ARTICLE IN PRESS

Journal of Research in Personality xxx (2012) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Journal of Research in Personality

journal homepage: www.elsevier.com/locate/jrp

Personality in Barbary macaques (*Macaca sylvanus*): Temporal stability and social rank

Martina Konečná [a,*], Alexander Weiss [b], Stanislav Lhota [a,c,1], Bernard Wallner [d]

[a] Department of Zoology, Faculty of Science, University of South Bohemia, Branišovská 31, 37005 České Budějovice, Czech Republic
[b] Scottish Primate Research Group, Department of Psychology, School of Philosophy, Psychology and Language Sciences, The University of Edinburgh, 7 George Square, Edinburgh EH8 9JZ, United Kingdom
[c] Ústí nad Labem Zoo, Drážďanská 23, 400 07 Ústí nad Labem, Czech Republic
[d] Department of Anthropology, University of Vienna, Althanstrasse 14, 1090 Vienna, Austria

ARTICLE INFO

Article history:
Available online xxxx

Keywords:
Primates
Macaque
Personality
Retest reliability
Individual differences
Dominance hierarchy

ABSTRACT

Tracing the evolutionary origins of species-specific personality structures requires comparative personality research. We used a 51 item questionnaire to examine the personality structure of 26 semi-free-ranging Barbary macaques assessed at two time points. Principal-components analysis revealed four dimensions: Friendliness, Activity/Excitability, Confidence, and Opportunism. These dimensions were reliable across raters, stable over time, and both similar to and different from the personality dimensions of free-ranging rhesus macaques and male Hanuman langurs. We modeled the relationships between Confidence and a behavioral measure of rank at both time points. The stability of rank over time could be explained by Confidence but not vice versa. These findings highlight how interspecies differences in personality structure reflect personality evolution and how rank is related to personality.

1. Introduction

Members of a species can be characterized by stable individual differences in characteristics such as behavior and affect, otherwise known as personality or temperament (Gosling, 2001). In addition, the personalities of species can be characterized by describing the dimensions along which personality traits are organized or their 'structure' (Gosling, 2001). Species differences in personality structure may be associated with species differences in social behavior and how the characteristics of societies emerge from the interactions of individual differences of their members (Capitanio, 2004; Uher, 2008). Comparing the personality structures of species that differ in their phylogenetic relatedness and/or socioecological characteristics may thus offer insights into personality evolution and reveal which personality dimensions are species-specific and which are shared (Gosling & Graybeal, 2007; Gosling & John, 1999; Uher, 2008).

Macaque species live in multi-male/multi-female groups and exhibit female philopatry; however, there are clear differences among macaque species in their social behavior, and particularly patterns of aggression and reconciliation (Thierry, 2004, 2006). These differences have been used to classify macaque species' inter-individual tolerance along a four-grade scale (Thierry, 2000). Grade 1 species (e.g., rhesus macaques) are "despotic" and characterized by steep dominance hierarchies, frequent high-intensity unidirectional aggression, and a high degree of kin bias. Grade 4 species (e.g., Sulawesi macaques) are "tolerant" and characterized by dominance hierarchies that are less steep, aggression that is less severe and often bidirectional, and only a modest degree of kin bias. A phylogenetic study of these social styles revealed that their distribution could be explained by macaque phylogeny and that the relatively tolerant (Grade 3) social style of species such as Barbary macaques was ancestral (Thierry, Iwaniuk, & Pellis, 2000).

While the personality structures of all macaque species have not been mapped out (Thierry, 2004), behavioral studies suggest that Grades 3 and 4 species explore their environment more and are less easily aroused (Clarke & Boinski, 1995; de Waal & Luttrell, 1989). Studies of captive macaques also revealed differences among species in aggression, reconciliation, the tendency to affiliate, mothering behavior, and other characteristics (reviewed in Capitanio, 2004; Thierry, 2004).

For this study we used ratings to identify the personality structure of semi-free-ranging Barbary macaques. To date, ratings-based studies of macaque personality have focused mostly on rhesus macaques (Freeman & Gosling, 2010). These studies found that ratings of rhesus macaques are consistent across raters (Capitanio,

* Corresponding author. Fax: +420 389022263.
E-mail addresses: konecnamar@yahoo.com (M. Konečná), alex.weiss@ed.ac.uk (A. Weiss), stanlhota.indo@gmail.com (S. Lhota), bernard.wallner@univie.ac.at (B. Wallner).
[1] Now at Department of Animal Breeding and Ethology, Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences, Kamycka 129, Prague 16521, Czech Republic.

0092-6566/$ - see front matter © 2012 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.jrp.2012.06.004

1999; Stevenson-Hinde & Zunz, 1978; Weiss, Adams, Widdig, & Gerald, 2011), stable across time (Capitanio, 1999; Stevenson-Hinde, Stillwell-Barnes, & Zunz, 1980; Weiss et al., 2011) and situations (Capitanio 1999), predict behaviors (Capitanio, 1999; Capitanio, 2002; Stevenson-Hinde et al., 1980), and are related to subjective well-being (Weiss et al., 2011) as well as physiological measures (Capitanio, Mendoza, & Baroncelli, 1999; Capitanio, Mendoza, & Bentson, 2004).

Studies have also been conducted on other macaque species (Caine, Earle, & Reite, 1983; Figueredo, Cox, & Rhine, 1995; Martau, Caine, & Candland, 1985). However, while these studies demonstrate that their personalities can be reliably rated by judges, these studies did not seek to identify personality dimensions specific to these species. Instead, they used confirmatory means to impose the structures of existing personality models (developed by Buirski, Plutchik, & Kellerman, 1978 or Stevenson-Hinde & Zunz, 1978) on these species.

For this study we also compared Barbary macaque personality structure to that of a small sample of free-ranging Hanuman langur males (Konečná et al., 2008) and that of a large sample of free-ranging rhesus macaques (Weiss et al., 2011). These comparisons will be an important step in understanding which personality dimensions reflect common descent from a macaque or Cercopithecidae ancestor species and which dimensions reflect convergent or divergent evolution.

Barbary and rhesus macaques descended from a relatively recent common ancestor some 5.5 million years ago (Abegg, 2006). This and their similar social structures lead us to expect some conservation of personality structure across these species. Barbary and rhesus macaques also exhibit similar group composition and diet preferences. We therefore expect that personality dimensions relevant to these shared characteristics would be conserved. However, given the considerable differences in social styles, with Barbary macaques being relatively tolerant and rhesus macaques being despotic, we also expect some differences. In particular, we expect differences in aspects of personality relevant to aggression, dominance aquisition, and choice of social partners.

Hanuman langurs were chosen as a comparison group because they represent the only species of the family Colobinae with available personality data (Konečná et al., 2008). Moreover, the Hanuman langurs were rated using the same instrument as was used to rate the Barbary macaques in the present study. Barbary macaques and Hanuman langurs shared a more distant common ancestor approximately 14 million years ago (Stewart & Disotell, 1998). We thus expect their personality structures to diverge. There are multiple differences that also lead us to expect differences in the personalities of Barbary macaques and Hanuman langurs. For one, Hanuman langurs live in one-male multi-female groups with extra males forming all male bands, although groups with multiple males are not rare in some populations (Koenig & Borries, 2001). Furthermore, while Hanuman langurs form linear dominance hierarchies within groups, ranks are less stable and both coalitions and nepotism are rare (Koenig & Borries, 2001). The two species also differ in diet preferences. Hanuman langurs have a higher proportion of leaves in their diet than do macaques. Moreover, unlike Barbary macaques, Hanuman langurs do not engage in extractive foraging for invertebrates or other food sources hidden in leaf litter (Ménard, 2004). However, there are similarities between Barbary macaques and Hanuman langurs, which may lead to similarities in their personality structures. For one, female philopatry is present in both species. Another similarity is that like Barbary macaques, Hanuman langurs are a generally tolerant species with less common severe aggression (Borries, 1993; Koenig & Borries, 2001). Moreover, given that these species are social primates, both likely face similar problems related to social living. Thus we expect similarities concerning traits relevant to social style, but differences concerning traits relevant to exploratory behaviors.

Finally, we also examined the relationship between personality and social rank. A common finding in nonhuman primate personality studies is that of a personality dimension labeled Confidence or Dominance (Freeman & Gosling, 2010). Given that social status is related to outcomes such as the frequency of aggressive interactions (Ostner, Heistermann, & Schülke, 2008) and hormonal levels (Sapolsky, 1990), it would not be surprising if social status influenced personality. However, McGuire, Raleigh, and Pollack (1994) found that changes in rank were not related to changes in personality and thus argued that high scores in a dimension they labeled "Socially Competent" are better thought of as prerequisites to reaching high social status. One would thus predict that individuals with particular personality profiles or high scores on relevant traits would be more likely to achieve high status. To address the relationship between personality and social rank we modeled the relationships between two waves of both personality ratings and behavioral assessments of rank.

To summarize, in our study we seek to identify the personality structure of Barbary macaques, evaluate the reliability and temporal stability of personality ratings, and compare Barbary macaque personality structure to that of rhesus macaques and male Hanuman langurs. Finally, we aim to examine the relationship between personality and social rank.

2. Methods

2.1. Study site, subjects, and raters/observers

Subjects were members of the "Apes' Den" group of Barbary macaques (*Macaca sylvanus*) that lives in the Upper Rock Natural Reserve, Gibraltar. This group is semi-free-ranging, provisioned daily by the Gibraltar Ornithological and Natural History Society (GONHS), and visited by tourists. Subjects were observed in two study periods covering two mating seasons. Subjects in the first season (4 November 2007 to 10 February 2008) consisted of 17 females and 6 males that were individually recognized by two observers. The group also included up to 15 juveniles and infants that were not included in the present study. Data were collected on the same subjects and three immigrant males (two subadults and one young adult) during the second season (20 October 2008 to 18 February 2009). Ages were based on the local pedigree maintained by GONHS. All subjects were over three years old, with only three females categorized as sub-adults (age = 3 years) in the first season and two males categorized as sub-adults (exact age unknown, category based on size) in the second season.

Behavioral observations and questionnaire ratings were conducted by the first author (MK) and a student assistant (VR). The first author has extensive experience with primate behavior and both raters/observers underwent behavioral data collection training with captive primates. Both raters based their ratings on their experience with the subjects during the study period (MK: 9 months including the preliminary phase; VR: 8 months).

2.2. Measures

2.2.1. Behavioral observations

During each season behavioral data were collected using focal continuous sampling together with focal instantaneous sampling and occasional *ad libitum* sampling (Altmann, 1974). The two observers recorded over 50 predefined behaviors covering a range of daily activities, including agonistic, affiliative, and sexual interactions. The behaviors were selected from previously published studies of macaque behavior (Berman, Ionica, & Li, 2004; Dolhinow, 1978). For each subject, data were collected evenly throughout the day and during the entire study. Each subject was observed at most once during a given day for a 30-min focal period. Thus, during almost 900 contact hours with the troop, the observers collected an average of 15.6 ± .4 *SD* hours and 13.8 ± 1.2 *SD* hours of observations per focal individual in seasons 1 and 2, respectively. This led to balanced knowledge of and experience with all individuals and their behavior.

Dominance ranks were determined on the bases of "displacement" interactions using sociometric matrices (Bayly, Evans, & Taylor, 2006). Displacement was defined as "one animal drives away another animal (usually from some kind of resource such as food) by its approach." Displacement interactions have been used to assess dominance hierarchies in a wide range of species (elephants: Archie, Morrison, Foley, Moss, & Alberts, 2006; fowl: Bayly et al. 2006; macaques: Ostner et al., 2008) and are based on the observed acceptance of a subordinate position by the displaced individual (which is not always the case in aggressive interactions) (Hinde, 1978). Separate dominance matrices were constructed for males and females in each season. Hierarchy characteristics were calculated using MATMAN 1.1.4 (Noldus, 2003). The resulting hierarchies were characterized as linear (median $h' = .72$, $p < .01$) and outcomes of interactions were highly consistent with the resulting hierarchy (median DC = .98). There were no rank changes during the season in either sex. However, there were several rank changes between the two seasons (by up to three positions in females and by up to five positions in males). The final rank orders were extracted from dominance matrices (Bayly et al., 2006) with the highest ranking individual assigned a score of 1 (in each season and each sex). These rank scores were transformed into *z*-scores (mean = 0 ± 1 *SD*).

2.2.2. Personality ratings

At the end of each season, after the behavioral data were collected, the two observers independently rated the 23 subjects present in both seasons for a total of 4 ratings per subject. The three immigrant males were rated by both raters at the end of season 2 for a total of two ratings each.

The questionnaire (Supplementary material S1) was identical to one used to rate Hanuman langur males (Konečná et al., 2008). This questionnaire contained 51 items that could be rated on a 7-point scale with "1" indicating "trait is not displayed" and "7" indicating "extreme amounts of the trait". Each item consisted of an adjective followed by one to three clarifying sentences that defined the trait with respect to nonhuman primate behavior. The items were adapted from the 43 items of the Chimpanzee Personality Questionnaire items (King & Figueredo, 1997), which, in turn, were derived from markers of the human Big Five (Goldberg, 1990). For this study, the items were translated into Czech. To ensure that translation did not change item meanings, the Czech translation of Costa and McCrae's (1992) Revised NEO Personality Inventory (Hřebíčková, Urbánek, & Čermák, 2000) was used as a guide.

The questionnaire was based on a measure of the five human factors as these factors are a useful starting point for understanding personality dimensions in a wide range of species (Gosling & John, 1999) and because these items describe a broad range of behavioral, affective, and cognitive traits (Konečná et al., 2008). It is important to note that we did not seek to find the Five-Factor Model or impose its structure on Barbary macaques. Finally, using the same questionnaire or a large overlapping set of items, allows one to directly compare species and more effectively rule out the possibility that differences are an artifact of the measures used (Gosling & John, 1999).

2.3. Data analysis

2.3.1. Interrater reliabilities of items

We computed interrater reliabilities of questionnaire items using two intraclass correlation (*ICC*) coefficients (Shrout & Fleiss, 1979). $ICC(3,1)$, indicates the reliability of individual ratings; $ICC(3,k)$ indicates the reliability of mean scores based on k raters (two in this study).

2.3.2. Data reduction

For all items that had $ICC(3,1)$ reliabilities in seasons 1 and 2 greater than zero[2] we used principal-components analysis (PCA) to identify the dimensions underlying the mean ratings in season 2. To determine the number of components we examined the scree plot and used parallel analysis, which indicates whether a component's eigenvalue is greater than expected under chance (Horn, 1965; O'Connor, 2000). After determining the number of components we subjected the components based on the 26 mean ratings from season 2 to an orthogonal (varimax) and oblique (promax) rotation. Based on the interfactor correlations derived from the latter, we retained and interpreted the components either after varimax or promax rotation.

In addition, given the relatively small sample size, we used two additional procedures to determine how stable the resulting components were. The first procedure was to use targeted orthogonal Procrustes rotation (McCrae, Zonderman, Costa, Bond, & Paunonen, 1996) to compare the structure derived from a PCA of mean ratings of the 26 subjects to the structure derived from a PCA of the 52 individual ratings. Because the number of observations that made up the latter structure was larger, comparable structures would indicate that the structure based on mean ratings was stable. The second procedure was to use regularized exploratory factor analysis (REFA), a new technique specifically designed to derive factors when the sample size is very small (Jung & Lee, 2011; Jung & Takane, 2008). For this analysis we specified unweighted least squares for factor extraction and assumed that unique variances were constant across items.

Finally, after determining the number of dimensions and structure, we computed four sets of unit-weighted component scores (Gorsuch, 1983) that we transformed into *z*-scores. The first two were based on the individual ratings made in season 1 and season 2 and used to determine interrater reliabilities of components in each season. The second two were based on the mean of ratings made in season 1 and season 2 and used in all other analyses.

2.3.3. Interrater reliabilities, internal consistencies, and re-test reliabilities of components

To determine the interrater reliabilities of components, we again used $ICC(3,1)$ and $ICC(3,k)$ (Shrout & Fleiss, 1979). We used Cronbach's alpha to assess the internal consistencies of components. Finally, we used Pearson correlations to assess re-test reliabilities of personality scores on the 23 subjects rated in both seasons.

2.3.4. Species comparisons

To compare the personality structure of Barbary macaques to the personality structures of rhesus macaques and male Hanuman langurs involved first scoring the Barbary macaques' personalities as if they were rhesus macaques or male Hanuman langurs (see

[2] We repeated these analyses using just those 39 items that had $ICC(3,k)$ reliabilities equal to or greater than .3 in season 1 and season 2. The additional excluded items were *erratic*, *stingy*, *submissive*, *irritable*, *disorganized*, and *depressed*. These analyses yielded four components that were similar to four factors derived via REFA on this restricted data set and similar to the four components derived in the original analyses (all Tucker congruence coefficients were greater than .97).

Please cite this article in press as: Konečná, M., et al. Personality in Barbary macaques (*Macaca sylvanus*): Temporal stability and social rank. *Journal of Research in Personality* (2012), http://dx.doi.org/10.1016/j.jrp.2012.06.004

Weiss et al., 2011 for details). To do so we used the definitions of personality dimensions from studies of rhesus macaques and male Hanuman langurs to create unit-weighted component scores from the season 2 Barbary macaque ratings.

The first set of scores was based on the definitions of the rhesus macaque personality dimensions Confidence, Openness, Dominance, Friendliness, Activity, and Anxiety (see Table 1 in Weiss et al., 2011). This structure was identified in 66 female (mean age = 7.62 ± 5.98 *SD* years) and 45 male (mean age = 6.92 ± 6.78 *SD* years) free-ranging rhesus macaques. Ratings in that study were made on 54 items by 11 researchers who were not raters in the present study. There were 41 items in common between the questionnaire used in the present study and that used in the study of rhesus macaques. We thus restricted our comparison to the items shared in common between these studies.

The second set of scores was based on the male Hanuman langur personality dimensions Agreeableness, Confidence, and Extraversion (see Table 1 in Konečná et al., 2008). The Hanuman langur personality structure was derived from ratings of 27 free-ranging males (24 adults and 3 subadults). Ratings were made on the same questionnaire as in the present study by 4 researchers, 1 of which was a rater in the present study. After generating these scores we obtained Pearson correlations between scores derived using the Barbary macaque structures and scores derived using the rhesus macaque or male Hanuman langur structure. For this analysis, we only considered comparisons significant at $p < .001$ as evidence that a pair of dimensions was comparable.

2.3.5. Personality and rank

To see how Barbary macaque personality and rank were related, we first obtained Pearson correlations between seasons 1 and 2 rank as well as between the personality component scores and rank in each season. We then modeled these relationships using structural equation modeling, which enables one to construct models of possible causal relationships among sets of variables and then statistically test whether these models are plausible (Loehlin, 2004). We tested model fit using a chi-square test. We conducted this analysis using M*plus* 6.11 (Muthén & Muthén, 1998–2010).

3. Results

3.1. Interrater reliabilities of items

Of the season 1 ratings, six items (*protective*, *impulsive*, *predictable*, *reckless*, *patient*, and *unemotional*) were unreliable with $ICC(3,1)$ coefficients equal to or less than zero. The $ICC(3,1)$ coefficients for the 45 remaining items ranged from .05 (*disorganized*) to .85 (*active*) with a mean reliability of .40. The $ICC(3,k)$ coefficients for these items ranged from .10 (*disorganized*) to .92 (*active*) with a mean reliability of .54. Of the season 2 ratings, two items (*reckless* and *patient*) were unreliable with $ICC(3,1)$ coefficients equal to or less than zero. The $ICC(3,1)$ coefficients for the 49 remaining items ranged from .04 (*unemotional*) to .76 (*confident*) with a mean reliability of .43. The $ICC(3,k)$ coefficients for these remaining items ranged from .07 (*unemotional*) to .86 (*confident*) with a mean reliability of .58 (see Supplementary materials S2, S3, and S4).

Table 1
Congruence coefficients.

Component congruences					
I	II	III	IV	V	Structure congruence
.98	.99	1.00	–	–	.99
.98	.99	.97	.95	–	.98
.99	.98	.99	.92	.62	.94

Note: Reference structure is 2009 individual scores.

Table 2
Correlations among components after promax rotation.

Factor	Friendliness	Activity/Excitability	Confidence
Activity/Excitability	−.18		
Confidence	−.03	.15	
Opportunism	−.23	.43	.13

3.2. Data reduction

The scree plot of the 26 mean ratings from season 2 suggested 4 components. Parallel analysis of the 26 mean ratings from season 2 suggested 3 components. The scree plot and parallel analysis of the 52 individual ratings from season 2, both suggested 5 components. To resolve these discrepancies, alongside using targeted orthogonal Procrustes rotation (McCrae et al., 1996) to determine how stable the structure was, we used a procedure described by Everett (1988) to determine the number of components. This procedure involved testing how many components in the 3, 4, and 5 component solutions based on the 52 individual scores from the second season replicated in the 26 mean scores for that season. Congruence coefficients indicated that all of the components and the total structure replicated for the three- and four-component solutions but that only the first four components replicated in the five-component solution (see Table 1). This suggests that we retain four-components (Everett, 1988).

We extracted the four components from the 26 mean ratings. The oblique (promax) rotation revealed that the absolute interfactor correlations ranged from .03 to .43 with a mean of .19 (see Table 2). We therefore retained the orthogonal components. The four components based on the 26 mean ratings from the second season accounted for 74.38% of variance (see Table 3). Consistent with prior studies (e.g., Weiss et al., 2011) we defined loadings $\geqslant |.4|$ as salient and, for the 20 items with 2 or more salient loadings, assigned the item to the component with the highest loading.

We extracted four factors from the 26 mean ratings using REFA and subjected these factors to a quartimax rotation.[3] As REFA loadings are shrunk toward zero (Jung & Lee, 2011), they are more conservative than loadings obtained via PCA. We therefore defined loadings $\geqslant |.3|$ as salient. The dimensions extracted by REFA and those extracted by PCA were highly comparable (see Table 3). With only five minor exceptions, none of which led to differences in how the dimensions were interpreted, the items had salient loadings on the same factors. Tucker's congruence coefficients (Wrigley & Neuhaus, 1955) for the four dimensions were .98, .98, .96, and .93, respectively.

This first component loaded positively on items related to Agreeableness (e.g., *affectionate*) and Sociability or Extraversion (e.g., *sociable*), and was similar to male Hanuman langur Agreeableness and rhesus Friendliness, and was the inverse of rhesus Dominance (see Table 4). We thus labeled this component Friendliness. The second component loaded on items related to activity (e.g., *active*), reactivity (e.g., *alert*), and exploratory behavior (e.g., *curious*). This component was similar to the rhesus Activity, Openness, and Dominance dimensions, and to the male Hanuman langur Extraversion dimension (see Table 4). We thus labeled this component Activity/Excitability. The third component loaded negatively on items, such as *dominant* and *confident* and positively on items such as *submissive*. After reflecting the loadings, i.e., multiplying them

[3] The REFA code can only rotate factors via the quartimax, quartimin, and geomin procedures.

Please cite this article in press as: Konečná, M., et al. Personality in Barbary macaques (*Macaca sylvanus*): Temporal stability and social rank. *Journal of Research in Personality* (2012), http://dx.doi.org/10.1016/j.jrp.2012.06.004

Table 3
Personality structure.

Item	Principal-components analysis				Regularized exploratory factor analysis			
	Frd	Act/Exc	Cnf[a]	Opp	Frd	Act/Exc	Cnf	Opp
Affectionate	**.90**	−.01	−.19	−.21	**.63**	.03	−.17	−.03
Helpful	**.85**	−.13	−.01	−.07	**.51**	−.06	−.04	−.07
Sociable	**.84**	.13	.03	.16	**.52**	.08	.05	−.23
Socialplay	**.84**	.24	−.17	.22	**.45**	.16	−.06	−.26
Popular	**.81**	−.23	**.40**	−.21	**.59**	−.19	.20	.06
Sensitive	**.80**	−.17	−.14	−.33	**.56**	−.07	−.16	.07
Friendly	**.80**	−.28	−.28	−.27	**.51**	−.12	−.24	.02
Solitary	**−.75**	−.23	−.16	−.13	**−.45**	−.13	−.13	.17
Sympathetic	**.70**	−.24	−.21	**−.43**	**.51**	−.11	−.23	.14
Permissive	**.64**	−.36	.04	**−.41**	**.50**	−.23	−.07	.18
Stable	**.62**	**−.40**	.37	−.39	**.46**	−.27	.13	.19
Bullying	**−.61**	.31	.09	**.51**	**−.43**	.15	.15	−.21
Gentle	**.56**	**−.54**	−.15	**−.49**	**.43**	**−.31**	−.23	.22
Aggressive	**−.54**	.34	**.44**	**.45**	**−.41**	.17	**.41**	−.17
Active	−.14	**.89**	−.07	.03	−.12	**.63**	.10	−.03
Lazy	.15	**−.87**	.11	.00	.11	**−.60**	−.05	.01
Excitable	−.30	**.85**	.08	.09	−.23	**.56**	.19	−.03
Inventive	−.04	**.82**	.08	.15	−.05	**.50**	.16	−.09
Alert	−.30	**.75**	**.43**	−.07	−.18	**.45**	**.39**	.12
Playful	**.41**	**.67**	−.19	.22	.18	**.36**	−.01	−.18
Curious	.10	**.66**	.11	.37	.00	**.41**	.19	−.25
Conventional	.27	**−.66**	−.23	−.12	.20	**−.40**	−.27	.02
Exploratory	.21	**.63**	.06	.29	.08	**.36**	.12	−.20
Irritable	−.39	**.58**	−.20	**.45**	−.26	**.31**	.00	−.21
Depressed	−.01	**−.56**	**−.49**	−.19	.00	−.27	**−.35**	.07
Eccentric	−.34	**−.47**	−.32	.35	−.28	−.29	−.22	−.19
Dominant	−.01	.01	**.89**	.17	.00	−.11	**.70**	−.01
Confident	−.02	**.41**	**.86**	.10	.00	.19	**.71**	.02
Submissive	.20	−.23	**−.84**	−.28	.15	−.05	**−.67**	.07
Fearful	−.01	.23	**−.80**	−.16	−.01	.26	**−.52**	.00
Timid	.28	.04	**−.77**	**−.43**	.22	.14	**−.57**	.14
Cautious	−.09	**−.45**	**−.70**	−.23	−.05	−.22	**−.61**	.10
Disorganized	−.02	**.46**	**−.70**	.19	−.06	**.31**	**−.30**	−.16
Independent	−.23	.07	**.68**	−.34	−.07	−.03	**.42**	**.33**
Intelligent	.14	**.52**	**.66**	.14	.09	.26	**.52**	−.05
Dependent	**.44**	−.01	**−.64**	.16	.22	.06	**−.36**	−.22
Defiant	−.17	**.43**	**.64**	.39	−.17	.21	**.57**	−.18
Erratic	−.32	−.01	**−.60**	.35	−.25	.04	−.29	−.21
Tense	−.39	**.43**	**−.54**	.07	−.27	**.33**	−.27	−.06
Jealous	−.03	.23	.06	**.88**	−.15	.11	.16	**−.55**
Opportunistic	−.22	.12	.06	**.86**	**−.30**	.06	.18	**−.55**
Stingy	−.38	−.03	−.10	**.73**	**−.31**	−.03	.01	**−.38**
Selective	−.05	**.40**	.28	**.71**	−.14	.22	**.33**	**−.43**
Manipulative	.37	.22	.35	**.71**	.16	.10	**.36**	**−.50**
Persistent	**−.43**	.08	.10	**.44**	**−.31**	.02	.11	−.19

Note: Frd = Friendliness; Act/Exc = Activity/Excitability; Cnf = Confidence; Opp = Opportunism. Loadings in boldface were salient.
[a] Loading on this component were reflected.

Table 4
Correlations between unit-weighted scores as defined by the Barbary macaque, Rhesus macaque, and Male Hanuman langur structures.

	Barbary macaque			
	Friendliness	Activity/Excitability	Confidence	Opportunism
Rhesus macaque				
Confidence	−.12 (−.49, .28)	.15 (−.25, .51)	**.97 (.93, .99)**	.27 (−.13, .59)
Openness	−.25 (−.58, .15)	**.84 (.67, .92)**	.26 (−.15, .59)	.46 (.09, .72)
Dominance	**−.62 (−.81, −.31)**	**.65 (.35, .83)**	**.70 (.43, .86)**	**.72 (.46, .87)**
Friendliness	**.87 (.72, .94)**	.04 (−.35, .42)	.06 (−.34, .43)	−.10 (−.47, .30)
Activity	−.31 (−.62, .09)	**.91 (.81, .96)**	.15 (−.25, .51)	.28 (−.12, .60)
Anxiety	−.43 (−.70, −.06)	.23 (−.17, .57)	−.14 (−.50, .26)	**.71 (.44, .86)**
Hanuman langur				
Agreeableness	**.93 (.84, .97)**	−.55 (−.78, −.21)	−.28 (−.60, .12)	−.59 (−.80, −.27)
Confidence	−.23 (−.57, .17)	.24 (−.16, .58)	**.96 (.91, .98)**	.42 (−.04, .69)
Extraversion	−.05 (−.43, .35)	**.88 (.74, .94)**	.27 (−.13, .60)	.47 (.10, .73)

Note: $N = 26$. For interpretation, we only regarded effects significant at $p < .001$ (boldface). 95% confidence intervals in parentheses.

by −1, this component was similar to rhesus macaque and male Hanuman langur Confidence as well as rhesus macaque Dominance (see Table 4). We thus labeled this component Confidence. The fourth component positively loaded on items such as

Please cite this article in press as: Konečná, M., et al. Personality in Barbary macaques (*Macaca sylvanus*): Temporal stability and social rank. *Journal of Research in Personality* (2012), http://dx.doi.org/10.1016/j.jrp.2012.06.004

Table 5
Interrater and re-test reliabilities.

Factor	Season 1 reliabilities[a]			Season 2 reliabilities[c]			Re-test reliability[b]	
	ICC(3,1)	*ICC*(3,*k*)	α	*ICC*(3,1)	*ICC*(3,*k*)	α	*r*	*p*
Friendliness	.54	.70	.92	.58	.73	.95	.77	<.001
Activity/Excitability	.78	.88	.91	.87	.93	.92	.86	<.001
Confidence	.61	.76	.92	.71	.83	.93	.88	<.001
Opportunism	.56	.71	.91	.74	.85	.89	.70	<.001

Note: α = Standardized Cronbach's alpha. *ICC*(3,1) = Reliability of individual scores. *ICC*(3,*k*) = Reliability of mean scores. *r* = Pearson correlation coefficient between season 1 and season 2 scores.
[a,b] $N = 23$.
[c] $N = 26$.

Table 6
Personality and rank correlations.

Factor	Rank	
	Season 1	Season 2
Season 1		
Friendliness	.30	.31
Activity/Excitability	.27	.03
Confidence	−.85***	−.85***
Opportunism	−.45*	−.53**
Season 2		
Friendliness	.27	.17
Activity/Excitability	.10	−.06
Confidence	−.77***	−.87***
Opportunism	−.33	−.36

Note: $N = 23$.
*** $p < .001$.
** $p < .01$.
* $p < .05$.

jealous and *opportunistic*, on items related to low Agreeableness (e.g., *manipulative*), and on items related to the ability of individuals to satisfy their needs. It was similar to rhesus macaque Dominance and Anxiety (see Table 4). We thus labeled this component Opportunism.

3.3. Reliability and stability of components

Interrater reliabilities, internal consistencies, and re-test reliabilities for both seasons are presented in Table 5. These coefficients indicated that the components were reliable across raters, internally consistent, and stable over time.

3.4. Rank and personality relationship

These analyses were based on the 23 subjects with data available in both seasons (see Table 6). Rank was highly correlated across seasons. Of the relationships between personality dimensions and rank, season 1 Confidence was significantly correlated with higher seasons 1 and 2 rank. Season 2 Confidence was also significantly correlated to higher seasons 1 and 2 rank. Opportunism was also significantly correlated with higher seasons 1 and 2 rank. There were no other significant correlations.

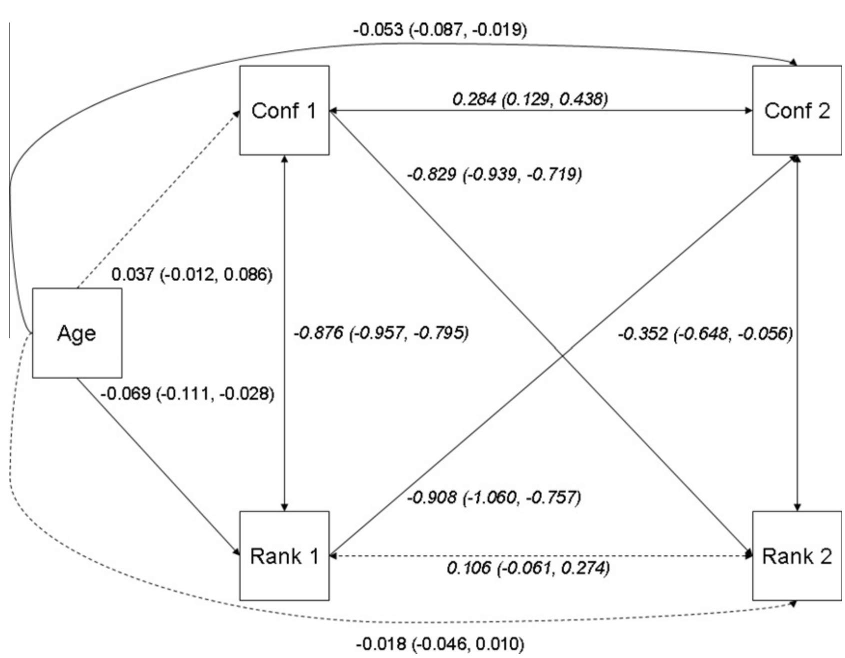

Fig. 1. Conf 1 = Season 1 Confidence; Conf 2 = Season 2 Confidence; Rank 1 = Season 1 rank; Rank 2 = Season 2 rank. Model of relationships between Confidence, rank, and age (non-significant paths from sex and sex × age effects are not presented). Lower rank values denote higher rank. Solid lines indicate significant paths ($p < .05$). Dashed lines indicate paths that were not significant ($p > .05$). Parameters not in italics denote 1 unit change in independent variable to the standard deviation change in dependent variable (b_{StdY}). Parameters in italics denote the standard deviation change in an independent variable related to a standard deviation change in the dependent variable (b_{StdYX}). Lower and upper values of the 95% confidence interval are in parentheses. Figure by the authors, licensed under a Creative Commons Attribution 3.0 Unported License and published under the terms of this license. See http://creativecommons.org/licenses/by/3.0/ for more information.

Please cite this article in press as: Konečná, M., et al. Personality in Barbary macaques (*Macaca sylvanus*): Temporal stability and social rank. *Journal of Research in Personality* (2012), http://dx.doi.org/10.1016/j.jrp.2012.06.004

Given that the associations between Confidence and rank were high across and within both seasons, and the limitations of our sample size, we only modeled the relationships among seasons 1 and 2 Confidence and rank (see Fig. 1). In this model, because they were measured contemporaneously, we specified that seasons 1 and 2 Confidence covary with seasons 1 and 2 rank, respectively. Because they were the same construct or behavior, we specified that seasons 1 and 2 Confidence covary and that seasons 1 and 2 rank covary. For these two pairs of relationships we did *not* specify a causal direction and they are thus depicted with double-headed arrows. We specified two causal paths depicted by single-headed arrows: season 2 Confidence predicted by season 1 rank and season 2 rank predicted by season 1 Confidence. To control age and sex effects, we included paths from age to rank in both seasons and from sex, age, and the sex × age interaction to Confidence in both seasons.

This model fit the data ($\chi^2 = 3.048$; $df = 4$; $p = .5498$). The model explained just under 11% of the variance in season 1 Confidence ($R^2 = .109$; 95% confidence interval [*CI*] = −.091, .309; $p = .285$) and nearly 70% of the variance in season 2 Confidence ($R^2 = .697$; 95% *CI* = .491, .903; $p < .001$). Finally, for seasons 1 and 2 rank the model explained nearly 20% ($R^2 = .195$; 95% *CI* = −.095, .485; $p = .189$) and nearly 75% ($R^2 = .745$; 95% *CI* = .567, .923; $p < .001$) of the variance, respectively.

Age was significantly related to higher season 1 rank ($b_{StdY} = -.069$; 95% *CI* = −.111, −.028; $p < .01$)[4] and lower season 2 Confidence ($b_{StdY} = -.053$; 95% *CI* = −.087, −.019; $p < .05$), but not season 2 rank ($b_{StdY} = -.018$; 95% *CI* = −.046, .010; $p = .298$) or season 1 Confidence ($b_{StdY} = .037$; 95% *CI* = −.012, .086; $p = .218$). Confidence in season 1 was not significantly associated with sex ($b_{StdY} = .420$; 95% *CI* = −.605, 1.444; $p = .500$) or sex × age ($b_{StdY} = .008$; 95% *CI* = −.082, .098; $p = .886$). Confidence in season 2 was also not significantly associated with sex ($b_{StdY} = .090$; 95% *CI* = −1.254, 1.074; $p = .899$) or sex × age ($b_{StdY} = .039$; 95% *CI* = −.063, .142; $p = .530$).

For the contemporaneous measures, higher Confidence was related to higher rank in season 1 ($b_{StdYX} = -.876$; 95% *CI* = −.957, −.795; $p < .01$) and in season 2 ($b_{StdYX} = -.352$; 95% *CI* = −.648, −.056; $p = .05$).[5] For the same measures taken at different times, season 1 and season 2 rank were not significantly related ($b_{StdYX} = .106$; 95% *CI* = −.061, .274; $p = .297$), but season 1 and season 2 Confidence were significantly related ($b_{StdYX} = .284$; 95% *CI* = .129, .438; $p < .01$). Finally, higher season 1 Confidence was related to higher season 2 rank ($b_{StdYX} = -.829$; 95% *CI* = −.939, −.719; $p < .001$) and higher season 1 rank was related to higher season 2 Confidence ($b_{StdYX} = -.908$; 95% *CI* = −1.060, −.757; $p < .001$).

4. Discussion

We found four Barbary macaque personality dimensions: Friendliness, Activity/Excitability, Confidence, and Opportunism. These dimensions were similar to single dimensions or blends of dimensions in rhesus macaques and male Hanuman langurs. These dimensions also exhibited interrater, internal consistency, and retest reliability. Modeling the relationship between Confidence and rank revealed that the cross-season consistency in rank could be completely explained by the indirect effects of Confidence. On the other hand, the cross-season consistency in Confidence was still significant when accounting for the indirect effects of rank.

Given the small sample size, it is too soon to draw strong conclusions. However, our comparisons of personality structures are suggestive in the context of the social organizations, dominance styles, and phylogenetic relatedness of Barbary macaques, rhesus macaques, and Hanuman langurs. Confidence was analogous to rhesus and male langur Confidence. Similar dimensions have been found in many nonhuman primate species (Freeman & Gosling, 2010). Thus, this finding is consistent with the noted importance of social hierarchy in primate groups (Gosling & John, 1999).

Friendliness was analogous to rhesus Friendliness (Weiss et al., 2011) and male langur Agreeableness (Konečná et al., 2008). Previous studies of rhesus macaques identified dimensions labeled Sociability, which were comprised of traits related to sociability and physical activity (Capitanio, 1999; Stevenson-Hinde & Zunz, 1978; Stevenson-Hinde et al., 1980). Consistent with a study of free-ranging rhesus macaques (Weiss et al., 2011), traits related to sociability were related to Friendliness, whereas traits related to physical activity were included in different dimensions.

Activity/Excitability was similar to rhesus Activity and Openness (Weiss et al., 2011) and male langur Extraversion (Konečná et al., 2008). This dimension's similarity to rhesus Activity and Openness arose from items related to physical activity and exploratory behavior. Dimensions related to negative affect, anxiety, and reactivity were identified in previous studies of rhesus macaques and labeled Excitability (Stevenson-Hinde & Zunz, 1978; Stevenson-Hinde et al., 1980) or Excitable (Capitanio, 1999). The Excitable dimension revealed in Stevenson-Hinde et al.'s (1978), 1980) studies of rhesus macaques included items such as *active*, *curious*, and *excitable* and thus resembled the Barbary macaque Activity/Excitability dimension. The present results were also consistent with those of previous studies which found that some items related to negative affect loaded onto Dominance or Confidence dimensions (Capitanio, 1999; King & Figueredo, 1997; Konečná et al., 2008; Stevenson-Hinde et al., 1980). The absence of a Neuroticism-like dimension in Hanuman langurs was discussed in terms of differences in aggression between langurs and rhesus macaques; lower levels of aggression in langurs might have led to relaxed selection pressure for divergence of Neuroticism- and Confidence-like traits in langurs (Konečná et al., 2008). In the rather tolerant Barbary macaques the absence of clear anxiety- or Neuroticism-related dimension may have also come about as a result of lower levels, compared to rhesus macaques, of intraspecific aggression.

Opportunism was comprised of traits related to rhesus Dominance and Anxiety (Weiss et al., 2011). It consisted of traits related to social skills relevant for achieving high rank or using others to one's advantage. Individuals high in Opportunism can thus be characterized as following their needs, basing their choice of social partners on how beneficial such an alliance would be, and being skilful at manipulating others. McGuire and his colleagues (1994) found a similar dimension in green monkeys. However, there is no dimension like Opportunism in rhesus macaques (Capitanio, 1999; Stevenson-Hinde et al., 1980; Weiss et al., 2011) or male langurs (Konečná et al., 2008).

One tentative explanation for the presence of Opportunism in Barbary but not rhesus macaques is that this difference reflects species differences in social style. As Barbary macaques have a more relaxed dominance style (Thierry, 2004), traits related to social tactics may be more important in their lives than kinship or rank. These circumstances may lead to more pronounced expressions of and covariance among behaviors described by traits such as *manipulative* and *opportunistic* in Barbary macaques. On the other hand, among rhesus macaques, the restriction of social bonds by kin and dominance relationships would not favor a pronounced independent expression or covariation among such behaviors. This

[4] b_{StdY} is the regression coefficient when the value for the dependent variable, *Y*, is standardized and that of the independent variable, *X*, is not. It therefore denotes how many standard deviations in *Y* are associated with each increment in *X*. b_{StdYX} is the regression coefficient when both *Y* and *X* are standardized. It therefore denotes how many standard deviations in *Y* are associated with a standard deviation in *X*. For more information, consult pages 641–644 of the *Mplus* manual (Muthén & Muthén, 1998-2010).

[5] While the *p*-value for this effect was not less than .05, we attributed this to rounding as the 95% confidence interval did not include 0.

may be because only high ranking rhesus macaques have opportunities to express these behaviors and thus related traits will more likely covary with traits related to Dominance or Confidence. Among Barbary macaques, individuals scoring high in Opportunism may benefit from this constellation of traits in unstable social situations or during shorter periods of time, but may be considered unreliable and less preferred as social partners under more stable conditions and in the long term.

The absence of an Opportunism dimension in male Hanuman langurs may be explained by weaker social bonds (Borries, 1993; Koenig & Borries, 2001) and the absence of coalition formation (Borries, 1993) and reconciliation (Sommer, Denham, & Little, 2002). Thus, although Hanuman langurs are, like Barbary macaques, characterized by a more relaxed social hierarchy, the lower importance of dyadic interactions did not lead to selection for an Opportunism dimension.

We did not find a Barbary macaque Openness dimension. Items related to Openness loaded onto Activity/Excitability (*playful*, *curious*) and Confidence (*intelligent*). A recent study using a questionnaire similar to that used in this study (but including more Openness-related items) identified a separate Openness dimension in free-ranging rhesus macaques (Weiss et al. 2011). The Activity/Excitability dimension identified in the present study was most similar to rhesus Openness. We previously hypothesized that the lack of an Openness dimension in male Hanuman langurs could be explained by differences in feeding ecology (Konečná et al., 2008) as Hanuman langurs are not considered extractive foragers when compared to chimpanzees or macaques (King, 1986). We thus predicted that Openness would be found in other extractive foragers, including Barbary macaques (Konečná et al., 2008). The present findings are not consistent with this prediction. The absence of Openness in Barbary macaques, a phylogenetically basal macaque species, and in Hanuman langurs, suggests that Openness may have evolved independently in some macaque species and in the hominid lineage leading to chimpanzees and humans. One possibility is that the presence of distinct Openness dimensions may be a consequence of inhabiting a greater number of habitats, frequently fluctuating environments, and food preferences and availability. The importance of habitat diversity in relation to Openness could be tested by, for example, comparing long-tailed macaques, which live in a range of habitats, to lion-tailed macaques, which live mostly in one type of habitat.

Modeling the relationships between personality and rank indicated that Confidence is more trait-like whereas rank is more state-like and prone to fluctuations, perhaps as a consequence of changes in social and natural environment. These results are consistent with the view of rank as a dynamic variable and at the same time a variable with predictive value for other characteristics and outcomes of a given individual (Bernstein, 1981; Hinde, 1978) and that Confidence and similar personality constructs assess competitive prowess (McGuire et al., 1994; Weiss et al., 2011). Our results support the view that a particular rank position is a social outcome resulting from and determined by personality as well as other (e.g. physical) characteristics (Gosling & John, 1999; McGuire et al., 1994). These findings generate testable predictions. For example, low ranking or immigrating individuals with high Confidence scores should be more likely to achieve high rank in a new troop. Moreover, high ranking individuals that are high in Confidence should maintain their position longer. Future studies incorporating more measurement periods over a longer time span could lead to further understanding of the dynamic relationship between personality and rank. Finally, different measures of rank (for examples see Bayly et al., 2006) may be applied in future studies to further reveal the complexities of the relationship.

Critics may argue that animal personality ratings are anthropomorphic and that such data cannot be trusted. Four lines of evidence suggest that this is not the case. First, ratings predict objective measures (Capitanio, 1999; Capitanio, 2002; Capitanio et al., 1999; Capitanio et al., 2004; Konečná et al., 2008; Stevenson-Hinde et al., 1980). Second, ratings made in a culture with a high degree of anthropomorphism yielded a similar structure to ratings from a culture with a low degree of anthropomorphism (Weiss et al., 2009). Third, when different species are assessed within the same culture, different structures are identified (King & Figueredo, 1997; Weiss, King, & Perkins, 2006; Weiss et al., 2011). Fourth, statistically adjusting for the effects of raters had little effect on the personality structures derived in chimpanzees and orangutans (Weiss, Inoue-Murayama, King, Adams, & Matsuzawa, 2012). Fifth, human personality dimensions are not the product of an implicit theory of personality but of genetic correlations among lower order traits (McCrae, Jang, Livesley, Riemann, & Angleitner, 2001).

The present study is not without limitations. For one, the sample size was smaller than typically recommended for PCA (see Guadagnoli & Velicer, 1988 for a brief review). However, recent studies have shown that previous recommendations for the number of subjects required for PCA were overly conservative and that even very small samples can yield stable structures (de Winter, Dodou, & Wieringa, 2009). Consistent with this finding, we found a highly comparable structure using REFA, which is specifically designed for small samples (Jung & Lee, 2011; Jung & Takane, 2008). Still, given the relatively high number of traits which loaded on two or more components, these results should be viewed with some caution and future studies should attempt to replicate this structure in larger samples.

A second limitation was that these results may not generalize beyond this sample of Barbary macaques as they were provisioned and frequently encountered tourists. Thus, attempts should be made to replicate these findings in troops of Barbary macaques that live in different conditions.

A third limitation was that there were differences between this study and those used to derive the Hanuman langur (Konečná et al., 2008) and rhesus macaque (Weiss et al., 2011) personality structures: the three samples were not matched for sex or age (in fact, as noted earlier, there were no female langurs); the three studies relied on different sets of raters; and, while the male Hanuman langurs were rated on the same questionnaire as used in the present study, the rhesus macaques were rated on a slightly different questionnaire. However, studies have shown that while differences in the age and sex composition of subjects for each species may influence the mean scores of ratings, i.e., how high or low samples are on a trait, these differences do not appear to impact personality structure. For example, personality dimensions derived from all male groups of rhesus macaques (Capitanio, 1999) do not differ greatly from those of mixed sex groups (Stevenson-Hinde & Zunz, 1978). Moreover, age does not appear to impact human personality structure (De Fruyt et al., 2006). Finally, studies of chimpanzees in different settings with different raters indicate that personality structure is consistent across different settings and sets of raters (King, Weiss, & Farmer, 2005; Weiss, King, & Hopkins, 2007; Weiss et al., 2009).

To test whether our mixed sex sample adversely influenced the comparison with Hanuman langurs, we conducted a supplementary analysis. First, we compared the four factors derived via PCA on only female Barbary macaques to those derived using the whole sample by computing Tucker's congruence coefficients. The analyses indicated that Friendliness (.91) and Activity/Excitability (.96) replicated while the Confidence (.78) and Opportunism (.12) did not. However, after rotating the female only components to those derived in the full sample using a targeted orthogonal Procrustes rotation (McCrae et al., 1996), all of the components replicated: overall congruence was .95 and congruences for Friendliness, Activity/Excitability, Confidence, and Opportunism were .96, .98, .95, and .91, respectively. Thus, it is unlikely that male and female Barbary macaque structure differ to a large extent. Nevertheless, future studies of multiple species of similarly comprised groups using comparable measures and raters are needed to fully rule out this possibility.

A fourth limitation was that the personality ratings and behavioral observations were made by the same individuals. Thus the two measures were not independent. However, observers who record behaviors and spend considerable time with subjects are more suitable for conducting ratings than naïve individuals (Gosling, 2001). In addition, we took steps to reduce this problem as questionnaire item definitions were phrased so that they did not include the observed behaviors (see Supplementary material and Konečná et al., 2008 for more details). Finally, a study of fallow deer showed that whether raters and observers were the same or different individuals had little impact on the size of correlations between ratings and observed behaviors (Bergvall, Schäppers, Kjellander, & Weiss, 2011).

This study offers a preliminary description of Barbary macaque personality dimensions and demonstrates that they are reliable, stable, and predict rank. Future studies of other groups of Barbary macaques and other macaque species will help us better understand the interplay between personality, social organization, and ecology. As such, these studies will enable us to answer questions concerning the evolution of the individual differences that underlie the uniqueness and common ancestry of all primates.

Acknowledgments

This study was noninvasive and adhered to the legal requirements of Gibraltar. Approval to conduct the study was granted by the Animal Care Appointee of the Gibraltar Ornithological and Natural History Society. Martina Konečná and Bernard Wallner were supported by Czech-Austrian Aktion Program for Cooperation in Science and Education in 2008 (Project 50p13) and in 2009 (Project 53p6). While preparing the manuscript, Martina Konečná and Stanislav Lhota were supported by grant MSMT 6007665801. We thank Veronika Roubová for her participation in ratings and behavioral data collection. We are grateful to Eric Shaw, John Cortes, Damian Holmes, and Dale Laguea of the Gibraltar Ornithological and Natural History Society (GOHNS). Finally, we thank Marieke Gartner for comments on an earlier draft and Sunho Jung for providing the MATLAB program for conducting the regularized exploratory factor analysis.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jrp.2012.06.004.

References

Abegg, C. (2006). The role of contingency in the evolution of Barbary macaque. In J. K. Hodges & J. Cortes (Eds.), *The Barbary macaque: Biology, management and conservation* (pp. 17–28). Nottingham: Nottingham University Press.

Altmann, J. (1974). Observational study of behavior: Sampling methods. *Behaviour, 49*, 227–267.

Archie, E. A., Morrison, T. A., Foley, C. A. H., Moss, C. J., & Alberts, S. C. (2006). Dominance rank relationships among wild female African elephants, *Loxodonta africana*. *Animal Behaviour, 71*, 117–127.

Bayly, K. L., Evans, C. S., & Taylor, A. (2006). Measuring social structure: A comparison of eight dominance indices. *Behavioural Processes, 73*, 1–12.

Bergvall, U. A., Schäppers, A., Kjellander, P., & Weiss, A. (2011). Personality and foraging decisions in fallow deer, *Dama dama*. *Animal Behaviour, 81*, 101–112.

Berman, C. M., Ionica, C. S., & Li, J. (2004). Dominance style among *Macaca thibetana* on Mt. Huangshan, China. *International Journal of Primatology, 25*, 1283–1312.

Bernstein, I. S. (1981). Dominance. The baby and the bathwater. *Behavioral and Brain Sciences, 4*, 419–457.

Borries, C. (1993). Ecology of female social relationships: Hanuman langurs (*Presbytis entellus*) and the van Schaik model. *Folia Primatologica, 61*, 21–30.

Buirski, P., Plutchik, R., & Kellerman, H. (1978). Sex differences, dominance, and personality in the chimpanzee. *Animal Behaviour, 26*, 123–129.

Caine, N. G., Earle, H., & Reite, M. (1983). Personality traits of adolescent pig-tailed monkeys (*Macaca nemestrina*): An analysis of social rank and early separation experience. *American Journal of Primatology, 4*, 253–260.

Capitanio, J. P. (1999). Personality dimensions in adult male rhesus macaques: Prediction of behaviors across time and situation. *American Journal of Primatology, 47*, 299–320.

Capitanio, J. P. (2002). Sociability and responses to video playbacks in adult male rhesus monkeys (*Macaca mulatta*). *Primates, 43*, 169–177.

Capitanio, J. P. (2004). Personality factors between and within species. In F. Aureli & F. B. M. de Waal (Eds.), *Natural Conflict Resolution* (pp. 13–33). Berkeley: University of California Press.

Capitanio, J. P., Mendoza, S. P., & Baroncelli, S. (1999). The relationship of personality dimensions in adult male rhesus macaques to progression of simian immunodeficiency virus disease. *Brain, Behavior and Immunity, 13*, 138–154.

Capitanio, J. P., Mendoza, S. P., & Bentson, K. L. (2004). Personality characteristics and basal cortisol concentrations in adult male rhesus macaques (*Macaca mulatta*). *Psychoneuroendocrinology, 29*, 1300–1308.

Clarke, A. S., & Boinski, S. (1995). Temperament in nonhuman primates. *American Journal of Primatology, 37*, 103–125.

Costa, P. T., Jr., & McCrae, R. R. (1992). *Revised NEO Personality Inventory (NEO-PI-R) and NEO Five-Factor Inventory (NEO-FFI) professional manual*. Odessa, FL: Psychological Assessment Resources.

De Fruyt, F., Bartels, M., Van Leeuwen, K. G., De Clercq, B., Decuyper, M., & Mervielde, I. (2006). Five types of personality continuity in childhood and adolescence. *Journal of Personality and Social Psychology, 91*, 538–552.

de Waal, F. B. M., & Luttrell, L. M. (1989). Toward a comparative socioecology of the genus *Macaca*: Dominance styles in rhesus and stumptail monkeys. *American Journal of Primatology, 19*, 93–109.

de Winter, J. C. F., Dodou, D., & Wieringa, P. A. (2009). Exploratory factor analysis with small sample sizes. *Multivariate Behavioral Research, 44*, 147–181.

Dolhinow, P. (1978). A behavior repertoire for the Indian langur monkey (*Presbytis entellus*). *Primates, 19*, 449–472.

Everett, J. D. (1988). Factor comparability as a means of determining the number of factors and their rotation. *Multivariate Behavioral Research, 18*, 197–218.

Figueredo, A. J., Cox, R. L., & Rhine, R. J. (1995). A generalizability analysis of subjective personality assessments in the stumptail macaque and zebra finch. *Multivariate Behavioral Research, 30*, 167–197.

Freeman, H. D., & Gosling, S. D. (2010). Personality in nonhuman primates: A review and evaluation of past research. *American Journal of Primatology, 71*, 1–19.

Goldberg, L. R. (1990). An alternative ''description of personality'': The Big-Five factor structure. *Journal of Personality and Social Psychology, 59*, 1216–1229.

Gorsuch, R. L. (1983). *Factor analysis* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Gosling, S. D. (2001). From mice to men: What can we learn about personality from animal research? *Psychological Bulletin, 127*, 45–86.

Gosling, S. D., & Graybeal, A. (2007). Tree thinking: A new paradigm for integrating comparative data in psychology. *Journal of General Psychology, 134*, 259–277.

Gosling, S. D., & John, O. P. (1999). Personality dimensions in nonhuman animals: A cross-species review. *Current Directions in Psychological Science, 8*, 69–75.

Guadagnoli, E., & Velicer, W. F. (1988). Relation of sample size to the stability of component patterns. *Psychological Bulletin, 103*, 265–275.

Hinde, R. A. (1978). Dominance and role – two concepts with dual meanings. *Journal of Social and Biological Structures, 1*, 27–38.

Horn, J. L. (1965). A rationale and test for the number of factors in factor analysis. *Psychometrika, 32*, 179–185.

Hřebíčková, M., Urbánek, T., & Čermák, I. (2000). Inventář přídavných jmen pro posouzení pěti obecných dimenzí osobnosti [Inventory of adjectives for assessment of five general personality dimensions]. *Československá Psychologie, 54*, 318–329.

Jung, S., & Lee, S. (2011). Exploratory factor analysis for small samples. *Behavioral Research, 43*, 701–709.

Jung, S., & Takane, Y. (2008). Regularized common factor analysis. In K. Shigemasu, A. Okada, T. Imaizumi, & T. Hoshino (Eds.), *New trends in psychometrics* (pp. 141–149). Tokyo: Universal Academy Press.

King, B. J. (1986). Extractive foraging and the evolution of primate intelligence. *Human Evolution, 1*, 361–372.

King, J. E., & Figueredo, A. J. (1997). The five-factor model plus dominance in chimpanzee personality. *Journal of Research in Personality, 31*, 257–271.

King, J. E., Weiss, A., & Farmer, K. H. (2005). A chimpanzee (Pan troglodytes) analogue of cross-national generalization of personality structure: Zoological parks and an African sanctuary. *Journal of Personality, 73*, 389–410.

Koenig, A., & Borries, C. (2001). Socioecology of Hanuman langurs: The story of their success. *Evolutionary Anthropology, 10*, 122–137.

Konečná, M., Lhota, S., Weiss, A., Urbánek, T., Adamová, T., & Pluháček, J. (2008). Personality in free-ranging Hanuman langur (*Semnopithecus entellus*) males: Subjective ratings and recorded behavior. *Journal of Comparative Psychology, 122*, 379–389.

Loehlin, J. C. (2004). *Latent variable models: An introduction to factor, path, and structural equation analysis* (4th ed.). Mahwah, NJ: Lawrence Erlbaum Associates.

Martau, P. A., Caine, N. G., & Candland, D. K. (1985). Reliability of the emotions profile index, primate form, with *Papio hamadryas, Macaca fuscata*, and two Saimiri species. *Primates, 26*, 501–505.

McCrae, R. R., Jang, K. L., Livesley, W. J., Riemann, R., & Angleitner, A. (2001). Sources of structure: Genetic, environmental, and artifactual influences on the covariation of personality traits. *Journal of Personality, 69*, 511–535.

McCrae, R. R., Zonderman, A. B., Costa, P. T., Jr., Bond, M. H., & Paunonen, S. V. (1996). Evaluating replicability of factors in the revised NEO Personality Inventory: Confirmatory factor analysis versus Procrustes rotation. *Journal of Personality and Social Psychology, 70*, 552–566.

McGuire, M. T., Raleigh, M. J., & Pollack, D. B. (1994). Personality features in vervet monkeys: The effects of sex, age, social status, and group composition. *American Journal of Primatology, 33*, 1–13.

Ménard, N. (2004). Do ecological factors explain variation in social organization? In B. Thierry, M. Singh, & W. Kaumanns (Eds.), *Macaque societies: A model for the study of social organization* (pp. 237–262). New York: Cambridge University Press.

Muthén, L. K., & Muthén, B. O. (1998-2010). Mplus user's guide. (6th ed.). Los Angeles, CA: Muthén and Muthén.

O'Connor, B. P. (2000). SPSS and SAS programs for determining the number of components using parallel analysis and Velicer's MAP test. *Behavior Research Methods, Instrumentation, and Computers, 32*, 396–402.

Ostner, J., Heistermann, M., & Schülke, O. (2008). Dominance, aggression and physiological stress in wild male Assamese macaques (*Macaca assamensis*). *Hormones and Behavior, 54*, 613–619.

Sapolsky, R. M. (1990). Adrenocortical function, social rank, and personality among wild baboons. *Biological Psychiatry, 28*, 862–878.

Shrout, P. E., & Fleiss, J. L. (1979). Intraclass correlations: Uses in assessing rater reliability. *Psychological Bulletin, 86*, 420–428.

Sommer, V., Denham, A., & Little, K. (2002). Postconflict behaviour of wild Indian langur monkeys: Avoidance of opponents but rarely affinity. *Animal Behaviour, 63*, 637–648.

Stevenson-Hinde, J., Stillwell-Barnes, R., & Zunz, M. (1980). Subjective assessment of rhesus monkeys over four successive years. *Primates, 21*, 66–82.

Stevenson-Hinde, J., & Zunz, M. (1978). Subjective assessment of individual rhesus monkeys. *Primates, 19*, 473–482.

Stewart, C. B., & Disotell, T. R. (1998). Primate evolution – in and out of Africa. *Current Biology, 8*, R582–R588.

Thierry, B. (2000). Covariation of conflict management patterns across macaque species. In F. Aureli & F. B. M. de Waal (Eds.), *Natural conflict resolution* (pp. 106–128). Berkeley: University of California Press.

Thierry, B. (2006). The macaques: A double-layered social organization. In C. J. Campbell, A. Fuentes, K. C. MacKinnon, M. Panger, & S. K. Bearder (Eds.), *Primates in perspective* (pp. 224–239). Oxford: Oxford University Press.

Thierry, B., Iwaniuk, A. N., & Pellis, S. M. (2000). The influence of phylogeny on the social behaviour of macaques (Primates: Cercopithecidae, genus *Macaca*). *Ethology, 106*, 713–728.

Thierry, B. (2004). Social epigenesis. In B. Thierry, M. Singh, & W. Kaumanns (Eds.), *Macaque societies: A model for the study of social organization* (pp. 267–290). New York: Cambridge University Press.

Uher, J. (2008). Comparative personality research: Methodological approaches. *European Journal of Personality, 22*, 427–455.

Weiss, A., Adams, M. J., Widdig, A., & Gerald, M. S. (2011). Rhesus macaques (*Macaca mulatta*) as living fossils of hominoid personality and subjective well-being. *Journal of Comparative Psychology, 125*, 72–83.

Weiss, A., Inoue-Murayama, M., Hong, K.-W., Inoue, E., Udono, S., Ochiai, T., et al. (2009). Assessing chimpanzee personality and subjective well-being in Japan. *American Journal of Primatology, 71*, 283–292.

Weiss, A., Inoue-Murayama, M., King, J. E., Adams, M. J., & Matsuzawa, T. (2012). All too human? Chimpanzee and orang-utan personalities are not anthropomorphic projections. *Animal Behaviour, 83*, 1355–1365.

Weiss, A., King, J. E., & Hopkins, W. D. (2007). A cross-setting study of chimpanzee (*Pan troglodytes*) personality structure and development: Zoological Parks and Yerkes National Primate Research Center. *American Journal of Primatology., 69*, 1264–1277.

Weiss, A., King, J. E., & Perkins, L. (2006). Personality and subjective well-being in orangutans (*Pongo pygmaeus* and *Pongo abelii*). *Journal of Personality and Social Psychology, 90*, 501–511.

Wrigley, C. S., & Neuhaus, J. O. (1955). The matching of two sets of factors. *American Psychologist, 10*, 418–419.

Please cite this article in press as: Konečná, M., et al. Personality in Barbary macaques (*Macaca sylvanus*): Temporal stability and social rank. *Journal of Research in Personality* (2012), http://dx.doi.org/10.1016/j.jrp.2012.06.004