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Relationships Between Personality Type and Cognitive Ability in Marmoset Monkeys (Callithrix jacchus)

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Relationships Between Personality Type and Cognitive Ability in Marmoset Monkeys (*Callithrix jacchus)*

A Thesis Presented

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Relationships Between Personality Type and Cognitive Ability in Marmoset Monkeys (*Callithrix jacchus)*

A Master's Thesis

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ABSTRACT

RELATIONSHIPS BETWEEN PERSONALITY TYPE AND COGNITIVE ABILITY IN MARMOSET MONKEYS (*CALLITHRIX JACCHUS)*

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Personality refers to multiple traits that are thought to be stable over time and across situations. It is recognized that personality has a neural basis and is associated with health outcomes. Whether personality is also associated with cognitive ability, however, is still a matter of intense debate.

One way to examine these potential relationships is to use a nonhuman primate model for which complexities present in humans can be minimized. Recent research into the varying personality types of marmoset monkeys suggests that there are predominantly three to five core primary domains that most marmosets and other primates can be categorized into, such as dominance, sociability, and neuroticism. The aim of the proposed study was to categorize a small colony of marmosets into respective personality domains, and to examine correlations between the monkeys' personalities and their cognitive ability.

This study was be conducted on 27 marmoset monkeys (14 male, 13 female) housed in the Lacreuse lab at the University of Massachusetts Amherst. A personality survey based on Koski (2015) containing 55 personality traits was utilized by 8 human judges, all of whom have been working with these monkeys daily for at least one year. Each judge rated each individual monkey on each individual trait on a 1 to 7-point scale; 1 indicating total absence of a trait and 7 indicating extreme presence of a trait.

Once the survey data was compiled, a principal component analysis (PCA) was conducted to condense the myriad of ratings into smaller distinguishable personality domains. Three personality types were identified in this population, consistent with other non-human primate species. An ICC(2) was performed to ensure the interrater reliabilities of the 8 judges were consistent enough to be considered. Lastly, a linear regression was conducted to reveal possible correlations between the observed personality domains and cognitive performance achieved in a reversal learning task.

The results of this experiment showed no statistically significant relationships between any of the three personality domains: Assertiveness, Neuroticism, and Inquisitiveness with the reversal learning cognitive scores. Although these findings suggest that personality and cognitive flexibility are independent in marmosets, we cannot rule out that personality may influence other cognitive domains. Additional studies are needed to examine this possibility.

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CHAPTER 1

INTRODUCTION

1.1 Personality in Humans

According to the American Psychological Society, personality refers to individual differences in characteristic patterns of thinking, feeling and behaving. Many would argue that our personalities are who we truly are at our core, the traits we portray seep into almost every aspect of our lives: our social skills, financial savviness, and world view. Are our personality traits shaped by our experiences, our genomes, and or are they mere evolutionary adaptations that have been formed by millenniums of human interactions with each other and the world around us? Scientists have hoped to capture the essence of what truly makes up our personalities for a long time; creating distinguished models of human behavior to classify our traits and to observe how each type of personality is structured. Evolutionary psychologists believe personality theories can be overshadowed by the idea that an overarching theory of human nature is more suitable to describe all of humanity's idiosyncrasies (Buss et al., 1991), while personality psychologists theorize that different personality types can indeed be categorized according to variances and correlations between individual traits (Hall et al., 1998).

1.2 Personality & Cognition in Humans

The concept that our individual personalities might have an impact on how we think, what we think, and how well we do on cognitive tasks is controversial to most. While tests of intelligence and cognition have the potential of being influenced to some degree by personality traits that do not relate to cognitive ability, the ideals of personality and intelligence are thought to be separate (Zeidner & Matthews., et al 2000). However, other believe that the development

of certain personality traits is essential for cognitive growth (Ackerman et al., 1996). Many models of human personality have been created and studied throughout the years but one of the most prolific is the OCEAN model, based on the idea that human traits fall into the categories of openness, conscientiousness, extraversion, agreeableness, and neuroticism (Rammstedt., et al 2016). In recent years Rammstedt and their colleagues set out to explore the potential relationship between human personality and cognition. Their results indicated a positive correlation between openness and emotional stability with cognitive ability, as well as a negative correlation between conscientiousness and cognitive ability (Rammstedt, 2016). However, outside variables such as levels of education, and labor force participation may have mediated these correlations.

Some personality components have been known to overlap with each other and can span cognitive abilities such as social skills and ability to cope with anxiety. For instance, Weiss et al, 2011 found that confidence was related to an individual's subjective wellbeing which is usually associated with a person's level of openness with others. While having confidence is perceived as a positive trait, it was found that confidence levels pertained to reactions to social stimuli. In this case higher levels of subjective well-being correlated with higher levels of confidence while lower levels of well-being were related to anxiety which will lead to anxious behaviors (Weiss et al., 2011).

Research examining potential correlations between specific traits and general intelligence has also been conducted. The psychological concept of crystallized intelligence pertains to an individual's ability to utilize knowledge that they have acquired over time. In some studies openness and friendliness/agreeableness has been found moderately correlated with crystallized intelligence as well as intellectual engagement (Altschul et al. 2016). This is consistent with prior

research showing a correlation between emotional stability which is characterized by higher openness and greater intellectual abilities (Altschul, 2016). However, social psychologists suggest that circumstantial demands, rather than individual traits may have a greater influence on behavior. In 2006, Harms and colleagues wanted to examine the effects of situational demands on personality and cognition by studying students in a college environment for four years. They found that that depending on how well the student fit with their surroundings, changes in personality traits linked to openness to experience and higher academic achievement were observed (Harms et al., 2006). While this is a small longitudinal case study, it shows that changes in human personality and cognition can be influenced by several factors. Therefore, it is important to examine the relationships between personality traits and cognitive ability in animals for which confounding variables can be minimized. Nonhuman primates, due to their close phylogenetic proximity with humans, provide an ideal model organism to explore these relationships.

1.3 Personality research in Non-Human Primates

The standard laboratory nonhuman primate has been for many years the rhesus macaque (*Macaca mulatta*). Rhesus monkeys can model many aspects of human behavior, due to their similarity with humans in brain architecture and organization, cognitive ability, stress and social behavior and physiology (Phillips et al., 2014). Older studies in this species have demonstrated that personality or temperament influences behavior and physiology (Mendoza & Mason, 1989). These older studies compared the individual patterns of behavioral and physiological responses by comparing extremes responders on a few variables (heart rate, HPA axis, aggression, social dominance etc.). For example, it was shown that testosterone and serotonin metabolites in CSF correlated with aggression rates in rhesus monkeys (Higley et al, 1996). It is only more recently

however, that nonhuman primate studies have used the methods typically employed in human personality research, by considering that personality comprises multiple, continuously distributed dimensions.

Capitanio (2004) reported that human ratings of male rhesus monkey behavior on a number of descriptive adjectives ("Aggressive; Confident; Fearful etc.) could be clustered in 4 dimensions, "Confidence, Sociability, Excitability, and Equitability" accurately describing their social behavior assessed over a 4.5-year time span and in social situations. Personality research has also been conducted in chimpanzees (King & Figueredo, 1997) and orangutans (Weiss, et al., 2006) and has highlighted close similarities between human and ape personality traits.

Research in New World monkey species is more recent and most of the research has been conducted with capuchin and spider monkeys (Koski, 2015). Several differences in the types and numbers of personality factors have been found between these species and Old-World monkeys. For example, for brown capuchin monkeys, only one factor observed related to positive social behavior whereas two factors were observed for these same types of behaviors in chimpanzees and humans (Koski, 2015). These initial finding suggest that traits representative of positive social behavior were originally conjoined in a common ancestor and were separated over time between New World and Old-World monkeys (Koski, 2015). However, traits correlated with conscientiousness in humans have also been observed in chimpanzees and brown capuchin monkeys (Koski, 2015). Another study examined differences between stump-tailed macaques and spider monkeys. Santillian-Doherty and colleagues wanted to observe traits in the two species by looking at a risk taking, curiosity, and novelty seeking behavior. Their results indicated that while spider monkeys scored higher in all three of these domains, macaques that

were perceived as dominant, were considered to be more novel seeking in nature (Santillian-Doherty et al., 2010).

Research on personality in marmosets is still in its infancy but has shown promising results in identifying personality domains and their potential evolutionary origins (Inoue-Murayama et al, 2018). Personality domains such as: dominance, sociability, and neuroticism appear to be the most represented amongst marmosets, but other personality domains like agreeableness, assertiveness, patience, inquisitiveness, and communality have also been reported (Koski et al, 2015).

1.4 Personality & Cognition in Non-Human Primates

Whether personality patterns affect cognitive ability is an important question that is difficult to study in humans, due to the presence of many confounding factors. Nonhuman primates can help minimize these confounds, but research into the relationship between personality and cognition in NHPs is relatively recent. Several studies have used macaque species. Pelakanos et al, (2017) compared cognitive performance of 4 species of macaques differing in their social style (different degrees of social tolerance). They tested less tolerant macaques (rhesus macaques, *Macaca mulatta*, and long-tailed macaques, *M. fascicularis) vs.* more tolerant macaques *(*Barbary macaques, *M. Sylvanus*, and Tonkean macaques, *M. tonkeana*) in a comprehensive cognitive task battery called the Primate Cognition Test Battery (PCTB). Designed by Herrmann et al. (2007), this battery includes several tasks of physical cognition and social cognition. They found that whereas all species performed at a comparable level on the physical cognition tasks, the more tolerant species were better at a social cognition task relevant to cooperation and an inhibitory control task. These findings point to a link between social

tolerance and the evolution of sophisticated socio cognitive skills. In a more recent study, Altschul et al 2016 tested 9 rhesus monkeys rated for personality traits in an abstract task of serial cognition. They found that across different measures, Friendliness and Openness were related to performance on the task. These two studies strongly suggest a link between some aspects of personality and cognitive performance in NHPs.

- **Why marmosets?**

This project utilized the common marmoset, *Callithrix Jacchus,* a rapidly increasing model for neuroscience research, mainly due to its amenability to gene editing. The marmoset has been employed in a multitude of research projects involving cognition, personality, aging, sex differences, and neuroendocrine functionality. Marmosets have a relatively short lifespan for an NHP, usually living for an average of 10-12 years (Nishijima et al., 2012). This makes them an excellent research animal for longitudinal studies and studies of aging. Furthermore, marmoset monkeys are much smaller than the average rhesus monkey, weighing 300-500g, meaning that they can be maintained in larger numbers, are less costly than other NHPs, and can be handled by experimenters with relative ease. In terms of cognitive functioning, marmosets can perform many cognitive tasks that have been used in other NHPs in the past. In addition, they are able to perform tasks administered on touchscreen, such as the computerized battery known as the Cambridge Neuropsychological Test Automated Battery (CANTAB; Spinelli et al., 2004).

Iwanicki & Lehmann in 2015 conducted the first personality tests in marmosets. They reported that their breeding colony of marmosets had a personality model that fit the human five factor model, which includes extraversion, agreeableness, neuroticism, openness, and conscientiousness (Iwanicki & Lehmann et al., 2015). Koski and colleagues, through the use of principal component analysis, parallel analysis, observer trait ratings, and multiple regressions

found a more distinct personality model comprised of agreeableness, conscientiousness, assertiveness, patience, and inquisitiveness. They discussed that their highly developed socio-cognitive abilities may be in part due to their cooperative breeding system, and indicated that their levels of assertive behavior correlated well with that of other non-human primates (Koski, 2015). Their agreeableness/openness domain resembled that of brown capuchin monkeys, while the inquisitiveness domain, which comprised traits such as curiosity and exploration, mirrored that of spider monkeys. They suggested that the rise of a patience domain may have originated from marmoset feeding ecology which involves "gum feeding": extracting food that is embedded within their gums, a more involved and time-consuming process (Koski, 2015).

These two studies form a solid basis to establish patterns of personality in our own marmoset colony. The objective of my Master's thesis is to determine whether and which personality traits correlate with cognitive performance on a hallmark test of cognitive flexibility, reversal learning.

CHAPTER 2
METHODOLOGY

2.1 Animal Subjects

This study included 27 common marmosets (*Callithrix jacchus*), all in the age range of 4 to 8 years (mean = 4.91, SD = .19), housed in the Lacreuse lab at the University of Massachusetts Amherst (see *appendix*). This sample included 14 males and 13 females, housed in male/female pairs in steel mesh cages (101 x 76.2 x 78.7 cm) equipped with perches, hammock, nest boxes and branches to encourage species-typical behaviors. There was an uneven amount of the male and female subjects because on the female marmosets died due to natural causes during the course of the study. Male marmosets were vasectomized in adulthood, prior to the start of the study, to avoid pregnancies. Food and water were provided twice daily, up until 1 hour before and immediately after cognitive testing. In addition, the monkeys were provided with daily enrichment activities. The animals were cared for in accordance with the guidelines published in the Guide for the Care and Use of Laboratory Animals, 8th edition. The studies were approved by the Institutional Animal Care and Use Committee of the University of Massachusetts at Amherst.

2.2 Human Judges

Eight judges (2 males, 6 females) among the Lacreuse lab research assistant staff were selected for this study, all of whom had worked daily and extensively with each individual marmoset for at least one year. Each judge was provided with a survey (see Table 2) in which they rated each marmoset on a 1 to 7 scale for a total of 55 specific personality traits. Individual judges might have specific predilections and predispositions towards certain animals that they might like more and or have worked with more closely which could lead to rater bias, which is a

confounding variable in this study. Therefore, the judges were instructed to have as little bias as possible when rating each monkey, and only draw from their observational experiences and direct interactions with the monkeys. Human raters were regularly exposed to the marmosets during behavioral observations, which is where the raters got most of their perceptions of the marmosets from. It is also important to note that the raters only assessed the monkeys once.

2.3 Procedures

2.3.1. Personality ratings

To conduct the personality testing, we used the survey constructed by Koski and their colleagues for assessments of marmoset personality. The survey includes specifically labeled personality traits, and a rating scale from 1 to 7. A rating of 1 indicating that there is a complete absence of a trait in a monkey and a rating of 7 indicating extreme presence of a trait. Every judge rated each of the 27 monkeys in the study on all the 55 traits, thereby all the traits were rated for each subject. A sample of the traits included are thoughtless, bullying, reckless, disorganized, impulsive, playful, assertive, friendly, sociable, and popular. See *appendix*, attached for full reference material of the survey.

2.3.2 Cognitive testing

To perform the cognitive testing, monkeys voluntarily entered a transport box (one side being a door and the other side being steel bar mesh) that was attached to the home-cage. Most of the marmosets were tested via the CANTAB, the Cambridge Neuropsychological Test Automated Battery , a computer system equipped with touch screen technology as well as a dispenser that supplies positive reinforcement (banana milk shake) for each correct answer

during the cognitive test. A few of the marmosets were unable or unwilling to use the CANTAB for their cognitive testing, thus they were tested using the Wisconsin General Testing Apparatus (WGTA) which is essentially a manual version of the CANTAB, where monkeys are presented with physical stimuli inside an opaque box (e.g., Crofts et al, 1999). In both situations, the cognitive apparatus was brought up to the transport box so that the monkey could perform the task.

Marmosets completed the Reversal Learning test, in which animals must choose one of two target stimuli appearing on random locations on the screen to receive the reinforcement (banana milkshake), (simple discrimination) and then adjust their response when the reward contingencies are reversed (reversal). This simple discrimination involved 40 trials a day, and once completed the data were automatically recorded in the computer system. In the case of monkeys that were tested via WGTA, they performed the same simple discrimination with physical stimuli WGTA testing except that only 20 trials were run per day and the monkeys were reinforced using miniature dried marshmallows instead of banana milkshake. For both tasks, the learning criterion was reached when the monkey obtained 90% of correct responses in 40 consecutive trials. They were then given the reversal task. The reversal continued for 40 trials per day until 90 % of correct responses was achieved. The monkeys were given a total of 3 pairs of stimuli. The trials needed to reach criterion (TTC), on the discrimination and reversal for each stimulus pair were the main dependent variables. A Reversal Index RI was calculated as followed: RI = (mean TTC on 3 reversals)/(mean TTC on 3 discriminations). This index estimated how many more trials the monkey needed to perform the reversals relative to the discriminations, with higher values reflecting worse performance because it took them longer to learn to the new correct stimulus.

2.4 Data Preparation and analysis

The methodology and results of this study revolved around applicable statistical computations and models that are imperative for analyzing the marmoset personalities observed (Koski, 2015). The first mathematical procedure employed was a principal component analysis (PCA) and the second was an intra-class correlation (ICC). The purpose of utilizing a PCA was to compute and separate the observable personality traits displayed by the marmosets into categorical components which essentially served as the personality domains. The ICC was used for testing the reliability of the judges/observers of the marmosets. Given that each observer had their own answers and separate biases, reliability testing ensured that the personality domains observed were accurate and reliable. Therefore, it aided in refining our personality data.

I used the ICC(2) test because it works better for studies that have the same raters for all the ratees. In this case we have 8 raters that rated each ratee on every single trait on the survey, meaning the raters were consistent. When analyzing the alpha coefficients for each trait, which indicates how reliable a given trait rating is, I looked at the "average measures" when determining if a trait was reliable. This is because "single-measures" are not involved in this study, every monkey was rated on every trait, by every rater meaning that the reliability of each trait rating had to be an average of all of the rater's inputs.

Another PCA was conducted to simplify the number of components. Each domain was then classified based upon the types of personality traits that had the highest correlation coefficient with each component. A linear regression was then performed with those domains as well as the cognitive data collected in order to identify any correlations between the personality domains and cognitive abilities (i.e., cognitive flexibility) of the marmosets.

The domains, also known as the predictor variables for predicting cognitive score outcomes, were calculated by taking the average of all the correlational coefficients for each set of traits that loaded onto a specific domain. For example, if the PCA analysis yielded a domain/component that had traits such as: impulsive, assertive, erratic loading on it, the correlational coefficients of all of those traits were averaged to create the numerical value score for that specific personality domain, so it could be used for further analysis and linear regressions.

2.5 Objectives, Hypothesis, & Predictions

The main hypothesis of this project was that there was an inherent connection between one's personality and one's cognitive ability. If one spends time with these marmosets, it quickly becomes clear how idiosyncratic their behavior can be with, each monkey having specific behavioral characteristics. Marmosets also have rather stable levels of cognitive performance.

Based on the human and NHP literature indicating a link between openness, emotional stability and some aspects of cognitive performance, I predict that a more neurotic marmoset would be worse at cognitive testing. In addition, I predict that more assertive marmoset would be better at cognitive testing.

CHAPTER 3

RESULTS

3.1 ICC (Intra-Class Correlations)

In this study, there were consistent raters across all of the ratee monkeys which merited the use of ICC(2). The way in which the ICC was calculated was by averaging the coded scores on the 1-7 scale given by each rater to each ratee. For example, the mean of rater 1: item 1 score, rater 2: item 1 score, rater 3: item 1 score, and so forth. This indicates that I am looking for the variance in the mean of all these ratings, therefore the important factor is "average measures". In **Table 1**, the average measures for eight raters and 55 traits: ICC(2,8) = .619 for trait 3. This means that 61.9% of the variance in the mean of these eight raters is indicated, which is the same for the alpha coefficient.

Table 1: ICC for Trait 3 (Clumsy)

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.169[a]	.064	.337	2.623	26	182	.000
Average Measures	.619[c]	.355	.802	2.623	26	182	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.619	.695	8

Upon completion of an ICC used to measure the reliability between raters for each of the 55 traits, there were thirty-three traits that had an alpha coefficient above .6, so they were included in this study: Bullying, Aggressive, Excitable, Assertive, Cautious, Anxious, Depressed, Dependent, Dominant, Submissive, Timid, Fearful, Vulnerable, Protective, Independent, Opportunistic, Thoughtless, Clumsy, Eccentric, Reckless, Disorganized, Erratic, Irritable, Impulsive, Affectionate, Helpful, Distractible, Quitting, Intelligent, Lazy, Solitary, Alert, and Tense. Table 1 gives an example of the ICC for the trait Clumsy. Descriptive statistics are also provided in Table 2 for each of the 33 traits. The means and standard deviations were also calculated for each trait for further use, see **Table 2.**

Table 2: Descriptive Statistics for all 33 traits

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
Thoughtless	2.5556	.75728	26
Bullying	2.9060	1.23019	26
Clumsy	2.4500	.57379	26
Eccentric	3.3146	.84947	26
Reckless	2.8869	.83511	26
Disorganized	2.7627	.74196	26
Erratic	3.4069	.98763	26
Aggressive	3.3154	1.09078	26
Irritable	3.3781	.77734	26
Impulsive	3.3819	.85413	26
Excitable	4.1608	.78397	26
Depressed	1.6085	.49923	26
Assertive	3.6238	.87430	26
Affectionate	3.7769	.85457	26
Helpful	2.7769	.59890	26
Protective	2.9981	.70664	26
Cautious	3.5408	1.00707	26
Dependent	2.9700	.73131	26
Dominant	3.5219	.89759	26
Independent	3.6081	.76228	26
Timid	2.8108	1.00577	26
Submissive	2.5942	.80144	26
Fearful	3.0015	1.04394	26
Tense	2.9838	.84056	26
Anxious	3.0158	.80341	26
Vulnerable	2.7523	.71631	26
Distractible	4.0900	.78258	26
Quitting	3.1088	1.27193	26
Intelligent	4.2385	.89112	26
Lazy	2.6512	1.04359	26
Opportunisti	3.7085	.73986	26
Solitary	2.4881	.79362	26
Alert	4.5215	.54482	26

3.2 Dimension Reduction: Principal Component Analysis

A principal component analysis was conducted to examine how many potential components/domains could be extracted from the initial 55 traits. The first PCA extracted 9 factor components, which was too large for further analysis, as working with 9 different personality domains would be too difficult going forward. So, after the ICCs whittled down the number of traits involved to 33, which meant that not all of the 55 traits had been reliably coded. Therefore, another PCA was conducted on the reliable 33 traits which yielded seven components. However, many of seven components had eigenvalues close to 1: 16.40, 10.34, 3.07, 2.84, 1.72, 1.38, and 1.24. This means that the first two of the seven components explained most of the statistical variance, the other components were increasingly insignificant, which meant I needed to reduce the number of components further. In addition, having seven personality types would be somewhat inconsistent with the current literature, with most studies as mentioned previously having three to five domains.

Therefore, I conducted another component analysis that fixed the number of factors extracted to five which is in line with the OCEAN model and other Big Five personality factor models. However, I noticed that at least two of the factors extracted had zero traits that explained partial variance, indicating that the traits for those two components had extremely low correlational coefficients, and there were no traits of the 33 that loaded onto them, therefore making those two components irrelevant. Therefore, I conducted a final PCA forced extraction for 3 factors, which is also consistent with some of the personality models in the marmoset literature (Inoue-Murayama et al, 2018). **Table 3** displays the descriptive statistics for the final

PCA with the 3 forced components, all of which explain a different degree of the overall variance.

Table 3: Total Variance Explained

Component	Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	11.829	35.846	35.846
2	8.452	25.613	61.458
3	3.043	9.220	70.678

Extraction Method: Principal Component Analysis.

Three components were extracted via varimax rotation from the 33 traits. **Table 4** depicts all the 33 reliable traits with their correlational coefficients. The coefficients that are bolded, indicate the most significant value across all three components for each trait, meaning that the bolded coefficients indicate why each trait loaded onto their respective components.

Table 4:

Rotated Component Matrix[a]

	Component		
	Assertiveness	Neuroticism	Cautiousness
Thoughtless	.131	**.869**	.098
Bullying	**.835**	.094	-.379
Clumsy	.002	**.685**	.031
Eccentric	**.672**	.526	-.186
Reckless	**.831**	.164	-.135
Disorganized	.231	**.837**	-.031
Erratic	**.848**	.380	.139
Aggressive	**.896**	-.017	-.293
Irritable	**.882**	.150	.148
Impulsive	**.788**	.071	-.069
Excitable	**.801**	-.066	.051
Depressed	-.177	**.515**	.237
Assertive	**.764**	-.192	-.469
Affectionate	**-.624**	-.074	-.329
Helpful	-.219	-.494	**-.517**
Protective	.115	**-.554**	-.039
Cautious	-.483	.106	**.768**
Dependent	**-.511**	.351	.329
Dominant	**.728**	-.212	-.446
Independent	**.474**	.032	-.116
Timid	-.389	.192	**.809**
Submissive	**-.609**	.321	.483
Fearful	-.359	.335	**.801**
Tense	.091	.197	**.913**
Anxious	-.120	.315	**.877**
Vulnerable	-.487	.405	**.702**
Distractible	.243	**.756**	.304
Quitting	.097	**.810**	.385
Intelligent	-.007	**-.797**	-.339
Lazy	.014	**.892**	.246
Opportunistic	**.633**	-.574	-.357
Solitary	.040	**.600**	.142
Alert	.320	**-.555**	.539

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.[a]

a. Rotation converged in 6 iterations.

3.3 Personality Structure

- **Component Reliability:**

To effectively measure the reliability of each component, I conducted a descriptive scale reliability analysis for each one. Each component scale was comprised of their respective component's traits. Presented here are the Cronbach's alpha levels for each of the components, each of which should have an alpha coefficient above .75, because that is an indicator of good reliability.

- **Domain1: Assertiveness**

Reliability Statistics

Cronbach's Alpha	N of Items
.946	15

Scale reliability analysis of Domain1/Assertiveness yielded alpha coefficient .946 > .75, meaning the overall reliability of Domain1 was high. Thus the traits that loaded onto the first component were highly correlated with each other and reflected the same domain therefore making Domain1 acceptable to use for further analysis. The items in this component scale were: Bullying, Eccentric, Reckless, Erratic, Aggressive, Irritable, Impulsive, Excitable, Assertive, Dominant, Independent, Affectionate, Dependent, and Submissive, meaning that there were 14 items in this scale.

- **Domain2: Neuroticism**

Reliability Statistics

Cronbach's Alpha	N of Items
.916	11

Scale reliability analysis of Domain2/Neuroticism yielded an alpha coefficient .916 > .75, meaning the overall reliability of Domain3 was high. This means the traits that loaded onto the second component were highly associated with each other and reflected the same component therefore making Domain2 acceptable to use for further analysis. This component scale was comprised of the traits: Thoughtless, Clumsy, Disorganized, Depressed, Protective, Intelligent, Alert, Distractible, Quitting, Lazy, and Solitary, 11 items in this scale.

- **Domain 3: Cautiousness**

Reliability Statistics

Cronbach's Alpha	N of Items
.947	7

Scale reliability analysis of Domain3/Cautiousness yielded alpha coefficient .947 > .75, meaning the overall reliability of Domain3 was high. This means the traits that loaded onto the third component were highly associated with each other reflected the same component therefore making Domain3 acceptable to use for further analysis. This scale was comprised of items: Helpful, Cautious, Timid, Fearful, Tense, Anxious, and Vulnerable, 7 items in this scale.

Personality Structure

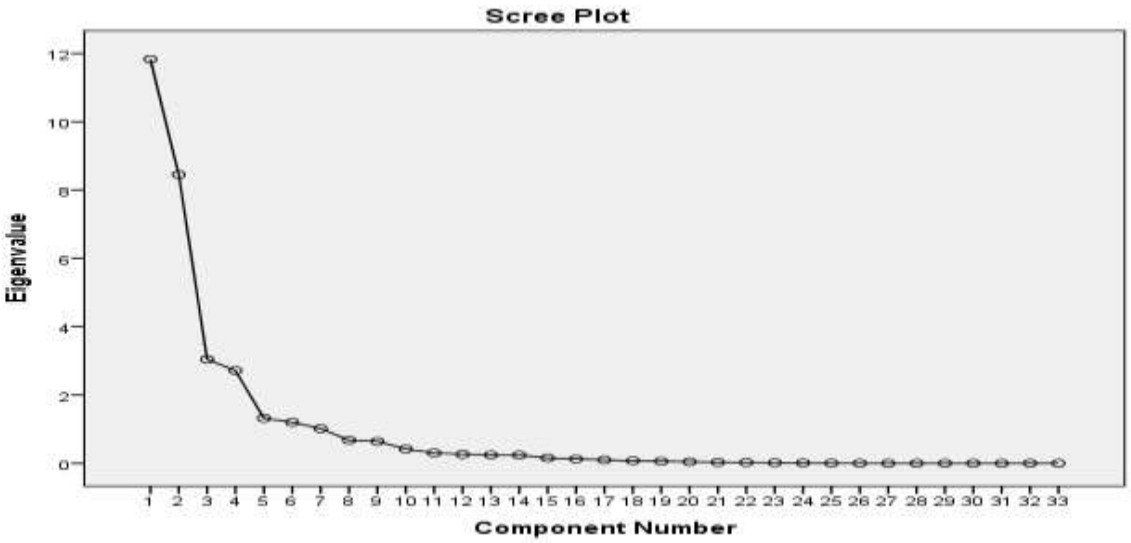
As can be seen in Table 4 and Fig 1, components 1 and 2 accounted for much more of the overall variance than the 3rd component. All three components were extracted via varimax-rotated solution, with the first component containing traits with positive correlational coefficients for aggressive, erratic, assertive, and dominant as well as negative loadings for affectionate, dependent, and submissive. This closely resembles the personality domains of assertiveness in

Koski, 2015 and dominance in Inoue-Murayama, 2018. This domain appears to contain trait loadings similar to both, so we combined them to label this domain “assertiveness”.

The second principal component was described largely by high positive loadings for disorganized, distractible, lazy, quitting, clumsy, and solitary ratings and negative loadings for protective, alert, and intelligent ratings. This resembles the classic personality domain of neuroticism in squirrel monkeys (Wilson et al, 2013), brown capuchin monkeys, orangutans, chimps, and macaques (Morton et al, 2013). Due to the consistencies between patterns of trait loadings between non-human primate species we labeled this component as “neuroticism”.

The third component was comprised of high positive loadings for cautious and tense as well as low negative loadings for helpful, which is indicative of domains related to fearfulness, inquisitiveness, and cautiousness. Due to the high correlational coefficients of traits related to cautious behavior, this domain was deemed “Cautiousness”.

Fig 1: Scree Plot for PCA



After the initial three components the line became flatter because each successive point on the graph was representative of a smaller and smaller component whose eigenvalues are below 1.

3.4 Cognitive Scores x Personality Types

Once the necessary domains were decided on, a linear regression was conducted in order to observe any potential relationships between the personality domains and the reversal index cognitive scores from the first year of the sex hormone and cognition study, as reported in LaClair et al, (2019). This score is calculated as such: Mean(SR1+SR2+SR3)/Mean (SD1+SD2+SD3). The total of the simple reversal tasks and simple disclinations tasks are indicative of the number of trials it took each marmoset to reach the 90% criterion. Therefore, a higher reversal index score means that the monkey did not perform well on the cognitive test, which is testing cognitive flexibility. This is the only cognitive performance measure that was readily available to utilize in this study.

It was found that females were consistently worse than males in performing the reversals, and therefore sex was included as a predictor of the reversal index RI in the regression. The sex variable shown as “female” in the table was coded numerically, with males coded as 0 and females coded as 1 within the dataset. **Table 5** shows the regression results.

Table 5: Linear Regression for Reversal Index scores x Personality Domains, and descriptive statistics for each variable

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.427	.791		1.805	.085
	Domain1	.133	.150	.181	.889	.384
	Domain2	-.117	.174	-.143	-.671	.510
	Domain3	.081	.140	.126	.576	.571
	Female	.535	.185	.557	2.892	.009

a. Dependent Variable: Reversal Index

Descriptive Statistics

	Mean	Std. Deviation	N
Reversal Index	2.0986	.48962	26
Domain1	3.7248	.66470	26
Domain2	3.0870	.59870	26
Domain3	3.3326	.76118	26
Female	.5000	.50990	26

Domain1 (Assertiveness) did not significantly predict reversal index scores, b = .133, t(4) = 889, $p > .05$. Furthermore, Domain2 (Neuroticism) did not significantly predict reversal index scores, b = -.114, t(4) = -.671, $p > .05$. Domain3 (Inquisitiveness) did not significantly predict reversal index scores, b = .081, t(4) = .576, $p > .05$. However, sex (Female variable) did significantly predict reversal index scores, b = .535, t (4) = 2.89, $p < .05$. This indicated that female monkeys scored higher than males on reversal index scores (i.e., worse performance) by an average of 53.5 points. This regression model explained 43.3% of the variance in the reversal index cognitive test scores. Importantly, the interaction between Sex and the domains was also not significant (**Table 6)**.

Table 6: Linear regression results between marmoset sex and personality domains.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.850	.132		13.964	.000
	Domain1centered	.233	.207	.316	1.124	.276
	Domain1centeredxfemale	-.247	.317	-.206	-.779	.446
	Domain2centered	-.104	.226	-.127	-.458	.652
	Domain2centeredxfemale	-.087	.384	-.061	-.226	.824
	Domain3centered	.057	.191	.089	.297	.770
	Domain3centeredxfemale	.089	.299	.087	.299	.769
	Female	.537	.195	.560	2.760	.013

a. Dependent Variable: Reversal Index

CHAPTER 4

DISCUSSION

4.1 Overall Results

The overarching hypothesis for this study is that there is indeed an inherent connection between personality and cognitive ability, as assessed by cognitive flexibility, in marmoset monkeys. In addition, it was also predicted that a neurotic marmoset would perform worse at cognitive testing, whereas an assertive/dominant personality type would perform better on cognitive testing. However, none of the personality domains, including assertiveness/dominance and neuroticism significantly predicted RI. Therefore, I must accept the null hypothesis that the personality types found in this population of marmosets did not predict cognitive flexibility ability.

Despite the lack of association between personality type and cognition, the reliability of the survey traits utilized for analysis and the personality domains that were found were consistent with other studies in marmosets like Koski, 2015, and Inoue-Murayama, 2018 as well as studies done in other primates such as Wilson, 2013, and Morton, 2013. However, of the original 55 personality traits that comprised the survey, based off the Koski, 2015 study, only 33 were reliable enough to employ in our study. In addition, the personality type observed lacked in diversity, with many of the traits and personality domains containing socio-negative loadings. For example, personality domains for openness, agreeableness, extraversion, or conscientiousness were not observed reliably, in contrast to the big-five personality model of the human literature. In fact, some of the personality traits that loaded onto the “Cautiousness” personality domain such as timid, fearful, tense, and vulnerable are actually more indicative of

introversion and even avoidant personality disorders (Wiggins & Pincus et al, 1989). Next I discuss some limitations that may explain at least partly these results

4.2 Limitations

Several factors may have influenced the types of personality domains that were found in these monkeys. The first of which, and arguably the most influential is the small sample size of marmosets available for this study as well as the small number of participating researchers involved. Other studies had a much larger sample of both subjects and participants, such as Koski, 2015 which utilized 100 marmosets and 18 researchers in a similar survey administration. This greatly increases the statistical power of the experiment and increases the variability in ratings. With only 27 monkeys and 8 human raters, statistical power was evidently low, and while the overall reliability of trait ICCs was not low, we found as many as 22 traits with alpha levels below .60, all of which had been observed and utilized by other marmosets' studies.

A great deal of the 22 traits with low reliability were social traits: socially playful, exploratory, sociable, confident, friendly, and popular to name a few. All of which one might expect social animals like marmosets to reliably exhibit. Firstly, studies that have found traits like this and personality domains with pro-social loadings like agreeableness and patience had monkeys housed in large social/communal groups. However, our monkeys were kept in heterosexual pairs, with each pair having their own cage separate from other monkeys, which limited the range of social interactions.

Other various influences that could have impacted our results include having a wide age range among the monkeys, and the reliability of trait ratings being subject to human bias. While it may seem apt to look at the varying personalities of a sample of monkeys that had a larger

span of age range such as our study, with some old, some middle ages, and some young. I think looking at a sample that is more uniform in age might yield more reliable results, because they might be more inclined to perform more similar patterns of behavior, which would be recognized more easily by the human raters.

Lastly, the most concerning confounding variable present in this study is rater bias. Although all eight of the human raters were instructed to draw from their knowledge and experiences when rating these monkeys it is impossible to eliminate potential bias entirely when working with human-raters that know these monkeys and understand their behavior. Unfortunately, most of these raters were undergraduate or graduate students, so many of them left the laboratory shortly after they completed their surveys, therefore we could not re-assess the monkeys with the same raters a few months after the first survey. While the inter-rater reliabilities of the 33 traits that remained were high and alpha coefficients of the domains themselves were also quite high, there is no question that having less human bias could have made an impact on how certain monkeys were ultimately rated.

4.3 Future Directions

Despite these many limitations, this type of study has the potential to be taken into numerous directions. To extend upon this current study's design, it would be interesting to utilize more cognitive data, since I was only able to utilize one year's worth of reversal index cognitive scores from a four yearlong study. In addition, the study only focused on cognitive flexibility.

Utilizing different types of cognitive tests such as tests of memory and measures of socio-emotional intelligence could potentially yield different results.

Finally, many additional data collected on the same monkeys could be used to examine associations with the personality data. For instance, motor data, handedness data, cortisol and stress reactivity measures could show interactions with personality types.

One could also take a more genetic approach much like that Inoue-Murayama, 2018 by looking at transgenic marmosets that have idiosyncratic genetic traits. Mutations on serotonin or dopamine receptors could influence the type of personality domains found in a sample.

4.4 Conclusions

This study in a small sample of subjects and a limited number of raters did not support a link between personality traits and one aspect of cognition, cognitive flexibility. Ultimately, I believe further research is needed to fully explore a potential link between personality and cognition in the marmoset, especially by extending the range of cognitive abilities that are examined. Such an approach will be useful for understanding more about our own psychology and personality.

APPENDIX A

MONKEY'S CHARACTERISTICS

Subject	Sex	Age
1	female	3.96
2	female	4.01
3	female	4.34
4	female	5.01
5	female	5.21
6	female	5.59
7	female	4.34
8	female	4.36
9	female	4.67
10	female	4.71
11	female	5.52
12	female	6.16
13	female	4.25
14	female	4.81
15	male	3.92
16	male	4.93
17	male	5.04
18	male	6.51
19	male	4.64
20	male	4.81
21	male	4.86
22	male	5.57
23	male	4.87
24	male	4.88
25	male	5.04
26	male	5.39
27	male	5.73

APPENDIX B

RATING SHEET SURVEY FOR HUMAN JUDGES

NAME			**Instructions**						
DATE			Please rate each subject on your overall impression of that monkey,						
			from a rating of 1 = absence of trait, to a rating of 7 = extreme presence of trait.						
			Do NOT discuss your ratings with other raters						
	Mario	**Froggie**	**Misty**	**Harvest**	**Nolan**	**Vera**	**Flash**	**Flynt**	**Skittles**
Thoughtless									
Bullying									
Clumsy									
Eccentric									
Reckless									
Disorganized									
Imitative									
Erratic									
Jealous									
Aggressive									
Irritable									
Impulsive									
Excitable									
Unperceptive									
Socially playful									
Depressed									
Stingy									
Playful									
Assertive									
Friendly									
Equable									
Affectionate									
Permissive									
Gentle									
Sociable									
Popular									
Helpful									
Predictable									
Unemotional									
Protective									
Cautious									
Dependent									
Dominant									
Independent									
Confident									
Timid									
Submissive									
Fearful									
Tense									
Anxious									
Vulnerable									
Selective									
Sympathetic									
Distractible									
Quitting									
Intelligent									
Inventive									
Sensitive									
Persistent									
Lazy									
Exploratory									
Inquisitive									
Assertive									
Opportunistic									
Solitary									
Alert									

APPENDIX C

ICC (RELIABILITY SCORES) FOR ALL TRAITS

Trait	ICC Chronbachs Alpha
Thoughtless	0.767
Bullying	0.825
Clumsy	0.619
Eccentric	0.732
Reckless	0.701
Disorganized	0.641
Imitative	0.355
Erratic	0.784
Jealous	0.587
Aggressive	0.793
Irritable	0.628
Impulsive	0.624
Excitable	0.703
Unperceptive	0.563
Socially playful	0.547
Depressed	0.694
Stingy	0.371
Playful	0.59
Assertive	0.72
Friendly	0.511
Equable	0.277
Affectionate	0.74
Permissive	0.378
Gentle	0.559
Sociable	0.362
Popular	0.545
Helpful	0.633
Predictable	-0.245
Unemotional	0.473
Protective	0.662
Cautious	0.778
Dependent	0.707
Dominant	0.738
Independent	0.71
Confident	0.405
Timid	0.791
Submissive	0.704

Fearful	0.847
Tense	0.714
Anxious	0.714
Vulnerable	0.798
Selective	0.376
Sympathetic	0.313
Distractible	0.684
Quitting	0.88
Intelligent	0.868
Inventive	0.57
Sensitive	0.415
Persistent	0.427
Lazy	0.85
Exploratory	0.477
Inquisitive	0.539
Oppurtunistic	0.748
Solitary	0.756
Alert	0.656

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