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Genetic and Environmental Influences on Individual Differences in Frequency of Play with Pets among Middle-Aged Men: A Behavioral Genetic Analysis

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Abstract

There is growing evidence that pet ownership and human–animal interaction (HAI) have benefits for human physical and psychological well-being. However, there may be pre-existing characteristics related to patterns of pet ownership and interactions with pets that could potentially bias results of research on HAI. The present study uses a behavioral genetic design to estimate the degree to which genetic and environmental factors contribute to individual differences in frequency of play with pets among adult men. Participants were from the ongoing longitudinal Vietnam Era Twin Study of Aging (VETSA), a population-based sample of 1,237 monozygotic (MZ) and dizygotic (DZ) twins aged 51–60 years. Results demonstrate that MZ twins have higher correlations than DZ twins on frequency of pet play, suggesting that genetic factors play a role in individual differences in interactions with pets. Structural equation modeling revealed that, according to the best model, genetic factors accounted for as much as 37% of the variance in pet play, although the majority of variance (63–71%) was due to environmental factors that are unique to each twin. Shared environmental factors, which would include childhood exposure to pets, overall accounted for <10% of the variance in adult frequency of pet play, and were not statistically significant. These results suggest that the effects of childhood exposure to pets on pet ownership and interaction patterns in adulthood may be mediated primarily by genetically-influenced characteristics.

Keywords

genetics; pets; twins

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During the past three decades, there has been an increase in research on the benefits of pet ownership and human–animal interaction. Studies have found that adult pet owners live longer and have fewer health problems than non-pet owners (Friedmann et al. 1980; Headey and Grabka 2007; Headey, Na and Zheng 2008; for comprehensive reviews, see Cutt et al. 2007; Wells 2009; O’Haire 2010). Studies have also shown positive psychological effects of pet ownership: pet owners tend to be less lonely, less depressed, and more socially engaged, and to perceive their communities as more cohesive than non-pet owners (Garrity et al. 1989; Allen et al. 1991; Wood, Giles-Corti and Bulsara 2005). Interactions with pets are also thought to reduce stress, with a number of studies reporting decreases in blood pressure and/or increases in heart rate variability following interactions with pets (Friedmann et al. 1983; Allen et al. 1991; Friedmann et al. 2003; Motooka et al. 2006; Friedmann et al. 2007). Interactions with dogs have been shown to reduce cortisol levels (Odendaal and Meintjes 2003; Barker et al. 2005; Barker et al. 2010), suggesting that the benefits of interactions with pets may be mediated, in part, through hypothalamic-pituitary-adrenal (HPA) axis activity. Similarly, interactions with dogs increase levels of oxytocin (Odendaal and Meintjes 2003; Miller et al. 2009; Nagasawa et al. 2009; Uvnäs-Moberg, Handlin and Petersson 2010), a neuropeptide expressed in many areas of the brain and related to attachment and social affiliative behavior.

One potential limitation of prior research, particularly research based on cross-sectional studies, is that there may be pre-existing differences between pet owners and non-pet owners. Only a handful of studies have randomly assigned individuals to pet ownership categories, and those that have (e.g., Allen, Shykoff and Izzo 2001; Viau et al. 2010) still have had to rely on the willingness of participants to welcome a pet into the home. As a result, it is unknown whether differences between pet owners and non-pet owners reflect differences brought about by pet ownership itself or by underlying differences in personality, health, and lifestyle between these two groups. Failure to consider selection effects on pet ownership and interaction with animals could potentially bias results. Indeed, research has found that pet ownership patterns are related to demographic characteristics. In the United States, pet ownership is more frequent among Caucasian families than among African American, Hispanic, or Asian families (Siegel 1995; Risley-Curtiss, Holley and Wolf 2006), with similar racial/ethnic differences seen in a large cohort of UK families with children under age 10 years (Westgarth et al. 2010). Pet ownership is also more common in families in which the mother works and in families with older children (Melson 1988; Westgarth et al. 2010), although evidence is inconsistent regarding associations between pet ownership and income and/or educational attainment (Marx et al. 1988; Siegel 1995; Poresky and Daniels 1998; Bryant and Donnellan 2007; Westgarth et al. 2010).

Differences in personality may also relate to differences in individuals’ tendencies to own or interact with a pet. For example, individuals who prefer dogs score higher than people who prefer cats on the Big Five personality dimensions Agreeableness, Conscientiousness, and Extraversion but lower on Neuroticism and Openness (Gosling, Sandy and Pottert 2010), although separate studies have found that Openness and Neuroticism are positively correlated with attachment to pet dogs (Kurdek 2008; Kotrschal et al. 2009). Positive associations between exposure to pets and empathy and enhanced social skills have been reported (Zasloff, Hart and Weiss 2003; Daly and Morton 2009), but whether pets enhance

social development or more empathic, socially adept individuals are more attracted to pets is unknown.

In addition to personality, other individual and family characteristics may influence the degree to which individuals interact with, and form emotional attachments to, their pets. Many studies have reported that women form stronger attachments to pets than do men (Kidd and Kidd 1989; Johnson, Garrity and Stallones 1992; Woodward and Bauer 2007), although there is some conflicting evidence (Bagley and Gonsman 2005; Cavanaugh, Leonard and Scammon 2008). Older children, singleton children, and children from single-parent households have stronger bonds with their dogs than do younger children, children with siblings, and children living with both biological parents (Siegel 1995; Bodsworth and Coleman 2001). Length of pet ownership positively influences attachment to pets, and age at first exposure to dogs is inversely correlated with the amount of oxytocin released during human–dog interaction (Nagasawa et al. 2009), suggesting that the degree of exposure to pets can moderate physiological responsivity during human–animal interactions.

Pet ownership patterns and attachment to pets during adulthood is determined, in part, by pet ownership patterns during childhood. In a study of 120 adults aged 18 to 84 years, 46% of adults who grew up with pets currently owned pets, compared with only 20% of individuals who did not grow up with childhood pets (Serpell 1981). Moreover, 84% of adults with pets owned the *same species of pet* that they owned in childhood, indicating a strong degree of continuity. In a recent longitudinal study of more than 14,000 children followed from birth through age 10 years, mothers' pet ownership histories at least partially influenced the probability of pet ownership during the course of the study (Westgarth et al. 2010). Finally, in an ongoing community-based family study of children aged 10 to 18 years at the University of Chicago, caregivers and children correlate on overall attitudes towards pets ($r = 0.40$, $n = 63$, $p < 0.01$), and on a measure of attachment to the family dog ($r = 0.27$, $n = 43$, $p = 0.07$) (Jacobson, unpublished data).

Given the association between parents and children for pet ownership patterns and attachment towards pets, it is plausible that pet ownership and related behaviors and traits may be heritable. Decades of behavioral genetic research has supported the importance of genetic factors on individual differences in a myriad of behaviors and traits (Plomin et al. 2008). In particular, significant genetic effects have been found for individual differences in many types of human relationships, including marital (McGue and Lykken 1992; Spotts et al. 2004; Jerskey et al. 2010), sibling and parent–child relationships (Rowe 1981; Rende et al. 1992; Pike and Plomin 1997; see Kendler and Baker 2007 for a review), and social support (Kendler 1997; Bergeman et al. 2001; Agrawal et al. 2002). Genetic factors typically account for ~40–50% of the variance in personality traits that might be related to pet ownership, including neuroticism (Jang, Livesley and Vernon 1996; Birley et al. 2006; Distel et al. 2009), openness (Jang, Livesley and Vernon 1996; Distel et al. 2009), and empathy (Davis, Luce and Kraus 1994; Rushton 2004). Finally, genetic factors have been shown to account for a substantial part of individual differences in depression (Kendler et al. 1994; Kendler et al. 2006; see Sullivan, Neale and Kendler 2000 for a review), loneliness (Boomsma et al. 2005), blood pressure (Hong et al. 1994; Hottenga et al. 2005), and heart rate variability (Singh et al. 1999), all of which have been associated with pet ownership and

human–animal interaction. Thus, it is important to characterize the extent to which genetic factors influence attributes of the human–animal bond in order to obtain a more complete understanding of potential causal processes.

To our knowledge, there are no published behavioral genetic studies investigating the extent to which genetic factors may influence individual differences in pet ownership and related characteristics. Therefore, the purpose of the present study is to examine correlations of frequency of pet play among a sample of adult, male identical (monozygotic, MZ) and fraternal (dizygotic, DZ) twin pairs to estimate the heritability of pet play. Stated simply, to the extent that MZ twins are more similar than DZ twins in patterns of pet play in adulthood, this implies that genetic factors have a role in relationships with pets. Conversely, if MZ twins are no more similar in their patterns of pet play than DZ twins, this indicates a significant effect of shared environmental factors, which are environmental influences and exposures that are shared among two twins growing up in the same family and include childhood exposure to pets. While there are a number of behavioral genetic designs, the twins-reared-together design is the most common. Moreover, the fact that twins are the same age adds the additional strength that any potential exposure to childhood family pets would occur during the same developmental period for two twins in the same family. Based on evidence of heritability for other types of human interactions, we expect that genetic factors will play a role in individual differences in pet play during adulthood. However, given that family history of pet ownership is a strong predictor of whether children are exposed to pets (Serpell 1981; Westgarth et al. 2010), we also expect that shared environmental factors may play a significant role in variation in pet play during adulthood.

Methods

Sample and Procedure

Data were obtained from Wave 1 of the Vietnam Era Twin Study of Aging (VETSA), a longitudinal study of cognition and aging beginning in midlife (Kremen et al. 2005). All participants in VETSA are from the Vietnam Era Twin Registry, a nationally representative sample of male–male twin pairs who served in the US military sometime between 1965 and 1975. The majority of twins did not experience combat during their enlistment. Detailed descriptions of the Registry and ascertainment methods have been previously reported (Eisen et al. 1987; Henderson et al. 1990). A majority of participants are Caucasian (88%), although VETSA twins resemble those of the larger Registry sample and are overall representative of the general population of similarly aged adult males (Lyons et al. 2009). During the Wave 1 VETSA study, twins had the option to travel to Boston University or to the University of California, San Diego, for a day-long session that included physical assessments and an extensive neurocognitive battery. Participants also filled out a detailed self-report questionnaire assessing current demographic characteristics, lifestyle factors, and relationships. The study was approved by local Institutional Review Boards in both Boston and San Diego. All participants signed written informed consent documents prior to participation in the study. Of the VETSA subjects, 48.5% of those who were contacted agreed to participate. This response rate is reasonable given that participation required a 2–3-day trip to either San Diego or Boston. The VETSA Wave 1 sample includes 1,237

individual twins (614 twin pairs and 9 unpaired twins). The mean age of participants during Wave 1 was 55.4 years (range: 51–60). Wave 2 data collection is ongoing through 2013.

Materials and Measures

Zygosity—Zygosity for the majority (92%) of the VETSA sample was determined by analysis of 25 satellite markers obtained from blood samples. For the remaining 8% of the sample, zygosity was determined through a combination of questionnaire and blood group methods. A comparison of these two approaches within the VETSA sample has demonstrated an agreement rate of 95%, similar to most other twin samples (Magnus, Berg and Nance 1983; Rietveld et al. 2000). Of the 1,237 individual twins, slightly more than half ($n = 697$; 56.3%) were determined to be monozygotic (MZ) twins, while the remaining 540 twins were dizygotic (DZ).

Pet Play—Frequency of play with pets was asked with a single question that was part of a larger measure on general activities. Individuals were asked “During the past 30 days, how often did you play with pets” and responded on a 5-point Likert scale, where 1 = never, 2 = once per month, 3 = once per week, 4 = several times per week, and 5 = daily. Figure 1 shows the percentages of MZ and DZ twins in each response category. A substantial proportion of both MZ (45.6%) and DZ (40.6%) twins reported playing with pets on a daily basis. Just over one-quarter (26.8% of MZ twins; 29.0% of DZ twins) reported never playing with pets. Given the bimodal distribution of scores, analyses were also run with the pet play variable recoded as a polychotomous variable, where 0 = never, 1 = > never but < daily, and 2 = daily.

Demographic Measures—Twins reported on their current marital status and level of educational attainment. The majority of the sample (78.7%) was currently married, 5.4% were never married, and the remaining 15.9% had been married, but were currently single. There was variability in the highest level of education obtained. A small proportion of twins (1.6%) had less than a high school education, 28.8% had a high school education or equivalent, 40.1% had some college, and 29.5% had at least four years of college or more.

Statistical Analysis

Due to the unique genetic relationships of twins, researchers can utilize twin data to partition out the genetic and environmental influences on the individual differences in a trait. In the twin design, three variance components are routinely estimated: additive genetic (A), common (or shared) environmental (C), and non-shared environmental (E) (Neale and Cardon 1992). Additive genetic effects refer to the total effects of multiple alleles on a behavior or trait. Monozygotic twins (MZ) are assumed to share 100% of their segregating alleles, while dizygotic twins (DZ), on average, share 50%. In other words, the correlation of additive genetic effects for MZ twins is constrained to $r = 1.0$, while it is constrained to $r = 0.5$ for DZ twins. Shared environmental effects are nongenetic effects that make twins reared in the same family similar. Both MZ and DZ twins are assumed to share 100% of their shared environment; thus, the correlation of shared environmental effects for both MZ and DZ twins is 1.0. Shared environmental effects can include such factors as childhood demographic characteristics (e.g., parental marital status, family socioeconomic status),

family characteristics (e.g., exposure to childhood pets, family religiosity), and community factors. Non-shared environmental factors, on the other hand, refer to non-genetic influences that make each twin within a given family unique. Non-shared environmental factors, by definition, are uncorrelated for both MZ and DZ twins. Non-shared environmental influences include exposure to different peers, differential treatment by parents, and accidents and illnesses. Measurement error is also a source of non-shared environment in twin models, as measurement errors are assumed to be random and uncorrelated across individuals.

Figure 2 depicts a univariate ACE model that estimates the variance components of a single phenotype. The parameters a , c , and e represent the regression coefficients of a phenotype on the respective latent factors of A, C, and E. Squaring these parameters calculates the variance (V) due to each factor ($a^2 = V_A$, $c^2 = V_C$, $e^2 = V_E$). Total phenotypic variance (V_P) of a trait can be estimated by summing these squared parameter estimates ($V_P = a^2 + c^2 + e^2$). Standardizing these estimates results in $a^2 + c^2 + e^2 = 1$, with a^2 equaling the heritability (also referred to as h^2).

All models were fit to raw data using the structural equation modeling program, Mx (Neale et al. 2003). The raw data option estimates means as well as variances. Dropping parameters from the full ACE model allows us to test whether pet play is significantly influenced by genetic and/or environmental factors. Models that were tested include a model without genetic influence (CE model), a model without shared environmental influence (AE model) and a model with only non-shared environmental influence (i.e., no familial influences; E only model). Model fit was assessed using the difference in two times the log likelihood ($-2LL$) between the full ACE model and each sub-model (AE, CE, and E only). This difference in model fit ($-2LL$) is distributed as a chi-square distribution (χ^2) with degrees of freedom equal to the difference in the number of parameters between the two models. A significant ($p < 0.05$) increase in the χ^2 indicates that the sub-model has a significantly poorer fit as compared to the full ACE model. For example, if dropping the additive genetic (A) influences (CE model) results in a significant increase in χ^2 , additive genetic (A) effects would then be considered a significant contributor to pet play. On the other hand, if dropping a parameter does not worsen the model fit as compared to the full model, that parameter is considered non-significant and can remain dropped in the final model. Another index commonly used to select the best model is Akaike's Information Criterion (AIC). The AIC takes into account the fit of a model along with its degrees of freedom ($AIC = \chi^2 - 2df$) to provide an estimate of parsimony. Lower AIC scores indicate greater parsimony.

Analysis of the pet play variable as a 3-level, polychotomous measure is similar to the approach described above, but instead of means, thresholds which correspond to the proportion of twins in each category (never, > never but < daily, daily) are estimated. Because the polychotomous data are considered ordinal with an underlying normal distribution, variances in these models are constrained to unity.

Results

Preliminary Results

There were no differences in frequency of pet play between MZ and DZ twins ($\chi^2_{(4)} = 5.57$, $p = 0.23$). Age did not correlate significantly with frequency of pet play ($r = -0.04$, $p = 0.12$), nor did education level ($r = -0.02$, $p = 0.51$). Marital status was significantly associated with frequency of pet play ($\chi^2_{(4)} = 34.64$, $p < 0.001$). A larger proportion of married twins reported daily play with a pet (46.3% versus 32.4%), and a smaller proportion of married twins reported never playing with a pet (25.3% versus 36.7%). However, there was no difference in marital status between MZ and DZ twins ($\chi^2_{(1)} = 0.08$, $p = 0.78$).

Genetic Analyses

Table 1 presents the MZ and DZ twin correlations for the continuous and polychotomous measures of pet play. In both instances, the MZ twin correlation was larger than the DZ twin correlation, indicating the presence of genetic factors. Heritabilities from the full ACE models (Table 1) were estimated at 0.22 (continuous measure) and 0.27 (polychotomous measure). Shared environmental factors accounted for modest amounts of variance (6–8%) but were not statistically significant based on the 95% confidence intervals. Non-shared environmental factors accounted for the majority of the variance in both analyses (71% for the continuous measure; 64% for the polychotomous measure).

Table 2 presents the model fit statistics from analysis of the continuous and polychotomous measures of pet play. In both instances, the lowest AIC value was for the model without shared environmental factors, indicating that the AE model was the most parsimonious model. In addition, the chi-square statistics indicated that shared environmental factors could be dropped from the models without a significant deterioration in fit. Heritabilities (h^2) estimated from the AE model were 0.29 (continuous measure; 95% CI = 0.23 to 0.36) and 0.37 (polychotomous measure; 95% CI = 0.28 to 0.44), with the remaining variance due to non-shared environmental factors. In contrast, dropping the genetic factors (CE model) resulted in a statistically significant ($p = 0.04$) change in model fit for the continuous measure, and a nearly significant ($p = 0.051$) change in model fit for the polychotomous measure. A model without any family resemblance (the E model) fit significantly more poorly ($p < 0.001$) than the full model for both measures.

Discussion

The present study used a behavioral genetic approach to investigate sources of individual differences in frequency of pet play among middle-aged males. To our knowledge, this study is the first to estimate the heritability of any characteristic related to human–animal interaction (HAI). Analyses revealed that genetic factors do significantly influence individual differences in frequency of pet play during adulthood. Surprisingly, the effects of shared environmental characteristics, which would include childhood exposure to pets, had only minimal effects on variation in pet play during adulthood. However, the largest proportion of variance was due to non-shared environmental factors, suggesting that certain

types of environmental experiences and exposures are related to adult patterns of interactions with pets.

Correlations of frequency of pet play were larger among MZ twins than among DZ twins, indicating the presence of genetic factors. Indeed, under the most parsimonious AE model, the heritability of pet play was estimated as high as $h^2 = 0.37$, supporting the importance of genetically influenced characteristics on individual differences in pet play. While our measure of frequency of play with pets was not a direct measure of attachment to pets *per se*, individuals who spend more time interacting with their pets report stronger emotional attachments to them (Shore, Riley and Douglas 2006). As such, the present study adds to a substantial body of existing research indicating that genetic factors are an important source of individual differences in social affiliative relationships among humans, including marital relationships (McGue and Lykken 1992; Spotts et al. 2004; Jerskey et al. 2010), sibling and parent–child relationships (Rowe 1981; Pike and Plomin 1997; Rende et al. 1992; see Kendler and Baker 2007 for a review), and social support (Kendler 1997; Bergeman et al. 2001; Agrawal et al. 2002).

A large body of behavioral genetic literature has focused on the genetic influences underlying both positive and negative aspects of close relationships. Genetic influences account for the majority of variance in whether someone is ever married ($h^2 = 0.58$) or divorced ($h^2 = 0.32$; Jerskey et al. 2010). Furthermore, the *quality* of familial relationships—including marriage, sibling, parent–child, and overall family interactions—is also influenced by genetic factors ($h^2 = 0.14$ to 0.61 ; Rowe 1981; Rende et al. 1992; Kendler 1997; Pike and Plomin 1997; Spotts et al. 2004). Finally, genetic influences also underlie non-familial social relations ($h^2 = 0.23$ to 0.75 ; Kendler 1997; Agrawal et al. 2002); moreover, these genetic influences appear to be stable over time (Kendler 1997; Bergeman et al. 2001). Our finding that genetic factors account for 29–37% of individual differences in HAI therefore adds to this growing body of literature, indicating that genetic factors do play a role in the development of human social relationships, both within and across species.

While the presence of significant genetic influence on individuals in frequency of play with pets was expected, a surprising result from the present study was the relatively weak effects of shared environmental factors. By definition, childhood exposure to pets is a shared environmental influence for children in the same family. Twin designs further control for potential developmental effects of pet ownership, as twins are necessarily the same age during exposure to pets. Because previous studies have found that pet ownership patterns in childhood are predictors of pet ownership patterns in adulthood (Serpell 1981; Westgarth et al. 2010), it was expected that there would be shared environmental influence on our measure of frequency of pet play in adulthood. Although we cannot definitively rule out shared environmental effects, under the full ACE models, the effects of shared environmental factors explained less than 10% of the overall variance, and these effects were not statistically significant.

Although these results are unexpected, they are again consistent with a large body of previous behavioral genetic studies indicating that shared family influences have little impact on individual differences (i.e., variation) in many behaviors and traits (Rowe 1995).

There are at least two possible explanations for why there may be limited effects of family influence on individual differences in frequency of play with pets in adulthood. First, family influences may be developmentally related; they may have a larger impact on behaviors and traits measured in childhood and adolescence, but the effects of family influence may decrease over time, as twins grow up and move out of the family home. Several studies have found this age-related decrease in shared environmental influence in other behaviors and traits. For example, Eaves (1997) found that, for twins 20 years and younger, MZ and DZ correlations on conservatism were nearly identical, indicating a strong shared environmental influence. However, for twins 21 years and older, DZ twin correlations dropped sharply, while MZ correlations remained stable, resulting in an increase in genetic influences and a corresponding decrease in shared environmental influences. One explanation for these age-related differences in shared environmental influence for conservatism was that individuals 21 years and older were more likely to be living away from their parents and siblings (e.g., in college, living with romantic partners), and were also more likely to be employed; thus, their current views on political and social attitudes were likely to be shaped by these extra-familial influences (Eaves et al. 1997). Behavioral genetic studies have also noted a decrease in shared environmental effects over time on individual differences in intelligence (McClearn et al. 1997; Haworth et al. 2009; Lyons et al. 2009), on weight and body mass index (e.g., Haworth et al. 2008; for a review, see Silventoinen et al. 2010) and for aggressive and antisocial behaviors (e.g., see Miles and Carey 1997; Jacobson, Prescott and Kendler 2002; Rhee and Waldman 2002, for reviews). Thus, it is possible that twin studies of HAI-related behaviors and traits in childhood and adolescence may find stronger effects of shared environmental influences on pet play than were found in the present study.

The second potential explanation for low shared environmental effects in the present study could be that HAI-related behaviors and traits are simply *not influenced* by shared environmental factors, even in childhood. While our study cannot assess the genetic and environmental influences on pet play on twins during childhood, studies of other phenotypes have provided evidence that some traits do not show significant effects of shared environmental influences either in adulthood or childhood. For example, propensities to play with pets could be linked to other traits, such as temperament or attachment styles. Childhood temperament has been shown to be strongly influenced by both genetic and non-shared environmental factors, with only a small portion of the variance explained by shared environmental factors, even in infancy and early childhood (Saudino 2005). Similarly, adult attachment styles also have been shown to have little influence from shared environmental factors (Franz et al. 2011). One important implication of the current results, therefore, is that the observed associations between history of pet ownership in childhood and pet ownership patterns in adulthood found in prior research (Serpell 1981; Westgarth et al. 2010) could be due to the fact that parents pass along genetically influenced behaviors and traits, in addition to providing environments to their children. This would result in a *passive gene-environment correlation* (Plomin, DeFries and Loehlin 1977; Scarr and McCartney 1983). In other words, associations between childhood pet exposure and adult experiences with pets may be genetically, not environmentally, mediated. Future genetically-informative studies of HAI in childhood and adolescence are thus warranted, as are future investigations of whether there are shared genetic influences between HAI-related characteristics (e.g., attachment to pets)

and characteristics of other human relationships (e.g., parent–child attachment, marital relationships, etc.).

While there was a limited effect of shared environmental influences on frequency of pet play, we note that the largest proportion of variance of frequency of play with pets in the current study was accounted for by *non-shared environmental* factors. Non-shared environmental influences do include measurement error, and unfortunately, we have no information on the reliability or the test-retest correlation for our single-item measure of frequency of play with pets. However, given that prior studies have shown that adults can accurately recall *childhood* experiences with pets (Svanes et al. 2008; Nicholas et al. 2009), it seems unreasonable to hypothesize that 63–71% of the variance in our current measure of frequency of play with pets *over the past month* could be due solely to measurement error. Thus, there are clearly critical environmental experiences unique to each twin that play important roles in adult HAI. There are many plausible environmental experiences that could contribute to within-pair *differences* in twins' patterns of pet interactions. One likely possibility is different adult family influences. For instance, a twin whose wife owned pets in childhood may be more likely to own a pet than a twin whose wife did not own pets because women's childhood pet ownership histories predict family pet ownership (Westgarth et al. 2010). Conversely, a twin whose child has animal allergies would be less likely to own pets than a twin whose child was not allergic, as allergies are a common reason that people cite for not owning pets (Eller et al. 2008; Bertelsen et al. 2010). Future studies are needed to uncover the specific environmental factors that contribute to pet ownership and interaction in adulthood.

Limitations and Conclusions

In addition to issues that have been discussed previously, there are other limitations to the current study. Most notably, given the demographic characteristics of the overall Vietnam Era Twin Registry, results from the present study may not generalize to females, or to racial and ethnic minority groups. There is some evidence for both gender (Kidd and Kidd 1989; Johnson, Garrity and Stallones 1992; Woodward and Bauer 2007) and racial/ethnic (Siegel 1995; Brown 2003; Risley-Curtiss, Holley and Wolf 2006; Westgarth et al. 2010) differences in patterns of pet ownership and attachments towards pets. The effects of HAI on health, behavior, and well-being may also vary depending upon these factors, although this hypothesis has rarely been tested in prior studies of HAI. Genetically informative analyses in other samples, as well as additional HAI research in general, would be needed to address these questions. Likewise, the VETSA study was designed to examine the effects of genetic, health, and psychosocial factors on cognitive aging beginning in middle-age; thus, the present results may not generalize to adults at other developmental stages (e.g., younger adults or elderly adults). VETSA is an ongoing longitudinal project, so we will be able to examine genetic influences on the stability of interactions with pets in future years.

Our single-item measure of frequency of pet play is also imperfect. Because this was the only HAI-related item in the current study, we do not know whether twins currently own pets, or what types of pets they may own. Thus, part of the genetic influence found in the present study may be related to the heritability of pet ownership, in addition to (or instead

of) attachment to pets. However, the fact that we found similar patterns of genetic and environmental influences when our measure was treated as a continuous measure versus as a polychotomous item indicates that we are likely picking up genetic influences related to both ownership and interaction. There are differences in levels of attachment to different species of pets (Albert and Bulcroft 1988; Rost and Hartmann 1994; Vidovic, Stetic and Bratko 1999), and patterns of “playing” with pets are expected to be quite different between dogs, for example, and fish. In fact, the unknown variation due to differences in types of pets may be part of the large non-shared environmental influence. In addition, the results may reflect personality differences across participants, as personality traits have been associated with pet ownership, type of pet owned, and pet attachment (Zasloff, Hart and Weiss 2003; Kurdek 2008; Daly and Morton 2009; Kotrschal et al. 2009; Gosling, Sandy and Pottert 2010). It is quite likely that if the current study had been able to measure frequency of play with only certain types of pets (e.g., dogs), genetic influences would actually have been stronger, as reducing estimates of nonshared environmental variance (including measurement error) generally increases the effects of genetic factors (Kendler, Karkowksi and Prescott 1999; Jacobson, Prescott and Kendler 2000; Baker et al. 2007).

Finally, demonstrating that there are genetic influences on frequency of pet play in an epidemiological, cross-sectional twin study in no way implies that HAI does not (or cannot) have a direct (environmental) effect on health and well-being in children and adults. Experimental designs that can manipulate HAI are still the best method to address this hypothesis. However, the results of the present study, which is the first to specifically address the question of genetic influence on HAI-related behaviors and traits, do suggest some caution in interpreting a causal relationship between pet ownership and related HAI variables on human outcomes, especially from prior cross-sectional studies. There may be genetically-influenced “third variables,” such as personality characteristics, that may account for both individual differences in pet ownership *and* individual differences in outcomes. Moreover, given that there do appear to be genetic influences on HAI-related characteristics, our study speaks directly to the question of individual differences in the effects of HAI. Future studies need to examine more carefully the questions of “for whom” and “under what conditions” is HAI likely to have the most positive effects.

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Figure 1.
Prevalence of pet play behavior during the past year among monozygotic (MZ) and dizygotic (DZ) twins.

Figure 2.

The univariate ACE model. Note: A = Additive genetic influence; C = Shared environmental influence; E = Non-shared environmental influence.

Twin correlations and estimates of genetic (a^2), shared environment (c^2), and non-shared environment (e^2) influence on individual differences in pet play.

Table 1

	r_{MZ}	r_{DZ}	a^2	c^2	e^2
Continuous Measure	0.29 (0.22; 0.35)	0.17 (0.09; 0.26)	0.22 (0.01; 0.35)	0.06 (0.00; 0.24)	0.71 (0.65; 0.78)
Polychotomous Measure	0.36 (0.27; 0.45)	0.21 (0.10; 0.32)	0.27 (0.00; 0.44)	0.08 (0.00; 0.31)	0.64 (0.56; 0.73)

Note: r_{MZ} = correlation among monozygotic (MZ) twin pairs; r_{DZ} = correlation among dizygotic (DZ) twin pairs; 95% confidence intervals are shown in parentheses.

Table 2

Model fit statistics for behavioral genetic analysis of frequency of pet play.

Model	-2 Log Likelihood	df	AIC	χ^2	df	p-value
Continuous Measure						
ACE	9480.08	2439	0	-	-	-
AE	9480.58	2440	-1.50	0.50	1	0.48
CE	9484.32	2440	2.25	4.24	1	0.04
E	9554.48	2441	70.40	74.40	2	< 0.001
Polychotomous Measure						
ACE	5189.22	2439	0	-	-	-
AE	5189.67	2440	-1.54	0.46	1	0.50
CE	5193.02	2440	1.81	3.81	1	0.051
E	5258.63	2441	65.41	69.41	2	< 0.001

Note: A = Additive genetic influence; C = Shared environmental influence; E = Non-shared environmental influence; AIC = Akaike's information criterion. Best-fitting model is indicated in bold.