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All too human? Chimpanzee and orang-utan personalities are not anthropomorphic projections

Alexander Weiss [a,*], Miho Inoue-Murayama [b], James E. King [c], Mark James Adams [a], Tetsuro Matsuzawa [d]

[a] Department of Psychology, School of Philosophy, Psychology and Language Sciences, The University of Edinburgh, Edinburgh, U.K.
[b] Wildlife Research Center of Kyoto University, Kyoto, Japan
[c] Department of Psychology, University of Arizona, Tucson, AZ, U.S.A.
[d] Primate Research Institute, Kyoto University, Inuyama, Japan

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Ratings of chimpanzee, *Pan troglodytes*, and orang-utan, *Pongo pygmaeus* and *Pongo abelii*, personality reveal dimensions resembling those found in humans. Critics have argued that this similarity derives from anthropomorphic projection or other rater-based effects. We developed two forms of data reduction analyses to determine whether these dimensions can best be explained by the inherent tendencies of the animals (e.g. orang-utans that are curious are playful) or anthropomorphic projections of raters (e.g. believing that orang-utans that are curious should be playful). We found that personality dimensions derived after differences between rater means and rater*item interactions had been removed from ratings replicated the previously discovered dimensions. Conversely, we found a different set of dimensions when analysing items from which differences between animal means and animal*item interactions had been removed. Finally, we used multilevel factor analysis to examine whether the published structure was replicated when we extracted factors based on the within-level animal differences in item scores effects while allowing between-rater differences to covary freely. Again, the personality dimensions were similar to those described in previous studies. These analyses can be used in combination with interrater reliability, temporal stability, and correlations between personality and other external variables to validate animal personality ratings. These analyses confirmed that personality similarities between humans and great apes are best explained by genetic and phylogenetic affinity and not by anthropomorphic artefacts.
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When Jane Goodall described the personalities of wild chimpanzees, her observations were criticized as being anthropomorphic (Goodall 1990). Decades after Goodall first presented her findings, critics continue to warn that ascribing human-like traits such as personality to animals, including nonhuman primates, is contaminated by anthropomorphism (Uher 2008; Wynne 2009). This caution is understandable. Attribution of human characteristics to animals and other nonhuman entities is common among laypersons and scientists alike and possibly reflects a basic process underlying social cognition (Andrews 2009; Waytz et al. 2010). However, no empirical studies support claims that anthropomorphism is always inconsistent with valid scientific inquiry. Moreover, when anthropomorphism is used to generate testable hypotheses, an approach referred to as 'critical anthropomorphism', it can lead to a better understanding of complex animal behaviour (Burghardt 2007). Within the field of animal personality research, the use of critical anthropomorphism has produced findings contrary to what one would expect if anthropomorphism had an inimical influence upon animal personality ratings (Gosling 2001; Maninger et al. 2003; Pederson et al. 2005; Konečná et al. 2008; Kwan et al. 2008; Uher & Asendorpf 2008).

We examined whether ratings-based personality dimensions of chimpanzees, *Pan troglodytes*, and orang-utans, *Pongo pygmaeus* and *Pongo abelii*, are products of anthropomorphic projections of individual raters or other rater biases. A previous study using ratings to study the personalities of chimpanzees revealed six dimensions (King & Figueredo 1997). The first dimension was labelled Dominance as it was apparently indicative of competitive prowess. The five remaining dimensions were similar to the five personality dimensions found in humans (Digman 1990), that is, Neuroticism, Extraversion, Openness, Agreeableness and Conscientiousness, and thus labelled similarly. A study of orang-utans with a slightly expanded rating form yielded only five dimensions. One of these dimensions was labelled Dominance as it appeared to be a more narrowly defined version of the chimpanzee Dominance dimension. Three dimensions resembled the human and chimpanzee Extraversion, Neuroticism and Agreeableness

* Correspondence: A. Weiss, Department of Psychology, The University of Edinburgh, 7 George Square, Edinburgh EH8 9JZ, U.K.
E-mail address: alex.weiss@ed.ac.uk (A. Weiss).

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dimensions. The remaining dimension was specific to orang-utans and labelled Intellect as it consisted of traits related to Openness and Conscientiousness (Weiss et al. 2006).

Considerable evidence suggests that these chimpanzee and orang-utan personality dimensions are real. First, chimpanzee and orang-utan personality dimensions exhibit interrater reliabilities comparable to those of human personality dimensions (King & Figueredo 1997; Weiss et al. 2006, 2007, 2009). Second, the chimpanzee personality dimensions are stable over time (Dutton 2008; King et al. 2008). Third, chimpanzee personality dimensions generalize across samples living in different environments and raters from different cultural backgrounds (King et al. 2005; Weiss et al. 2007, 2009). Fourth, these dimensions are related to observed behaviours (Pederson et al. 2005) and affect (King & Landau 2003; Weiss et al. 2006, 2009). Finally, chimpanzee and orang-utan personality dimensions are heritable (Weiss et al. 2000; Adams et al., in press), and chimpanzee personality dimensions are related to neuroanatomical structures (Blatchley & Hopkins 2010) and genetic polymorphisms (Hong et al. 2011).

There is thus little doubt that personality ratings assess real characteristics of individual animals. However, this does not rule out the possibility that the striking similarities between human personality dimensions, on the one hand, and those of chimpanzees or orang-utans, on the other, are at least partially products of anthropomorphic projections. This possibility arises when ratings on multiple items are used. Correlations between items should reflect individual differences in the personality characteristics of animals. The correlations, however, could also reflect prior anthropomorphic assumptions by individual raters about species-wide characteristics. For example, some raters may believe that chimpanzees in general are both 'active' and 'friendly.' This assumption would cause those raters to assign similar ratings to the 'active' and the 'friendly' descriptors, thus spuriously increasing the correlation that would have otherwise occurred between 'active' and 'friendly.' In addition, if the strength of the anthropomorphic belief about the linkage between active and friendly varied among raters, a rater*item interaction would occur. A similar bias towards a negative correlation would occur if some raters have an anthropomorphic belief that two descriptors are negatively related.

Raters' beliefs about the linkage of paired personality descriptors could emerge from their global assumptions about the personality of chimpanzees or orang-utans or possibly assumptions about chimpanzees or orang-utans generalized from an implicit personality theory about humans. A failure to find effects of such biases would support the view that these dimensions are not mere anthropomorphic artefacts but offshoots of ancestral variants in the common ancestor of great apes and humans 15 million years ago.

METHODS

Subjects

The first sample (the ChimpanZoo sample) comprised 78 male and 124 female chimpanzees ranging in age from 0.8 to 55.2 years (mean $\pm$ SD = 16.5 $\pm$ 12.2). This sample was housed in 17 U.S. zoos and one Australian zoo (King et al. 2008) that participated in the ChimpanZoo project of the Jane Goodall Institute.

The second sample (the Japanese sample) comprised 64 male and 91 female chimpanzees ranging in age from 0.2 to 51.7 years (mean $\pm$ SD = 22 $\pm$ 10.6). This sample was housed in nine zoos, one sanctuary and two research centres in Japan. Of this sample, 60 males and 86 females were described in a previous study (Weiss et al. 2009). The additional chimpanzees included two males and three females housed in the Higashiyama Zoo and two males and two females housed in the Fukuoka Zoo.

The third sample (the orang-utan sample) comprised 70 male and 104 female orang-utans ranging in age from 1.8 to 51.2 years (mean $\pm$ SD = 21.7 $\pm$ 12.1). Of this sample, 58 males and 94 females were housed in 34 U.S., two Canadian and one Australian zoo and were described in a previous study (Weiss et al. 2006). The additional 12 males and 10 females were housed in the Singapore Zoo.

Personality Ratings

Raters of all three samples were employees, volunteers or researchers at the institutions who regularly interacted with the apes. For the ChimpanZoo sample, there were 90 raters. Each chimpanzee was rated by one to eight raters (mean = 3.9). Length of time raters knew the chimpanzees before rating them (mean $\pm$ SD = 5.4 years $\pm$ 4.2) was available for 43 raters of 141 chimpanzees.

For the Japanese sample, there were 52 raters. Each chimpanzee was rated by two to five raters (mean = 3.2). Length of time raters knew the chimpanzees before rating them (mean $\pm$ SD = 5.1 years $\pm$ 4.8) was available for 52 raters of the entire sample.

For the orang-utan sample, there were 107 raters. Each orang-utan was rated by one to six raters (mean = 2.6). Length of time raters knew the orang-utans before rating them (mean $\pm$ SD = 5.9 years $\pm$ 5.6) was available for 107 raters of the entire sample.

Questionnaires instructed raters to base ratings on their impressions of individuals and to use a seven-point scale in which 1 indicated 'Displays either total absence or negligible amounts of the trait.' and 7 indicated 'Displays extremely large amounts of the trait'. The ChimpanZoo sample was rated on the Chimpanzee Personality Questionnaire (King & Figueredo 1997). This questionnaire contains 43 personality descriptor adjectives taken from the human literature (Goldberg 1990). To place adjectives within the context of primate behaviour, each was defined by one to three sentences (e.g. 'FEARFUL: Subject reacts excessively to real or imagined threats by displaying behaviours such as screaming, grimacing, running away or other signs of anxiety or distress.'). Each orang-utan was rated on one of two expanded and slightly modified versions of the questionnaire used to rate chimpanzees. Most of these subjects were rated on a 48-item questionnaire that included the 43 original items used to rate chimpanzees and five new items. A smaller number of subjects in this sample were assessed on a questionnaire that included the 48 items used to rate most of the subjects and six additional items. To maximize our sample size, we only used the 48 items on which all orang-utans in our sample were rated. The Japanese sample was rated on a Japanese-language version of the questionnaire that included all 54 items (Weiss et al. 2009).

While the original item set was sampled from markers of the human Five-Factor Model (Goldberg 1990), the purpose of selecting these items was not to impose the human personality dimensions on nonhuman species. Instead, these items were chosen because they represented a broad range of different traits relevant to the behaviour of nonhuman primates. Moreover, using a common set of items enables direct comparison of the dimensions arising in different samples and species (Weiss & Adams, in press).

Analyses

The standard approach to analysing animal personality ratings involves first computing each animal's mean of the ratings across raters. In other words, each subject's score on each item is equal to the mean of the ratings by raters on that item. Then, to determine the personality dimensions of that species, those mean ratings are subjected to principal components analysis or factor analysis. This approach has the virtue of eliminating the effects of individual raters' nonsystematic deviations from the mean of all raters' scores

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for each combination of animal and item (Rushton et al. 1983). However, this approach cannot reduce the effects of individual differences in raters' systematic deviations from mean ratings as noted in the Introduction. In other words, it would not eliminate rater*item interactions, which could lead to spurious between-item correlations.

The three analyses in the present study differ from this standard approach. These analyses can be illustrated using a modified version of a framework developed by Cattell (1966). This framework acknowledges that, because multiple animals are rated on multiple items by multiple judges (the raters), ratings reflect the animal's behavioural tendencies, item content and rater effects (Fig. 1a). As described below, it is possible to adjust ratings and remove the effects of individual differences in raters' systematic deviations as described above. It is also possible to remove a comparable effect to obtain correlations based on raters' scores independent of differences between animals.

M-Type analysis

For the first analysis (Fig. 1b), each rating of an animal on an item by a judge is adjusted by subtracting that judge's average rating across all animals that they rated on that item (for details see Appendix). These adjusted ratings no longer include rater effects, that is, the mean scores of all raters across animals will be identical. Therefore, any distortion of between-item correlations resulting from between-rater differences in overall item means or from rater*item interactions, as described by the example above, must be zero. Thus, principal components analyses or factor analyses of these adjusted ratings yield personality dimensions that are based on rater discriminations among individual animals and not by between-rater differences in item means or rater*item interactions. If the personality dimensions derived via the standard approach were products of anthropomorphism or implicit personality theories about global prior assumptions about species-wide personality correlations, then principal components analysis or factor analysis of the adjusted ratings should derive different dimensions from the standard approach. On the other hand, if the personality dimensions derived using the standard approach are based mainly on characteristics of individual animals, not raters' implicit or global assumptions about the species in general, then dimensions derived from adjusted ratings should not differ.

We conducted four of these analyses to determine whether these anthropomorphic rater effects were responsible for the previously described chimpanzee personality dimensions (King & Figueredo 1997; Weiss et al. 2009). In all four we used parallel analysis to determine the number of statistically significant dimensions derived from the adjusted scores (Horn 1965; Dinno 2008). If the number of dimensions was the same as the number of dimensions obtained via the standard approach for that species, we compared the dimensions based on adjusted scores and dimensions based on the standard approach. In these cases, we used targeted orthogonal Procrustes rotations (McCrae et al. 1996) to compare the dimensions. Targeted orthogonal Procrustes rotation provides congruence coefficients, which indicate the degree to which the two sets of dimensions are similar (Haven & ten Berge 1977). Congruence coefficients greater than 0.85 indicate that the dimensions are comparable. If the number of components differed from those derived from the standard approach, we rotated the dimensions using the promax procedure. Next, we extracted the same number of components as derived via the standard approach and used a targeted orthogonal Procrustes rotation to compare the dimensions based on adjusted scores and those based on the standard approach.

In the first analysis we compared dimensions derived via principal components analysis of the adjusted ratings of the ChimpanZoo sample to dimensions derived using the standard approach. We derived the latter dimensions using the same 100 chimpanzees and factor analysis procedures described by King & Figueredo (1997). In the second analysis we compared the

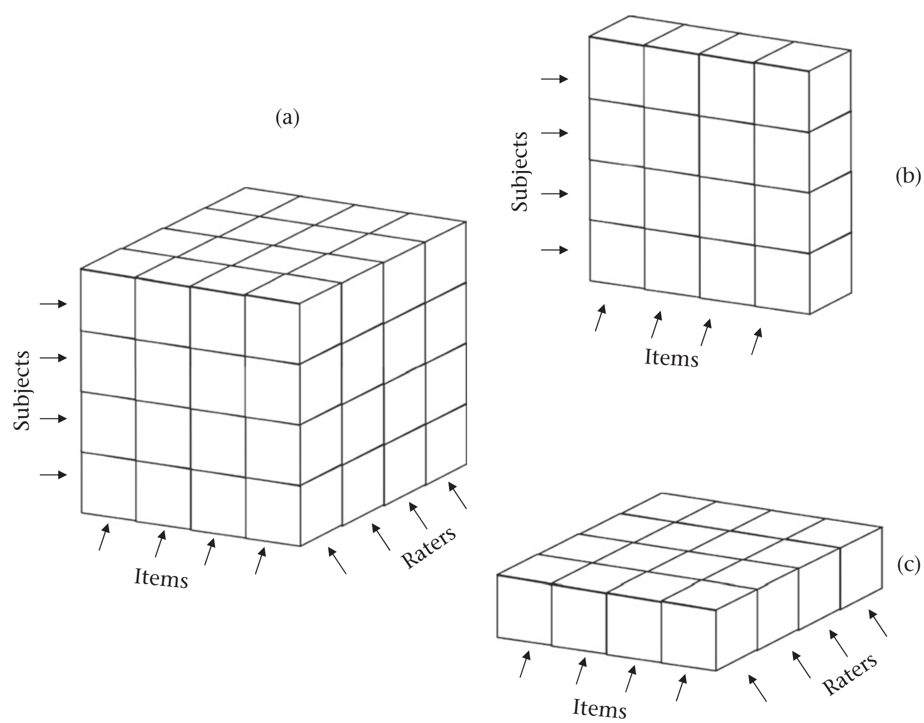

Figure 1. Representation of data using Cattell's data cube. (a) Ratings before adjustment comprise item, subject and rater effects. (b) After rater effects are removed, ratings comprise only subject and item effects. (c) After subject effects are removed, ratings comprise only rater and item effects. Figure by the authors, licensed under a Creative Commons Attribution 3.0 Unported Licence and published under the terms of this licence. See http://creativecommons.org/licenses/by/3.0/ for more information.

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dimensions derived via principal components analysis of the adjusted ratings of the Japanese sample to the dimensions derived using the standard approach for this sample. In the third M-Type analysis, to conduct a more stringent test, we compared the dimensions derived via principal components analysis of the Japanese sample to the dimensions derived using the same 100 chimpanzees and factor analysis procedures, that is, the standard approach, described by King & Figueredo (1997). This analysis was limited to the 43 items both samples shared in common. In the fourth analysis we compared the dimensions derived from the adjusted ratings of the 174 orang-utans to the dimensions derived via the standard approach. We derived the latter dimensions using the same 152 orang-utans and principal components analysis procedures as in Weiss et al. (2006). We conducted these analyses using R (R Development Core Team 2008; Revelle 2009).

G-Type analysis

For the second analysis (Fig.1c), each rating of an animal on an item by a judge is adjusted by subtracting the average rating of that item for that animal by all judges that rated the animal (for technical details see Appendix). These adjusted ratings do not include animal effects. Thus, principal components analysis or factor analysis of these adjusted ratings yield personality dimensions defined by characteristics of the judges and not the animals. We interpreted and assessed these dimensions based on an inspection of the component loadings and likewise compared them to existing dimensions. If the personality dimensions arrived at using the standard approach reflected anthropomorphism or implicit personality theories, the dimensions derived from the adjusted scores should be similar. If the personality dimensions derived using the adjusted scores differ, it would suggest that the personality dimensions derived via the standard approach cannot be attributed to anthropomorphism or implicit personality theories. Finally, examining whether G-Type dimensions are similar or dissimilar across different species rated within the same culture (the ChimpanZoo sample and the orang-utan sample) or the same species rated within different cultures (the ChimpanZoo sample and the Japanese sample) can lead to insights regarding the sources of rater effects.

We conducted one such analysis for each of our three samples. In all three we used parallel analysis to determine the number of significant dimensions (Horn 1965; Dinno 2008). Moreover, in all three cases, because these analyses were exploratory, we rotated the resulting dimensions using the promax procedure. Similarly, we did not label the rater-based dimensions because without understanding the processes involved in rating animal personality that are unrelated to the animal's dispositions, it would be premature to interpret these dimensions. We conducted these analyses using R (R Development Core Team 2008; Revelle 2009).

Multilevel exploratory factor analysis

The third analysis can also be understood within Cattell's (1966) framework. However, instead of adjusting scores by holding the effects of raters or animals constant to determine the dimensions defined by animal or raters, respectively, this approach uses maximum likelihood to find the parameters at both the animal and the rater level that best fit the data (Muthén & Muthén 1998–2010; Reise et al. 2005). In other words, this approach enables us to estimate the factor loadings for the animal effects and the covariances among rater effects simultaneously.

To allow for model convergence, for each species, we analysed one dimension at a time. In addition we combined the ChimpanZoo and Japanese samples into a single sample. There were thus six analyses on the chimpanzees and five analyses on the orang-utans. In each analysis we extracted a single within-rater, that is, animal-based, factor from items that had been identified as defining that dimension in previous studies (King & Figueredo 1997; Weiss et al. 2006, 2009). In the case of chimpanzee Openness, because exploratory factor analysis requires at least three items, we defined this factor by the two items (inventive and inquisitive) identified by King & Figueredo (1997) and the item imitative.

We compared the animal-based factor loadings obtained via multilevel exploratory factor analysis to the loadings on dimensions derived from unadjusted ratings (King & Figueredo 1997; Weiss et al. 2006). We used two methods to compare the dimensions derived using multilevel exploratory factor analysis and those derived via the standard approach. The first method was to compare the two sets of loadings with Tucker's congruence coefficients (Gorsuch 1983, page 285). The second method involved comparing correlations between factor scores of individual animals generated using factor definitions from the standard approach and those generated using the animal-based factor definitions derived via the multilevel factor analyses (Nunnally & Bernstein 1994, page 550).

RESULTS AND DISCUSSION

Relation Matrix Analysis

M-Type analysis

The adjusted ratings of the ChimpanZoo sample defined six significant dimensions. The Procrustes rotation revealed that four of these dimensions were clearly similar to those derived via the standard approach (see first row of Table 1). Neuroticism and Openness were not congruent, probably reflecting the small number of items defining these dimensions (King et al. 2005, pp. 401–402).

The adjusted ratings of the Japanese sample defined seven dimensions. The first was recognizable as Dominance. The second was a blend of Extraversion and Openness. The next three were recognizable as Agreeableness, Conscientiousness and Neuroticism, respectively. The final two reflected Social Confidence and Negative Affect, respectively. Extraction of six dimensions from the adjusted ratings of the Japanese sample yielded dimensions that replicated those derived in the Japanese sample using the standard approach (see second row of Table 1). Comparison of dimensions derived from adjusted ratings of the Japanese sample to the dimensions derived from the original 100 chimpanzees using the standard approach indicated that the entire structure and Dominance, Extraversion, Conscientiousness and Agreeableness replicated. Again, Neuroticism and Openness did not clearly replicate (see

Table 1
Congruence coefficients between animal-based structures derived via the standard approach and M-Type structures

Comparison		Congruences							
Standard	Adjusted	Dom	Ext	Agr	Neu	Con	Opn	Int	Total
ChimpanZoo	ChimpanZoo	0.99	0.98	0.97	0.78	0.98	0.82	–	0.95
Japan (54-item)	Japan (54-item)	0.99	0.97	0.99	0.94	0.95	0.99	–	0.97
ChimpanZoo	Japan (43-item)	0.89	0.92	0.90	0.75	0.90	0.69	–	0.87
Orang-utan	Orang-utan	0.99	1.00	0.97	0.99	–	–	0.97	0.99

Dom = Dominance, Ext = Extraversion, Agr = Agreeableness, Neu = Neuroticism, Con = Conscientiousness, Opn = Openness, Int = Intellect, Total = Total structure.

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third row of Table 1). These congruencies were virtually identical to those obtained when comparing dimensions derived in the Japanese and ChimpanZoo samples using the standard approach (see Table I in Weiss et al. 2009).

For the orang-utan sample, Procrustes rotation revealed that, after adjusting ratings, principal components analysis defined the same personality dimensions as those found using the standard approach (Weiss et al. 2006). In fact, the five dimensions that emerged from adjusted ratings were almost identical to those derived from unadjusted ratings (see fourth row of Table 1).

G-Type analysis

For the ChimpanZoo sample, after adjustment of ratings for animal effects, the intercorrelations among items defined seven dimensions (see Tables 2 and 3). Upon inspecting the rater-based structure, the most striking feature was the lack of a Dominance dimension, which had been a pronounced feature of chimpanzee personality in previous studies (King & Figueredo 1997; Dutton 2008). If the loadings are reflected, that is, multiplied by −1, component I resembled the Agreeableness dimensions found in previous studies (King & Figueredo 1997; Dutton 2008). Component II described individual differences in aggression or hostility.

Table 2
Rater-based G-Type structure of ratings for chimpanzees (ChimpanZoo Sample)

Item	Component						
	I	II	III	IV	V	VI	VII
Affectionate	**−0.74**	−0.02	0.05	−0.25	−0.01	0.06	0.07
Sympathetic	**−0.70**	−0.16	0.09	−0.05	−0.04	−0.02	−0.14
Friendly	**−0.68**	−0.11	0.01	−0.29	−0.08	0.04	0.03
Helpful	**−0.65**	−0.16	−0.03	−0.04	0.07	0.02	−0.22
Sociable	**−0.62**	0.08	−0.03	**−0.50**	−0.05	0.01	0.05
Protective	**−0.62**	0.05	−0.09	−0.01	0.01	−0.05	−0.18
Sensitive	**−0.59**	0.04	0.08	0.01	0.05	0.22	0.10
Gentle	**−0.58**	**−0.43**	0.16	0.07	−0.12	0.03	0.02
Intelligent	**−0.47**	0.07	−0.15	0.00	0.06	0.47	0.04
Jealous	0.09	**0.67**	0.11	0.02	0.01	−0.03	−0.08
Stingy/Greedy	0.18	**0.65**	−0.01	0.16	−0.10	0.04	0.17
Bullying	0.14	**0.63**	−0.14	−0.08	0.15	−0.05	−0.08
Defiant	−0.02	**0.61**	−0.20	0.02	0.25	0.02	−0.22
Aggressive	0.23	**0.60**	−0.14	−0.04	0.25	−0.14	−0.07
Manipulative	−0.17	**0.59**	0.02	−0.20	0.02	0.03	−0.09
Irritable	0.18	**0.56**	−0.04	0.18	0.16	−0.30	0.02
Persistent	−0.22	**0.46**	−0.26	−0.08	0.02	0.09	−0.09
Reckless	0.02	**0.45**	−0.30	0.12	0.36	−0.16	0.13
Timid	0.11	0.02	**0.68**	0.20	−0.01	−0.20	−0.09
Dependent/ Follower	−0.24	−0.02	**0.66**	−0.07	0.02	−0.11	0.06
Fearful	0.03	0.09	**0.63**	0.11	0.31	−0.03	−0.06
Cautious	−0.07	−0.13	**0.63**	0.12	−0.15	0.12	−0.04
Submissive	−0.03	−0.08	**0.62**	0.04	0.09	−0.09	0.11
Independent	−0.10	0.17	**−0.53**	0.13	0.04	0.26	−0.05
Dominant	−0.02	**0.46**	**−0.50**	−0.08	−0.18	0.07	−0.18
Solitary	0.16	−0.07	0.13	**0.69**	−0.03	0.03	−0.25
Depressed	0.19	0.13	0.11	**0.64**	0.03	−0.16	−0.08
Active	−0.16	0.29	−0.02	**−0.55**	0.03	−0.01	−0.33
Lazy	−0.03	0.05	0.02	**0.54**	−0.14	−0.25	0.23
Playful	−0.33	0.19	0.14	**−0.48**	−0.04	0.00	−0.34
Excitable	−0.05	0.38	0.17	−0.04	**0.61**	−0.10	0.02
Unemotional	0.09	0.05	0.02	0.35	**−0.59**	−0.16	−0.12
Impulsive	−0.07	**0.43**	0.00	0.10	**0.56**	−0.17	−0.20
Stable	−0.33	−0.05	−0.29	−0.02	**−0.52**	0.06	0.09
Disorganized	0.03	0.24	0.16	0.15	0.09	**−0.71**	0.06
Decisive	−0.22	0.21	−0.29	0.06	−0.03	**0.56**	0.14
Clumsy	−0.05	0.09	0.12	0.24	−0.02	**−0.55**	0.16
Erratic	0.05	**0.43**	0.01	0.16	0.35	**−0.50**	−0.04
Inventive	−0.34	0.23	−0.13	0.07	−0.01	0.18	**−0.62**
Predictable	−0.18	−0.11	0.04	0.15	−0.34	0.35	**0.50**
Inquisitive	**−0.45**	0.27	0.03	−0.11	−0.06	0.11	**−0.46**
Imitative	−0.21	0.34	0.30	−0.02	−0.08	−0.09	−0.29
Autistic	−0.03	0.27	0.15	0.33	−0.02	−0.09	0.25

Salient loadings (≥|0.40|) are in boldface.

Table 3
Interfactor correlations of rater-based G-Type components of chimpanzees (ChimpanZoo Sample)

Component	I	II	III	IV	V	VI
I						
II	0.09					
III	0.02	−0.22				
IV	−0.11	0.12	0.02			
V	−0.18	0.22	−0.06	0.00		
VI	−0.33	0.13	0.22	0.18	0.28	
VII	0.08	0.18	0.02	−0.35	0.11	0.05

Component III described individual differences in timidity. Component IV was seemingly indicative of negative affect. After its loadings were reflected, component V closely resembled Neuroticism dimensions found in previous studies (King & Figueredo 1997; Dutton 2008). After their loadings were reflected, components VI and VII bore similarities to the Conscientiousness and Openness dimensions, respectively, that were identified in previous studies (King & Figueredo 1997).

The adjusted ratings of the Japanese sample contained eight dimensions (see Tables 4 and 5). Unlike the rater-based dimensions of the ChimpanZoo sample, there was a Dominance dimension (component I), which resembled Dominance dimensions in previous studies (King & Figueredo 1997; Dutton 2008). Component IV was somewhat similar to the previously described Conscientiousness dimension (King & Figueredo 1997). Components V and VI could be best described as dimensions related to individual differences in excitability and timidity, respectively. Component VII, after reflection, and component VIII were similar to the Openness and Agreeableness dimensions described in previous studies (King & Figueredo 1997; Dutton 2008). Components II and III were not easily interpretable.

For the orang-utan sample, principal components analysis of the adjusted ratings yielded six dimensions (see Tables 6 and 7). Components I, II and IV were similar to the Dominance, Agreeableness and Neuroticism dimensions, respectively, that were identified using the standard approach (Weiss et al. 2006). Component III appeared to resemble the Openness dimension identified in chimpanzees (King & Figueredo 1997) and partly resembled Extraversion dimensions identified in orang-utans (Weiss et al. 2006). When reflected, component V appeared to capture individual differences in tameness, which had been identified as a subcomponent of chimpanzee Conscientiousness (King et al. 2008). Component VI was also not previously identified in chimpanzees or orang-utans. This dimension described individual differences in a combination of low activity and low or negative affect.

Multilevel Exploratory Factor Analysis

The animal-based factor loadings replicated those derived using the standard approach (see Tables 8 and 9). The animal-based loadings defining the combined chimpanzee sample were highly congruent with unadjusted loadings: 0.99, 1.00, 0.98, 0.99, 0.98 and 1.00 for Dominance, Extraversion, Conscientiousness, Agreeableness, Neuroticism and Openness, respectively. The animal-based loadings defining the orang-utan sample were also highly congruent: 0.99, 0.99, 0.99, 0.96 and 0.93 for Extraversion, Dominance, Neuroticism, Agreeableness and Intellect, respectively.

Comparison of factor scores computed using the animal-based loadings from the multilevel exploratory factor analysis and factor scores derived from the unadjusted loadings shows that the factor scores are comparable for chimpanzees and orang-utans (Figs 2 and 3, respectively). The correlations for chimpanzee

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Table 4
Rater-based G-Type structure of ratings for chimpanzees (Japanese Sample)

Item	Component							
	I	II	III	IV	V	VI	VII	VIII
Aggressive	**0.73**	0.21	−0.03	0.02	0.11	−0.02	−0.13	−0.11
Bullying	**0.65**	0.19	−0.02	0.04	0.05	0.18	−0.09	−0.24
Dominant	**0.65**	0.10	−0.03	0.21	−0.14	−0.23	−0.09	−0.08
Defiant	**0.64**	−0.02	−0.10	−0.03	0.18	−0.11	−0.09	−0.06
Irritable	**0.64**	−0.09	0.08	−0.15	0.11	0.12	−0.04	−0.07
Jealous	**0.62**	−0.14	−0.03	0.07	−0.04	0.31	−0.13	−0.07
Manipulative	**0.59**	0.23	0.00	0.19	−0.07	−0.04	−0.31	0.13
Excitable	**0.57**	−0.21	0.05	−0.11	0.28	0.13	0.03	0.07
Reckless	**0.55**	−0.02	0.22	−0.33	0.17	−0.01	0.04	0.17
Stingy/Greedy	**0.53**	−0.33	0.19	0.06	−0.01	0.04	0.06	−0.05
Thoughtless	**0.46**	−0.23	0.12	−0.12	0.13	0.09	0.10	0.30
Impulsive	**0.44**	−0.18	0.07	−0.19	0.34	0.10	−0.02	0.09
Distractible	**0.43**	−0.07	0.03	−0.38	0.17	0.17	0.13	0.24
Cautious	**−0.42**	−0.03	0.13	0.35	0.02	0.37	−0.14	−0.01
Unemotional	−0.14	**0.58**	0.12	0.03	−0.13	0.16	−0.04	0.20
Cool	−0.22	**0.50**	0.19	0.14	−0.26	0.06	−0.18	0.10
Helpful	0.18	**0.47**	−0.15	0.12	0.05	−0.13	−0.23	0.38
Clumsy	0.17	**0.41**	0.31	−0.25	0.27	0.19	0.03	0.11
Solitary	0.00	0.06	**0.72**	0.04	0.13	0.09	−0.04	−0.07
Individualistic	0.18	0.00	**0.63**	−0.01	0.06	0.01	−0.02	−0.04
Lazy	0.02	0.21	**0.46**	−0.17	0.18	0.13	0.23	0.16
Sensitive	0.07	−0.05	−0.05	**0.68**	−0.03	−0.06	−0.03	0.25
Intelligent	0.05	0.19	−0.14	**0.64**	−0.05	−0.07	−0.18	0.16
Decisive	0.01	0.14	0.22	**0.50**	−0.11	−0.01	−0.30	0.12
Unperceptive	0.17	0.33	0.16	**−0.46**	0.02	0.33	0.06	0.11
Predictable	−0.23	0.29	0.29	**0.42**	−0.30	0.19	0.12	0.05
Conventional	−0.18	0.21	0.13	**0.40**	−0.26	0.20	0.29	0.06
Erratic	0.10	−0.10	0.12	−0.08	**0.73**	0.04	0.02	−0.05
Disorganized	0.16	0.15	0.03	−0.17	**0.60**	0.21	0.02	0.09
Anxious	0.09	0.06	0.11	−0.14	**0.54**	0.19	0.04	0.00
Autistic	0.10	−0.15	0.09	0.07	**0.51**	−0.13	0.01	−0.14
Timid	0.15	−0.04	0.09	−0.16	0.14	**0.64**	0.08	−0.01
Vulnerable	0.09	0.15	0.11	0.00	0.06	**0.57**	0.00	−0.12
Dependent	−0.01	0.11	−0.09	−0.08	−0.20	**0.51**	−0.13	0.35
Fearful	0.02	−0.28	−0.09	0.25	0.35	**0.44**	0.06	−0.13
Depressed	−0.05	−0.07	0.38	0.00	0.26	**0.42**	0.06	−0.08
Inventive	0.00	0.00	0.01	−0.02	0.00	0.01	**−0.76**	0.19
Inquisitive	0.03	0.05	0.01	0.10	−0.13	0.02	**−0.72**	0.16
Innovative	0.13	0.26	0.06	−0.01	−0.01	0.01	**−0.68**	0.21
Curious	0.00	−0.10	−0.11	0.23	0.08	−0.09	**−0.67**	0.09
Playful	0.16	**0.42**	−0.32	0.03	−0.03	0.01	**−0.44**	0.25
Affectionate	0.03	0.08	−0.06	0.19	0.00	−0.16	−0.14	**0.70**
Sociable	0.07	0.18	−0.28	0.15	−0.07	−0.03	−0.21	**0.61**
Gentle	−0.29	0.14	0.19	0.08	−0.02	−0.09	−0.16	**0.61**
Friendly	−0.31	0.04	0.13	0.13	−0.06	0.09	−0.15	**0.57**
Sympathetic	0.00	**0.42**	−0.33	0.10	0.05	−0.10	−0.14	**0.54**
Imitative	0.17	0.13	−0.05	−0.05	0.08	0.17	−0.34	**0.50**
Submissive	−0.06	−0.02	0.10	−0.06	−0.12	**0.44**	−0.07	**0.50**
Active	0.28	0.26	−0.31	−0.02	0.13	0.19	−0.36	0.07
Independent	−0.10	0.36	0.25	0.19	0.39	−0.09	−0.09	−0.01
Persistent	0.27	0.22	0.06	0.22	−0.16	−0.13	−0.39	0.02
Protective	−0.05	0.38	−0.10	0.31	0.20	0.17	−0.09	0.20
Quitting	0.18	0.27	−0.05	0.06	0.28	0.37	0.21	0.13
Stable	−0.29	0.38	0.08	0.26	−0.29	−0.18	−0.09	−0.02

Salient loadings (≥|0.40|) are in boldface.

Table 5
Interfactor correlations of rater-based G-Type components of chimpanzees (Japanese Sample)

Component	I	II	III	IV	V	VI	VII
I							
II	0.19						
III	−0.12	0.25					
IV	−0.26	0.17	0.21				
V	0.29	−0.03	0.03	−0.22			
VI	0.14	−0.09	−0.01	−0.09	0.22		
VII	−0.03	−0.27	−0.17	−0.07	0.03	0.25	
VIII	0.29	0.29	0.26	−0.22	0.10	0.23	0.02

Dominance ($r = 1.00$), Extraversion ($r = 1.00$), Conscientiousness ($r = 1.00$), Agreeableness ($r = 1.00$), Neuroticism ($r = 0.99$) and Openness ($r = 1.00$) were all significant (all $Ps < 0.001$). The correlations for orang-utan Extraversion ($r = 0.81$), Dominance ($r = 0.97$), Neuroticism ($r = 0.93$), Agreeableness ($r = 1.00$) and Intellect ($r = 0.98$) were significant (all $Ps < 0.001$).

GENERAL DISCUSSION

The previously described personality dimensions based on ratings of two great ape species were not appreciably affected by

Table 6
Rater-based G-Type structure of ratings for orang-utans

Item	Component					
	I	II	III	IV	V	VI
Bullying	**0.64**	−0.06	−0.11	0.03	−0.07	0.02
Aggressive	**0.62**	−0.05	−0.10	0.11	0.18	−0.14
Stingy/Greedy	**0.59**	−0.15	0.08	0.18	0.07	−0.03
Dominant	**0.53**	−0.01	0.09	−0.20	−0.02	0.05
Jealous	**0.51**	0.01	0.13	0.24	0.18	−0.08
Manipulative	**0.46**	0.37	−0.07	−0.13	0.16	−0.12
Independent	**0.47**	−0.12	0.29	−0.25	−0.08	0.21
Submissive	**−0.46**	0.16	0.00	0.33	0.09	0.10
Persistent	**0.41**	−0.09	0.35	−0.07	0.21	−0.05
Sympathetic	−0.12	**0.70**	0.24	−0.13	−0.14	0.00
Helpful	−0.12	**0.68**	0.08	−0.10	−0.01	−0.19
Sensitive	−0.02	**0.56**	0.06	0.14	−0.17	0.04
Protective	0.12	**0.54**	0.15	−0.09	0.01	−0.03
Affectionate	−0.34	**0.51**	**0.43**	−0.07	0.02	−0.09
Gentle	**−0.45**	**0.46**	0.10	−0.27	−0.11	−0.02
Imitative	−0.02	**0.45**	0.09	0.06	0.07	−0.06
Curious	0.01	0.01	**0.68**	−0.03	−0.04	−0.08
Inquisitive	0.04	0.18	**0.62**	−0.15	−0.08	−0.05
Inventive	0.22	0.24	**0.53**	0.01	−0.13	−0.05
Sociable	−0.23	0.27	**0.52**	−0.06	−0.10	−0.11
Intelligent	0.14	0.35	**0.46**	−0.12	−0.05	−0.09
Friendly	−0.24	0.33	**0.45**	0.09	−0.20	−0.18
Decisive	**0.40**	0.06	**0.44**	−0.13	−0.19	0.25
Fearful	0.08	0.02	0.00	**0.74**	−0.06	0.07
Timid	−0.11	−0.03	−0.22	**0.60**	0.12	0.07
Cool	−0.16	0.17	0.09	**−0.60**	−0.03	0.29
Stable	−0.04	0.14	0.27	**−0.59**	0.17	0.12
Excitable	0.19	0.02	0.15	**0.55**	0.21	−0.26
Anxious	0.03	0.06	−0.06	**0.54**	0.21	0.16
Erratic	0.14	−0.10	0.00	0.15	**0.71**	−0.14
Clumsy	0.00	0.03	−0.08	0.00	**0.63**	0.24
Disorganized	−0.02	−0.04	−0.14	0.09	**0.58**	0.15
Irritable	**0.45**	−0.09	−0.16	0.09	**0.52**	−0.01
Defiant	**0.43**	0.09	−0.07	−0.12	**0.50**	−0.14
Predictable	−0.03	0.13	0.06	−0.09	**−0.46**	0.29
Impulsive	0.27	−0.01	0.18	0.33	**0.40**	−0.27
Lazy	0.00	−0.09	−0.18	0.08	0.10	**0.66**
Active	0.02	0.28	0.19	−0.09	0.17	**−0.58**
Conventional	−0.13	−0.03	0.08	0.04	0.00	**0.56**
Unemotional	−0.06	0.01	0.02	−0.21	0.11	**0.56**
Playful	0.00	0.23	0.25	0.00	0.11	**−0.45**
Depressed	0.09	0.03	**−0.42**	0.28	0.16	**0.44**
Cautious	−0.14	0.29	−0.11	0.25	−0.07	0.13
Autistic	0.13	0.26	−0.25	0.12	0.30	0.08
Reckless	0.37	0.02	−0.08	0.14	0.13	−0.03
Solitary	0.19	0.16	−0.36	0.07	−0.11	0.35
Vulnerable	−0.12	0.03	−0.02	0.38	0.22	0.15
Dependent	−0.27	0.38	−0.11	0.19	0.23	−0.07

Salient loadings (≥|0.40|) are in boldface.

Table 8
Comparison of within-rater factor loadings and factor loadings derived using the standard approach for chimpanzees (combined ChimpanZoo and Japanese Sample)

Item	Loading	
	Standard	Within-rater
Dominance		
Dominant	0.90	0.82
Submissive	−0.86	−0.76
Dependent	−0.86	−0.70
Independent	0.83	0.57
Fearful	−0.82	−0.54
Decisive	0.82	0.50
Timid	−0.81	−0.63
Cautious	−0.63	−0.52
Intelligent	0.63	0.33
Persistent	0.61	0.51
Bullying	0.58	0.55
Stingy	0.52	0.41
Extraversion		
Solitary	−0.85	−0.67
Lazy	−0.83	−0.65
Active	0.83	0.77
Playful	0.81	0.78
Sociable	0.80	0.72
Depressed	−0.78	−0.59
Friendly	0.65	0.51
Affectionate	0.60	0.52
Imitative	0.52	0.52
Conscientiousness*		
Impulsive	−0.78	−0.66
Defiant	−0.74	−0.71
Reckless	−0.73	−0.64
Erratic	−0.72	−0.53
Irritable	−0.62	−0.64
Predictable	0.61	0.42
Aggressive	−0.60	−0.73
Jealous	−0.58	−0.58
Disorganized	−0.53	−0.33
Agreeableness		
Sympathetic	0.84	0.86
Helpful	0.74	0.70
Sensitive	0.74	0.53
Protective	0.70	0.57
Gentle	0.61	0.62
Neuroticism		
Stable	0.73	0.60
Excitable	−0.71	−0.80
Unemotional	0.57	0.40
Openness		
Inventive	0.65	0.77
Inquisitive	0.64	0.89

* Within-rater loadings for this factor were reflected.

removal of rater effects via the M-Type analysis or via multilevel exploratory factor analysis. If the expectations of raters influenced their assessment of the personalities of nonhuman primates, we would expect a lower congruence between the animal-based factors and conventionally defined factors. Thus, biases, preconceptions and projections (anthropomorphic and otherwise) cannot account for the personality dimensions in these three samples.

Table 7
Interfactor correlations of rater-based G-Type components of orang-utans

Component	I	II	III	IV	V
I					
II	0.09				
III	0.12	0.44			
IV	0.08	0.26	0.04		
V	0.18	−0.30	−0.13	−0.11	
VI	−0.13	0.18	−0.15	0.34	−0.30

These findings are consistent with studies that demonstrated interrater reliability and those showing that ratings are related to behaviours and other outcomes (Freeman & Gosling 2010). They also agree with studies showing that personality dimensions derived using behavioural observations and measures are comparable to those derived from ratings (Konečná et al. 2008; Bergvall et al. 2011). Finally, they are consistent with those showing that humans do not project their personalities onto their dogs (Kwan et al. 2008) and that human personality dimensions reflect genetic correlations among lower-order traits and not implicit personality theories or correlations based entirely on the semantic meaning of items (Rowe 1982; McCrae et al. 2001).

Our findings therefore suggest that similarities among great ape and human personality dimensions are most parsimoniously

Table 9
Comparison of within-rater factor loadings and factor loadings derived using the standard approach for orang-utans

Item	Loading	
	Unadjusted	Within-rater
Extraversion		
Playful	0.84	0.84
Active	0.83	0.90
Lazy	−0.80	−0.85
Curious	0.77	0.62
Conventional	−0.76	−0.56
Inquisitive	0.70	0.58
Inventive	0.69	0.53
Depressed	−0.64	−0.56
Imitative	0.63	0.63
Solitary	−0.59	−0.54
Unemotional	−0.53	−0.46
Dominance		
Bullying	0.87	0.88
Aggressive	0.82	0.81
Stingy	0.78	0.72
Jealous	0.75	0.62
Dominant	0.75	0.72
Gentle	−0.72	−0.68
Defiant	0.68	0.55
Submissive	−0.67	−0.63
Manipulative	0.66	0.46
Persistent	0.62	0.59
Irritable	0.60	0.58
Reckless	0.56	0.37
Neuroticism		
Anxious	0.83	0.67
Fearful	0.82	0.72
Cool	−0.73	−0.77
Timid	0.70	0.56
Stable	−0.66	−0.61
Excitable	0.58	0.62
Impulsive	0.56	0.53
Cautious	0.55	0.37
Vulnerable	0.48	0.38
Erratic	0.48	0.42
Predictable	−0.47	−0.48
Agreeableness		
Sympathetic	0.82	0.71
Helpful	0.79	0.70
Protective	0.73	0.35
Affectionate	0.67	0.81
Sensitive	0.63	0.47
Friendly	0.63	0.80
Sociable	0.61	0.77
Intellect		
Intelligent	0.72	0.38
Decisive	0.70	0.69
Clumsy	−0.66	−0.37
Disorganized	−0.66	−0.36
Independent	0.64	0.79
Dependent	−0.52	−0.74

explained as evolutionarily conserved features. The conservation of behavioural dispositions across species suggests that processes of balancing selection (environmental heterogeneity, negative frequency-dependent selection, and migration) that have been implicated in the evolution of human personality (Penke et al. 2007) have also maintained variation in chimpanzee and orang-utan personality.

While the present study describes dimensions related to the effects of between-rater differences, it cannot explain the processes that give rise to these dimensions. One possibility is that these rater-based dimensions arise via the semantic similarity of the items (D'Andrade 1965). However, our finding that the rater-based dimensions for the ChimpanZoo and orang-utan samples differ diminishes the likelihood of this possibility. Another possibility is that the rater-based dimensions describe raters' general prior beliefs about the species that is being rated. However, our finding of different rater-based dimensions in raters from Western and Eastern cultures seems to rule against this possibility, too. This difference also suggests the possibility that the rater-based dimensions reflect culturally specific views and expectations about the personalities of these species. Future studies comparing the beliefs about the personalities of great apes in Japan and in English-speaking countries are needed to test this possibility.

Rater-based dimensions can aid researchers in understanding how people perceive animal personality in other ways. Because the effects of the animals have been removed from the rater-based dimensions, they potentially reflect the diversity among raters in their dispositions and assumptions. Future studies should therefore examine correlations between rater-based dimensions and characteristics of raters, including their personalities, dispositions toward primates or preconceptions concerning the personality structure of given species.

Our study does not suggest that ratings-based approaches should replace behavioural observations or tests. Instead, ratings should be viewed as complementing behavioural observations or tests and used alongside such tests (Konečná et al. 2008; Uher & Asendorpf 2008; Nettle & Penke 2010; Bergvall et al. 2011) or used when behavioural observations or tests would not be feasible.

The present study is not without shortcomings. The M-Type factor analysis only removes the main effects of raters and rater*item interactions. As such, the remaining covariances describe animal effects and the interaction of rater and animal effects. This interaction may be responsible for some or all of the consistency of the animal-based dimensions and those described in previous studies. However, we found similar results using multilevel exploratory factor analysis, which does not suffer from this shortcoming. Another shortcoming is that, given the sample size, number of items and the unbalanced design, conducting the multilevel exploratory factor analysis required examining one personality dimension at a time. As such, information about cross-loadings of items onto different dimensions was lost. We therefore recommend that future studies of this sort use more subjects and a balanced design.

These findings strongly rule out the possibility that similarities between the personalities of humans and great apes derived via ratings are anthropomorphic projections. Instead, they suggest that Goodall's (1990) impressions of the human-like personalities of the chimpanzees she studied reflected the chimpanzees' individual behavioural differences. Naturally, researchers should remain leery of attributing human-like personality traits such as 'thoughtlessness' to invertebrates or other distantly related species (Hebb 1946). However, researchers should also avoid engaging in 'anthropodenial' (de Waal 2009), that is, rejecting, without evidence, and even in the face of contradictory evidence, the possibility that the genetic similarity of closely related species may be expressed in behavioural similarities.

Even though 50 years have passed since Goodall's observations of chimpanzee personalities were criticized as being anthropomorphic, critics have not tested their claims. By conducting this study, we took up the mantle that critics refused to don themselves. In doing so, we found evidence refuting their worst fears and concerns over anthropomorphism, which, in fact, casts nary a shadow over great ape personality.

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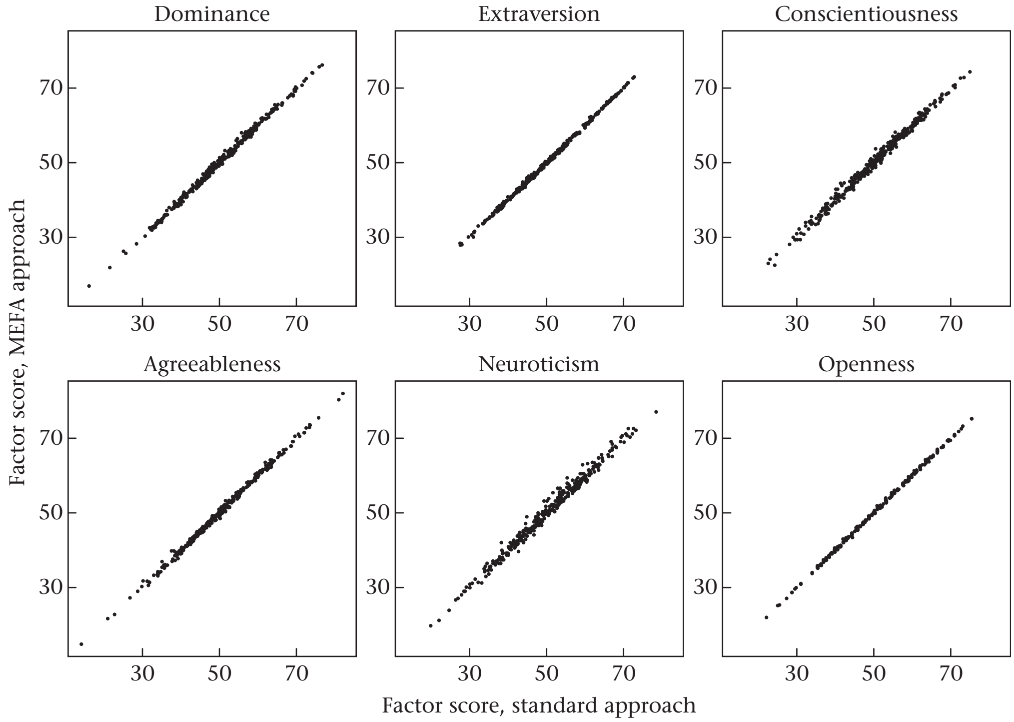

Figure 2. Chimpanzee factor scores. A factor score in each personality domain was calculated for all individuals weighted by the factor loadings derived via the standard approach or by the within-rater factor loadings. Raw scores were converted to *T* scores (mean ± SD = 50 ± 10). Strong correlations between the two factor scores indicate high congruence in structure before and after covariances attributable to raters were removed. Figure by the authors, licensed under a Creative Commons Attribution 3.0 Unported Licence and published under the terms of this licence. See http://creativecommons.org/licenses/by/3.0/ for more information.

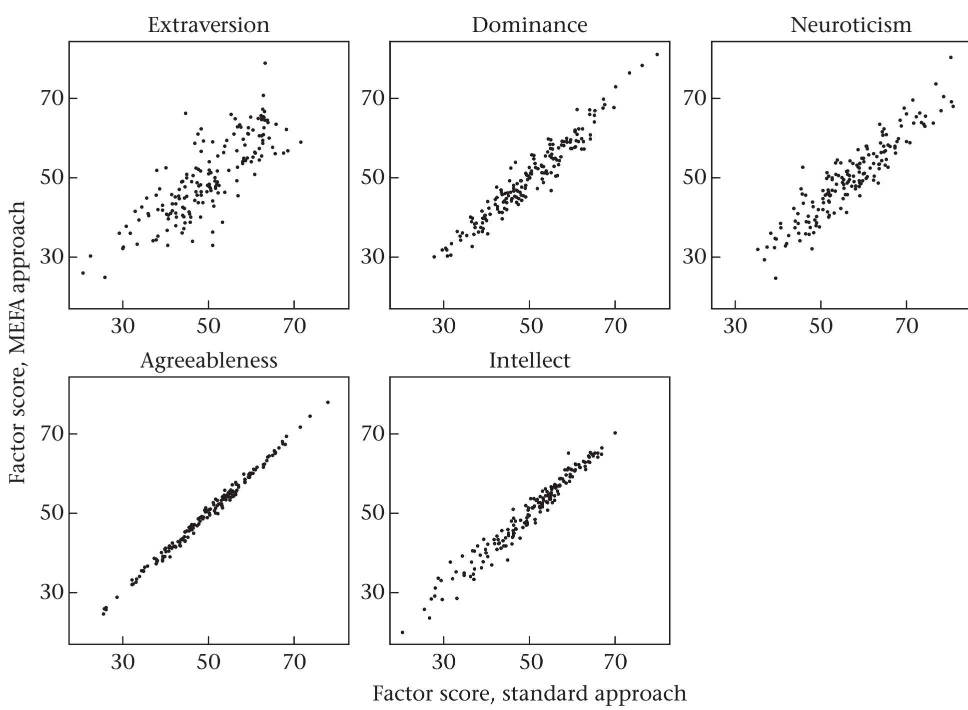

Figure 3. Orang-utan factor scores. A factor score in each personality domain was calculated for all individuals weighted by the factor loadings derived via the standard approach or by the within-rater factor loadings. Raw scores were converted to *T* scores (mean ± SD = 50 ± 10). Strong correlations between the two factor scores indicate high congruence in structure before and after covariances attributable to raters were removed. Figure by the authors, licensed under a Creative Commons Attribution 3.0 Unported Licence and published under the terms of this licence. See http://creativecommons.org/licenses/by/3.0/ for more information.

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Appendix

M-Type and G-Type Analysis

The analyses used are based on the nested nature of the data, that is, the fact that each animal is rated by more than one knowledgeable rater on multiple items. When data are nested in this manner, items may correlate with each other for multiple reasons (Cattell 1966). In these analyses, we can statistically remove sources of covariance among items related to raters or animals.

The M-Type analysis involves extracting dimensions that describe the animals. We calculated the deviation of each rater *j*'s raw score of animal s on item i (x_{sji}) from the rater's mean score for that item across all animals

$$m_{sji} = x_{sji} - \sum_{l=1}^{n_j} \frac{x_{lji}}{n_j} \quad \text{(A1)}$$

where rater j rated n_j subjects and x_{lji} is the rater's rating of their lth subject. Raters' mean scores are equal to the predicted score of rater j on item i from a regression on a rater identity matrix

$$m_{sji} = x_{sji} - \hat{x}_{ji} \quad \text{(A2)}$$

$$\hat{x}_{ji} = \mu_i + u_{ji0} \quad \text{(A3)}$$

We then subjected the m_{sji} scores to a parallel and principal components analysis.

We used a corresponding procedure for the G-Type analysis to extract the rater dimensions, subtracting each animal's predicted score on an item from the raw score. This, too, can be derived in a similar way from regression

$$g_{sji} = x_{sji} - \sum_{m=1}^{k_j} \frac{x_{smi}}{k_j} \quad \text{(A4)}$$

$$g_{sji} = x_{sji} - \hat{x}_{si} \quad \text{(A5)}$$

$$\hat{x}_{si} = \mu_i + u_{si0} \quad \text{(A6)}$$

We then subjected the g_{sji} scores to a parallel and principal components analysis.

R Code

For the M-Type analysis, let `Scores` be a data frame with columns `subject` and `rater` of type factor and numeric columns with names `item.names` of the rater's score of the subject on each item. For convenience we massage the vector `item.names` into a list

```
items <- as.list(item.names)
names(items) <- item.names
```

and transform this list into a list of formulae of the form `item ~ rater`

```
item.formulae <- lapply(items,
function(x) {formula(paste(x, '~ rater'))})
```

We then have a function that runs a linear model using each formula on the `Scores` data and returns the residuals

```
m.lm <- function(item.formula, data) {
model <- lm(item.formula, data=data);
m <- model$residuals
return(m)
}
```

We apply this function to each formula and turn the resulting list of residuals back into a data frame

```
M <- as.data.frame(lapply(item.formulae, m.lm,
data=Scores))
```

The data frame `M` is then suitable as an input to functions for parallel and principal components analyses

```
library(paran)
library(psych)
m.pa <- paran(M, graph=TRUE)
m.pca <- principal(M, nfactors=m.pa$Retained)
```

The G-Type analysis proceeds as above except that the formula construction is of the form

```
item.formulae <- lapply(items,
function(x) {formula(paste(x, '~ subject'))})
```

SAS Code

For the M-Type analysis, let `Scores` be a data set with columns `subject` and `rater` which are nominal variables and numeric columns with names `item_1`, `item_2`, … `item_i` of the rater's score of the subject on each of i items. We will output the residuals to a temporary data set named `m_Scores`

```
proc glm data=Scores;
class rater;
model item_1-item_i =rater;
output out=m_Scores r=m_item_1-m_item_i;
run;
```

The residualized variables stored in the temporary data set `m_Scores` can then be subjected to parallel analysis and principal components analyses.

We can use a similar method to obtain the variables for the G-Type analysis

```
proc glm data=Scores;
class subject;
model item_1-item_i =subject;
output out=g_Scores r=g_item_1-g_item_i;
run;
```

SPSS Code

For the M-Type analysis, let `Scores` be a data set with columns `subject` and `rater` which are nominal variables and numeric columns with names `item_1`, `item_2`, … `item_i` of the rater's score of the subject on each of i items

```
DATASET ACTIVATE Scores.
UNIANOVA item_1 to item_i BY rater
/METHOD=SSTYPE(3)
/INTERCEPT=INCLUDE
/SAVE=ZRESID
/CRITERIA=ALPHA(0.05)
/DESIGN=rater.
```

The residualized variables, that is, the `m_scores` will be stored at the end of the `Scores` data set. These variables can be subjected to parallel analysis and principal components analyses. We can use a similar approach to obtain the variables for the G-Type analysis

```
DATASET ACTIVATE Scores.
UNIANOVA item_1 to item_i BY subject
/METHOD=SSTYPE(3)
/INTERCEPT=INCLUDE
/SAVE=ZRESID
/CRITERIA=ALPHA(0.05)
/DESIGN=subject.
```

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