

## RESEARCH ARTICLE

# Developing a Comprehensive and Comparative Questionnaire for Measuring Personality in Chimpanzees Using a Simultaneous Top-Down/Bottom-Up Design

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One effective method for measuring personality in primates is to use personality trait ratings to distill the experience of people familiar with the individual animals. Previous rating instruments were created using either top-down or bottom-up approaches. Top-down approaches, which essentially adapt instruments originally designed for use with another species, can unfortunately lead to the inclusion of traits irrelevant to chimpanzees or fail to include all relevant aspects of chimpanzee personality. Conversely, because bottom-up approaches derive traits specifically for chimpanzees, their unique items may impede comparisons with findings in other studies and other species. To address the limitations of each approach, we developed a new personality rating scale using a combined top-down/bottom-up design. Seventeen raters rated 99 chimpanzees on the new 41-item scale, with all but one item being rated reliably. Principal components analysis, using both varimax and direct oblimin rotations, identified six broad factors. Strong evidence was found for five of the factors (Reactivity/Undependability, Dominance, Openness, Extraversion, and Agreeableness). A sixth factor (Methodical) was offered provisionally until more data are collected. We validated the factors against behavioral data collected independently on the chimpanzees. The five factors demonstrated good evidence for convergent and predictive validity, thereby underscoring the robustness of the factors. Our combined top-down/bottom-up approach provides the most extensive data to date to support the universal existence of these five personality factors in chimpanzees. This framework, which facilitates cross-species comparisons, can also play a vital role in understanding the evolution of personality and can assist with husbandry and welfare efforts. *Am. J. Primatol.* 75:1042–1053, 2013. © 2013 Wiley Periodicals, Inc.

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## INTRODUCTION

It is now well established that chimpanzees exhibit consistent individual differences in behavior that can usefully be conceptualized as personality, and that these traits can be summarized in terms of broad personality dimensions [e.g., Freeman & Gosling, 2010]. Recent papers provide further support for the validity of chimpanzee personality ratings by showing that ratings are related to the behavior of chimpanzees and cannot be explained in terms of anthropomorphism by human raters [Pederson et al., 2005; Weiss et al., 2012]. Of the multiple ways to develop a personality-rating instrument for non-human animals, previous studies of chimpanzees have relied on two: top-down methods and bottom-up methods [Freeman & Gosling, 2010].

Both top-down and bottom-up methods are associated with characteristic advantages and dis-

advantages. The danger with top-down methods is that they can lead to the inclusion of traits that may not be relevant to the species being assessed or they may fail to include all relevant aspects of personality

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for the species being assessed [Freeman et al., 2011; Uher, 2008]. For example, some chimpanzee scales are derived from instruments originally developed to assess humans [e.g. King & Figueredo, 1997; King et al., 2005; Weiss et al., 2007, 2009] or rhesus macaques [Martin, 2005; Murray, 1995]. In response to the limitations of a top-down approach, some researchers have taken a bottom-up approach, which derives items tailored to the individual species [Dutton et al., 1997; Uher et al., 2008]. However, the limitation of pure bottom-up approaches is that direct comparisons with findings from other species are difficult because the measures differ across studies [Weiss & Adams, in press].

To address the limitations of both methods, researchers have suggested using a third method that combines these top-down and bottom-up methods [Gosling, 1998; Gosling & John, 1999; Uher et al., 2008; Weiss & Adams, 2008]. Such a combined approach holds the greatest promise for identifying the structure of animal personality because it includes species-specific traits and it facilitates comparison with previous scales. Theoretically, knowing the number and nature of dimensions underlying chimpanzee personality is needed to understand the developmental and evolutionary bases of personality traits in all species. Practically, information about chimpanzee personality can be integrated into management applications for chimpanzee husbandry (e.g., improving welfare and aiding in socialization management).

What personality dimensions are needed to characterize individual differences in chimpanzee personality? Previous factor-analytic studies have identified between four and six factors, with the majority finding either five or six [Dutton, 2008; Dutton et al., 1997; Freeman & Gosling, 2010 for a review; Martin, 2005; Murray, 1995; King & Figueredo, 1997; King et al., 2005; Weiss et al., 2007, 2009]. To make matters more complex, items that load onto a factor in one study are often not measured in other studies, making it difficult to compare the factor solutions, even amongst those that ultimately found the same number of factors. For example, Martin [2005] identified a five-factor solution for chimpanzees, including one factor that was made up of the single item “protective”, but in another chimpanzee study that also identified five factors [Dutton, 2008], the item “protective” was not measured. Consequently, these two five-factor solutions for chimpanzees cannot be compared quantitatively.

The challenges faced by researchers of nonhuman primate personality parallel those faced by researchers of human personality before they converged on the now widely accepted Five-Factor Model [FFM; McCrae & John, 1992]. One of the ways that the FFM gained acceptance was through convergence across studies using different methods so the factor

analytic solution could not be attributed to artifacts of the individual methods [John et al., 2008]. The same strategy is likely to be productive in determining the structure of chimpanzee personality.

The first goal of the current study was to collect data using a combined top-down and bottom-up approach and perform a factor analysis on those data. Doing so would allow the data to be both comprehensive—capturing all the relevant facets of chimpanzee personality (as is done with a bottom-up approach)—as well as being comparable to previous studies that have taken top-down approaches. If the personality structure is determined by elements of the methods, then the different methods are likely to produce different solutions; findings derived using a top-down/bottom-up combined method would differ from the structures identified in previous research using either top-down or pure bottom-up approaches. However, if all methods tap into the same underlying personality structure, then the overriding finding should be convergence across methods and we wished to test this explicitly. Based on previous studies, we expected to find five or six factors. The most commonly identified factors in chimpanzees are Dominance, Extraversion/Sociability, Agreeableness, and Openness/Intellect, with Neuroticism and Conscientiousness also appearing frequently [Freeman & Gosling, 2010]. Convergence between our factors and those found in previous research would support the construct validity and generalizability of the personality dimensions.

Further evidence for construct validity would be provided by links between the dimensions and theoretically relevant behaviors [Gosling & Vazire, 2002; Murray, 2011]. Therefore, the second goal of this study was to determine the predictive validity of the newly created dimensions by comparing the factors to behavioral measures collected independently on the same chimpanzees. Previously, only three studies looked at predictive validity of chimpanzee personality factors in relation to either the full range of chimpanzee behavior or a subset thereof [Murray, 1995; Pederson et al., 2005; Vazire et al., 2007]. These studies found positive correlations between specific behaviors and previously identified personality factors. We expected to find similar results to those found in previous studies, such that, for example, dominant behaviors, such as *displace*, *charge*, and *display*, would correlate with a Dominance factor while social behaviors, such as *play*, would correlate with an Extraversion factor.

## METHODS

The research for this study complied with protocols approved by the Institutional Animal Care Committee (IACUC #07-92-03887). The research also adhered to the legal requirements of the United States of America. In addition, the

research adhered to the American Society of Primatologists (ASP) Principles for the Ethical Treatment of Non Human Primates.

### Exploratory Analysis

Our top-down and bottom-up approach consisted of two phases: Generating an item pool of potential descriptors and selecting a subset of the descriptors for inclusion in the final instrument.

### Item Pool Generation

Our goal in generating items was to create a pool of items that comprehensively captured the range of potential behaviors and could be meaningfully applied to chimpanzees. To achieve this, we surveyed both the chimpanzee and broader nonhuman primate literatures. This process followed three steps.

Step 1 (top-down) ensured that the scale was comparable to previously used instruments. To accomplish this goal, we included items from the two most commonly used scales in primate personality: The Hominoid Personality Questionnaire [King & Figueredo, 1997; Weiss et al., 2009] and the Madingley Questionnaire [Stevenson-Hinde & Zunz, 1978]. This step resulted in a list of 55 items.

Step 2 (bottom-up) ensured that the list did not omit traits that are unique to chimpanzee behavior and personality. To accomplish this goal, five experts, who each had a minimum of three years of day-to-day experience with captive chimpanzees, individually nominated a list of items that were most relevant to chimpanzee personality. This step generated 71 terms, 45 of which overlapped with the 55 items identified in Step 1.

Step 3 (bottom-up) ensured that the full range of chimpanzee behavior was captured by the trait list [Uher et al., 2008]. To further bolster the comprehensive nature of our generated list, we compared it against chimpanzee behaviors identified by Uher et al. [2008] from their review of the published literature on chimpanzee behavior and those behaviors listed in the ethogram for the wild chimpanzees of Mahale, Tanzania [Nishida et al., 1999]. This list of behaviors revealed only two traits (self-caring and sexual) not previously identified in Steps 1 and 2, underscoring the rigor and efficacy of these previous steps. Our item pool at the end of these three steps consisted of 83 items.

### Selection of Items

Three of the authors (HDF, LMH, and SDG) read through the item pool to eliminate redundancy and, when necessary, redefine items to improve clarity, reduce ambiguity, and make the items species appropriate. To ensure that the key broad dimensions can be estimated reliably, a small amount of

redundancy is desirable, so, therefore, we included some redundancy for the broad domains of Sociability, Aggression, and Fearlessness, which have demonstrated considerable cross-species generality [Gosling & John, 1999].

To ensure comparability with the human personality literature, we made sure all five dimensions of the human FFM personality domains were included in the final list of traits, assigning each trait to one or more FFM dimension using the list of categorized traits in Goldberg [1990]. In addition to the FFM traits, some research has identified a sixth factor, Dominance, in chimpanzees [King & Figueredo, 1997], so we made sure that traits tapping into Dominance were retained in our item set too.

### Rating Scale Creation and Rating Process

The final list of traits consisted of 41 items presented in questionnaire format for the raters (online Supplementary materials). Each trait was listed with an associated Likert scale, ranging from 1 (*least descriptive of chimpanzee*) to 7 (*most descriptive of chimpanzee*). Behavioral definitions for each trait were also provided, similar to previous studies in order to clarify the meaning of the adjectives [King & Figueredo, 1997; Murray, 1995].

The raters assessed 99 chimpanzees (43 males), socially housed in groups of 5–15, at the Michale E. Keeling Center for Comparative Medicine and Research, UT MD Anderson Cancer Center, Bastrop, TX (hereafter, KCCMR). Chimpanzees ranged from 8 to 48 years old, with an average age of 27 years ( $SD = 11.2$ ). The majority were captive born (70), and, of these, 54 were mother-reared. All chimpanzees had lived at the facility for a minimum of 2 years.

The raters were 17 staff members at KCCMR who had worked with the chimpanzees from 6 months to 21 years. The raters were instructed to only rate animals with whom they felt that they had enough experience for an accurate rating of their personalities. Of the 99 chimpanzees, each rater scored an average of 72 chimpanzees (range: 9–99). The majority of the raters (13) were full-time care staff. The remaining four were a trainer, an enrichment technician, the colony manager, and the behavioral research coordinator. Ratings were completed at weekly meetings from 2006 to 2008. Raters were given instructions to rate the chimpanzees based on all of their previous experiences with them, rather than focusing on one particular situation. During the first meeting the raters were instructed to read over the definitions and any questions about the definitions were clarified to the group. The first author was also available to answer any questions about the questionnaire at each of the meetings.

There were three different forms that had the traits listed in different orders, making it particularly difficult for the raters to get information from each

other's sheets. In addition, raters were instructed not to speak to each other about the ratings during or outside of the meetings.

### Behavioral Observations for Factor Validation

To provide behaviors against which the personality dimensions would be validated, we used behavioral data collected on 60 of the 99 chimpanzees. The behaviors were collected 2 years prior to the collection of the personality ratings as part of a separate study [Silk et al., unpublished data]. Each group was observed for an average of 41 hours (range: 10–61 hr). Three observers collected the behavioral data and did not rate the personalities of the chimpanzees.

The behavioral ethogram used for the observations (online Supplementary material) included both scan sampling (for common state behaviors) and ad libitum (for rare behaviors and/or point behaviors) data. Each observation session lasted 60 min with scan samples taken every 3 min. Scan data included the items *groom*, *proximity*, *contact*, *play*, and *begging*. Ad libitum observations included the groupings of behavior: aggressive (*display*, *non-contact aggression*, *contact aggression*, *solicit*, *displace*, and *intervene*) and sexual, post-contact affiliation, submissive (*begging*, *fear grimace*, *flee*, and *submissive*) and food sharing.

## RESULTS

### Reliability of Ratings (Interjudge Consistency)

Common with previous studies [e.g., Weiss et al., 2007], we computed the reliability of ratings using intra-class correlation coefficients [ICCs, Shrout & Fleiss, 1979]. See online Supplementary material for the ICC (3,1) and (3,k) values for each trait (Table SI).

The ICCs for the average ratings ICC (3,k) were generally strong, indicating that raters tended to agree in their judgments about the personality traits of the chimpanzees. The only unreliable item was “predictable”, which was excluded from subsequent factor analyses (this item was also found to be unreliable in Murray [1995], where it was also excluded from further analyses). Some traits had low reliabilities (affiliative, autistic, considerate/kind, eccentric, methodical, self-caring, and socially inept) but nonetheless had positive reliability values. Some researchers have eliminated traits with low reliabilities at this phase [e.g., Capitanio, 1999], but others have found that such traits still have sufficient consistency to contribute meaningfully to factor definitions in exploratory factor analyses, as long as reliability values are positive [e.g., Gosling, 1998;

King & Figueredo, 1997; Weiss et al., 2007]. Note, the majority of the traits (33 of 41) had reliability values that were both positive and strong (i.e., >0.50).

### Reliability of Behaviors

For each chimpanzee, the reliability of each behavior was computed across the years of behavioral data collection. The reliability for the behaviors varied substantially (Table SII). The low reliabilities indicate that, for some behaviors, the relative frequency varied across years. In most cases, the low reliabilities may have been driven by the fact that the behaviors did not occur often. If a behavior occurred rarely, then it is possible that it could have low reliability because it was not expressed during observation periods. However the behavior could still show strong validity with personality traits because it reflected underlying traits [Gosling, 1998]. This low base-rate issue appeared to be the case for *contact aggression*, *displace*, *fear grimace*, *food sharing*, *intervene*, *post-conflict affiliation*, and *solicit*; all behaviors that were observed very rarely. *Self-groom* was the only behavior with a reliability <0.50 that occurred frequently. However, there may be other cases where the low reliability was not driven by low-base rates, and the behavior was not captured reliably during the observation periods. In these cases, the behavior would not serve as a meaningful validity criterion for the ratings. For the sake of these exploratory analyses, however, all behaviors, including the low-reliability behaviors, were retained.

### Exploratory Factor Analysis

Principal components analysis (PCA), with varimax rotation, was conducted on the means of the 40 rating items found to be reliable. Several criteria can be used to determine the number of factors to extract and these criteria do not always converge on the same solution. Therefore, to determine the number of factors to retain, we searched for converging evidence across several criteria [Hayton et al., 2004]. The Kaiser rule extracts only factors with an eigenvalue >1 [Kaiser, 1970], and pointed to a six-factor solution (Table SIII). An examination of the scree plot of the eigenvalues showed the “elbow” at the sixth factor, suggesting that five factors should be retained [Cattell, 1966].

To determine the number of factors that would arise by chance, we conducted a parallel analysis [Dinno, 2012] that matched the target sample in terms of sample size and number of variables. We plotted the eigenvalues, generated from the PCAs of the permutations, alongside the eigenvalues obtained from the real rating data and looked at where the current rating data exceed the 95th percentile for the permutations (online Supplementary material Fig. 1). The parallel analyses revealed four factors in

the rating data with eigenvalues greater than those found for the permuted data.

Last, the interpretability of the factors was evaluated by a panel of three expert informants, all of whom were behavioral researchers that had worked with the subject chimpanzees at KCCMR for at least 3 years. None of these experts were raters in the study. Each expert worked independently and used two main procedures to evaluate the factor definitions. First, the experts examined the factor loadings to understand which traits loaded strongly on each factor. Second, the experts characterized the individual animals falling at the extreme poles of the dimensions. These expert evaluations of the interpretability of the solutions suggested that a six-factor solution fit the data best.

The three quantitative criteria suggested that between four and six factors be extracted while the interpretability criterion suggested that six factors was the most meaningful interpretation. We used the six factor solution in order to allow us to examine the viability of all six factors in terms of reliability, convergent validity, and predictive validity (see Table I for the full set of factor loadings). We have included the five-factor solution as well as the oblique direct oblimin-rotation in supplementary material for comparison with our findings (Tables SIV and SV, respectively).

When choosing factor labels, to avoid using the same name to describe different entities or using different names to describe the same entity, we aimed to use labels that accurately reflected the factor

**TABLE I. Factor Loadings of Chimpanzee Personality Traits on Six Varimax-Rotated Factors**

Trait	Reactivity/Undependability	Dominance	Extraversion	Openness	Agreeableness	Methodical
Irritable	<b>0.87</b>	-0.09	-0.05	-0.09	-0.13	0.15
Temp./moody	<b>0.85</b>	-0.01	0.04	-0.02	-0.08	0.18
Deceptive	<b>0.79</b>	-0.13	0.12	0.18	0.18	0.05
Impulsive	<b>0.77</b>	-0.04	0.28	0.27	0.00	-0.12
Defiant	<b>0.74</b>	-0.06	0.31	0.22	-0.03	-0.10
Mischievous	<b>0.73</b>	0.07	0.41	0.33	-0.01	-0.13
Jealous	<b>0.70</b>	-0.07	0.35	<b>0.40</b>	0.02	0.05
Manipulative	<b>0.68</b>	-0.35	0.14	0.18	0.25	0.09
Stingy	<b>0.68</b>	<b>-0.49</b>	0.07	-0.06	0.23	0.03
Bullying	<b>0.68</b>	<b>-0.56</b>	0.25	-0.07	0.06	0.03
Aggressive	<b>0.66</b>	<b>-0.42</b>	<b>0.41</b>	-0.12	-0.06	0.14
Eccentric	<b>0.62</b>	0.13	-0.22	0.36	-0.04	-0.14
Socially-inept	<b>0.58</b>	0.36	0.02	0.07	-0.37	-0.06
Calm	<b>-0.57</b>	-0.06	<b>-0.50</b>	0.02	0.37	-0.10
Excitable	<b>0.56</b>	-0.08	<b>0.49</b>	0.19	-0.22	0.09
Autistic	<b>0.42</b>	0.36	-0.22	0.05	-0.03	-0.28
Fearful	0.03	<b>-0.88</b>	-0.11	0.05	-0.12	-0.01
Timid	-0.14	<b>-0.84</b>	-0.27	-0.23	-0.09	-0.04
Cautious	-0.23	<b>-0.81</b>	-0.11	-0.13	0.07	-0.01
Dominant	<b>0.40</b>	<b>0.78</b>	0.16	-0.03	0.18	0.13
Dependent	-0.02	<b>-0.76</b>	0.21	0.01	0.30	-0.15
Anxious	0.32	<b>-0.75</b>	0.28	-0.07	-0.05	0.20
Bold	<b>0.53</b>	<b>0.61</b>	0.35	0.29	0.12	0.05
Relaxed	<b>-0.44</b>	<b>0.48</b>	<b>-0.46</b>	0.05	0.31	-0.15
Solitary	-0.18	0.16	<b>-0.77</b>	-0.18	-0.29	0.08
Depressed	0.03	0.32	<b>-0.76</b>	-0.13	0.02	0.01
Active	0.26	0.09	<b>0.72</b>	<b>0.47</b>	-0.10	0.12
Playful	0.20	0.06	<b>0.67</b>	<b>0.58</b>	-0.06	-0.09
Sexual	0.29	-0.07	<b>0.65</b>	0.01	0.30	0.22
Affiliative	0.09	0.09	<b>0.53</b>	<b>0.43</b>	<b>0.49</b>	0.02
Human oriented	0.08	-0.14	-0.02	<b>0.83</b>	0.01	0.05
Inq./Curious	0.26	-0.01	0.30	<b>0.80</b>	-0.03	0.00
Inventive	0.28	0.03	0.20	<b>0.76</b>	0.12	0.14
Intelligent	-0.01	-0.19	0.09	<b>0.70</b>	-0.08	<b>0.50</b>
Aff./Friendly	-0.28	-0.03	0.27	<b>0.61</b>	<b>0.41</b>	-0.11
Persistent	<b>0.46</b>	-0.34	0.10	<b>0.54</b>	0.11	0.15
Protective	0.15	-0.20	0.06	-0.08	<b>0.78</b>	0.15
Considerate	<b>-0.44</b>	0.16	-0.01	0.25	<b>0.63</b>	0.14
Self-caring	0.05	0.06	0.20	0.31	0.32	<b>0.55</b>
Methodical	0.16	<b>-0.44</b>	-0.26	0.30	0.33	<b>0.54</b>

Numbers in boldface have a loading >0.40 for that factor. Underlined numbers have the highest loadings on that factor.

content and at the same time matched those used in other areas of research. To achieve this, we based the labels both on the traits that loaded strongly on the factors and also on the existing scales from the chimpanzee personality [i.e., King & Figueredo, 1997] and human personality [i.e., the FFM; Goldberg, 1990] literatures. Based on the previously-used names, the six factors were labeled: Reactivity/Undependability, Dominance, Openness, Extraversion, Agreeableness, and Methodical. The Reactivity/Undependability label was used to reflect our two labeling goals. First, the label conveys the fact that the items loading strongly on the factor (i.e. impulsive, irritable, aggressive, jealous, defiant, temperamental/moody) were best represented by the label of reactivity/undependability. The label also reflects the fact that the factor contains some items that load negatively on a factor labeled “dependability” in previous studies [King & Figueredo, 1997; Weiss et al., 2009].

### Reliability of the Factors

We computed the interrater reliability of the factors using ICC (3,1) and (3,k). The results for each of the scales are as follows, with the ICC (3,1) value followed by the (3,k) value: Reactivity/Undependability (0.48, 0.61), Dominance (0.48, 0.64), Extraversion (0.48, 0.65), Openness (0.49, 0.63), Agreeableness (0.37, 0.51), and Methodical (0.28, 0.36). Despite recent concerns regarding the usefulness of Cronbach’s alpha [e.g., McCrae et al., 2011], it is still widely used and so we computed it here. The results of calculating alpha for each of the scales are as follows: Reactivity/Undependability (0.94), Extraversion (0.87), Dominance (0.86), Openness (0.86), Methodical (0.58), and Agreeableness (0.48).

### Convergent Validity

To determine the extent to which the obtained factors replicated those found in previous chimpanzees studies, we computed unit-weight scale scores derived from the scales in the comparison studies [Dutton, 2008; King & Figueredo, 1997; Martin, 2005; Murray, 1995; Weiss et al., 2007, 2009]. Other papers have presented data on chimpanzee personality, but only these six presented factor solutions based on rating scales assessing the full range of chimpanzee personality.

Convergent validity was assessed by creating scales from the items in our study that overlapped with those defining the factors in these six previous studies. For example, Dutton’s [2008] factor Openness was made up of several items that we also measured including: intelligent, inventive, inquisitive/curious, and persistent. To compare Dutton’s [2008] Openness factor to our Openness factor we computed scale scores for both scales based on the

items that defined each. We then computed the correlations between these scale scores. The resulting correlations, between the scale scores in this study compared with those in previous studies, are shown in Table III. With the exception of the factor Methodical, there was strong overlap between the previous factors and the factors identified in this study. Correlations ranged between 0.48 (Extraversion, [Weiss et al., 2009],  $P < 0.001$ ) and 1.0 (Agreeableness, [King & Figueredo, 1997],  $P < 0.001$ ).

### Predictive Validity

To determine the extent to which the scales predicted observed behavior, we examined the correlations between each of the factors and the coded behaviors (Table IV).

Reactivity/Undependability was positively correlated with aggressive behaviors such as *display*, *intervene*, and *sexual behavior*, and was negatively correlated with *post-conflict affiliation*. Dominance was positively correlated with aggressive behaviors such as *display*, *intervene*, *noncontact aggression*, and *sexual behavior*, as well as some affiliative behaviors, including *proximity* and *social groom*. Dominance was negatively correlated with submissive behaviors. Openness was positively correlated with *submissive* and *playful*, and was negatively correlated with *proximity* and *social groom*. Extraversion was positively correlated with *contact aggression*, *sexual behavior*, *begging*, and *play*. There was a trend toward Extraversion being negatively correlated with *solicit* and *social groom*. Agreeableness was positively correlated with *affiliation* and was negatively correlated with *displace* and *solicit*. Methodical was negatively correlated with *intervene*.

To determine whether the personality factors related to broader behavioral dimensions, we performed a PCA with varimax rotation on the means of the behavioral observations. To determine the number of factors to retain, we searched for converging evidence across several criteria, as was done for the personality ratings [Hayton et al., 2004]. The Kaiser rule, which extracts only factors with an eigenvalue  $> 1$  [Kaiser, 1970], pointed to a six-factor solution. An examination of the scree plot of the eigenvalues showed the “elbow” at the fourth factor, suggesting that three factors should be retained [Cattell, 1966]. Last, the interpretability of the factors was evaluated by HDF who examined the factor loadings to understand which traits loaded strongly on each factor. This evaluation of the interpretability of the solutions suggested that a four-factor solution fit the data best (Table II). We named the factors Dominance, Affiliation, Proximity, and Solitary.

We created behavioral scales based on the items that loaded onto each of the four factors. We

**TABLE II. Factor Loadings of Chimpanzee Behaviors on Four Varimax-Rotated Factors**

Behavior	Dominance	Affiliation	Proximity	Solitary
Solicit	<b>0.71</b>	0.04	-0.05	-0.09
Sexual	<b>0.70</b>	0.07	0.18	0.03
Contact aggression	<b>0.69</b>	0.04	-0.06	0.13
Noncontact aggression	<b>0.61</b>	0.06	0.00	0.55
Displace	<b>0.48</b>	-0.25	0.20	-0.24
PostConflict Affiliation	0.10	<b>0.76</b>	-0.11	-0.14
Affiliation	0.16	<b>0.74</b>	0.18	0.06
Contact	-0.15	<b>0.69</b>	-0.15	-0.13
Play	0.07	0.17	<b>-0.75</b>	-0.11
Begging	0.05	0.35	<b>-0.72</b>	-0.04
Groom other	0.20	0.27	<b>0.60</b>	-0.17
Proximity	0.28	0.18	<b>0.56</b>	-0.16
Display	<b>0.53</b>	0.04	0.34	<b>0.59</b>
Fear grimace	-0.05	0.02	-0.21	<b>0.54</b>
Submissive	0.38	0.31	0.06	<b>-0.48</b>
Groom self	0.08	-0.15	0.04	<b>0.48</b>
Intervene	-0.11	0.34	0.32	0.38

Numbers in boldface have a loading >0.40 for that factor. Underlined numbers have the highest loadings on that factor.

examined the correlations between each of the personality factors and the behavior-based factors. Reactivity/Undependability, Dominance, and Extraversion were all significantly correlated with the behavioral factor of Dominance (Table IV). The personality factors Dominance and Agreeableness were significantly correlated with the behavioral factor Proximity. The personality factors of Openness and Methodical were not correlated with any of the behavioral scales.

## DISCUSSION

### How Many Dimensions?

The primary aim of this study was to use a new approach (combined top-down/bottom up scale development) to identify the major dimensions underlying chimpanzee personality and derive scales to measure the dimensions. Similar to previous chimpanzee personality studies, the PCAs yielded between four and six factors. We proceeded with the six-factor solution because the interpretability criterion suggested it was the most meaningful in terms of illuminating personality differences among the chimpanzees. We found strongest support for five of the factors (Reactivity/Undependability, Dominance, Extraversion, Openness, and Agreeableness) but we provisionally retained the sixth (Methodical) pending further investigation. It would be irresponsible to either adopt or drop Methodical at this stage. We thus urge researchers to add the two items that load onto methodical as well as other items that could be related to Methodical to their scales in order to continue assessing it in their studies.

The scales derived from the factors had reliabilities of comparable magnitude to those found in previous primate personality studies [Dutton, 2008;

King & Figueredo, 1997; King et al., 2005; Murray, 1995; Weiss et al., 2007, 2009]. In addition, the amount of variance explained by the six factor solution (74%) is comparable to, or in some cases higher than, previous studies that have assessed chimpanzee personality factors [Dutton, 2008; King & Figueredo, 1997; King et al., 2005; Murray, 1995; Weiss et al., 2007, 2009]. However, in light of the relatively small sample size, the generalizability of the solution to other samples needs to be established.

Somewhat surprisingly, despite the fact that we used a new approach to develop our questionnaire, the analyses of convergent validity revealed that five factors identified in three previous studies using either top-down [King & Figueredo, 1997; Weiss et al., 2009] or bottom-up [Dutton, 2008] approaches were strongly correlated with five factors in this study: Reactivity/Undependability, Dominance, Openness, Extraversion, and Agreeableness. In some cases, other studies labeled these factors differently, but the items that made up those factors overlapped with the factors from our study. Three different methods of scale development—top-down [e.g., King & Figueredo, 1997], bottom-up [Dutton, 2008], and our combined top-down/bottom-up approach—all converged on the same underlying factor structure for at least five factors in chimpanzee personality. This convergence provides strong support for these five factors in chimpanzee personality and indicates that they are the results of the factor structure of chimpanzee personality, rather than the results of confirmation bias.

### Differences From Previous Scales

Neuroticism has been identified as a separate factor in several previous studies [Dutton, 2008; King

TABLE III. Convergent Validity Between Dimensions Identified in the Current and Previous Studies

Scales	Reactivity/ Undependability	Dominance	Openness	Extraversion	Agreeableness	Methodical
Murray [1995]						
Confident	0.48**	0.98**	0.37**	0.48**	0.05	0.32**
Sociable	0.12	0.22**	0.74**	0.76**	0.40**	0.40**
Excitable	0.83**	0.27**	0.73**	0.45**	0.01	0.23**
King and Figueredo [1997]						
Dominance	0.65**	-0.93**	0.45**	0.39**	-0.01	0.35**
Surgency	0.22**	-0.25**	0.61**	0.93**	0.27**	0.30**
Dependency	-0.94**	0.37**	-0.32**	-0.47**	0.16	0.1
Agreeableness	-0.12	-0.04	0.23**	0.20*	1.0**	0.33**
Emotionality	-0.65**	0.22**	-0.39**	-0.57**	0.08	-0.18*
Openness	0.47**	-0.28**	0.90**	0.56**	0.15	0.48**
Martin [2005]						
Confident	0.19	-0.93**	0.27*	0.21**	0.05	0.20*
Reactivity	0.87**	-0.38**	0.24**	0.43**	-0.16	0.16
Extraversion	0.30**	-0.21*	0.54**	0.94**	0.22**	0.27**
Openness	-0.20*	0.29**	-0.86**	-0.56**	0.21*	-0.52**
Protective	0.11	-0.08	0.04	0.18	0.27*	0.24
Weiss et al. [2007]						
Dominance	0.84**	-0.80**	0.42**	0.44**	-0.11	0.30**
Extraversion	0.32**	-0.28**	0.77**	0.91**	0.26**	0.39**
Conscientiousness	-0.94**	0.35**	-0.45**	-0.47**	0.04	-0.27**
Agreeableness	0.19*	-0.31**	0.59**	0.39**	0.65**	0.54**
Dutton [2008]						
Agreeableness	-0.09	-0.15	0.52**	0.44**	0.85**	0.36**
Dominance	0.92**	-0.69**	0.40**	0.35**	-0.08	0.23**
Neuroticism	-0.31**	0.91**	-0.35**	-0.34**	-0.04	-0.24**
Extraversion	0.41**	-0.24**	0.95**	0.60**	0.03	0.27**
Intellect	0.47**	0.40**	0.58**	0.95**	0.14	0.60**
Weiss et al. [2009]						
Dominance	0.66**	0.91**	0.40**	0.49**	0.06	0.42**
Openness	0.25**	0.26**	0.92**	0.66**	0.35**	0.33**
Conscientiousness	-0.96**	-0.42**	-0.43**	-0.37**	0.15	-0.21*
Agreeableness	-0.35**	-0.02	0.24**	0.29**	0.87**	0.32**
Neuroticism	0.75**	-0.13	0.38**	0.16	-0.23**	-0.11
Extraversion	0.47**	0.28	0.59**	0.90**	0.15	0.48**

Correlations are computed between unit-weighted scales derived from the factor-analytic solutions in the current and previous studies.

\*Statistical significance,  $P < 0.05$ .

\*\*Statistical significance,  $P < 0.001$ .

& Figueredo, 1997; Weiss et al., 2009]. In the present study, however, the items that defined Neuroticism in previous studies loaded on the Reactivity/Undependability or Dominance factors. Note, one other study [Weiss et al., 2007] also failed to identify a separate Neuroticism factor. Both the current study and Weiss et al. [2007] assessed chimpanzees living in a laboratory setting, whereas the other three studies that found a Neuroticism factor assessed chimpanzees living in zoos. So, one possibility is that behaviors that define different levels of Neuroticism are more readily expressed in zoo settings than in laboratory settings. We welcome future work that can focus on behavioral tasks related to the Neuroticism factor to investigate the dynamic interplay between environmental influences and individual differences [Dall et al., 2004].

Methodical was the one factor found in this study that was not strongly correlated with factors found other studies. In addition it also had poor discriminant validity. This factor was defined by the items, methodical and self-caring, both of which had interrater reliabilities in the lower range. This low reliability could indicate that it was difficult for the raters to clearly detect these traits. In addition, the factor had poor discriminant validity because the item methodical loaded strongly onto the Dominance factor as well as Methodical. Moreover, it was hard to evaluate cross-study convergence for this dimension because only one of the items (i.e., disorganized, the opposite of methodical) was assessed in King & Figueredo [1997] and Weiss et al. [2007, 2009], but neither of these items were assessed in Dutton [2008]. Therefore, future studies should include these

TABLE IV. Predictive Validity of Scales With Behavioral Items and Behavioral Scales

Variables	Reactivity/ undependability	Dominance	Openness	Extraversion	Agreeableness	Methodical
Aggressive behaviors						
Cont Agg	0.23	0.29*	0.24	0.37*	0.18	0.22
Displace	-0.02	0.16	-0.16	0.08	-0.29*	-0.25 <sup>+</sup>
Display	0.21	0.43**	-0.08	0.19	-0.09	-0.15
Intervene	0.29*	0.27*	0.00	0.18	-0.02	0.20
Noncont Agg	0.09	0.34*	-0.05	0.16	-0.08	-0.13
Sexual Behav	0.26*	0.29*	0.05	0.35**	0.00	0.13
Solicit	0.06	0.11	-0.13	-0.24 <sup>+</sup>	-0.23 <sup>+</sup>	-0.08
Submissive behaviors						
Begging	0.20	-0.13	0.12	0.46**	-0.03	0.16
Fear grimace	0.21	0.00	0.03	0.09	0.00	0.01
Flee	-0.10	-0.07	0.08	-0.05	0.08	0.11
Submissive	0.06	-0.28*	0.23*	0.08	-0.05	-0.17
Affiliatory behaviors						
Affiliation	-0.02	0.02	0.06	0.07	0.34**	0.01
Postconf Aff.	-0.28*	-0.04	-0.17	-0.09	-0.13	-0.12
Contact	0.16	0.12	-0.03	0.16	0.17	0.10
Proximity	0.08	0.29*	-0.31*	-0.10	0.22	0.06
Play	0.15	0.12	0.29*	0.52**	-0.19	-0.01
Social groom	0.02	0.33*	-0.23 <sup>+</sup>	-0.23 <sup>+</sup>	0.15	-0.08
Solitary behaviors						
Self-groom	0.12	0.17	0.08	0.13	-0.08	-0.12
Behavior scales						
Dominance	0.35**	0.44**	0.06	0.44**	0.02	0.21
Affiliation	-0.02	-0.01	-0.06	0.05	0.23	0.04
Proximity	0.16	0.42**	0.23	-0.13	0.32*	0.07
Solitary	0.07	-0.17	0.04	0.17	-0.05	-0.10

Correlations are computed between unit-weighted scales derived from the factor-analytic solutions in the current and previous studies.

<sup>+</sup> $P < 0.10$ .

\*Statistical significance,  $P < 0.05$ .

\*\*Statistical significance,  $P < 0.001$ .

items to determine whether they can be measured reliably in chimpanzees.

### Predictive Validity

The six factors showed mixed results in terms of predicting the chimpanzees' behaviors (i.e., predictive validity). The findings linking personality factors to specific behaviors were stronger than those linking personality to the broader behavioral factors. In some cases, particularly for the factors of Reactivity/Undependability, Dominance, and Agreeableness, the findings indicated that the personality factors are tapping elements of personality that they were intended to measure. Such strong correlations are particularly impressive given that the behavioral and personality data were collected two years apart by different individuals so there was no overlap in method variance.

### Reactivity/Undependability, Dominance, and Agreeableness

The predictive validity for the Reactivity/Undependability, Dominance, and Agreeableness factors

paralleled findings from previous primate studies [Murray, 1995; Pederson et al., 2005; Vazire et al., 2007]. The Dominance factor was positively correlated with agonistic behaviors and negatively correlated with submissive behaviors, as would be expected. The Dominance personality factor was also positively correlated with the behavioral factor of Dominance. Consistent with common operational definitions of Dominance, based on the frequency or direction of submissive behaviors shown by other group members [Lewis, 2002], animals rated as more dominant individuals were generally more aggressive and showed fewer submissive behaviors than did animals rated as low on dominance.

Previous studies have found that Extraversion is positively correlated with affiliative behaviors and negatively correlated with aggressive behaviors [Capitaino, 1999, rhesus macaques; Vazire et al., 2007, chimpanzees]. We also confirmed the anticipated correlation between affiliative behavior and Extraversion, but there was also a positive correlation between *contact aggression* and Extraversion. This unexpected correlation could be a result of the low base rate of the behavioral measure of *contact aggression*. As discussed above, the low reliability of

contact aggression was likely due to the fact that it occurred very rarely (note that the groups from which observational data were taken had been together for decades and were fairly stable, which may have limited the frequency of contact aggression). However, it is also possible that this positive correlation, between contact aggression and Extraversion, occurred because chimpanzees that are more social are also involved in more conflicts, just by virtue of being involved in more social interactions, both affiliative and aggressive [de Waal & van Roosmalen, 1978]. In addition, there was a positive correlation between Extraversion and the behavioral factor of Dominance that includes items such as *contact aggression*, *non-contact aggression*, and *sexual* behavior. This correlation is consistent with the idea that those chimpanzees who scored higher on the factor of Extraversion were also involved in more social interactions.

Openness, which includes traits such as intelligent, inquisitive, human oriented, and inventive, had mixed predictive validity. There was a positive correlation between *play* behavior and Openness, as has been found previously for the trait “curious” [Murray, 1995]. However, with Openness, there was also a positive correlation with *submissive* behavior and negative correlations with *proximity* and *social grooming* behaviors, none of which had been seen in previous studies [Murray, 1995; Pederson et al., 2005]. It is interesting that for the present study, one of the traits that loaded most strongly on Openness was the “human oriented” trait, an item that was not assessed in previous research. It is possible that the raters might have been more familiar with these “human oriented” chimpanzees, leading to greater reliability in their assessment. Future studies could assess Openness by observing the chimpanzees in cognitive testing situations. This would allow for a more comprehensive assessment, than was possible here, for traits such as human oriented, intelligent, inquisitive, and inventive. As a recent study found a correlation between Openness and chimpanzees’ performance on cognitive tasks [Herrelko et al., 2012], this relationship should be further explored.

There were few behaviors in the behavioral assessment that should show conceptual connections to Methodical. The only behavior with clear connections to self-care or methodical (the traits making up Methodical) was *self-groom*, which did not correlate with Methodical. There are several reasons why *self-groom* might not have correlated with Methodical. One reason is that the self-groom behavior was not reliable. We attempted to correct for the unreliability of the measure, but the reliability was too low to perform the calculation. Another reason may be that Methodical measured something different from self-grooming behavior. For example, the *self-groom* behavior may also include situations

where chimpanzees over-groom, which would be considered the opposite of self-care. In these cases the over-grooming could have been due to stress, rather than a methodical personality. To determine whether it is low reliability or a low validity that accounts for the issues in predictive validity for Methodical, it is important for future studies to assess other behaviors that might be related to Methodical. For example, perhaps behaviors related to following a certain goal, as suggested by the definition of methodical, could be a better measure of behavior related to Methodical (e.g., in the context of tool-use or problem-solving tasks).

### Limitations

This study had several limitations. First, most of the raters were care-staff employees, so the behavioral bases of the ratings might have been limited compared with what would be obtained from a broader range of care staff, trainers, veterinarians, enrichment personnel, and behavioral researchers. It would have been ideal to have a more balanced mix of perspectives to compare the effects of different jobs on the ratings. Second, it was difficult to assess the validity of the Openness and Methodical factors given the particular set of behaviors assessed. Cognitive tasks could be better suited to assessing the items in the Openness factor, and other situations could be devised to provide some criterion data with which to evaluate the validity of the Methodical factor.

### SUMMARY AND CONCLUSIONS

There is now strong evidence that personality exists in other animals, including chimpanzees [Gosling, 2001; Wolf & Weissing, 2012]. One method of assessing primate personality that has been shown to be reliable and valid is ratings of individual animals collected by humans familiar with them [Freeman & Gosling, 2010].

Here we provide a factor structure for chimpanzees derived from a method that simultaneously draws on the strengths of two previously separate methods (top down and bottom up). Consequently, the resulting scale is comprehensive, can usefully be applied to chimpanzees, and also permits comparisons with existing scales for other species, including the human FFM.

The present findings have important implications in three main areas briefly discussed here. On a theoretical level a unified scale will enable more meaningful investigations of biological, genetic, and environmental influences on behavior than has been possible using scales that are not as comprehensive and comparable. In addition, our ratings can be combined with other cognitive and behavioral studies to illuminate how individual differences in personality influence chimpanzee decision-making [e.g., in

studies of social learning or behavioral economics]. Lastly, our findings can inform decisions regarding the management of captive chimpanzees, allowing managers to tailor specific care requirements to each individual animal [Powell & Gartner, 2011; Watters & Powell, 2011].

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### Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's web-site.

**Fig. S1.** Parallel analysis of random data

**TABLE SI.** Interrater Reliability of Trait Ratings

**TABLE SII.** Reliability of Behaviors

**TABLE SIII.** Eigenvalues for Factors Determined Using EFA

**TABLE SIV.** Factor Loadings of Chimpanzee Personality Traits on Five Varimax-Rotated Factors

**TABLE SV.** Factor Loadings of Chimpanzee Personality Traits on Six Direct Oblimin-Rotated Factors