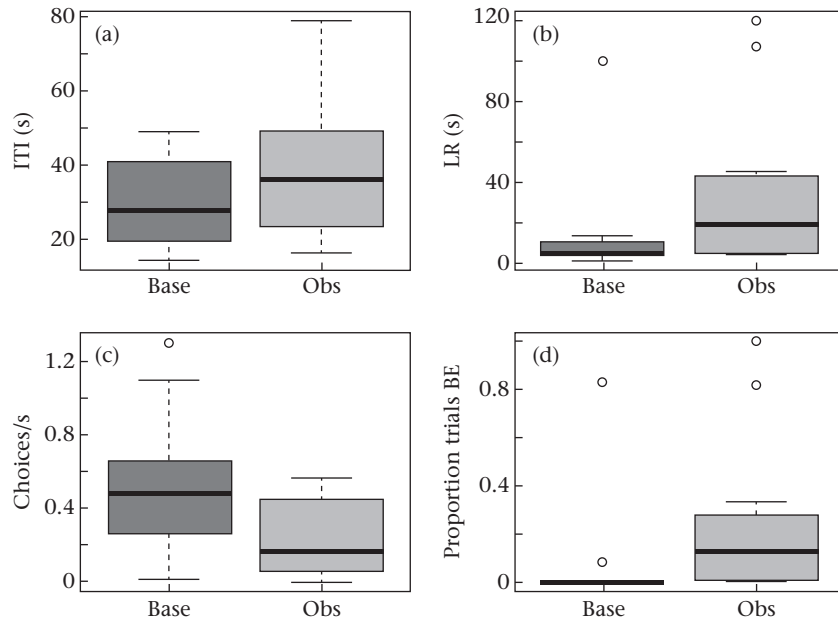
**Figure 2.** Temporal consistency of (a) neuroticism and (b) extraversion scale scores for *A. amazonica*.

circumstances, such as in a high-threat environment (Haselton & Nettle, 2006; Nettle, 2006).

Subjective assessment has a long history of use in comparative personality and has been used for mammals (see reviews for primates: Freeman & Gosling, 2010; felids: Gartner & Weiss, 2013; dogs: Jones & Gosling, 2005) and at least one avian species (cockatiels: Fox & Millam, 2010). Three of the big five dimensions (extraversion, neuroticism and sociability) are consistently found across animals (Gosling & John, 1999), but there are exceptions (e.g. Sussman, Ha, Bentson, & Crockett, 2013). Using methodology from primate and other mammalian comparative personality studies (Gosling, 1998, 2001), we found a similar structure for personality dimensions in *A. amazonica*, with a two-factor solution accounting for 66% of the total variance. It is unsurprising that we failed to find a sociability factor, because the individual housing provided little opportunity for the parrots to interact. Given that parrots are highly gregarious animals, we expect that a sociability dimension does exist in this species, and plan to re-evaluate their behaviour in a flock setting in the future.

According to Gosling and Vazire (2002), in order to be useful, comparative personality assessment has to meet criteria applied to human personality, as outlined by Kenrick and Funder (1988): have validity in predicting behaviours/outcomes (i.e. above 0.3 correlation level reported in the human literature), have strong levels of interobserver agreement and reflect genuine attributes of individuals. The personality dimensions we found in *A. amazonica* met at least two of these three criteria. The correlation between neuroticism and attention bias for threat exceeded the 0.3 criterion. This may be because we used aggregate ratings, which are well documented to decrease measurement error and increase the predictive power of personality ratings (Epstein, 1979). In addition, our outcome variable, attention bias, was measured using quantifiable changes in performance indicators, while our predictor variable, neuroticism, was measured using a subjective personality instrument. The use of different methods to measure the two variables reduces the risk of a common method bias (Podsakoff, MacKenzie, Jeon-Yeon, & Podsakoff, 2003). The dimensions we identified also had strong levels of interobserver agreement. Each rater in our study had at least 2 months experience with the parrots and this may have contributed to the significant agreement between raters, because familiarity with the animals being rated is known to influence the reliability of personality ratings (Gosling, 2001).

In addition to meeting the criteria described above, there was a large degree of between-individual variation on each of the two scales; such variation is necessary if personality is to explain differences in behaviour (Bell, 2006). Furthermore, scale scores varied widely across individuals in a manner that was more reflective of a continuous trait than a dichotomous variable. Measuring personality as a continuous variable increases its predictive power for correlating with other variables, such as state differences, that are related to differences in personality (MacCallum, Zhang, Preacher, & Rucker, 2002). Behavioural syndromes of wild animals are often treated as dichotomous, with animals classified as, for example, ‘bold’ or ‘shy’ (Wolf et al., 2008). This may overlook important consequences of personality, since actual position along the continuum can affect fitness under varying environmental conditions (e.g. Both et al., 2005). For example, birds at extreme ends of the bold–shy continuum are less behaviourally flexible and have greater variability in survival in the wild than intermediate conspecifics (Dingemanse et al., 2004). Together with our results, such findings indicate that personality should be treated as a continuous variable to improve predictive power. Almost all long-term behavioural syndrome studies have investigated a single dimension, such as bold or aggressive (Dingemanse & Wolf, 2010), or

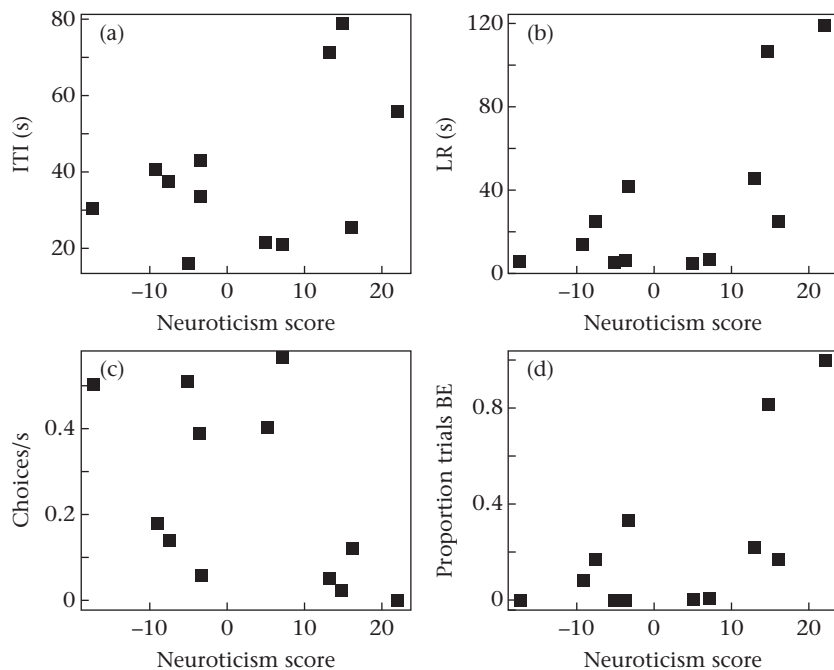


**Figure 3.** Hamilton search task performance. Difference in (a) intertrial interval (ITI), (b) latency to reward (LR), (c) number of choices per second per trial (choices/s) and (d) proportion of trials with balks and errors (proportion trials BE) between baseline (Base) and observer (Obs) testing conditions. Box plots show medians and first and third quartiles; open circles show outliers.

individual personality traits (e.g. [Dammhahn & Almeling, 2012](#); [Herborn et al., 2010](#)). Few studies have characterized multiple personality dimensions in avian species (only seven of the 187 papers reviewed by [Gosling, 2001](#); avian personality reviewed in: [Groothuis & Carere, 2005](#); [van Oers & Naguib, 2013](#)), and only a single study has done so for a Psittaciformes species (cockatiels: [Fox & Millam, 2010](#)). [Raykov and Marcoulides \(2011\)](#) suggested that assessing the relationship between multiple traits (i.e. dimensions), as opposed to a single personality trait, increases the reliability of

the resultant scale, and our findings support this. We examined the relationship of a single trait from the neuroticism scale, 'fearful', and cognitive bias. We chose fearful because of all the traits on the neuroticism scale, we expected this would be the most likely to influence performance in the presence of an observer. Unlike the neuroticism dimension, the trait fearful was not significantly correlated with cognitive bias.

Both personality ([Gosling, 2001](#)) and behavioural syndromes ([Sih et al., 2004](#)) are expected to be consistent across animals' lives,



**Figure 4.** Relation between neuroticism score of *A. amazonica* and (a) intertrial interval (ITI), (b) latency to reward (LR), (c) number of choices per second per trial (choices/s) and (d) proportion of trials with balks and errors (proportion trials BE) in the presence of a passive human observer.

but this is not always measured (e.g. Gosling, 2001; Uher, Asendorpf, & Call, 2008). Although nonhuman primates may demonstrate ontogenetic changes in personality (Sussman & Ha, 2011), there is evidence in birds, and particularly in the great tit *Parus major*, that behavioural syndromes are stable (reviewed by Groothuis & Carere, 2005). We found a high degree of temporal stability for individual rank order over a 1-year period; the correlations for both extraversion and neuroticism were above 0.8. This mirrors the human literature, where individuals' consistency in personality traits exhibit correlations of around 0.9 (Fleeson, 2004). Our ratings were based on aggregate experiences with the parrots, thereby reducing the influence of stochastic events on the assessment of personality (e.g. Gabriel & Black, 2010). The flock mean for neuroticism did change over the 1-year period, whereas the extraversion flock mean showed temporal stability over the same period. This is again consistent with the human literature, where meta-analyses of longitudinal studies find that neuroticism scores are more likely than other dimensions to change across the course of individuals' lives (Roberts & DelVecchio, 2000). Therefore, it is possible for individual animals' relative position to be highly consistent while the group mean changes over time. Our parrots ranged in age from 12 to 32 months old at the time of the initial personality assessment, and therefore were all juveniles at the time of both ratings. Future studies should evaluate stability of personality across multiple developmental stages.

We assessed cognitive differences in the parrots by the change in their performance on the Hamilton search task. The task is a spatial foraging task; one would expect the parrots to make as few choices as possible to obtain the reward. A previous study with the same group of subjects showed that, under normal conditions, the parrots approached the minimum average number of choices necessary to find the almond slivers (Cussen & Mench, 2013). We found that the presence of a passive observer in the room significantly increased the parrots' latencies to find reward, choices per second and proportion of trials with balks and errors. However, individuals varied widely in their performance under both conditions. Personality is related to foraging behaviour in other species; for example, bold animals are less risk sensitive when foraging (e.g. Bergvall, Schäpers, Kjellander, & Weiss, 2011; Dammhahn & Almeling, 2012). We found that performance measures on the search task were significantly correlated to neuroticism score. Our findings indicate that high neuroticism individuals cannot disengage their attention from the observer to perform the task at all or, if they do, they take longer to find the food reward or fail to find the food reward. We interpret this as indicating that those individuals had an attention bias for threat, because we observed parrots with increased latencies adopting a rigid, 'freezing', body position associated with aversive stimuli. The parrots in our study were provided with environmental enrichment and were accustomed to a variety of socializers, which could mean that an unfamiliar observer would not be perceived as threatening (e.g. Meehan & Mench, 2002). However, our experience with these parrots is that they required multiple weeks of socializing before they habituated to a new person. The reactions of the parrots to the observer were consistent with this experience.

Our findings support hypotheses that there is a cost associated with increased vigilance, because individuals with attention biases performed significantly more poorly on the foraging task. The increased proportion of balk and error trials resulted in an increased proportion of trials where the parrots received no reward, either because no choice was made or the correct choice was not made during the trial period. Because the parrots were fed ad libitum, the failure to receive a reward did not result in a metabolic cost. However, the almond slivers used as rewards were highly preferred by the parrots to their pelleted ration, and the

failure to attend to the task resulted in a cost in the sense that a highly desirable food item was not obtained.

In summary, our description of personality dimensions in a parrot species expands the limited data on questions of species differences and mechanisms in personality (Bell, 2006; Sih et al., 2004). In addition, our findings demonstrate that individual differences in a personality dimension (neuroticism) are correlated with biologically relevant individual differences in cognition, as measured by attention biases for environmental stimuli. To our knowledge, this is the first experimental evidence supporting the hypothesized relationship between a cognitive state difference and personality.

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