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The Southern California Twin Register at the University of Southern California: III

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The Southern California Twin Register at the University of Southern California (USC) was initiated in 1984 and continues to provide an important resource for studies investigating genetic and environmental influences on human behavior. This article provides an update on the current register and its potential for future twin studies using recruitment through school district databases and voter records. An overview is also provided for an ongoing longitudinal twin study investigating the development of externalizing psychopathology from childhood to young adulthood, the USC Study of Risk Factors for Antisocial Behavior. Characteristics of the twins and their families are presented, including recruitment and participation rates, as well as attrition analyses and a summary of key findings to date.

■ **Keywords:** twins, Southern California, anti-social behavior, externalizing psychopathology

Large metropolitan areas provide enormous potential for twin research. As the second-largest combined area in the country, the Greater Los Angeles Area — including five counties in southern California, namely Los Angeles, Orange, San Bernardino, Riverside, and Ventura counties — and its enormous population (estimated to be over 17.6 million in 2009; http://en.wikipedia.org/wiki/Greater_Los_Angeles_Area) makes it a rich resource for recruiting twins across the lifespan. Given the current population and the recent twinning rates in California (incidence: 30.3 per 1,000 births http://www.cdc.gov/nchs/data/nvsr/nvsr61/nvsr61_01.pdf), we estimate there to be over half a million twins residing in this five-county, densely populated area.

We previously described our recruitment efforts in identifying twins in Southern California (Baker et al., 2002, 2006). In this article, we provide an update on the ongoing University of Southern California (USC) longitudinal study of Risk Factors for Antisocial Behavior (RFAB), including a full description of the sample characteristics, recruitment procedures, and a summary of measures across the various occasions (Waves 1–4 are complete; Wave 5 is ongoing). Attrition analyses are presented, along with a summary of key findings. We also provide a brief overview of the potential for recruiting school-age twins based on public school district databases, using the most recent enrollment and multiple birth rate statistics, to highlight the enormous opportunities for doing large-scale twin research in Southern California.

The USC Longitudinal Twin Study of RFAB

The USC RFAB twin study uses a prospective, longitudinal design in which both monozygotic (MZ) and dizygotic (DZ) twins who have been studied approximately every 2–3 years beginning from age 9–10. The RFAB uses a comprehensive multi-informant, multi-measure approach with a key focus on externalizing psychopathology and its biological and social risk factors. An overview of the study design is presented in Figure 1, which indicates the ages at which data are available, and the major areas of assessment, including anti-social outcomes as well as four major domains of risk factors (psychosocial, psychophysiological, neurocognitive, and personality). Assessments are made using three informants — twins provide self-report as well as ratings of their co-twins, while the twins' primary caregiver (the biological mother in over 92% of families) and teachers

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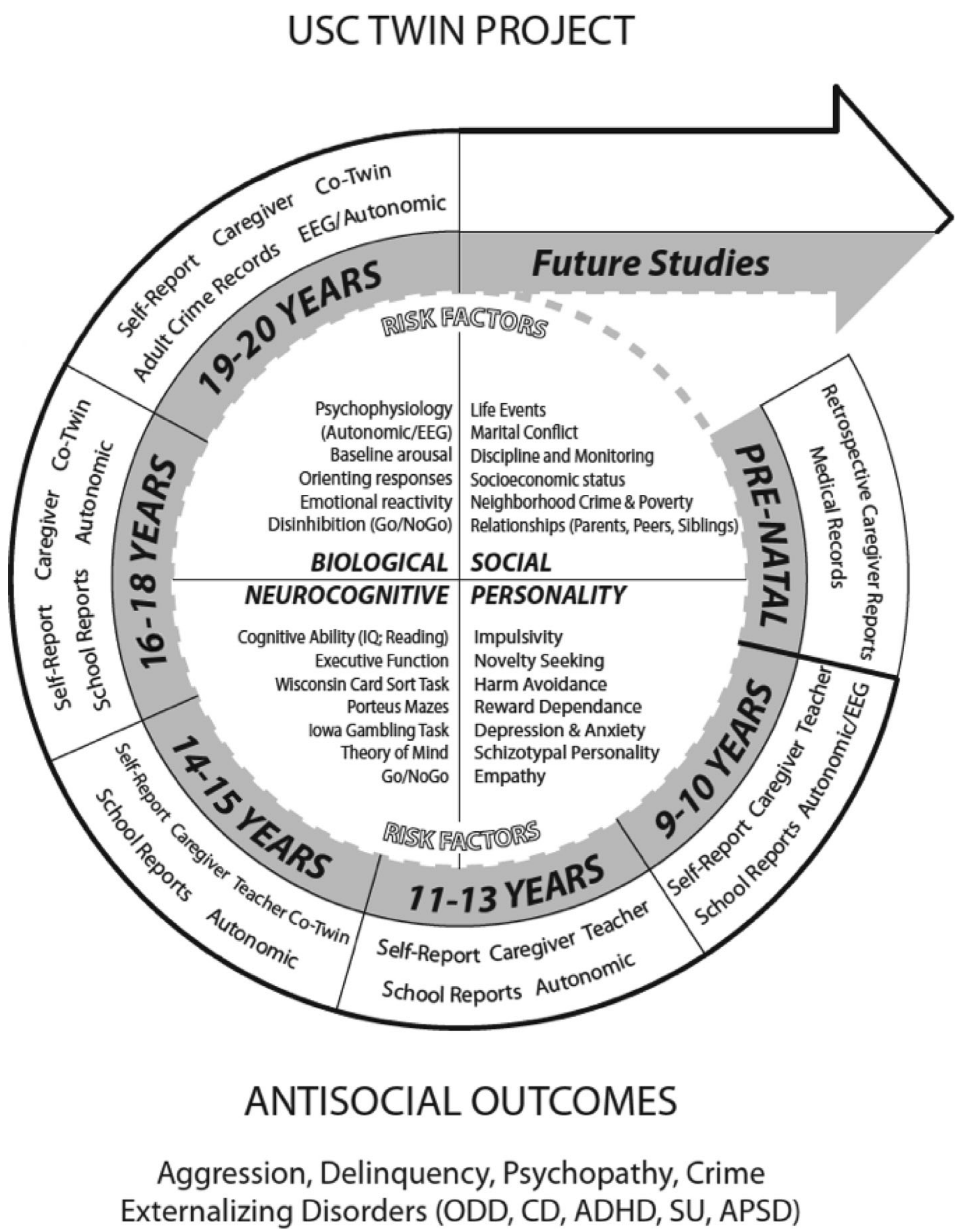

FIGURE 1

The USC Longitudinal Twin Study of Risk Factors for Antisocial Behavior (RFAB): Design, Constructs and Informants

also provide ratings of each twin. Official records are obtained from schools regarding both academic performance and discipline, and criminal justice records will be sought as the twins reach adulthood. To date, twins in the RFAB study have been assessed on at least one of five occasions, including four waves which are complete (Wave 1: age 9–10 years, 614 pairs; Wave 2: age 11–13 years, 445 pairs; Wave 3: age 14–15 years, 604 pairs; and Wave 4: age 16–18 years, 504 pairs), as well as an ongoing assessment (Wave 5: age 19–20 years, with a target sample of 625 pairs).

Sample

The RFAB participants include 780 sets of twins and triplets ($N = 1{,}569$ subjects), with males and females represented in

TABLE 1

Number of Families of Twins Participating in Waves 1–4, and Projected for Wave 5

	Wave 1: 9–10 years	Wave 2: 11–13 years	Wave 3: 14–15 years	Wave 4: 16–18 years	Wave 5:[a] 19–20 years
MZ males	138	104	132	105	135
MZ females	146	105	123	111	136
DZ males	88	58	93	78	96
DZ females	93	73	108	88	97
Opposite sex	149	105	148	122	161
Total	614	445	604[b]	504[c]	625

Note: [a]Wave 5 *N*'s predicted from previous participation; [b]Wave 3 total *N* includes 166 new families + 438 returning families recruited in Wave 1; [c]Wave 4 total *N* includes 139 new families + 365 returning families recruited in Wave 1.

TABLE 2

Key Psychopathology Measures in Twins in USC-RFAB Across Waves 1–5

	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5
Age (in years) of twins *N* twin pairs	9–10 *N* = 614	11–13 *N* = 445	14–15 *N* = 604	16–18 *N* = 504	19–20 *N* = 625
Diagnostic interviews and surveys					
Conduct Disorder (CD; Schaffer et al., 2000)	Y P	Y P	Y P	Y P	—
Oppositional Defiant Disorder (ODD; Schaffer et al., 2000)	P	Y P	P	—	—
Substance Use (SU; Pokorny et al. 1972; Pomerleau et al., 1998; Schaffer et al., 2000)	Y	Y P	Y P C	Y P C	Y P C
Attention Deficit Hyperactivity Disorder (ADHD; Schaffer et al., 2000)	P T	P T	**P T**	**Y P T**	**Y P**
Anxiety and depression (First et al., 1997; Radloff, 1977; Schaffer et al., 2000)	P	P	**Y P**	**Y**	**Y**
Antisocial Personality Disorder (ASPD; First et al., 1997)	—	—	—	—	**Y**
Borderline Personality Disorder (BPD; Morey, 1991; First et al,. 1997)	—	—	—	**Y**	**Y**
Psychopathy (Forth et al., 2003; Frick & Hare, 2001; Hare, 2003; Lynam, 1997)	Y P	Y P	Y P	Y P	Y P
Aggression, delinquency, and crime					
Child Behavior Checklist (CBCL; Achenbach 1991)	P T	P T	**Y P T**	**Y P T**	**Y P**
Reactive/proactive aggression (RPQ; (Raine et al., 2006))	Y P T	Y P T	Y P T	Y P T	Y P
Delinquency/criminal behavior (Elliot & Huizinga, 1988)	Y	Y O	Y O C	Y O C	Y O C
Point Subtraction Aggression Paradigm (Cherek et al., 1997)	Y	Y	—	—	**Y**

Note: Y = youth report; P = parent report; T = teacher report; C = co-twin report; O = official records from schools in Waves 1–4 and justice system (for ASB) in Wave 5.

approximately equal numbers. Both same-sex MZ and DZ pairs as well as opposite-sex DZ pairs are included. Zygosity of same-sex pairs was determined using DNA microsatellite analysis, which measures concordance of DNA markers to assess whether DNA is identical (any pair with a discordant marker was to be DZ, while any pair with 7 concordant markers was considered to be MZ). In pairs where results were inconclusive (usually due to weak signal), zygosity was assessed with the Twin Similarity Questionnaire (Lykken, 1978), a measure found to be 90% concordant with DNA zygosity in cases for which both measures were available (Baker et al., 2006).

The sample is representative of the ethnic and socioeconomic diversity of the greater Los Angeles area (Baker et al., 2007), with 28,6% Caucasians, 34.3% Hispanics, 13.1% Blacks, 4.1% Asians, 0.1% Native Americans, 17.6% mixed, and 2.2% other or unknown.

The numbers of families who participated in each completed wave (1–4) are presented in Table 1, along with expected *N*'s for ongoing Wave 5. Of the 614 original Wave 1 families, 72% ($n = 445$) returned for Wave 2, 71% ($n = 438$) returned for Wave 3, and 59% ($n = 365$) returned for Wave 4. While these retention rates for individual follow-up waves are modest (albeit quite favorable for a diverse urban sample and comparable to similar twin studies (Kendler et al., 2009), the overall retention rate for original Wave 1 families returning to *any* subsequent wave (including 2, 3, and 4) is quite favorable: 529 out of 614 (86%) of original Wave 1 families participated in at least one subsequent wave to date. The twin sample at Wave 5 will entirely consist of previous participants in the RFAB, drawn from the total longitudinal sample of 780 families (i.e., 614 original families who participated at Wave 1, plus 166 new families recruited at Wave 3). We have current contact information on >85% of the total pool of participants.

Measures

In addition to using three informants, that is, twin self-report, co-twin report, and parent ratings, we also obtain school records for each twin, including both academic performance (e.g., standardized achievement test scores) and behavioral (i.e., discipline) data. The assessments of externalizing psychopathology in this study are summarized in Table 2, indicating key constructs and informants used in

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TABLE 3

Measures of Social and Biological Risk Factors for Externalizing Behavior Problems of Twins in USC-RFAB across Waves 1–5

	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5
Age (in years) of twins	9–10	11–13	14–15	16–18	19–20
N twin pairs	*N* = 614	*N* = 445	*N* = 504	*N* = 605	*N* = 625
Peers, activities, and social risk factors					
Peer Delinquency and SU*	Y P	Y P	Y P	Y P	Y P
Peer Victimization*	YT	Y T	Y T	Y T	—
Romantic Relationships*	—	—	Y	Y	Y
Parental Monitoring (Kerr & Stattin, 2000)	Y P	Y P	Y P	Y P	—
Parent to Child Affect (adapted from Deater-Deckard, 1996)	Y P	Y P	Y P	Y P	Y P
Conflict Tactics Scale (Harsh Discipline/Marital Conflict; Straus et al., 1998))	Y P	Y P	Y P	Y P	Y P
Socioeconomic Status (SES; [48])	P	—	P	—	Y
Psychophysiology (Autonomic)					
Arousal (Heart rate and skin conductance, during rest) (Lang & Hnatiow, 1962)	Y	Y	Y	Y	Y
Orienting (Raine et al., 1990)	Y	Y	Y	Y	Y
Skin conductance responses (during rest and tasks) (Lykken, 1957)	Y	Y	Y	Y	Y
Vagal tone/heart rate, during rest and tasks (Porges, 1995; Lang & Hnatiow, 1962)	Y	Y	Y	Y	Y
Anticipatory fear (Countdown Task; Hare, 1965)	Y	Y	Y	Y	Y
Affective (startle) response (Patrick et al., 1993)	Y	Y	Y	Y	Y
Stressor (Jern et al., 1991; McNair et al., 1982)	—	—	Y	Y	Y
Fear conditioning (Hare, 1965, 1978)	—	—	—	Y	Y
Electrocortical (EEG and ERP)					
EEG power spectra	Y	—	—	—	Y
Go/NoGo (ERP – P300; Halperin et al., 1991)	Y	—	—	—	Y
Oddball (ERP – P300; Kiehl et al., 1999)	Y	—	—	—	Y
Neuropsychological and cognitive tasks					
Empathy Quotient (Baron-Cohen & Wheelwright, 2004)	—	—	Y	Y	Y
Iowa Gambling Task (IGT; Bechara et al., 1994)	—	Y	Y	Y	Y
Impulsivity/inattention (Go/NoGo Task; Halperin et al., 1991)	Y	Y	Y	Y	Y
Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999)	Y	—	—	—	Y
Executive function (Grant & Berg, 1948; Porteus, 1965; Reitan & Wolfson, 2004)	Y	Y	Y	Y	Y
Woodcock Johnson — Reading Ability/Comprehension (Woodcock & Mather, 1989)	Y	—	Y	—	Y

Note: Y = youth report; P = parent report; T = teacher report ; * = developed specifically for this study.

each case. Social and biological risk factors for externalizing psychopathology are also assessed during each wave, using both surveys and laboratory tasks. These are summarized in Table 3. The longitudinal data on measures of anti-social behavior (ASB), including psychopathic personality, rule-breaking behavior and aggression, as well as psychiatric symptoms, autonomic measures of arousal and reactivity, are particularly represented across multiple (at least three, and in most cases five) time points. The only measures for which there are only two repeated observations are those involving electrocortical measures (electroencephalogram (EEG) and event-related potentials (ERPs)) and IQ, which are obtained at Waves 1 and 5.

Attrition Analysis and Efforts for Tracking and Retention

Attrition analyses were carried out to examine whether those who discontinue participating during Waves 2, 3, or 4 differ from responders on baseline measures at Wave 1. Logistic regression analyses showed non-significant odds ratios (OR) for family socio-economic status, based on the Hollingshead Four-Factor index of Social Status (Hollingshead, 1979; OR = 0.99, 95% CI, 0.98–1.01), twin's gender (OR = 0.79, 95% CI, 0.59–1.07), interview language (OR = 1.13, 95% CI, 0.76–1.69), nor for ASB (Child Psychopathy Scale (CPS; total score; Lynam, 1997) OR = 1.00, 95% CI, 0.97–1.03), reactive-proactive aggression total score (Raine et al., 2006; OR = 1.00, 95% CI, 0.98–1.02). However, responders and non-responders were significantly different in ethnicity (OR = 0.70, 95% CI, 0.50–0.99), indicating that Caucasians were slightly less likely to drop out. Apart from the slight ethnic difference, those who discontinue participating in our study do so in a random manner.

To stay in contact with participating families we send out newsletters, annual birthday cards, and email personalized notecards to remind participants of upcoming lab visits. We also use various tracking procedures, including telephone number searches, returned mailings' forwarding address information, and utilizing popular media (e.g., searches of Facebook and MySpace). We also periodically request that they verify/update current contact information. Additionally, we establish communication with their close friends and family members to learn their whereabouts if we have lost contact with them over time. Families are also invited to attend organized events of interest to twins, including a recent panel discussion on twins by top experts in the area of twins' development, genetics, and psychotherapy, which helps create an atmosphere of inclusion. We provide each twin with a list of phone numbers and Web sites of agencies they can turn to for help. Finally, we offer a small monetary incentive for referrals.

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Key Findings From the USC-RFAB

Several important findings have emerged from the RFAB, including both phenotypic and genetic analyses of externalizing psychopathology and its various social and biological risk factors. Below is a short summary of some of the key findings to date.

Genetic Effects in Externalizing Behavior Problems: Variations Across Definitions and Informants

Our findings show ASB (measured by symptom counts of conduct disorder, ratings of aggression, delinquency, and psychopathic personality) can be defined by a common ASB factor with strong heritability (96%; Baker et al., 2007). Similarly, the covariance among attention deficit hyperactivity disorder (ADHD), oppositional defiant disorder (ODD), and conduct disorder (CD) symptoms could be explained by a latent externalizing behavior factor at ages 9–10 years. Genetic influences explained 57% of variance in this externalizing factor (Tuvblad et al., 2009b). We also examined the genetic and environmental influences on the two factor scores Callous/Disinhibited and Manipulative/Deceitful (CPS; Lynam, 1997 2002) and found significant genetic influences between 46 and 64% (Bezdjian et al., 2010). These findings together show that genetic influences vary depending on how ASB is defined, and that there are measurement-specific genetic and environmental influences, suggesting some etiological independence among different types of ASB. Further, our findings show that different informants only partly share a 'common view' regarding the same behaviors, thus, additional factors that influence the 'rater-specific' view of the child's ASB vary for different informants, especially for complex traits including psychopathic personality (Bezdjian et al., 2010) and aggression (Baker et al., 2007).

Relationships of ASB With Biological Risk Factors

A novel finding from the current sample was that the association between low-resting heart rate measured at ages 9–10 and ASB measured at ages 9–10 and 11–13 was entirely explained by genetic covariation. Although the heritable component of heart rate explained only a small portion (1–4%) of the substantial genetic variance in ASB, children with low-resting heart rate appear genetically predisposed toward externalizing behavior problems as early as 9 years old (Baker et al., 2009).

Reduced skin conductance response (SCR) magnitude (hyporeactivity) was only characteristic of boys with higher psychopathic scores, suggesting that it is a biological marker of a manipulative and deceitful orientation in males. No association was found between SCRs and psychopathic personality in girls, suggesting sex-specific etiologies of these traits in childhood (Isen et al., 2010).

Atypical electrodermal and cardiovascular response patterns in psychopathic individuals are thought to be biological indicators of fearless and disinhibition. Larger heart rate acceleration and fewer non-specific SCRs (NS-SCRs) were found to be significantly associated with psychopathic traits during anticipation of signaled white-noise bursts when the twins were 9–10 years old. These findings suggest that autonomic deficits present in children at risk may predispose them to later psychopathy (Wang et al., 2012).

Relationships of ASB With Social Risk Factors

We also found a significant biosocial interaction, whereby risky decision making was associated with psychopathic tendencies, but only in children from benign (i.e., high socio-economic status), non-adverse home environments. This finding supports the biosocial interaction perspective, suggesting that risky decision making may particularly predispose psychopathic personality in children from benign home backgrounds (Gao et al., 2008).

Yet another study found that parenting has less impact on ASB among children who are high on psychopathic personality traits. Children low on psychopathy scores showed decreasing aggressive and conduct disorder symptoms as positive affect increased. Children high on psychopathy scores showed elevated aggressive and conduct disorder symptoms regardless of affect level. This interaction was not found for negative affect. Results imply that negative parenting detrimentally affects children's problem behavior regardless of existing psychopathic traits, while children high on psychopathy scores may be less responsive to ineffective parenting (Yeh et al., 2011).

We recently examined the direction and the genetic and environmental etiology of the association between negative parent-to-child affect and psychopathic personality from ages 9–10 to 14–16 years. Negative parent-to-child affect at ages 9–10 years influenced psychopathic personality at ages 14–16 years. Both genetically and environmentally mediated parent-driven effects were important in development of psychopathic personality. Psychopathic personality at ages 9–10 years influenced negative parent-to-child affect at ages 14–16 years. Thus, children's genetically influenced psychopathic personality seemed to evoke parental negativity at ages 14–16 years, These results illustrate the importance of investigating causal relationships in the development of psychopathic personality (Tuvblad et al., 2012).

Stability and Change in ASB and Its Risk Factors

Genetic and environmental stability in reactive and proactive aggression was investigated when the twins were 9–10 and 11–13 years old. We found that the stability in reactive aggression was due to genetic and non-shared environmental influences, whereas the continuity in proactive aggression was primarily genetically mediated (Tuvblad et al., 2009a).

The genetic and environmental stability of impulsivity was investigated using data from the Barratt Impulsiveness Scale (BIS) in Waves 2 and 3. Univariate genetic analyses for the three sub-scales (inattention, motor, and non-planning impulsivities) yielded moderate heritability estimates of 38–55% at ages 11–13, and 31–37% at ages 14–15. Multivariate genetic analyses at each wave suggest a latent common impulsivity factor, with 72% of the stability between these two latent impulsivity factors is accounted for by genetic effects (Niv et al., 2012).

We also investigated longitudinal stability and change in motor impulsivity using errors of commission from the Go/NoGo task in Waves 1, 2, and 3. Latent growth curve analyses revealed variation in initial levels in motor impulsivity was predominantly due to genetic factors, while non-shared environmental factors also played a significant role. Change (slope) variation in motor impulsivity was due to both genetic and non-shared environmental factors (Bezdjian et al., 2012). Taken together, the genetic influences on impulsive behavior appear to take effect early in (pre-adolescent) childhood, and non-shared environmental influences play an increasingly important role during adolescence. It appears that the temporal stability of impulsivity, both in NoGo errors and self-reported BIS scores, is due to early appearing genetic influences, while changes across adolescence are primarily due to unique individual environments.

We examined the genetic and environmental etiology of skin conductance orienting response (SCOR) at ages 9–10, 11–13, and 14–16 years. The SCOR is an autonomic response to novel stimuli and indirectly reflects how much a person attends to and processes novel stimuli in the environment (Dawson et al., 2007). SCOR deficits have been linked to a variety of externalizing problems, including psychopathy, ASB, and ADHD (see Tuvblad et al., 2012). Genetic influences explained 55%, 82%, and 48% of the total variance in SCOR at Waves 1, 2, and 3, respectively, with the remaining variance explained by non-shared environment. SCOR was moderately stable phenotypically across ages ($r = .38$ to .51). Genetic influences contributed between 7% and 30% to the stability of SCOR. The genetic correlations among the three waves were high, ranging between 0.53 and 0.90, indicating a substantial continuity in genetic influences from ages 9 to 16 (Tuvblad et al., in press).

Genetic and Environmental Bases of Biological Risk Factors

We examined the genetic and environmental etiology of the associations among respiratory sinus arrhythmia, heart rate, skin conductance level, and NS-SCRs. Nearly all of the genetic and environmental influences on these measures were accounted for by two latent factors, supporting the validity of separate sympathetic and parasympathetic constructs (Tuvblad et al., 2010).

Resting frontal asymmetry and alpha power were examined when the twins were 9–10 years old. Results displayed a modest but significant amount of variance in frontal asymmetry accounted for by genetic factors (11–27%), with the remainder accounted for by non-shared environmental influences. Alpha power was highly heritable, with 70–85% of the variance accounted for by genetic factors (Gao et al., 2009).

Identifying Twins for Future Studies

Public school districts are a valuable resource for future twin studies. Sort-match procedures of school district databases can be used to identify twins as two students with the same last name, birth date, and home address. We successfully used this method previously and found >99% accuracy identifying twins. Based on the average twinning birthrate in California from 1995 to 2007 (3% of all live births; http://multiples.about.com/od/funfacts/a/twinbirthrate.htm) and the recently published enrollments for grades K–12 in 2011–2012 (3,058,535 students; California Department of Education: http://data1.cde.ca.gov, accessed on 9/6/2012), we estimate the number of school-age twin pairs living in the five-county area of Greater Los Angeles to be over 45,000 pairs. This would provide a sufficiently large potential from which to draw future twin samples. Families of identified twins are generally sent letters (from district offices) inviting them to participate in studies, and those interested are asked to return postage-paid information forms or call us to register their twins for study. Based on past experience, we expect >30% return rate among identified twins. Additional efforts to identify twins within private schools, advertisements and referrals can be used to add more twin pairs beyond those from public schools, that is, at least another 15%. Using these same recruitment methods, we previously demonstrated success in forming a sample that is representative of the ethnic and socio-economic distribution in Southern California (Baker et al., 2002, 2006). As previously described (see Baker et al., 2006), Los Angeles County birth records can also be used to identify twins from the target birth years, and these can be cross-matched to voter records to find recent addresses for either parents or the twins themselves (i.e., for age 18+ twins).

Technological developments in the last decade have made the recruitment of twins from large urban populations highly accessible with minimal resources. Computerized databases from schools and public records through state and county sources can yield large samples of twins interested in participating in research projects. We have successfully used these methods in the past to identify and recruit twins for research at USC, and our methods could be used to successfully recruit large samples for future research.

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