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Assessing Eysenck's PEN model to describe personality in chimpanzees

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ABSTRACT

Questionnaires based on human models can be used to reliably assess personality also in non-human primates. In this study, we used an adapted version of Eysenck's Psychoticism-Extraversion-Neuroticism (PEN) model that focuses on three higher-order personality traits. Extending previous work on a small group of chimpanzees (*Pan troglodytes*), we tested 37 chimpanzees housed at Fundació Mona (Girona, Spain) and the Leipzig Zoo (Germany). We assessed personality with a 12-item questionnaire, which raters scored using a 7-point Likert scale. To identify the personality traits, we conducted data reduction with Principal Components Analysis and Robust Unweighted Least Squares. The ICCs for the single (3, 1) and average (3, k) ratings indicated substantial agreement between raters. Parallel analyses identified two factors to retain, whereas the scree plot inspection and eigenvalues larger than one rule identified three factors. Factor 1 and 2 in our study were identical to the ones previously described for this species (labelled Extraversion and Neuropsychoticism, respectively) and we also obtained a third factor that could be related to Dominance (Fearless Dominance). Thus, our results confirm the potential of the PEN model to describe chimpanzee personality structure.

1. Introduction

In the last three decades, personality assessment in captive animals has become increasingly popular as a non-invasive tool to improve animal management and welfare, while also providing valuable data to the field of animal personality research (Gartner and Weiss, 2017, for a review see: Norman et al., 2021). Understanding inter-individual differences of animals kept in captivity allows us to predict how subjects may respond when they face certain situations. This may be especially useful in zoos and other captive settings, because it can lead to the optimization of husbandry practices and environmental enrichment strategies according to the needs of each individual (Baker, 2012; Goswami et al., 2020; Quintavalle Pastorino et al., 2019). For example, it can help to increase success and decrease risks when forming social groups or transferring individuals to other centres (Gartner and Weiss, 2017). Furthermore, personality can have an impact on subjects' interest and performance in cognitive experiments, which are usually conducted in captive populations (Altschul et al., 2016; Altschul et al., 2017; Herrelko et al., 2012). This may have implications for animal management, but also for the study design. For example, highly neurotic individuals, which may be more likely to show excessive stress or anxiety during testing (Herrelko et al., 2012), may be excluded from the study or chosen to participate last, after seeing other group members performing the experiments.

Non-human primates, and more specifically great apes, are among the most studied animals in the field of animal personality (Freeman and Gosling, 2010; Norman et al., 2021; Weiss et al., 2011b). Historically, there have been two main methodological approaches to the study of animal personality: one based on behavioural ecology, which uses behavioural coding, and one based on human differential psychology, which uses a rating methodology (Weiss and Adams, 2013). Behavioural coding implies direct observations of subjects' spontaneous behaviour (Brandão et al., 2019; Koski, 2011) or their assessment during experimental situations (Massen et al., 2013). By contrast, the rating or

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questionnaire-based approach involves human raters who are familiar with the animals (e.g., keepers, researchers) scoring a list of adjectives or descriptions of behaviours, usually employing a Likert scale (Vazire and Gosling, 2004). Furthermore, some authors have combined the psychological and behavioural approaches by developing questionnaires based on observed behaviours (Stevenson-Hinde and Hinde, 2011; Stevenson-Hinde and Zunz, 1978; Uher, 2008; Uher and Asendorpf, 2008). This "bottom-up" approach contrast the "top-down" approach typically used in comparative psychology, in which questionnaire items are selected from human models.

Both methodologies, behavioural coding and trait rating, have been widely used to assess personality in non-human primates (Blaszczyk, 2020; Freeman et al., 2011; Gosling et al., 2003a; Highfill et al., 2010) and they both have strengths and limitations. For instance, although behavioural coding is assumed to be more objective, human studies have shown that it can also provide unreliable estimates (Borkenau, 1992; Gosling et al., 1998), as single measures of specific behaviours tend to have low cross-situational consistency. By contrast, ratings provide a more global perspective, as they encompass the experience of the raters across time and situations (Gosling et al., 2003a). Another popular criticism regarding the use of questionnaires, especially those based on human models, is the risk of anthropomorphism, which would imply that raters are falsely attributing human features to animals (Weiss et al., 2011b). Nonetheless, studies in the wild and in captivity have showed that great apes have intrinsic personality structures and that similarities with humans can be attributed to our genetic and phylogenetic closeness rather than to anthropomorphism (King et al., 2005; Weiss et al., 2012; Weiss et al., 2017). In fact, it has been extensively demonstrated that questionnaires based on human models provide a reliable approach (Freeman et al., 2013; Freeman and Gosling, 2010; Úbeda and Llorente, 2015; Weiss, 2017; Weiss and Adams, 2013; Weiss et al., 2009; Weiss et al., 2017), and that personality traits similar to those found in humans are expressed, with some modifications, across species (Weiss, 2018). Moreover, the use of questionnaires is especially effective for species that are phylogenetically close to humans, like great apes, as it is possible to more easily interpret their behaviour, rate their personality, and establish direct comparisons with human personality traits (Weiss and Adams, 2013). Some researchers have questioned the validity ratings (Ślipogor et al., 2021; Uher and Asendorpf, 2008; Uher and Visalberghi, 2016), implying that the traits obtained with this method are not descriptive of actual behaviours. However, several studies have found correlations between trait rating and behavioural observations both in monkeys (Ebenau et al., 2020; Iwanicki and Lehmann, 2015; Konečná et al., 2008) and in great apes (Eckardt et al., 2015; Pederson et al., 2005; Schaefer and Steklis, 2014; Vazire et al., 2007), thus revealing that, at least to some extent, traits obtained from questionnaires can estimate behaviour. Finally, it is also worth noting that, in general, questionnaires are easier to implement and less time-consuming than behavioural observations (Freeman et al., 2011).

A common top-down approach to describe non-human primate personality is based on the human Five Factor Model (Goldberg, 1990; McCrae and Costa Jr, 1999; McCrae and John, 1992), a hierarchical model constituted by five higher-order personality traits onto which several related lower-order traits cluster (Digman, 1990). This model has been successfully used to assess personality in chimpanzees (*Pan troglodytes*; King and Figueredo, 1997), bonobos (*Pan paniscus*; Weiss et al., 2015), gorillas (*Gorilla gorilla*; Eckardt et al., 2015; Schaefer and Steklis, 2014) and orangutans (*Pongo pygmeaus*, *P. abelii*; Weiss et al., 2006). The most popular adaptation of the Five Factor Model (FFM) for non-human primates is the Hominoid Personality Questionnaire (HPQ), developed by Weiss and colleagues (2009) and based on the previous attempt by King and Figueredo (1997) to describe chimpanzee personality. Using a larger sample of 146 chimpanzees and a revised version of the questionnaire containing 54 items, Weiss and colleagues (2009) obtained five personality traits homologous to the human traits in the FFM: Neuroticism, Extraversion, Agreeableness, Conscientiousness, and Openness (to Experience), plus the trait Dominance, which was already described in the original study by King and Figueredo (1997).

Besides the FFM, other human models have also been adapted to evaluate personality in non-human primates, such as Eysenck's Psychoticism-Extraversion-Neuroticism (PEN) model (Chamove et al., 1972; Úbeda and Llorente, 2015) or Cattell's 16 Personality Factors (PF) model (Ortín et al., 2019). One of the main advantages of these models is that the adapted questionnaires are shorter (i.e., they contain fewer items to evaluate) than the HPQ, making them more appealing and less time-consuming for raters (Hopper and Cronin, 2018). Furthermore, despite being psychometrically inferior to longer questionnaires, in human personality research, shorter scales have proved to be reliable and valid alternatives (Burisch, 1984, 1997; Føllesdal and Soto, 2022; Gosling et al., 2003b; Gouveia et al., 2021; Nunes et al., 2018; Romero et al., 2012). Eysenck's model (Eysenck, 1967; Eysenck and Eysenck, 1964), in particular, follows a psychobiological approach to personality that focuses on three higher-order traits (Psychoticism, Extraversion and Neuroticism) based on genetic and neurophysiological factors (Eaves et al., 1989; Eysenck, 1967; Eysenck, 1997). The PEN model shares two common dimensions or traits with the FFM (Neuroticism and Extraversion), which have reported to be very similar across models (McCrae and Costa, 1985; Zuckerman et al., 1993) and which have been identified in a wide range of primate species (Freeman and Gosling, 2010). Moreover, according to Eysenck and colleagues (1985), Agreeableness and Conscientiousness in the FFM are facets of the trait Psychoticism, a hypothesis which has been partially supported by later studies (Draycott and Kline, 1995; Goldberg and Rosolack, 1994; Heaven et al., 2013; Ruch et al., 2020; Saggino, 2000). It is also worth noting that, some features of Eysenck's Psychoticism, such as aggressiveness and impulsivity are commonly displayed behaviours by non-human primates, especially in competitive contexts and dominance-related interactions (de Almeida et al., 2015; Fairbanks et al., 2004; Higley et al., 2011). We can therefore conclude that Eysenck's model holds great potential to describe non-human primates' personality.

The first attempt to describe chimpanzee personality using the PEN model was conducted by Úbeda and Llorente (2015) with a small sample of captive chimpanzees. They developed a 12-item questionnaire, in which the items corresponded to primary scales or traits that are integrated into the three higher-order factors described by Eysenck (Eysenck, 1967; Eysenck et al., 1992; Eysenck and Eysenck, 1964, 1991; Eysenck et al., 1985). For each factor (i.e., Extraversion, Neuroticism and Psychoticism), the authors selected four primary scales, ensuring that they were appropriate to characterize chimpanzee personality. After performing factorial analyses, the authors identified three dimensions: Extraversion, Neuropsychoticism and Dominance. The items that loaded onto Extraversion were very similar to those reported for humans in that same dimension, facilitating the interpretation of this trait. The trait Neuropsychoticism was identified as a combination of Neuroticism and Psychoticism, because it included items that in humans load on these two traits. Moreover, the authors identified a third factor, labelled Dominance, which had been already described in other studies evaluating adaptations of human personality models in chimpanzees (Freeman and Gosling, 2010; King and Figueredo, 1997) and other non-human primates (Adams et al., 2015; Weiss et al., 2011b). Finally, personality traits assessed with the PEN model correlated with observational data collected over a 11-year period, supporting convergent validity (Padrell et al., 2020). Nonetheless, these studies assessing Eysenck's model in chimpanzees were strongly limited by the small sample size and the fact that all the chimpanzees were from the same centre and shared a similar background (i.e., they were all former pets or used in the entertainment industry). In this study, we therefore aimed to extend the research by Úbeda and Llorente (2015) and assess Eysenck's PEN model on a larger and more diverse sample ($N = 37$) of captive chimpanzees from two different sites. We expected that, if the PEN model is a suitable approach to assess personality in chimpanzees, we would find a clear factor structure, with similar dimensions or

personality traits (i.e., Extraversion, Neuropsychoticism and Dominance) as compared to previous studies (Úbeda and Llorente, 2015), as well as substantial agreement between raters.

2. Material and methods

2.1. Subjects and study sites

The study sample consisted of 37 chimpanzees (*Pan troglodytes*), 16 males and 21 females, that ranged in age from 3.5 to 53 years at the time of personality assessment (mean age ± SD = 25.76 ± 12.37 years). They were housed at two different centres: 14 chimpanzees lived at Fundació Mona (Girona, Spain), a centre dedicated to the rescue and rehabilitation of primates that have been previously used as pets or for entertainment, and 23 lived at the Wolfgang Köhler Primate Research Centre (WKPRC), also known as Pongoland, at Leipzig Zoo (Germany). Table 1 contains information on the subjects' characteristics and background.

The 14 chimpanzees from Fundació Mona lived in two separate groups (mean age ± SD = 21.64 ± 8.85 years, range = 8–33 years), which have been mostly stable over the years: one group of 5 males and another group of 9 individuals (4 males and 5 females). In 2017, two of the females (África and Waty) from the larger group were moved to the only-males group. The chimpanzees spent most of the day in an outdoor enclosure, divided into two areas (2420 m2 and 3220 m2), one for each group. This enclosure was covered by natural vegetation and it contained enrichment elements such as wooden platforms, towers, and ropes. There were also 140 m2 of indoor facilities, divided into four rooms, to which the chimpanzees had access at nights and during bad weather conditions. The chimpanzees were fed four times a day and water was provided ad libitum in both enclosures. Their diet consisted mainly of seasonal vegetables and fresh fruits, and it also included small portions of dried fruits and nuts, boiled rice and some protein-rich items (e.g., eggs, meat, tofu). Most of the food was distributed along the outdoor area, in order to encourage foraging behaviour. The 23 chimpanzees from the Leipzig Zoo also lived in two separate groups (mean age ± SD = 28.26 ± 13.67 years, range = 3–53 years): a large group including 17 chimpanzees (6 males, 11 females) and a small group of 6 chimpanzees (1 male, 5 females). Each group had two types of enclosures: large outdoor enclosures for summer and hot days (4000 m^2 and 1400 m^2), and inside enclosures for the winter season (430 m^2 and 175 m^2). Both facilities were covered with natural vegetation and included other elements such as rocks and streams. They also had trees, ropes and wooden platforms for climbing and shelter, and environmental enrichment devices, such as artificial termite mounds and food mazes. The chimpanzees were also fed four times a day (twice in the indoor enclosures and twice with food being scattered in the outdoor area) and they had access to water at all times. Their diet predominantly consisted of vegetables and fruits, along with small portions of seeds, grains, and sources of protein (e.g., eggs, meat). Pellets (dry food) were also occasionally provided as rewards directly by the keepers or hidden in enrichment devices.

2.2. Questionnaires

We assessed personality using a questionnaire based on the Psychoticism-Extraversion-Neuroticism (PEN) model of personality (Eysenck, 1967; Eysenck and Eysenck, 1964). This tool was used for the first time in a previous study, in which the authors evaluated the

Table 1
Biographical information on the chimpanzees from the study sample.

Study site	Subject	Sex	Age (at personality assessment)	Origin	Former use	Age of arrival at the centre (years)	Time spent at the centre (years)
Fundació Mona	Africa	F	12	Wild	Pet	10	2
	Bea	F	33	Wild	Entertainment	27	6
	Bongo	M	11	Captive	Entertainment	2	9
	Charly	M	22	Captive	Entertainment	12	10
	Cheeta	F	28	Wild	Entertainment	25	3
	Coco	F	24	Wild	Pet/Entertainment	18	6
	Juanito	M	8	Captive	Pet/Entertainment	2	6
	Marco	M	27	Captive	Entertainment	17	10
	Nico	M	10	Captive	Pet/Entertainment	3	7
	Tico	M	24	Wild	Entertainment	18	6
	Tom	M	33	Wild	Entertainment	26	7
	Toni	M	28	Wild	Entertainment	18	10
	Victor	M	29	Captive	Entertainment	24	5
	Waty	F	14	Captive	Pet/Entertainment	4	10
Leipzig Zoo	Alex	M	18	Captive	Zoo	1	17
	Azibo	M	4	Captive	Zoo	Since birth	4
	Bambari	F	19	Captive	Zoo	16	3
	Corrie	F	43	Captive	Zoo	25	18
	Daza	F	33	Wild	Zoo	27	6
	Dorien	F	39	Captive	Zoo	21	18
	Fraukje	F	43	Captive	Zoo	25	18
	Frederike	F	45	Wild	Zoo	39	6
	Frodo	M	26	Captive	Zoo	8	18
	Hope	F	29	Captive	Zoo	26	3
	Jeudi	F	53	Wild	Zoo	47	6
	Kisha	F	15	Captive	Zoo	9	6
	Lobo	M	15	Captive	Zoo	Since birth	15
	Lome	M	18	Captive	Zoo	Since birth	18
	Maja	F	33	Captive	Zoo	30	3
	Natascha	F	39	Captive	Zoo	21	18
	Ohini	M	3	Captive	Zoo	Since birth	3
	Riet	F	42	Captive	Zoo	24	18
	Robert	M	44	Captive	Zoo	26	18
	Sandra	F	26	Captive	Zoo	8	18
	Swela	F	24	Captive	Zoo	10	14
	Tai	F	17	Captive	Zoo	Since birth	17
	Zira	F	22	Captive	Zoo	19	3

chimpanzees housed at Fundació Mona at that time (Úbeda and Llorente, 2015). The authors developed a 12-item questionnaire, with items corresponding to primary scales that are integrated into the three higher-order factors described by Eysenck (Eysenck and Eysenck, 1964, 1991; Eysenck et al., 1985). Each scale consists of two adjectives representing the opposite pole of the trait. For example, the factor Extraversion was defined by the scales "active-inactive", "social-unsociable" and "assertive-submissive", among others. A complete list of the primary scales and how are integrated into the higher-order factors can be found in Eysenck and colleagues (1992). To develop the questionnaire, the authors selected four descriptive items (i.e., four primary scales) for each factor, considering their suitability and relevance for describing chimpanzee personality. In the questionnaires, each item was also associated with two adjectives representing the two opposite poles of the trait, which raters had to score using a 7-point Likert scale (i.e., they had to select a number between 1 and 7). For instance, for the item "aggressiveness", raters had to provide a score from (1) "pacific" to (7) "aggressive". Additionally, a brief definition for the lower pole (i.e., corresponding to the lower value, 1) of each trait was included at the end of the questionnaire, in order to assist the raters in the interpretation of the traits. The raters at Fundació Mona completed the questionnaires in their native language (Spanish or English). An English version of the questionnaire, including the instructions provided to the raters, can be found in Supplementary Material 1.

To assess the chimpanzees at the Leipzig Zoo we used the same questionnaire previously employed at Fundació Mona, which was translated (and back translated) from English to German, so that the raters could complete it in their native language. Before conducting the statistical analyses, some of the ratings were reversed following the procedure of the previous study (Úbeda and Llorente, 2015). As in the former study, the reversed ratings corresponded to the following pair of adjectives: "social-antisocial", "active-passive", "dominant-submissive", "spontaneous-not spontaneous". For the pair "social-antisocial", for example, low values in the questionnaire (1) corresponded to more social individuals, and high values (7) to more antisocial ones. However, before conducting the analyses, the ratings were reversed, so that higher scores on this pair of items corresponded to more social individuals. This facilitated the comparison between the two studies and the interpretation of the personality structure.

2.3. Raters and ratings

The chimpanzees at Fundació Mona were assessed in two previous studies: 10 subjects were assessed in 2012 (Úbeda and Llorente, 2015) and 4 subjects were later evaluated in 2018 (Padrell et al., 2020). The 10 chimpanzees evaluated in 2012 were assessed by 28 raters (75% women, 25% men), who knew the animals for at least 6 months. The 4 chimpanzees evaluated in 2018 were assessed by 15 raters (73.33% women, 26.67% men) who had been working with the animals for at least 4 months. All raters were highly familiar with the subjects, as they worked as researchers, volunteers or keepers and had daily contact with them. The chimpanzees from the Leipzig Zoo were assessed in 2019 by a total of 8 raters (25% women, 75% men), which had been working as keepers for 4–18 years (mean ± SD = 12.8 ± 5.8 years). However, not all keepers evaluated all chimpanzees, as not all of them worked with all the animals. Thus, each chimpanzee was rated by 6 keepers that were highly familiar with them.

When raters did not answer a question, missing data on the ratings was substituted by a neutral score of 4 (Costa and McCrae, 2008; Weiss et al., 2009). Following the methodology of previous studies (Úbeda and Llorente, 2015; Weiss et al., 2009), we assessed inter-rater reliability by calculating two intraclass correlation coefficients (ICC) (Shrout and Fleiss, 1979): ICC (3,1), which indicates the reliability of the scores for individual single raters, and ICC (3, k), which indicates the reliabilities of scores based on the mean of the total number of raters. To do so, we used the function ICC from the package "psych" version 2.0.8 in R (Revelle, 2020).

2.4. Personality structure

To identify the personality traits or domains we conducted data reduction with two different tools, Principal Components Analysis (PCA) and exploratory factor analysis using a Robust Unweighted Least Squares (RULS) as a method for factor extraction (Ferrando and Lorenzo-Seva, 2017). On the one hand, PCA is a widely used method in current personality research (i.e., Šlipogor et al., 2022; Talbot et al., 2021). On the other hand, regularized exploratory factor analyses such as RULS are commonly applied to extract factors in small samples studies (Jung, 2013; Jung et al., 2020). In both analyses we set an orthogonal normalised Equamax rotation (Lorenzo-Seva and Ferrando, 2019), which generates uncorrelated factors. This rotation needs a previous orthogonal Weighted Equamax rotation, implemented with the Clever Start method, to select the position of the factor axes based on the most stable correlation values in the sample correlation matrix (Browne, 2001; Lorenzo-Seva, 1999). The analysis was based on polychoric correlations (a method adequate to Likert-scale ordinal data with asymmetric or with excess of kurtosis data) to achieve factor simplicity and determine factorial structure and goodness of fit (Lorenzo-Seva and Ferrando, 2019; Muthen and Kaplan, 1992). Correction for robust Chi square was calculated with LOSEFER empirical correction (Lorenzo-Seva and Ferrando, 2022). Following Hair et al. (2010) and Úbeda and Llorente (2015), factor loadings of the rotated loading matrix were considered as salient when they were equal or higher than 0.5. We combined three procedures for determining the number of dimensions. First, the inspection of the scree plot (i.e., factors with eigenvalues above the 95th quantile); second, eigenvalues above 1; and third, the optimal implementation of Parallel analysis based on minimum rank factor analysis (Timmerman and Lorenzo-Seva, 2011) obtaining random correlation matrices with permutation of the raw data (Buja and Eyuboglu, 1992). Finally, we assessed a robust goodness of fit using the Root Mean Square Error of Approximation (RMSEA). RMSEA values below 0.05 are considered excellent fit, while values greater than 0.08 would indicate poor fit (Lloret-Segura et al., 2014). We conducted all the analyses using JASP (version 0.17.2.1; JASP Team, 2023) and FACTOR 12.04.01 softwares (Lorenzo-Seva and Ferrando, 2013).

3. Results

3.1. Inter-rater reliabilities

Considering the 37 chimpanzees, the ICCs for the single (3, 1) and average (3, k) ratings showed substantial agreement between raters, with no unreliable coefficients equal to or less than zero to remove from the analysis. The mean ICC (3, 1) was 0.32 (SD = 0.08; range = 0.21 – 0.47) and the mean ICC (3, k) was 0.95 (SD = 0.02; range = 0.93 – 0.98). The interrater reliabilities for each item are presented in Table 2.

3.2. Personality structure

Parallel analyses identified two factors (Timmerman and Lorenzo-Seva, 2011) to retain, whereas the scree plot and eigenvalues above 1 identified three factors (Table 3), as also suggested by the PCA and the RULS. The three factors accounted for 67.76% of the variance, based on eigenvalues above 1. According to the PCA and the RULS, the value of the Kaiser-Meyer-Olkin (KMO) test was 0.802 (good) [CI 0.744, 0.822] and Bartlett's Test of Sphericity was significant (B=2812.2; df=66, $p < 0.001$), thus indicating the adequacy of the polychoric correlation matrix. Based on the normed MSA (Measure of Sampling Adequacy) all the items obtained values above 0.5, suggesting that they correlated with other items and indicating its adequacy in representing the underlying constructs. Thus, all the items were retained in the factor analysis (Lorenzo-Seva and Ferrando, 2021) (Table 4). RMSEA fit was

Table 2
Intraclass correlation coefficients (ICCs) for the 12 items of the questionnaire. ICC (3, 1) indicates the reliability of the scores for a single rater, and ICC (3, k) indicates the reliabilities of scores based on the mean of the total number of raters.

	ICC (3,1)	ICC (3,K)
Social	0.27	0.95
Active	0.47	0.98
Dominant	0.42	0.97
Spontaneous	0.31	0.96
Anxious	0.32	0.96
Bad-tempered	0.25	0.94
Fearful	0.32	0.96
Sad	0.26	0.94
Aggressive	0.40	0.97
Impulsive	0.33	0.96
Cruel	0.23	0.93
Creative	0.21	0.93
Mean ± SD	**0.32 ± 0.08**	**0.95 ± 0.02**

Note: The table shows the positive pole of each pair of adjectives (e.g., the item "social", is the positive pole of the pair (1) "antisocial - (7) "social").

Table 3
Explained variance based on eigenvalues.

Variable	Eigenvalue	Proportion of the variance	Cumulative proportion
1	4.108	0.342	0.342
2	2.961	0.247	0.589
3	1.062	0.089	0.678
4	0.808	0.067	
5	0.655	0.055	
6	0.541	0.045	
7	0.450	0.038	
8	0.413	0.034	
9	0.303	0.025	
10	0.275	0.023	
11	0.230	0.019	
12	0.195	0.016	

Table 4
Values of the normed Measure of Sampling Adequacy for the PEN items according to the PCA and the RULS.

Items	Normed MSA
Sad	0.865
Bad-tempered	0.839
Cruel	0.809
Aggressive	0.786
Fearful	0.730
Anxious	0.727
Impulsive	0.760
Dominant	0.792
Creative	0.893
Spontaneous	0.862
Active	0.776
Social	0.787

Note: The table shows the positive pole of each pair of adjectives (e.g., the item "social", is the positive pole of the pair (1) "antisocial - (7) "social").

fair (0.071; [Bootstrap 95% CI 0.043, 0.050]) for the RULS and mediocre (0.089; [Bootstrap 95% CI 0.057, 0.062) for the PCA.

The factors extracted by the PCA and the RULS did not differ appreciably, except for one item ("creative") loading on factor 1 in the PCA, but not in the RULS (see Table 5). In the PCA, the items positively loading on factor 1 were "active", "social", "spontaneous" and "creative", whereas the items "sad" and "bad-tempered" had negative loadings. In both the PCA and the RULS, the items with positive salient loadings on factor 2 included "aggressive", "impulsive", "anxious," "cruel," and "bad-tempered". Finally, the third factor included two items with salient loadings: "fearful" with a negative loading and "dominant" with a positive loading. "Bad-tempered" was the only item with salient loadings on more than one factor (factors 1 and 2) in the PCA and in the RULS, loading higher on factor 2 in both analyses. Table 5 also displays the communalities for each item in the PCA and the RULS (i.e., the proportion of variance in each item accounted for by the underlying factors). Overall, item communalities were above 0.5, suggesting a moderate to high degree of variance explained by the factors, except for the item "creative".

Finally, to facilitate comparison with previous research on the PEN model in both chimpanzees and humans, Table 6 shows the personality structure obtained in this study and the one reported by Úbeda and Llorente (2015) for chimpanzees, as well as the distribution of the items within the higher-order traits as described by Eysenck and Eysenck (1991) in humans.

4. Discussion

In our study, the personality structures obtained using the two data reduction tools (PCA and RULS) were very similar to each other and highly comparable to the ones described by Úbeda and Llorente (2015) in the first attempt to adapt Eysenck's PEN model to chimpanzees. As in their study, we obtained three factors, and very similar loadings of adjectives or items for each factor. In particular, the items loading on factors 1 and 2 were identical to those reported in the study by Ubeda and Llorente (2015) (labelled Extraversion and Neuropsychoticism, respectively), and the items loading on factor 3 (i.e., Dominance) differed only slightly in the more restrictive analyses. Therefore, our results provide further support for this three-factor solution and for the existence of a Dominance-related factor, also reported for chimpanzees in the Five Factor Model (King and Figueredo, 1997).

In terms of inter-observer reliability, intraclass correlation coefficients suggested that raters tended to agree in their judgments about personality items. The intraclass correlation coefficients for average ratings (3,k) were all above 0.9, which is indicative of excellent reliability (Koo and Li, 2016). Although the intraclass correlation coefficients for single ratings (3,1) were lower, they were similar to those reported in other studies assessing chimpanzee personality through questionnaires adapted from human models (King and Figueredo, 1997; Ortín et al., 2019; Úbeda and Llorente, 2015; Weiss et al., 2009). Furthermore, they are also in the range of intraclass correlations reported for human models (Costa and McCrae, 1992; McCrae and Costa, 1989; McCrae and Costa, 1987).

In this study, we performed an orthogonal rotation, which assumes that the factors are uncorrelated. Some authors argue that, oblique rotations, which allow factors to correlate, are the most advisable approach (Browne, 2001). In fact, moderate correlations (0.4–0.59) between personality factors have been reported in chimpanzees (King and Figueredo, 1997), barbary macaques (*Macaca sylvanus*; Konečná et al., 2012) and in humans (Borkenau and Ostendorf, 1990; Costa et al., 1991; Graziano and Ward, 1992; Zhang et al., 2022). Nonetheless, orthogonal rotations produce simpler structures, that are easier to interpret and more likely to be replicated in future studies (Kieffer, 1998).

The factors or traits obtained in our analyses are not only comparable with the ones reported in the previous study in chimpanzees (Úbeda and Llorente, 2015) but also with the human dimensions from the PEN model. For example, three of the four items included in factor 1 (Extraversion) according to the RULS ("active", "social", "spontaneous") have also been attributed to Extraversion in humans (Eysenck and Eysenck, 1991; see Table 6. However, in both this and the former study in chimpanzees, the item "sad" loaded on Extraversion, whereas in humans, sadness is considered an aspect of Neuroticism (Eysenck and Eysenck, 1991). This would be in line with the study of King and Figueredo (1997), in which the item "depressed" also had a negative salient loading on Surgency (or Extraversion) and not on Emotionality (or

Table 5
Factor loadings of personality items for PCA and RULS and item communalities.

	Principal Component Analysis				Robust Unweighted Least Squares			
	Component 1	Component 2	Component 3	Item communalities	Factor 1	Factor 2	Factor 3	Item communalities
*Active	**.826**	.144	.258	.770	**.838**	.128	.219	.767
*Social	**.774**	-.012	.159	.639	**.725**	-.134	.128	.562
*Spontaneous	**.713**	.051	.405	.675	**.675**	.019	.373	.595
Sad	**-.717**	.307	-.244	.668	**-.672**	.313	-.228	.602
Creative	**.557**	-.149	-.053	.335	.393	-.182	.062	.192
Aggressive	-.141	**.867**	.216	.819	-.121	**.877**	.227	.836
Impulsive	.303	**.729**	.262	.692	.267	**.637**	.278	.555
Anxious	-.049	**.742**	-.450	.756	-.114	**.636**	-.310	.513
Cruel	-.362	**.683**	.126	.614	-.315	**.629**	.101	.505
Bad-tempered	**-.553**	**.647**	.018	.703	**-.499**	**.626**	.024	.641
Fearful	-.270	.017	**-.835**	.770	-.284	.028	**-.811**	.739
*Dominant	.142	.288	**.766**	.690	.206	.277	**.591**	.468

Note: The table shows the positive pole of each pair of adjectives (e.g., the item "social", is the positive pole of the pair (1) "antisocial - (7) "social"). *Scores on these items were reversed before the factorial analyses following the procedure conducted by Úbeda and Llorente (2015).

Table 6
Comparison of the personality structure obtained in this study with the PEN model in humans (Eysenck and Eysenck, 1991) and with the previous study in chimpanzees (Úbeda and Llorente, 2015).

	Humans (Eysenck and Eysenck, 1991)	Chimpanzees (Úbeda and Llorente, 2015)	Chimpanzees (this study)
Active	Extraversion	Extraversion	Extraversion
Social	Extraversion	Extraversion	Extraversion
Spontaneous	Extraversion	Extraversion	Extraversion
Sad	Neuroticism	Extraversion	Extraversion
Creative	Psychoticism	Extraversion[a]	Extraversion[a]
Aggressive	Psychoticism	Neuropsychoticism	Neuropsychoticism
Impulsive	Psychoticism	Neuropsychoticism	Neuropsychoticism
Anxious	Neuroticism	Neuropsychoticism	Neuropsychoticism
Cruel	Psychoticism	Neuropsychoticism	Neuropsychoticism
Bad-tempered	Neuroticism	Neuropsychoticism	Extraversion/ Neuropsychoticism[c]
Fearful	Neuroticism	Dominance[b]	Fearless Dominance
Dominant	Extraversion	Dominance	Fearless Dominance

[a]The item "creative" yielded a salient loading on Extraversion in the PCA, but not in the more restrictive analyses (REFA in Úbeda and Llorente, 2015 and RULS in this study). [b]In the study by Úbeda and Llorente (2015), the item "fearful" only yielded a salient loading on Dominance in the PCA, but not in the REFA. [c]In the present study, the item "bad-tempered" loaded on both Extraversion and Neuropsychoticism in the PCA and in the RULS, but higher on Neuropsychoticism.

Neuroticism). Moreover, Extraversion in humans has been negatively correlated to sensitivity to negative stimuli (Park et al., 2014) and to depression (Grav et al., 2012; Yu and Hu, 2022).

When comparing the two analyses (PCA and RULS), the only difference in the results was the item "creative", which loaded positively on factor 1 (Extraversion) in the PCA but not in the RULS. This is also in line with the results reported by Úbeda and Llorente (2015), in which "creative" did not load on Extraversion when using a more restrictive analysis (i.e., Regulatory Exploratory Factor Analyses, REFA). According to Eysenck, "creativity" was connected to Psychoticism, because highly psychotic individuals are overinclusive in their thinking (i.e., they have wide associative networks which allow divergent thinking and originality) (Eysenck, 1993; Eysenck, 1995). Later studies also support that manifesting psychotic traits (i.e., cold, unemphatic, aggressive and impulsive) is associated with creativity, and particularly with originality (Abraham et al., 2005; Acar and Runco, 2012; Fink et al., 2014; Fink et al., 2012). Nonetheless, in our analyses, "creative" did not load on Psychoticism and its inclusion within Extraversion was not supported by the more restrictive analyses. It is also worth noting that "creative" exhibited the lowest item communality, revealing that it explains a very small proportion of the variance of the underlying factor (Extraversion). Overall, our findings suggest that, contrary to humans, the item "creative" is not clearly included in any of the higher-order traits in chimpanzees. However, it is also worth noting that creativity is hard to assess in non-human animals (Kaufman and O'Hearn, 2017), and/or on captive environments offering limited opportunities to exhibit innovative behaviours, except when cognitive enrichments like problem-solving tasks are provided (Cronin, 2017; Padrell et al., 2021). Thus, the interpretation of this item may have been challenging for the raters.

As in Úbeda and Llorente (2015), we identified a dimension that included both aspects of Neuroticism and aspects of Psychoticism from the human model (factor 2, see Table 6), which the authors labelled Neuropsychoticism. Considering that the items loading on this factor ("aggressive", "impulsive", "anxious", "cruel" and "bad-tempered") were identical to the ones reported in the former study, our results provide further evidence for this compound dimension in chimpanzees, and suggest that Neuroticism and Psychoticism may not be as distinct in this species as they are in humans. In the first study that compared non-human primates' personality traits with Eysenck's factors, Chamove and colleagues (1972) conducted factor analyses of coded behaviours in rhesus macaques obtaining the traits: Affiliative, Hostile and Fearful, which, according to the authors, were similar to Extraversion, Psychoticism, and Neuroticism found in humans. In our results, the items loading on factor 2 could also be related to hostility (and therefore to human Psychoticism), except for "anxious". In humans, anxiety-related behaviours are clearly attributed to Neuroticism (Eysenck, 1991; Fullerton, 2006). Nonetheless, a link between anxiety and psychotic symptomatology (e.g., schizophrenia) has been reported by several authors (Deng et al., 2020; Hartley et al., 2013; Wigman et al., 2012).

Factor 3 differed from the one described by Úbeda and Llorente (2015) (labelled Dominance), but only in one of the data reduction methods. Particularly, according to the more restrictive analysis (REFA), in the former study factor 3 only included the item "dominant", with a positive and very salient loading (0.97), whereas in the PCA it also included the item "fearful" with a negative loading (−0.68). By contrast, we obtained the same pattern of loadings with both data reduction methods (RULS and PCA), with "fearful" and "dominant" yielding salient loadings on factor 3. In particular, in the RULS we obtained a positive salient loading for "dominant" (0.591) and a negative salient loading for "fearful" (−0.811). Therefore, in our study, factor 3 could also be interpreted as a Dominance-related factor, but considering the high negative loading of "fearful", it could also be identified as Boldness or Confidence. Thus, we decided to combine both elements and name factor 3 Fearless Dominance/Boldness (Crowe et al., 2021). The item "fearful" or "fearfulness" has a negative loading on Dominance across several nonhuman primates' species (Adams et al., 2015; Eckardt et al., 2015; Konečná et al., 2008; Konečná et al., 2012; Manson and Perry,

2013; Morton et al., 2013; Weiss et al., 2011a; Weiss et al., 2015; Wilson et al., 2018), including chimpanzees (King and Figueredo, 1997; Weiss et al., 2009). Although fear in humans is mostly related to the Neuroticism dimension (Eysenck, 1967), in chimpanzees it also plays an important role in dominance-related interactions and relationships. In particular, power conflicts usually involve aggression by more dominant individuals (Noë et al., 1980) and, as a response, submissive animals may display fear through different behaviours (e.g., fleeing, retreating) and by displaying vocal or facial signals (e.g., fear grimace and "bared-teeth" display; Kim et al., 2022; Parr and Waller, 2006).

Finally, our findings support the hypothesis that the Dominance-related factor found in this study may not be directly comparable to any of the human traits described by the PEN model, as it contains items that in humans load on different traits (i.e., Neuroticism and Extraversion). The absence of a Dominance factor in humans may be a consequence of our species having evolved in small-scale egalitarian societies (Weiss, 2022), in contrast to the dominance hierarchies that characterize chimpanzees and other non-human primates, and that are mostly based on agonistic interactions (Bernstein, 1981; Walters and Seyfarth, 1987). Nonetheless, although humans do not have an identifiable Dominance factor, there have been some attempts to develop a dominance scale in our species. For instance, Benning et al., (2003, 2005) defined the trait Fearless Dominance/Boldness in humans using the Psychopathic Personality Inventory (Lilienfeld and Andrews, 1996). Fearless Dominance/Boldness has been identified as an element of psychopathy, describing individuals as resilient to stress and anxiety, social influencers and fearlessness (Crego and Widiger, 2016; Lilienfeld et al., 2016). Further, it is associated with social boldness, egoism, narcissism, and thrill-seeking (Benning et al., 2005) and, according to Weiss (2022), it resembles dominance factors described in chimpanzees, bonobos and orangutans. Thus, factor 3 in our analyses could also be comparable to Fearless Dominance/Boldness in humans (Lilienfeld et al., 2016).

Overall, this study provides further evidence of the possible use of Eysenck's PEN model to describe chimpanzee personality. Eysenck's three higher-order personality traits have been empirically validated in humans (Eysenck and Eysenck, 1994) and they are based on underlying biological mechanisms, including brain activity and hormones (Ergüneş, 2018; Eysenck, 1967; Eysenck, 1983, 1997), which may facilitate inter-species comparison. Another key advantage of using an adaptation of Eysenck's model in non-human primates is that, in contrast to other rating tools, the questionnaire is short and therefore less time-consuming for raters. Furthermore, when the sample size is small, as in this study, fewer items are likely to increase statistical robustness and provide more stable and accurate estimates, because higher subject-to-item ratios are desirable in factorial analyses (Osborne and Costello, 2004). Nonetheless, the PEN model is not without limitations. First, compared to other human models of personality, such as the FFM, or its adaptation to non-human primates, the HPQ, the three factors proposed by Eysenck may not capture some features of non-human primates' personality, such as Openness (to Experience). In addition, the only study that compared behavioural observations with personality ratings obtained with Eysenck's adapted model in chimpanzees reported limited discriminant validity (Padrell et al., 2020). Thus, future research should focus on validating the suitability of the PEN model in chimpanzees and other non-human primates by comparing personality ratings with behavioural measures in different contexts, including spontaneous behaviour, but also behavioural responses under experimental conditions (Massen et al., 2013), which would provide a complementary approach.

5. Conclusions

This study provides further evidence of the potential use of Eysenck's PEN model to assess personality in captive chimpanzees. First, we obtained good reliability between raters, demonstrating that human raters can adequately evaluate the traits from the adapted 12-item questionnaire developed by Úbeda and Llorente (2015). Second, we showed that, using a larger sample, the personality structure and the pattern of loadings for each factor were highly similar to previous research. Overall, our results support the use of shorter questionnaires to evaluate primate personality, especially when assessing small samples, as it increases statistical robustness and accuracy. Furthermore, shorter questionnaires are particularly advantageous for animal keepers in zoos and sanctuaries, who usually have limited time to dedicate to research activities.

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CRediT authorship contribution statement

Maria Padrell: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Visualization, Funding acquisition. **Federica Amici**: Resources, Writing – review & editing, Supervision, Funding acquisition. **Yulán Úbeda:** Investigation, Data curation, Writing – review & editing. **Miquel Llorente**: Conceptualization, Methodology, Formal analysis, Resources, Data curation, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Data Availability

Data will be made available on request.

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Ethics statement

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed. All procedures involving animals were in accordance with the ethical standards of the institution at which the studies were conducted and with the Spanish Government RD 53/2013. In compliance with the General Data Protection Regulation (RGPD-UE 2016/679), raters were provided with an informed consent in which they were informed that their personal data and their responses to the questionnaires would be used anonymously. This project also received the ethical approval from the Ethics Committee of the Universitat de Girona (Project Code: CEBRU0020–2019).

Declarations of conflict of interest

none.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.beproc.2023.104909.

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