Fullerton Virtual Twin Study: An Update

Nancy L. Segal,[1] Shirley A. McGuire,[2] Jamie L. Graham,[1] and Joanne Hoven Stohs[1]
[1]Department of Psychology, California State University, Fullerton, CA, USA
[2]Department of Psychology, University of San Francisco, San Francisco, CA, USA

Virtual twins (VTs) are same-age unrelated siblings reared together from early infancy. These unique sibling sets replicate twinship, but without the genetic link. The first VT pair was identified and studied at the University of Minnesota in 1990, launching the development of the Fullerton Virtual Twin Study at California State University, Fullerton (CSUF) in 1991. The registry currently includes 151 pairs, mostly children, with new pairs identified on a continuous basis. Research with VTs includes studies of general intelligence, body size, interpersonal trust, social coordination, social networks, and parenting. In some cases, VTs have been studied in conjunction with pairs of monozygotic twins, dizygotic twins, full siblings, and friends as part of TAPS (Twins, Adoptees, Peers and Siblings), a collaborative project conducted between CSUF and the University of San Francisco, 2002–2006. VTs will also serve as a comparison group for epigenetic analyses of young Chinese twins reared apart and together.

∎ **Keywords:** virtual twins, adoptees, twins, intelligence, epigenetic analyses

Virtual Twins (VTs): An Overview

VTs are same-age unrelated siblings, reared together from early infancy. They are unique sibling sets in that they replicate twinship, but without the genetic link, offering a direct estimate of environmental influence on variation in behavioral and physical traits (Holden, 2000). VTs are, in fact, the opposite of monozygotic (MZ) reared apart twins who share 100% of their genes, but are raised in different environments. VTs are a more informative comparison group with twin samples because, like twins and unlike ordinary adoptive siblings, VTs are the same age and share residential histories.

VTs are broadly classified as one of two types: adoptive-biological or adoptive-adoptive. Families facing conception difficulties may seek adoption and reproductive technologies simultaneously, yielding adoptive-biological pairs. Alternatively, families seeking adoption only may be offered two children, resulting in adoptive-adoptive sets. VTs have also been configured in more unusual ways, such as: (1) sperm donation for maternal surrogacy, coupled with adoption; (2) unrelated embryo transfer, plus adoption; and (3) natural conceptions by same-sex female partners, via different males. In several cases, the adoption or delivery of twins or triplets plus the adoption or delivery of a nontwin child has yielded multiple VT sets within families.

The Fullerton Virtual Twin Study (FVTS) currently includes 151 VT pairs, of which 98 or 65% are adoptive-adoptive. Opposite- and same-sex pairs occur with approximately equal frequency, as shown in Table 1. The mean age of the siblings is 7.79 years, $SD = 8.01$, with a range of 4.01 to 54.84 years. (Mean age is based on 291 individuals, following elimination of siblings who are members of more than one pair.) The majority of individuals (72.5%) are, however, less than 7 years of age. The mean age difference between siblings is 3.19 months ($SD = 2.78$), with a range of 0 to 9.87 months.

Goals and Directions

The Fullerton VT Registry was designed with two major goals in mind. The first was to estimate the contribution of shared environmental influences to individual differences in a wide range of behavioral and physical traits. These traits include general intelligence, personality, behavioral problems, height, weight, and other measures. Comparative data from available twin, sibling, and adoption studies are referenced in order to evaluate the findings. Comparative data are also derived from TAPS (Twins, Adoptees, Peers and Siblings), a collaborative effort between California State University, Fullerton (CSUF) and the University of

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TABLE 1

Virtual Twin Pairs Organized by Pair Type and Sex Composition

Pair type	MM	FF	MF	Total
Adopted-adopted	25	22	51	98
Adopted-biological	17	13[a]	23	53
Total	42	35	74	151

Note: [a]same-sex couple, each with a biological child. MM = male–male, FF = female–female, MF = male–female.

San Francisco (McGuire et al., 2010). Many VTs have been regular participants in that project.

The second aim of the FVTS is to assess the nature of VT pairs' social relationships with one another and to compare them with those of MZ and dizygotic (DZ) twins, peers, and siblings. Given the varying degrees of genetic relatedness across these twin and sibling sets, applying an evolutionary framework adds depth and dimension to the interpretations. Other areas of interest include decision making, peer networks, and parenting.

Criteria for Participation

Study participation requires that VT pairs meet all the criteria listed below; failure to fulfill even one of these requirements means disqualification. These criteria were generated to make VTs match as closely to twins as possible; the rationale that guided these decision rules is provided in parentheses.

1. Adoptive siblings must be placed in the family before 1 year of age. (Some cotwins are separated early in life due to differential prematurity, hospitalizations, and other events, so early separation periods between co-VTs are acceptable.)

2. The age difference between siblings cannot exceed 9 months. (Nine months is the maximum age difference between classmates.)

3. Pair members attending school must be enrolled in the same grade. (Like twins, VT siblings may attend different classes or different schools, but must be in the same grade.)

4. Both siblings must be free of birth trauma that may interfere with normal cognition. (Freedom from adverse birth events is determined via parental interviews. Information is occasionally lacking, incomplete, and/or requires judgment on the part of the examiner.)

5. Participants must be at least 4 years of age to take part in the study. (Siblings of this age are generally comfortable with test situations and have formed social relationships with one another.)

VTs who differ in sex and/or ethnicity qualify for participation. The justification for their inclusion is that opposite-sex twins occur naturally and some ordinary DZ twins born to mixed-race couples differ physically (Segal, 2000b).

Recruitment of VTs and Procedures

Participants are recruited from multiple sources. The majority of VTs are identified through publications and organizations (print and online) targeted to families with adopted children. Other sources of VTs include personal referrals, other research projects, the media, and multiple birth organizations. Most VTs reside in the United States, although one pair lives in Canada, and pair members in another family live in the United States and Norway.

Following identification of a potentially qualified pair, the senior investigator contacts the family to make certain that the criteria specified above are fulfilled. If VTs are too young to participate, some preliminary forms are sent to families to complete because some types of information are most easily accessible when children are young. Such forms cover children's birth and adoption circumstances, and early health history.

A complete packet of materials is sent by mail to families who qualify for participation. Forms request information on children's birth and adoption histories; parental age, occupation and education; children's school history; physical facilities in the rearing home; and other background measures. Parents also complete medical and dental forms with reference to their children's health, the Child Behavior Checklist (CBCL), the Adjective Checklist (describing their children), the Index of Pre-Adoption/Initial Adaptation to Adoption (Tan et al., 2010), a Social Relationship Survey, the Sibling Inventory of Differential Experience, the Runco Ideational Behavior Scale (RIBS) that assesses creativity (Runco, 2012), and a Big Five personality questionnaire (Saucier & Goldberg, 1998). Older VTs complete different versions of these forms on their own. Parents also receive the teacher versions of the CBCL and RIBS to forward to their children's schools.

A key part of the assessment battery is administration of the age-appropriate Wechsler Intelligence test to each sibling. With only a few exceptions, pair members are tested locally on the same day by separate examiners. All intelligence test protocols are reviewed and scoring questions are resolved with examiners by the primary investigator (NLS) prior to data entry and preparation of parental reports.

Publications

Publications include papers on general intelligence (Segal, 1997a, 2000a; Segal & Hershberger, 2005; Segal et al., 2007), body size (Segal & Allison, 2002; Segal et al., 2008), tacit coordination (TC; Segal et al., 2008), parenting (McGuire et al., 2012), trust beliefs (McGuire et al., 2010), and friendships (McGuire & Segal, in press). Empirical papers are supplemented by several general project overviews (McGuire et al., 2010; Segal, 2010, 2011). Book chapters, some detailing procedures and findings, are also available (Segal, 1997b, 2000b, 2004; Segal & Hill, 2005), as are several unique case studies (Segal, 2005, 2012).

Very brief summaries of key findings in selected areas are presented below. The sample sizes vary across studies, based upon the time of analysis.

General intelligence. A modest, but consistent, contribution of the shared family environment to individual differences in IQ has been observed. The latest analysis yielded an intraclass correlation of 0.28 ($n = 142$ pairs; Segal et al., 2011). This correlation is based on a sample composed mostly of young children, so it is likely that the magnitude of the correlation will decrease as they age. This expectation is based on the findings that unrelated siblings' IQ correlation decreases from 0.31 in childhood to 0.19 in adolescence (Scarr et al., 1993), and (based on a summary of the literature) from 0.25 to 0.00 in childhood to 0.00 in adulthood (McGue et al., 1993). Note that an earlier analysis of 43 VT pairs showed the expected decline in IQ similarity from 0.30 (age 5.11 years) to 0.11 (age 10.77 years; Segal et al., 2008). Profile analyses of the IQ subtests yielded a VT correlation of 0.11, in contrast with 0.45 for MZ twins and 0.24 for DZ twins, consistent with genetic effects (Segal & Hershberger, 2005).

Body size. Body size, as indexed by body mass index (BMI), was analyzed using VTs, MZ twins, and DZ twins from the TAPS project and previous twin studies ($n = 929$ individuals). Significant effects were detected for both nonadditive genetic and shared environmental influences (Segal et al., 2008). Specifically, 63.6% of the BMI variance was explained by a nonadditive genetic component, 25.7% by a common environmental component, and 10.7% by an unshared component. It appears that both genetic and shared family factors (e.g., diet) contribute to individual differences in body size.

Tacit Coordination (TC) refers to conditions in which 'two parties have identical interests and face the problem not of reconciling interests but only of coordinating their actions for their mutual benefit when communication is impossible' (Schelling, 1960, p. 54). MZ, DZ, and VT pairs completed a TC task to assess genetic influence on this behavior (Segal et al., 2008). The measure of interest was the number of matched responses to questions answered under two experimental conditions: *Self* (instructions were to simply answer the questions), and *Coordination* (instructions were to answer as if each participant had discussed the question with his or her twin/sibling and reached an agreement). MZ twins obtained the highest number of matches under both conditions, followed by DZ twins and VTs, as predicted. These results were consistent with both behavioral-genetic and evolutionary psychological expectations.

Parenting. Parental warmth was assessed among parents and children using an eight-item scale, based on the 'acceptance-rejection' subscale of the Children's Report of Parent Behavior Inventory (McGuire et al., 2012). Evidence of genetic and nonshared environmental effects on children's reports was found. In contrast, par-ents' reports reflected genetic and shared environmental influence.

Interpersonal trust beliefs. Interpersonal trust beliefs were assessed via the Children's Generalized Trust Belief Scale (Rotenberg et al., 2005). MZ twins indicated significantly higher trust beliefs in their siblings than the other sibling types (McGuire et al., 2010). This finding agrees with evolutionary psychological expectations that interactants' genetic relatedness should affect within-pair social behavior.

Friendships. Twins, VTs, full siblings (FS) and friends independently listed the names of friends and indicated those they had in common (McGuire & Segal, in press). Following this exercise, the dyadic partners discussed their answers and reached an agreement as to total number of friends and total number of shared friends. Hierarchical regression models identified dyad age, sex composition, and genetic relatedness as significant predictors of peer overlap ($p < .001$). MZ twins showed the highest percentage of peer overlap (82%), while opposite-sex FS showed the lowest (27%). Same-sex DZ twins (67%) and VTs (62%) showed relatively high agreement, in contrast with opposite-sex DZ twins (42%) and VTs (37%).

Current and Future Directions

Coding of observational data is underway with the goal of testing for dyadic differences in coordination, joint decision making, cooperation, positivity, and conflict, using a puzzle completion task and Gottman's Island Game. Item analyses of questions on the TC task, using VTs, twins, and other dyadic types, is also in progress.

The availability of data on young Chinese twins raised apart and together, collected at CSUF, is also enabling a series of unique analyses (see Segal et al., 2011). Twin-Virtual Twin comparison of similarity in behavioral responses to adoption and early infant behaviors is being conducted in collaboration with Dr. Tony Tan (Department of Educational Psychology, University of South Florida, Tampa, Florida). Epigenetic analyses of VT pairs, in conjunction with young Chinese twins raised apart and together, are also planned. These studies will be conducted in collaboration with Drs Jeff Craig (Murdoch Childrens Research Institute, Melbourne, Australia) and Will Brown (Institute of Sport and Physical Activity Research, University of Bedfordshire, United Kingdom).

Acknowledgments

References

Holden, C. (2000). Offbeat twins. *Science, 288,* 1735.

McGue, M., Bouchard, T. J. Jr., Iacono, W. G., & Lykken, D. T. (1993). Behavioral genetics of cognitive ability: A lifespan

perspective. In R. Plomin & G. E. McClearn (Eds.), *Nature, Nurture and Psychology* (pp. 59–76). Washington, DC: APA Press.

McGuire, S. A., & Segal, N. L. (in press). Peers networks: Overlapping twin, sibling and friend dyads. *Child Development.*

McGuire, S. A., Segal, N. L., & Hershberger, S. L. (2012). Parenting as phenotype: A behavior genetic approach to understanding parenting. *Parenting: Science and Practice, 12,* 192–201.

McGuire, S., Segal, N. L., Whitlow, B., Gill, P., & Clausen, J. (2010). Sibling trust and trustworthiness. In K. J. Rotenberg (Ed.), *Interpersonal Trust During Childhood and Adolescence* (pp. 133–154). Cambridge, England: Cambridge University Press.

Rotenberg, K. J., Fox, C., Green, S., Ruderman, L., Slater, K., Stevens, K., & Carlo, G. (2005). Construction and validation of a children's interpersonal trust belief scale. *British Journal of Developmental Psychology, 32,* 271–292. Runco, M. A. (Ed.). (2012). *Divergent Thinking and Creative Ideation.* Cresskill, NJ: Hampton Press.

Saucier, G., & Goldberg, L. R. (1998). What is beyond the big five? *Journal of Personality, 66,* 497–524.

Scarr, S., Weinberg, R. A., & Waldman, D. (1993). IQ correlations in transracial adoptive families. *Intelligence, 17,* 541–555.

Schelling, T. C. (1960). *The Strategy of Conflict.* Cambridge, MA: Harvard University Press.

Segal, N. L. (1997a). Same-age unrelated siblings: A unique test of within-family environmental influences on IQ similarity. *Journal of Educational Psychology, 89,* 381–390.

Segal, N. L. (1997b). Twin research perspective on human development. In N. L. Segal, G. E. Weisfeld, & C. C. Weisfeld (Eds.), *Uniting Psychology and Biology: Integrative Perspectives on Human Development* (pp. 145–173). Washington, DC: APA Press.

Segal, N. L. (2000a). Virtual twins: New findings on within-family environmental influences on intelligence. *Journal of Educational Psychology, 92,* 442–448.

Segal, N. L. (2000b). *Entwined Lives: Twins and What They Tell us About Human Behavior.* New York: Plume.

Segal, N. L. (2004). Evolutionary studies of cooperation, competition and altruism: A twin-based approach. In R. L. Burgess & K. B. MacDonald (Eds.), *Evolutionary Perspectives on Human Development* (2nd ed., pp. 275–304). Thousand Oaks, CA: Sage.

Segal, N. L. (2005). *Indivisible by Two: Lives of Extraordinary Twins.* Cambridge, MA: Harvard University Press.

Segal, N. L. (2010). Twins: The finest natural experiment. *Personality and Individual Differences, 49,* 317–323.

Segal, N. L. (2011). Twin, adoption and family methods as approaches to the evolution of individual differences. In D. M. Buss & P. Hawley (Eds.), *The Evolution of Personality and Individual Differences* (pp. 303–337). Oxford: Oxford University Press.

Segal, N. L. (2012). *Born Together-Reared Apart: The landmark Minnesota Twin Study.* Cambridge, MA: Harvard University Press.

Segal, N. L., & Allison, D. B. (2002). Twins and virtual twins: Bases of relative body weight revisited. *International Journal of Obesity, 26,* 437–441.

Segal, N. L., Feng, R., McGuire, A. S., Allison, D. B., & Miller, S. (2008). Genetic and environmental contributions to body mass index: Comparative analysis of monozygotic twins, dizygotic twins and same-age unrelated siblings. *International Journal of Obesity, 33,* 37–41.

Segal, N. L., & Hershberger, S. L. (2005). Virtual twins and intelligence: Updated and new analyses of within-family environmental influences. *Personality and Individual Differences, 39,* 1061–1073.

Segal, N. L., & Hill, E. M. (2005). Developmental behavioral genetics and evolutionary psychology: Tying the theoretical and empirical threads. In B. J. Ellis & D. F. Bjorkland (Eds.), *Origins of the Social Mind: Evolutionary Psychology and Child Development* (pp. 10–136). New York: Guilford.

Segal, N. L., McGuire, S. A., Havlena, J., Gill, P., & Hershberger, S. L. (2007). Intellectual similarity of virtual twin pairs: Developmental trends. *Personality and Individual Differences, 42,* 1209–1219.

Segal, N. L., McGuire, S. A., Miller, S., & Havlena, J. (2008). Tacit coordination in monozygotic twins, dizygotic twins and virtual twins: Effects and implications of genetic relatedness. *Personality and Individual Differences, 45,* 607–612.

Segal, N. L., McGuire, S. A., & Hoven Stohs, J. (2012). What virtual twins reveal about general intelligence and other behaviors. *Personality and Individual Differences, 53,* 405–410.

Segal, N. L., Stohs, J. H., & Evans, K. (2011). Chinese twin children reared apart and reunited: First prospective study of co-twin reunions. *Adoption Quarterly, 14,* 61–78.

Tan, T. X., Marfo, K., & Dedrick, R. F. (2010). Early developmental and psychosocial risks and longitudinal behavioral adjustment outcomes for preschool-age girls adopted from China. *Journal of Applied Developmental Psychology, 31,* 306–314.