The Swedish Twin study of CHild and Adolescent Development: The TCHAD-Study

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The Swedish Twin study of CHild and Adolescent Development (TCHAD) is a longitudinal study of how genes and environments contribute to development of health and behavioral problems from childhood to adulthood. The study includes 1480 twin pairs followed since 1994, when the twins were 8 to 9 years old. The last data collection was in 2005 when the twins were 19 to 20 years old. Both parents and twins have provided data. In this article we describe the sample, data collections, and measures used. In addition, we provide some key findings from the study, focusing on antisocial behavior, criminality, and psychopathic personality.

The longitudinal Swedish Twin study of CHild and Adolescent Development (TCHAD) started in 1994. The overall scientific goal was to establish a longitudinal database which could be used to study how genes and environments contribute to development of health and behavioral problems from childhood to adulthood. We have since then studied several health (Lichtenstein & Svartengren, 1997; Svensson et al., 1999) and behavior problems (Lichtenstein & Annas, 2000) with a focus on externalizing behaviors (Larsson et al., 2004; Tuvblad et al., 2005). The purpose of this paper is to describe the sample and provide some key findings from the study.

Sample and Response Rates

TCHAD is a longitudinal study of all 1480 twin pairs born in Sweden between May 1985 and December 1986 followed with four waves of measurements from childhood (age 8–9), throughout early (age 13–14) and late adolescence (age 16–17), into emerging adulthood (age 19–20). In Wave 1 the parent-questionnaire had a response rate of 75% (*n* = 1109 parents; Figure 1). Nonresponders to the questionnaire were approached with up to three reminders. After a telephone follow-up we reached a response rate of 91% (*n* = 1339 parents; Lichtenstein & Svartengren, 1997). In Wave 2, 73% of the parents (*n* = 1063), and 78% of the twins responded (*n* = 2263). Complete information from the whole family between Wave 1 and Wave 2 is available for 911 of the twin pairs. In Wave 3, 74% of the parents (*n* = 1067), and 82% of the twins (*n* = 2369)

responded to the questionnaire. In addition, we obtained responses from an additional 5% of the twins when we used a telephone follow-up with a reduced battery of questions to the nonrespondents. Complete information from the whole family between Wave 2 and Wave 3 is available for 906 of the twin pairs. Further, an overwhelming majority of the parent reported information was supplied by mothers rather than fathers (range: 75%–90%).

Data collection for Wave 4 is expected to be completed during 2006 and thus final response rates for this part of the study are not available yet. In Wave 4 we approached mothers and fathers separately.

In addition to the questionnaires to parents and twins, we have also conducted two smaller substudies. At Wave 2 we tried to collect questionnaire information from teachers. However, we were required to obtain written permission from both the child and their parent in order to contact the teacher. Therefore, we reached a very low response rate on this part of the study. We received permission to contact 1120 teachers. Of these 745 (67%) responded. During the years 2001 and 2002 we conducted a clinical study of the 271 twin pairs living in the Stockholm area. In total, 156 twin pairs were, among others, examined through a clinical psychiatric interview (K-SADS-PL; Ambrosini, 2000) by a child psychiatrist.

Measures

The measures that have been used in the different data collections are described in Table 1. Sociodemographic measures have been collected through the questionnaires, but also on aggregate level where neighborhood socioeconomic conditions (ethnic diversity, educational level, unemployment level, buying power, and crime rate) were available on zip code levels (Tuvblad et al., 2006). We have several measures of physical health problems. Birthweight was acquired from the nationwide Medical Birth

Table 1

Measures Used in the Different Waves of TCHAD-Study

Construct		Provider of data		
Instrument	Parent (about twin)	Parent (about self)	Twins	Other
Sociodemographic factors				
Occupational status (Lichtenstein et al., 1992)		1,2,3		
Educational level (Lichtenstein et al., 1992)		1,2,3	4	
Ethnicity		3		
Neighborhood sociodemographic status (Tuvblad et al., 2006)				NR
Physical health				
Birthweight				NR
Height and weight	1,2,3		2,3,4	
Asthma and allergy (own measure: Lichtenstein & Svartengren, 1997)	1,2			
Headache (own measure: Svensson et al., 1999)	1			
Disease status (own measures)	1,2	3	3,4	
EQ-5D (General health status; Burstrom et al., 2001)	1,2,3		4	
Competence, behavior, personality				
Child Behavior Checklist/Youth Self-Report/Teacher Report Form (Achenbach, 1991a, 1991b, 1991c; Achenbach & Rescorla, 2000)	1,2,3,4	4	2,3,4	T
Physical activity (own measure)			3,4	
I think I am (self-competence: Ouvinen-Birgerstam, 1985)			2,4	CI
The tridimensional personality questionnaire (Cloninger et al., 1991)		4	4	
Eysenck Personality Inventory (Eysenck & Eysenck, 1964)		4	4	
The Youth Psychopathic traits Inventory; YPI (Andershed et al., 2002)			3,4	T
Externalizing behavior and symptoms				
DSM-based symptoms of ADHD (Larsson et al., 2004, 2006b)	1,2,3,4	4	3,4	CI
Self-reported delinquency (Junger-Tas et al., 1994)			2,3,4	
Drug, alcohol and tobacco use (own measure)		4	2,3,4	
Psychiatric diagnoses (K-SADS-PL; Ambrosini, 2000)				CI
Internalizing behavior and symptoms				
Eating Disorders Inventory (Garner, 1991)			3	
DSM-based symptoms of phobias (Fredrikson et al., 1996)	1,2,3	4	2,3,4	
Center for Epidemiologic Studies — Depression Scale (Weissman et al., 1977)		4	4	
Psychiatric diagnoses (K-SADS-PL; Ambrosini, 2000)				CI
Life events				
Minor parenting stresses (Crnic & Greenberg, 1990)	1			
Stressful life events (Hook et al., 1995)			4	
Relationships				
Quality of relationships with parents, partners, friends, and siblings (Furman & Buhrmester, 1985; Hetherington & Clingempeel, 1992)	4		3, 4	
Expressed emotion (Hansson & Jarbin, 1997)	3,4		3,4	
The Relationship Closeness Inventory (Berscheid et al., 1989)			4	
Clinical investigations				
Dental test				CI
MAO-activity				CI
Virus load				CI
Zygosity				
Twin similarity	1,2,3		2,3	
DNA collection			4	CI

Note: 1, 2, 3, 4 = questionnaire responses used at different waves, CI = clinical interview

T = teacher questionnaire, NR = data provided by linkages to national registries

Register. Competence, behavioral problems, and personality have among others been collected with the Achenbach System of Empirically Based Assessment (ASEBA) measures as reported by children, parents, and teachers, about both the twins and the parents (Achenbach, 1991a, 1991b, 1991c; Achenbach & Rescorla, 2000, http://www.aseba.org/). A focus of the study have been on externalizing symptoms, including attention-deficit/hyperactivity disorder (ADHD; Larsson et al., 2004), criminal behavior (Tuvblad et al., 2006), and psychopathic personality (Larsson et al., 2006a), but we have also measured internalizing symptoms (e.g., Lichtenstein & Annas, 2000), life events, relationships, and different clinical assessments.

Zygosity Determination

The current zygosity determination of the same-sexed twin pairs is based on algorithms derived from discriminant analyses on 106 like-sexed twin pairs participating in the clinical study with known zygosity (based on 16 polymorphic DNA-markers). The algorithms only classify pairs that have a 95 % probability of being correctly classified as monozygotic (MZ) or dizygotic (DZ). Zygosity was classified by using separate algorithms to parent's response (Wave 1, Wave 2, and Wave 3) and to children's response (Wave 2 and Wave 3) using four questions dealing with the twins' physical similarity and the frequency with which people confuse them. Zygosity was scored as unknown in cases of contradictions between any of the five zygosity assignments. Of the 960 pairs of like-sexed twins with information from at least one of the questionnaires, 508 pairs were diagnosed as MZ and 366 as DZ. Zygosity could not be assigned to 86 twin pairs, mainly due to differences between two algorithms.

It should be noted that in earlier reports from the TCHAD-study we have used other algorithms for zygosity classification. However, we have used the best available zygosity diagnose at each time point, and the variations between the different methods are small and of limited importance. During Wave 4, DNA from all twin were collected with oragene® via mail which will allow further refinements of the zygosity classification.

Representativeness of the Sample

We have conducted some analyses in order to detect differences between participants and nonparticipants at Wave 3 with regard to neighborhood characteristics. No significant differences were found for unemployment level ($t = -1.13$, $df = 2925$, $p = .26$), educational level ($t = -1.65$, $df = 2,925$, $p = .10$), buying power ($t = -1.27$, $df = 2925$, $p = .21$) or neighborhood crime-rate ($t = .97$, $df = 2937$, $p = .33$). However, for ethnic diversity ($t = -3.63$, $df = 2925$, $p < .001$) there was a significant difference, indicating that nonparticipating families more often live in neighborhoods characterized by ethnic heterogeneity (Tuvblad et al., 2006).

Attrition Rate

We have shown that there are no significant differences in sex ratio, externalizing symptoms, or ADHD symptoms at Wave 1 between responders and subjects lost to follow-up at Wave 2 (Larsson et al., 2004; Tuvblad et al., 2005). We have also tested whether subjects lost to follow up at Wave 3 differed from responders on measures at Wave 2. Multivariate logistic regression analyses showed nonsignificant odds ratios (OR) for sex (OR = .69, 95% confidence intervals [CI] .48–1.00) and twin reported antisocial behavior (OR = 1.22, 95% CI .77–1.93). A similar analysis using the parent-report data showed a significant risk for hyperactivity-impulsivity (OR = 1.15, 95% CI 1.01–1.30), and nonsignificant risks for sex (OR = 1.01, 95% CI .76–1.35), family socioeconomic status (SES; OR = .92, 95 % CI .85–1.00), and inattention (OR = .99, 95% CI .85–1.16) measured at Wave 2 (Larsson et al., 2006b).

Telephone Interview

We conducted a telephone follow-up for the twins who did not respond to the twin's self-report questionnaire in Wave 3. Of the nonresponders ($N = 533$), we could find valid telephone numbers for 362 twins. Lack of time and interest was the most common response by those who gave a reason for nonresponding.

Of the 362 twins we phoned, 156 also participated in a telephone interview. To avoid making the interview too long we used a reduced battery of items from selected parts of the self-report questionnaire (psychopathic personality, antisocial behavior, fears and phobias, parental education and occupation, legal and illegal drug use).

Seventy-two of the twins who participated in the telephone interview also later responded to the questionnaire. For these twins we could test the reliability and systematic differences between the questionnaire and telephone responses. Correlations between questionnaire and telephone scores were high (psychopathic personality $r = .72$; antisocial behavior $r = .73$; fears $r = .87$). There were no systematic differences between the two groups for psychopathic personality or antisocial behavior. However, girls scored lower in telephone assessments of fears as compared to questionnaire ratings. We found moderate to good kappa-values for parental occupational status (.55), smoking status (.75), and alcohol (.87) and drug use (.88). In contrast, there was a low agreement for parental educational status (kappa = .25).

Telephone-responders scored higher than questionnaire-responders in the measure of psychopathic personality (responders: mean = 34.15; nonresponders: mean = 37.76; $t = -5.92$, $df = 2310$, $p < .001$) and for tobacco and alcohol consumption. Twins who responded to the questionnaire more often came from families with higher SES ($\chi^2 = 27.63$, $p < .001$) than the twins who responded to the telephone interview. For antisocial behavior, fears and phobias, and illegal drug use there were no differences between responders to the questionnaire and telephone interview.
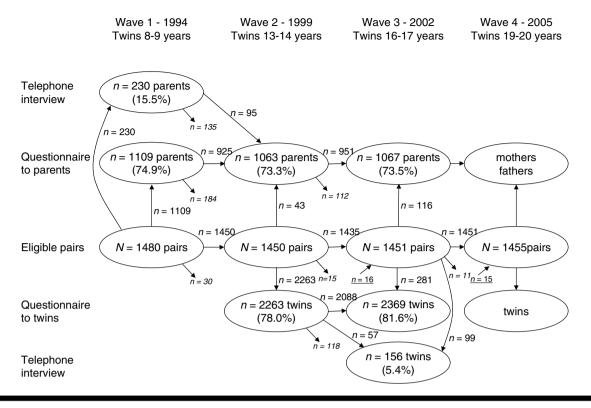
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Figure 1

Response rates to parents' and twins' questionnaires in the TCHAD study.

Note: Numbers in italics show responders who did not respond to the subsequent questionnaire (or were not eligible, mainly because families were moving abroad). Underlined numbers are individuals who have become eligible (mainly because families were moving back to Sweden).

In conclusion, the study has very good response rates, but as with all volunteer twin samples there seems to be a slight underreporting of individuals from lower SES groups. Further, it is not certain that all of the results are generalizable to individuals with the most extreme externalizing behaviors.

Summary of Key Findings

There exist several reports from the TCHAD study (http://www.meb.ki.se/research/projects/lichtenstein_p/tchad_en.html). Much of the research has been targeted at the development of psychopathology, in particular antisocial behavior, ADHD, and psychopathic personality traits. In the following section we briefly describe some reports from these three areas.

Antisocial Behavior

Antisocial behavior is a pattern of behavior in which societal norms and rules are violated. In the TCHAD study, antisocial behavior has been measured at all waves, with the Child Behavior Checklist/Youth Self-Report/Teacher Report form depending on the reporter, as well as with self-reported delinquency as reported by the youth themselves at Wave 2, 3, and 4 (Table 1).

It has been argued that aggressive (overt) and nonaggressive (covert/delinquent) antisocial behavior represent different developmental trajectories (Achenbach, 1991b; Loeber & Hay, 1997). Eley et al. (1999, 2003) examined this using parental-reported measures of aggressive and nonaggressive behavior at Waves 1 and 2, using parent reports of the aggressive and delinquency scales of the Child Behavior Checklist (Achenbach, 1991b). In childhood, aggressive behavior was highly heritable (70%) and showed little influence of shared environment, whereas nonaggressive behavior was significantly influenced both by genes and shared environment (Eley et al., 1999). In early adolescence, both variables were influenced by genes as well as shared environment. The continuity in aggressive behavior from childhood to early adolescence was largely mediated by genetic influences, whereas continuity in nonaggressive behavior was mediated both by the shared environment and genetic influences. The findings are in agreement with the hypothesis that aggressive behavior is a stable heritable trait, whereas nonaggressive behavior, which is more strongly influenced by the environment, shows less genetic stability over time (Eley et al., 2003).

Next we investigated stability and change in self-reported antisocial behavior (measured with an extensive self-report delinquency questionnaire; Junger-Tas et al., 1994) between early and late adolescence. Univariate results indicated that heritability for antisocial behavior increased by age in girls (Wave 2 heritability = 40%;

Wave 3 heritability = 59%), whereas it decreased in boys (Wave 2 heritability = 27%; Wave 3 heritability = 6%; Tuvblad et al., 2005, 2006). The stability in antisocial behavior from early to late adolescence for both boys and girls was due to genetic and shared environmental factors, suggesting the possibility that persistent antisocial behavior mediates genetic effects into heritable adult psychopathology. Shared environmental effects were also important for continuity, indicating the importance of vulnerability to psychosocial or environmental risk factors. The aim of future studies will be to investigate whether the well-known genetic effects on adult psychopathology are mediated by the persistent genetic effects from earlier antisocial behavior.

In another study, we could show that socioeconomic conditions moderated the influence of genetic and environmental factors on antisocial behavior. Genetic influences on self-reported antisocial behavior at Wave 3 were more important in adolescents in socioeconomically more advantageous environments, whereas shared environment was higher for antisocial behavior in adolescents in socioeconomically less advantageous environments (Tuvblad et al., 2006).

Attention-Deficit/Hyperactivity Disorder

ADHD is a highly heritable, disruptive, childhood-onset condition. In the TCHAD study, ADHD has been measured using a parental-reported checklist of *Diagnostic and Statistical Manual of Mental Disorders* (DSM) based symptoms for ADHD at Waves 1 to 3 (Larsson et al., 2004, 2006b).

At Wave 1 in 1999, when the twins were 8 to 9 years old, we showed that genetic, shared and nonshared environmental factors were important for individual differences in parental-reported DSM-III-R (3rd ed., rev.; American Psychiatric Association, 1987) based ADHD symptoms (Steffensson et al., 1999). By age 13 to 14, however, Larsson et al. (2004), found a relatively high influence of genetic effects (around 70%), and a negligible influence of the shared environment. Between the two waves there was a strong continuity that was mainly genetically mediated (Larsson et al., 2004).

Next, Larsson et al. (2006b) examined how genetic factors influence the development of the DSM-IV ADHD subtypes from childhood to adolescence. Results showed that a common genetic component (i.e., persistent cross-subtype effects) influences inattention and hyperactivity–impulsivity over time. However, despite a strong genetic overlap between inattention and hyperactivity–impulsivity over time, we also found etiologic independence (i.e., persistent subtype-specific effects). The finding of both persistent cross-subtype and subtype-specific genetic effects may suggest a genetic basis for the DSM-IV (4th ed.; American Psychiatric Association, 1994) subtypes of ADHD (Larsson et al., 2006b). We plan further investigations of the development of ADHD subtypes from childhood to adulthood using information from the fourth wave of data collection.

Psychopathic Personality

Psychopathic personality can be described with three interrelated dimensions: (1) an interpersonal style of glibness, grandiosity and manipulation , (2) an affective disposition of callousness, lack of empathy and unemotionality, and (3) a behavioral/lifestyle dimension of impulsivity, need for stimulation and irresponsibility, underpinning a higher order construct; psychopathic personality. In the TCHAD study, we have used the Youth Psychopathic traits Inventory (YPI), a 50-item self-report questionnaire developed to measure the core traits of the psychopathic personality constellation (Andershed et al., 2002), at Waves 3 and 4.

We have examined the genetic and environmental contribution to the covariation between the three psychopathic personality dimensions (i.e., grandiose/manipulative, callous/unemotional, and impulsive/irresponsible). Results showed that the three dimensions were significantly linked to a highly heritable 'psychopathic personality' factor (Larsson et al., 2006a), which is consistent with a hierarchical model of the psychopathic personality constellation (Cooke & Michie, 2001). The relatively large heritability (63%) for the psychopathic personality factor makes it a novel target for future research.

We have recently used a co-twin control design to examine the nature of the associations among persistent ADHD and externalizing problems in childhood with psychopathic personality in adolescence (Forsman, in press). The co-twin-control design was used because we used dichotomized independent variables (persistent ADHD and persistent conduct problems) when we studied the effect on psychopathic personality. The study showed that the etiology of the association between persistent externalizing problems and psychopathic personality is due to shared genetic factors. However, the study did not find a significant association between persistent ADHD and psychopathic personality, nor did it support the suggestion that the combination of ADHD symptoms and externalizing problems confers a special risk for psychopathic personality.

We will, in the future, further investigate how genetic effects associated with psychopathic personality in turn is related to antisocial behavior.

Conclusion

Collectively, the reports from the TCHAD study strongly highlight the importance of having longitudinal and multivariate data to understand the development of psychopathology. Continuing follow-ups of this sample will provide opportunities for understanding how genetic and environmental effects in childhood contribute to the development of physical and mental health into adulthood.

Acknowledgment

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