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Evaluating the Heritability of Temperament Traits in Pet Birds

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Abstract Temperament traits, such as aggressiveness, sociability, and fearfulness, are key factors in determining the adaptability of pet birds. This study reviews the definition and common assessment methods of temperament traits in pet birds, delves into the genetic basis of these traits in avian species, and evaluates the heritability of various temperament traits in pet birds using quantitative and molecular genetic approaches. It also examines the impact of environmental factors, such as early life experiences, socialization, and training, on the development of these traits. Through a case study of specific species, this study reveals the heritability of temperament traits in pet birds and discusses its application in breeding and daily care practices. The findings indicate that understanding and applying the heritability of temperament traits can help breeders select birds better suited for domestic life, thereby enhancing the adaptability of pet birds. This study aims to provide a theoretical foundation for more scientifically informed breeding and care practices by uncovering the genetic patterns of these traits across different avian species.
Keywords Temperament traits; Heritability; Pet birds; Breeding practices; Environmental influence

1 Introduction

Temperament traits in pet birds, much like in other animals, refer to consistent individual differences in behavior that are observable over time and across various situations. These traits encompass a range of behaviors such as anxiety, curiosity, neophobia, activity levels, and social interactions. For instance, studies have identified specific temperament traits in parrots, such as anxiety/vigilance and curiosity/neophilia, which are comparable to neuroticism and extraversion in other species (Coutant et al., 2018). Similarly, in cockatiels, temperament traits have been measured using both observer ratings and direct behavioral observations, revealing consistent patterns that can predict behaviors towards novel objects (Fox and Millam, 2010).

Understanding the heritability of temperament traits in pet birds is crucial for several reasons. Firstly, it can provide insights into the evolutionary and ecological significance of these traits. Temperament traits are known to influence survival and reproductive success, as well as interactions with the environment and conspecifics (Azevedo and Sant'anna, 2023). For example, in great tits, exploration behavior in novel environments has been shown to be moderately heritable and subject to natural selection, with variations influenced by environmental factors (Quinn et al., 2009). Knowledge of heritable temperament traits can inform breeding programs aimed at enhancing desirable traits and improving animal welfare. For instance, identifying fearful individuals through temperament tests can help in managing their responses to routine handling and stress, thereby improving their overall well-being (Ramos et al., 2023).

This study evaluates the heritability of temperament traits in pet birds, with a focus on parrots and other commonly kept species, including developing and validating reliable methods for assessing temperament traits in pet birds, investigating the genetic basis of these traits and their heritability, examining the effects of environmental factors on the expression of temperament traits, and exploring the impact of temperament traits on bird welfare and management practices, with the aiming of contributing to a deeper understanding of the behavioral ecology of pet birds and providing practical insights for their care and management.

2 Temperament Traits in Pet Birds

2.1 Commonly observed temperament traits

Temperament traits in pet birds encompass a range of consistent behavioral patterns that can be observed over time and across different situations. Commonly observed traits include aggressiveness, Sociability and Fearfulness. Aggressiveness refers to the tendency of a bird to exhibit hostile or combative behavior towards other birds or humans. It can manifest as biting, lunging, or other forms of physical aggression. Sociability describes a bird's inclination to seek out and enjoy the company of others, whether they are conspecifics or humans. Birds with high sociability are often more interactive and engaging. Fearfulness is characterized by a bird's tendency to react with caution or avoidance to new stimuli or environments. This can include behaviors such as freezing, fleeing, or excessive vocalization when confronted with unfamiliar situations (Nicolaus et al., 2016; Coutant et al., 2018).

2.2 Methods of temperament assessment in pet birds

Assessing temperament in pet birds can be approached through various methods, each with its own strengths and limitations. Observational tests involve direct observation of the bird's behavior in controlled settings. For example, a study developed a quantitative temperament test for parrots by measuring specific behavioral parameters such as anxiety/vigilance and curiosity/neophilia (Valente et al., 2017). Another study used a simple cage test to assess neophobia-related behavior and activity in wild-caught birds (Kluen et al., 2012). Rating scales involves expert observers rating birds on predefined behavioral descriptors. Although this approach can be subject to observer bias, it has been successfully used in various species, including cockatiels, to identify and measure temperament traits (Yu et al., 2020). Behavioral assays are standardized tests designed to elicit specific behaviors from the birds. For instance, a study on blue tits used a 15-minute cage test to measure neophobia and activity levels, capturing repeatable and heritable differences in personality traits.

2.3 Factors influencing temperament traits

Several factors can influence the temperament traits observed in pet birds. Heritability plays a significant role in the expression of temperament traits. Studies have shown that traits such as exploration behavior and neophobia have a genetic basis, with heritability estimates varying across different species and traits (Réale et al., 2007; Rozempolska-Rucińska et al., 2017). The environment in which a bird is raised and kept can significantly impact its temperament. Factors such as socialization, handling, and exposure to novel stimuli can shape behaviors like sociability and fearfulness. For example, parrots exhibited more curiosity/neophilia when retested after a brief exposure to experimental conditions, indicating habituation (Haskell et al., 2014). The specific context in which a bird is observed can also affect its behavior. For instance, the presence of conspecifics, the type of enclosure, and the nature of the stimuli presented can all influence the expression of temperament traits. By understanding and assessing these temperament traits, researchers and pet owners can better manage and care for pet birds, ensuring their well-being and improving human-animal interactions.

3 Genetic Basis of Temperament in Animals

3.1 Overview of genetic heritability

Genetic heritability refers to the proportion of phenotypic variance in a trait that can be attributed to genetic variation among individuals in a population. This concept is crucial in understanding how traits are passed from one generation to the next and how they can evolve over time. Heritability can be estimated using various methods, including family studies, twin studies, and more recently, genome-wide association studies (GWAS) which utilize single nucleotide polymorphisms (SNPs) to estimate heritability in unrelated individuals (Yang et al., 2017). The heritability coefficient can be divided into narrow-sense heritability, which considers only additive genetic effects, and broad-sense heritability, which includes all genetic variance, including gene-gene interactions (Dochtermann et al., 2015). Recent advancements have also introduced methods like relatedness disequilibrium regression (RDR) to estimate heritability while minimizing environmental biases.

3.2 General Insights into heritability in avian species

In avian species, heritability of various traits, including temperament, has been a subject of extensive research. For instance, studies on the great tit (*Parus major*) have shown that exploration behavior, a temperament trait, is

moderately heritable, with both genetic and permanent environmental effects contributing to phenotypic variance (Quinn et al., 2009). Similarly, research on house sparrows (*Passer domesticus*) has demonstrated that morphological traits exhibit varying levels of heritability, with some traits showing higher heritability in females than in males, indicating sex-specific genetic architectures (Young et al., 2018). These findings suggest that while genetic factors play a significant role in shaping temperament traits in birds, environmental factors and sex-specific differences also contribute to the observed phenotypic variation.

3.3 Examples of heritability in other pet species

Heritability of temperament traits is not unique to avian species and has been documented in various other pet species. For example, in yellow-bellied marmots (*Marmota flaviventris*), studies have shown that personality traits such as docility, sociability, and exploration exhibit nonzero additive genetic variance, indicating that these traits are heritable (Petelle et al., 2015). Additionally, a meta-analysis on the heritability of behavior across different taxa found that behavioral traits generally have moderate heritability, with migratory behaviors being particularly heritable (Dochtermann et al., 2019). These findings underscore the importance of genetic factors in shaping temperament traits across a wide range of animal species, including common pets. By understanding the genetic basis of temperament traits in both avian and other pet species, researchers can gain insights into the evolutionary processes that shape these traits and their potential for selection and adaptation in changing environments.

4 Methodologies for Assessing Heritability of Temperament Traits

4.1 Quantitative genetic approaches

Quantitative genetic approaches are fundamental in assessing the heritability of temperament traits in pet birds. These methods often involve the use of animal models to estimate genetic parameters such as heritability and genetic correlations. For instance, a study on the great tit (*Parus major*) utilized a restricted maximum likelihood-based animal model with a long-term pedigree to analyze exploration behavior, a temperament trait. The study found that exploration behavior was moderately heritable, with permanent environmental effects contributing significantly to phenotypic variance (Valente et al., 2017). Similarly, heritability estimates for various traits in blue tits were derived using both social pedigrees and genomewide relatedness matrices (GRM), with GRM providing slightly higher heritability estimates (Riley et al., 2014). These approaches highlight the importance of accurate pedigree information and the potential for genomic data to enhance heritability estimates.

4.2 Molecular genetic techniques

Molecular genetic techniques, such as the use of genomewide relatedness matrices (GRM) and single nucleotide polymorphism (SNP) genotyping, have become increasingly valuable in heritability studies. For example, a study on blue tits used nearly 50 000 filtered SNPs derived from RAD-seq to estimate heritability for several quantitative traits. The GRM-based approach provided higher heritability estimates compared to traditional pedigree methods, suggesting that genomic data can improve the accuracy of heritability estimates by correcting for pedigree errors such as extra-pair paternity. The use of microsatellite loci to identify extra-pair offspring in blue tits demonstrated that misassigned paternities could lead to underestimation of heritability, emphasizing the need for genetic data to correct social pedigrees (Nkrumah et al., 2007; Perrier et al., 2018).

4.3 Challenges and limitations in heritability studies

Heritability studies in pet birds face several challenges and limitations. One major challenge is the potential for misassigned paternities, which can lead to erroneous pedigree links and underestimation of heritability. Studies have shown that typical rates of extra-pair paternities in birds can result in an underestimation of heritability by up to 15% (Firth et al., 2015). Another limitation is the small sample sizes often available in wild populations, which can reduce the power of genetic analyses and lead to large credible intervals for heritability estimates (Perrier et al., 2018). The context-dependent nature of temperament traits, as observed in the great tit, suggests that environmental factors can significantly influence the expression and selection of these traits, complicating the interpretation of heritability estimates. Despite these challenges, the integration of quantitative genetic approaches with molecular techniques holds promise for improving the accuracy and reliability of heritability estimates in pet birds.

5 Heritability Studies in Pet Birds

5.1 Review of existing research on pet birds

Research on the heritability of temperament traits in pet birds has been relatively sparse compared to other animal species. However, several studies have begun to shed light on this important area. For instance, a study on the great tit (*Parus major*) demonstrated that exploration behavior, a key temperament trait, is moderately heritable. The study utilized a quantitative genetic analysis and found that both genetic and environmental factors contribute to the phenotypic variance of this trait (Quinn et al., 2009).

In another study, researchers developed a quantitative temperament test for three common parrot species, including the African Grey Parrot (*Psittacus erithacus*) and the Amazon parrot (*Amazona spp.*). This study identified two main temperament traits: anxiety/vigilance and curiosity/neophilia, and found significant differences between the species. The traits showed high consistency over time, suggesting a genetic basis for these behaviors. Additionally, a study on cockatiels (*Nymphicus hollandicus*) compared two methods for measuring temperament traits: observer ratings and direct behavioral observation. Both methods yielded similar results, indicating that temperament traits in cockatiels are consistent and can be reliably measured, further supporting the heritability of these traits (Hradecká et al., 2015).

5.2 Comparative analysis across bird species

Comparative studies across different bird species have revealed interesting patterns in temperament traits. For example, the study on parrots found that Blue-Fronted Amazon Parrots were more anxious/vigilant and curious/neophilic compared to African Grey Parrots (Kluen et al., 2012). This suggests that different species, even within the same family, can exhibit distinct temperament profiles, likely influenced by both genetic and environmental factors. The research on great tits also highlighted the context-dependent nature of temperament traits. Exploration behavior in great tits was subject to natural selection, with varying selective pressures observed across different environmental gradients (Cava et al., 2019). This indicates that the heritability and expression of temperament traits can vary significantly depending on the ecological context.

5.3 Gaps in current knowledge

Despite these advancements, there are still significant gaps in our understanding of the heritability of temperament traits in pet birds. One major gap is the limited number of species studied. Most research has focused on a few common species, such as parrots and great tits, leaving a vast number of bird species unexplored (Figure 1) (Barrozo et al., 2012; Coutant et al., 2018; Ramos et al., 2023). Another gap is the need for long-term studies that can provide more comprehensive data on the heritability and stability of temperament traits over time. While some studies have shown consistency in traits over several months, longer-term studies are necessary to fully understand the genetic and environmental influences on these behaviors. There is a lack of standardized methods for measuring temperament traits across different species. The variation in methodologies makes it challenging to compare results and draw broader conclusions about the heritability of these traits. Developing and adopting standardized testing procedures would greatly enhance the comparability and reliability of future research in this field.

The images depict several experimental scenarios from a study on the heritability of temperament traits in Amazon parrots. These experiments aim to explore the parrots' behavioral responses in different situations and whether these responses can reflect their temperament traits. Although the study provides profound insights into the temperament traits of parrots, there are still some limitations, such as the limited sample size of the species studied and the need for further refinement of standardized experimental methods. To gain a more comprehensive understanding of the heritability and stability of these temperament traits, future research should be expanded to include more species and involve longer-term observations.

6 Environmental vs. Genetic Influence on Temperament

6.1 Role of early life experiences

Early life experiences play a crucial role in shaping the temperament of pet birds. Studies have shown that the social environment during the juvenile stages can significantly influence behavioral traits. For instance, research

on wild house sparrows demonstrated that nestling activity is affected by social brood effects, indicating that the early social environment can shape certain personality traits (Hope et al., 2022). Additionally, the stability of personality traits increases with age, suggesting that early life experiences contribute to the continuity and crystallization of these traits over time (Morinay et al., 2019).

Figure 1 Temperament Test (Adopted from Ramos et al., 2023)
Image caption: (a) Interaction between the parrot and the colored stick used as a novel object in the first novel object test; (b) Flight distance measurement performed after the unknown person reaction test; (c) Manual restraint test (Adopted from Ramos et al., 2023)

6.2 Impact of socialization and training

Socialization and training are pivotal in the development of temperament traits in pet birds. The interaction with humans and other birds can lead to significant changes in behavior. For example, the study on the great tit (*Parus major*) highlighted that exploration behavior, a key temperament trait, is influenced by the environment, including local breeding density and habitat quality. This suggests that socialization and training, which alter the bird's environment, can have a profound impact on their temperament. Furthermore, the heritability of certain traits, such as boldness and exploration, can be modified by social contexts, emphasizing the importance of socialization in shaping these traits (Winney et al., 2018).

6.3 Gene-environment interactions

The interaction between genetic predispositions and environmental factors is complex and significant in determining temperament traits. Research has shown that both genetic and environmental influences on personality traits increase in stability with age, indicating a dynamic interplay between these factors (Briley and Tucker-Drob, 2014). In humans, studies have identified numerous genes associated with temperament, which interact with environmental influences to shape behavior (Zwir et al., 2018). Similarly, in birds, the heritability of traits like exploration behavior is context-dependent, with environmental gradients playing a crucial role in the expression of these traits (Winney et al., 2018). This gene-environment interaction underscores the necessity of considering both genetic and environmental factors in the study of temperament. The temperament of pet birds is shaped by a combination of genetic predispositions and environmental influences. Early life experiences, socialization, and training play significant roles in the development and stability of these traits, while gene-environment interactions further complicate the picture, highlighting the need for a comprehensive approach to understanding avian temperament.

7 Case Study: Heritability of Temperament Traits in a Specific Pet Bird Species

7.1 Selection of species for case study

For this case study, we selected the African Grey Parrot (*Psittacus erithacus*) and the Blue-Fronted Amazon Parrot (*Amazona aestiva*). These species were chosen due to their well-documented communicative and cognitive skills, which make them ideal candidates for studying temperament traits. Additionally, previous research has developed a reliable and valid temperament test for these species, providing a solid foundation for our analysis (Coutant et al., 2018).

7.2 Analysis and findings

The temperament traits of anxiety/vigilance and curiosity/neophilia were quantitatively measured in both African Grey Parrots and Blue-Fronted Amazon Parrots using a set of 26 behavioral parameters. The study found significant differences between the two species: Blue-Fronted Amazon Parrots exhibited higher levels of anxiety/vigilance and curiosity/neophilia compared to African Grey Parrots. These traits were consistent over time, with high intra-observer reliability and validity (Coutant et al., 2018).

The study on the great tit (*Parus major*) provides additional insights into the heritability of temperament traits. Exploration behavior, a temperament trait, was found to be moderately heritable with significant contributions from permanent environmental effects. This suggests that while genetic factors play a role, environmental influences are equally important in shaping these traits (Quinn et al., 2009).

7.3 Implications of the case study

The findings from this case study have several important implications. The significant heritability of temperament traits in parrots suggests that selective breeding could be used to enhance desirable traits in pet birds. However, the strong influence of environmental factors indicates that management practices and environmental enrichment are crucial for the development of these traits. The consistency of temperament traits over time highlights the potential for using these traits as reliable indicators of individual differences in behavior. This could be particularly useful for pet owners and breeders in selecting birds that are better suited to specific environments or roles, such as companion animals or therapy birds.

8 Implications for Pet Bird Breeding and Care

8.1 Considerations for breeders

Breeders should prioritize selecting breeding pairs based on desirable temperament traits that are conducive to pet life. Studies have demonstrated that temperament traits such as anxiety, vigilance, and curiosity in birds like parrots are heritable and can be shaped through selective breeding (Coutant et al., 2018). Breeding programs should focus on maintaining a balance between temperament traits and physical traits to ensure that birds remain adaptable and stress-resistant in domestic environments. The ability to influence such traits through breeding has significant implications for reducing stress-related behaviors and improving the overall well-being of birds.

8.2 Guidelines for pet owners

For pet owners, understanding the inherent temperament of their birds can greatly improve care practices. Owners should recognize that certain temperament traits, such as increased vigilance or curiosity, may require specific environmental adjustments to ensure the bird's comfort and well-being. For example, parrots that exhibit high levels of curiosity or neophilia may benefit from environments rich in stimulation and variety, while more anxious birds may require a stable and predictable environment to thrive (Coutant et al., 2018). Understanding these traits can help owners create more suitable living conditions that cater to the individual needs of their birds, thereby enhancing their quality of life.

8.3 Ethical considerations

Ethical considerations in breeding and care practices are paramount, particularly when it comes to the welfare of the birds. Breeders must avoid selecting for extreme traits that could compromise a bird's well-being or adaptability to domestic environments. It is essential to strike a balance between aesthetic traits and temperament traits to prevent the propagation of birds with behavioral tendencies that may lead to heightened stress or aggressive behaviors in captivity (Figure 2) (Cava et al., 2019; Morrill et al., 2022). Furthermore, the ethical treatment of birds should involve ensuring that their environment is conducive to their natural behaviors, promoting not only their physical health but also their mental well-being.

The image illustrates how dogs exhibit various temperament traits, such as prosociality towards humans, toy-driven movement patterns, and compliance, which are susceptible to selection pressure during breeding. However, research shows that although these traits may be more prominent in certain breeds, there is significant variability among individuals, and most behavioral traits have the potential to exist across all breeds. Therefore,

breeders should strike a balance between aesthetic traits and temperament traits, avoiding the pursuit of extreme behaviors or appearances at the expense of the animal's overall adaptability and welfare. This principle is especially applicable to birds as well. When selecting specific traits for breeding, breeders need to consider whether these traits might lead to increased stress or aggressive behaviors in captive environments. Over time, some extreme aesthetic traits, such as specific feather colors or body sizes, may be associated with undesirable behavioral traits, which could negatively impact the bird's health and quality of life. Thus, establishing a breeding standard that balances aesthetics with good temperament is crucial for ensuring the welfare of birds.

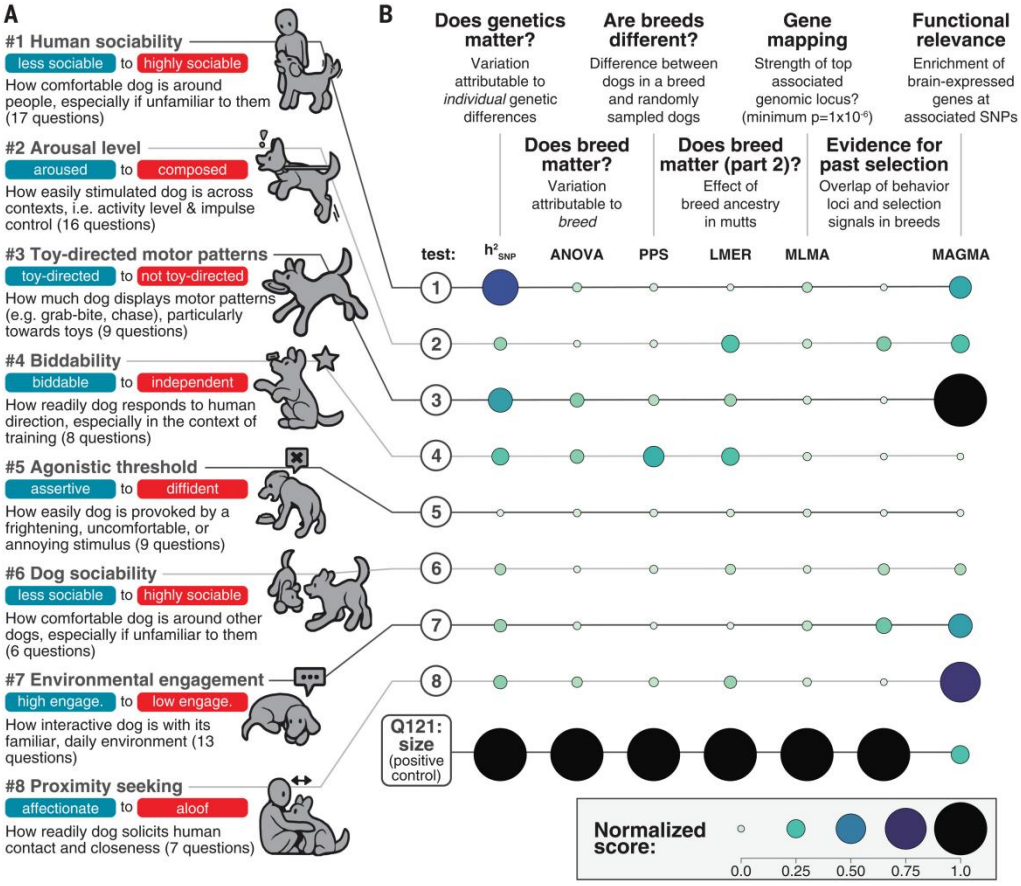

Figure 2 Exploratory factor analysis (Adopted from Morrill et al., 2022)

Image caption: (A) The exploratory factor analysis categorized behavioral issues into 8 inferred factors, corresponding to underlying behavioral tendencies (blue: negative scores; red: positive scores). (B) The relationship between behaviors and breed in the context of size (Adopted from Morrill et al., 2022)

9 Concluding Remarks

The research on the heritability of temperament traits in pet birds has yielded several significant insights. Firstly, temperament traits such as exploration behavior in novel environments have been shown to be moderately heritable, with both genetic and environmental factors contributing to phenotypic variance. In cockatiels, both trait-nomination-and-ratings and direct behavioral observation methods have been effective in identifying and describing temperament traits, with the former showing higher internal consistency. Additionally, a study on African Grey Parrots and Amazon Parrots identified two reliable temperament traits—anxiety/vigilance and curiosity/neophilia-demonstrating species-specific differences and high consistency over time.

Future research should focus on expanding the range of bird species studied to include a broader phylogenetic spectrum, which could provide deeper insights into the evolutionary aspects of temperament traits. Longitudinal studies that track changes in temperament traits over extended periods and across different environmental conditions would be valuable. Additionally, integrating genetic analyses with behavioral studies could help in pinpointing specific genetic markers associated with temperament traits. Finally, exploring the impact of

domestication and human interaction on the heritability and expression of these traits could offer practical applications for pet bird management and welfare.

The heritability of temperament traits in pet birds is a complex interplay of genetic and environmental factors. While moderate heritability has been observed, the significant role of environmental influences cannot be overlooked. The consistency of certain traits over time and across different species suggests that these traits are deeply rooted in the birds' biology. Understanding these traits not only enriches our knowledge of avian behavior but also has practical implications for improving the care and management of pet birds. As research progresses, it will be crucial to adopt multidisciplinary approaches that combine behavioral, genetic, and ecological perspectives to fully unravel the intricacies of temperament traits in pet birds.

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Conflict of Interest Disclosure

Author affirms that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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