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Reared-apart/reared-together Chinese twins and virtual twins: Evolving research program and general intelligence findings

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ABSTRACT

China's One-Child Policy (1979–2015) limited rural families to two children and urban families to one child. This practice, which led to the abandonment of hundreds of thousands of female infants, is indirectly responsible for the separate placement of infant twins. The availability of this sample launched the first prospective study of these pairs. Participants include families and twins comprising 15 monozygotic (MZA) pairs and 7 dizygotic (DZA) pairs from countries throughout the world. The research program is described, and the initial wave of IQ scores for MZA and DZA twin pairs is examined in the first comprehensive report from this study. The twins' mean age at participation was 9.41 years (*SD* = 6.36), and their ages ranged from 3.19 to 24.98 years. Informative contrasts with adopted-together Chinese twins and virtual twins (same-age unrelated individuals reared together) highlight shared genetic and environmental effects on intellectual development. Applied directions based on findings from these novel samples are described.

Introduction

China's One-Child Policy, enacted in 1979, limited rural families to two children and urban families to one child (Evans, 2000). This practice, which resulted in the abandonment of hundreds of thousands

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of female infants, is indirectly responsible for separating pairs of twins, mostly female. It also led to the first prospective study of young reared-apart pairs, known as the Fullerton Study of Chinese Twins Reared Apart (CTA).

Twins reared apart

Twins reared apart comprise a rare subgroup of the multiple birth population. Twins occur in approximately 16.9/1000 births in Caucasian populations such as the United States, 11.5/1000 births in Asian populations such as Japan, and 27.9/1000 births in African populations such as Benin. Monozygotic (MZ or identical) twins occur in 3–4/1000 births worldwide; thus, it is the dizygotic (DZ or fraternal) twinning rate that explains the national differences (Pison, Monden, & Smits, 2015; Smits & Monden, 2011). The U.S. twinning rate has escalated dramatically during recent decades, from 1/60 births in 1980 to 1/33.3 births in 2017, owing to advanced maternal age and assisted reproductive technologies. This increase was followed by a 2% decline to 1/32.6 births in 2018 (Martin, Hamilton, Osterman, & Driscoll, 2018).

The value of separated twins for highlighting genetic and environmental factors underlying trait variation is widely recognized. Resemblance between monozygotic reared-apart (MZA) twins yields direct estimates of genetic influence on measured behaviors given that MZ co-twins share 100% of their genes and were raised in different families and communities—sometimes in different countries and cultures. The relative resemblance between dizygotic reared-apart (DZA) twins, who share 50% of their genes (on average and by descent), offers estimates of other gene–environment interactions (Segal, 2012).

Several classic, large-scale studies of mostly adult reared-apart twins have been conducted. These studies took place in the United States (Bouchard, Lykken, McGue, Segal, & Tellegen, 1990; Newman, Freeman, & Holzinger, 1937; Segal, 2012), England (Shields, 1962), Denmark (Juel-Nielsen, 1980), and Sweden (Kato & Pedersen, 2005). Other reared-apart twin analyses have been undertaken, or are ongoing, in Finland (Langinvainio, Kaprio, Koskenvuo, & Lönnqvist (1984), Japan (Hayakawa et al., 2006), and China (Gao et al., 2015), and several case reports are available (Segal & Cortez, 2014; Segal, Cortez, et al., 2015; Segal, Hur, & Graham, 2015). Collectively, these studies show that genetic influence is pervasive, affecting a wide range of behavioral and physical characteristics. At the same time, differences in educational resources and health care can explain co-twin differences in intellectual performance and medical status (Segal & Montoya, 2018; Segal, Montoya, Peña, Burgos, & Katz, 2019). However, these sets of findings are not contradictory given that MZA co-twins typically resemble each other to a greater degree relative to the members of other pairs (Segal, 2012).

Past and present

As indicated, most extant reared-apart twin studies have included twins whose reunions mostly occurred during early or middle adulthood. Therefore, childhood influences in the home and school have relied on retrospective reporting by twin participants, lacking input from parents and teachers. The current study is the first prospective investigation of young reared-apart twins to take place and to include observations from others. (A controversial prospective study of separated twins took place in New York City during the 1960s and 1970s, but it produced no systematic findings; Segal, in press). The primary purpose of the current study was to describe a comprehensive program of research and to present the first wave of reared-apart twins' intelligence test findings. These findings are contrasted with data from companion projects of Chinese twins adopted together and virtual twins (i.e., same-age unrelated individuals reared together), thereby addressing the same class of questions using several informative kinships.

Studies of Chinese twins

The CTA twin study was launched in 2001 when a mother who had adopted a single Chinese twin daughter contacted the university's Twin Studies Center for information regarding her child's unique rearing situation (Segal, 2007). This contact led to the identification of other twin pairs, mostly young

female pairs, whose behavioral development has been tracked as it unfolds. An early analysis of the quality of the twins' first meetings (n = 10 pairs) showed that twins older than 18 months expressed stronger attraction toward their co-twin upon meeting, but expressed more varied behaviors upon departing, relative to younger twins (Segal, Stohs, & Evans, 2011). Companion projects (albeit less comprehensive) involve 50 pairs of Chinese twins reared together (CTT) and 169 pairs of virtual twins (VT). Factors affecting developmental delays and risks have been compared using these two samples (Segal, Tan, & Graham, 2015).

Virtual twin and adoption research

Prior research has consistently shown that the IQ intraclass correlations of MZ and DZ twins exceed those of virtual twins and adoptive siblings (Knopik, Neiderhiser, DeFries, & Plomin, 2016; Segal, McGuire, & Hoven Stohs, 2012). In addition, children from lower socioeconomic classes adopted by higher socioeconomic class families tend to outperform their nonadopted half-siblings, evidence of favorable environmental effects; however, these adoptees do not perform as well as expected given this family advantage (Dumaret & Stewart, 1985; Schiff et al., 1978; van Ijzendoorn, Juffer, & Poelhuis, 2005). Genetic factors and/or teachers' knowledge of adoption have been suggested as explanations for this finding. More recently, Gibson (2009) found that parents raising both adopted and biological children directed greater efforts toward educating their adoptees but that their biological children's intellectual outcomes were more favorable. Parents' actions on behalf of their adopted children were attributed to differential parental solicitude rather than parental favoritism.

Most interesting is that extant studies have generally found that the Full Scale IQ, Verbal IQ, and Performance IQ scores *and* intraclass correlations for adopted–biological siblings (AdBi) exceed those of adopted–adopted (AdAd) siblings (Horn, Loehlin, & Willerman, 1982; Segal et al., 2012; Segal, Li, Graham, & Miller, 2015).[1] This effect is expected because biological parents transmit both genes and environments to their children, resulting in a passive gene–environment (GE) correlation. Passive GE is the association between genetic and environmental factors arising from, for example, parental transmission of genes linked to superior intellect and parental provision of a well-stocked home library (Knopik et al., 2016). In the case of AdBi pairs, the genotype of the biological child is correlated with the environment of the adoptive child, predicting greater resemblance between AdBi pairs than between AdAd pairs (Bouchard & McGue, 1981; Loehlin, 1978). Thus, the VT–AdBi pairs share a component of variance that is lacking in the VT–AdAd pairs that is likely to account for their more coordinated test performance.

It has been reported that genetic effects on IQ fall to near zero in impoverished families, with environmental factors explaining 60% of the variance. However, the reverse is true among financially secure families (Turkheimer, Haley, Waldron, D'Onofrio, & Gottesman, 2003). The higher mean scores of the biological children in AdBi pairs most likely reflect genetic and environmental factors associated with the high socioeconomic status of the biological children's parents and/or more heterogeneous backgrounds of the parents of the adoptees. The higher mean scores of the members of AdBi pairs in general, relative to the those of the AdAd pairs, probably have a similar explanation together with the positive influence of the high socioeconomic status adoptive home on the adoptee.

Novel kinships

Provocative questions and issues can be examined given the availability of the three novel kinships (CTA, CTT, and VT). First, comparing young separated and nonseparated pairs highlights the effects of shared environmental influences on general intelligence *during childhood.* If reared-apart twins are less alike than reared-together twins, this suggests that co-twin differences in their early and later environments may be responsible. Second, such efforts address the generalizability of research findings from young separated sets. Research on adult reared-apart twin pairs shows that their resem-

[1] Despite their prediction, Bouchard and McGue (1981) showed a slightly higher correlation for Ad–Ad pairs (r_i = .34) than for Bi–Ad pairs (r_i = .29).

blance does not differ appreciably from adult reared-together twins in personality, social attitudes, and religiosity, supporting the applicability of the data to non-twin populations (Bouchard et al., 1990; Segal, 2012). The IQ correlation is slightly higher for monozygotic reared-together (MZT) twin pairs than for MZA twin pairs (.86 and .77, respectively; see Segal, 2012). However, the MZT correlation is based largely on studies of young twins living at home and sharing educational activities.

Comprehensive comparative assessments of the IQ correlations of separated and nonseparated twins and other relatives show greater similarity with greater relatedness. The first such report, compiled by Ehrlenmeyer-Kimling and Farvik (1963), was later updated by Bouchard and McGue (1981), Plomin, DeFries, McClearn, and McGuffin, 2008), and Segal (2012). None of the later reports included virtual twins with the exception of Segal (2012), and none included young separated twins or twins adopted together.

Third, virtual twins provide direct estimates of shared environmental influences, just as MZA twins provide direct estimates of heritability. VTs offer an environmentally based sibship that preserves the twin-like nature of the relationship, a feature lacking in ordinary adoption studies, that identifies VTs as a more suitable comparison for ordinary twins. In summary, the current research program attempts to rectify the aforementioned difficulties, allowing more realistic appraisal of the nature and implications of data from twin and adoption research. Applied directions of these findings can be considered with reference to the rearing and educating of twins and near-in-age children.

The current project, by contrasting the three twin and twin-like kinships, provides a range of unique research opportunities. Beyond examining genetic and environmental influences on behavior, these sibships afford opportunities to link specific early life and family factors to differences in the reared-apart twins' intellectual outcomes in real time. To this end, the current article sets forth the research program and findings from the initial wave of IQ scores for reared-apart, reared-together, and VT pairs in the first comprehensive report from this study.

Method

Participants

CTA, CTT, and VT families

Families raising adopted-apart and adopted-together Chinese twins were identified via the internet (e.g., websites for parents with adopted Chinese twins and siblings), the media (newspaper articles/television programs about the project), and personal referrals to the principal investigator (N.L.S.). Most CTA twins were separated due to the One-Child Policy, whereas insufficient family resources or other circumstances led to the separation of others. Some families raising singleton twins found their child's co-twin when they received their child in China and noticed a striking resemblance to another child. Other parents discovered identical images of their children posted on social media platforms, leading to the twins' reunion. Families in the VT sample came to the attention of the principal investigator in similar ways. Once families were identified, the principal investigator determined that they met the strict criteria for participation, namely that (a) the age difference between co-VTs could not exceed 9 months (but on average was 3.06 months); (b) VTs needed to be in their permanent home by 1 year of age; (c) VTs enrolled in school needed to be in the same school grade; and (d) adverse birth events that might affect the behavioral measures needed to be ruled out. Opposite-sex pairs and pairs of different ethnicities were accepted into the study. Justification for these parameters and further details about the research are available in Segal et al. (2012) and Segal, Li, et al. (2015). Background characteristics for the three sibling groups are displayed in Table 1.

CTA sample

The 44 individual twin participants are the members of 15 monozygotic (MZA) pairs and 7 dizygotic (DZA) pairs who reside in various countries and continents. Co-twins in four pairs were raised in different countries, and co-twins in three of these pairs speak different first languages. All twins are female with the exception of twins in one MZA male pair, twins in one DZA male pair, and a male co-twin in one DZA opposite-sex pair. All twins are originally from mainland China with the exception

Table 1
Background characteristics and age-related data for reared-apart Chinese twins, reared-together Chinese twins, and virtual twins.

Measure	Rearing status	*N* (individuals)	*M*	(*SD*)	Range
Age at participation (years)[a]	CTA	44	9.41	(6.36)	3.19–24.98
	CTT	97	7.32	(2.58)	3.73–17.63
	VT	325	8.73	(9.18)	4.01–54.84
	VT–Ad	209	7.07	(6.33)	4.01–54.61
	VT–Bi	116	11.73	(12.28)	4.01–54.84
Time in orphanage (days)	CTA	35	368.49	(264.05)	4.00–1354
	CTT	89	393.10	(433.06)	1.00–2791
	VT	–	–	–	–
Age at adoption (years)[b]	CTA	44	1.53	(2.60)	0.35–17.93
	CTT	97	1.12	(0.60)	0.00–3.50
	VT	325	0.14	(0.25)	0.00–1.02
	VT–Ad	261	0.18	(26.46)	0.00–1.02
	VT–Bi	64	0.02	(0.03)	0.00–0.16

Note. Age at adoption for biological virtual twins (VTs) was entered as age when brought home from the hospital. CTA, reared-apart Chinese twins; CTT, reared-together Chinese twins; Ad, adopted; Bi, biological.
[a]CTA > CTT, $t(49.55) = 2.10$, $p < .05$
VT > CTT, $t(419.16) = -2.46$, $p < .05$
VT–Bi > VT–Ad, $t(149.57) = -3.82$, $p < .001$
[b]CTA > CTT, $F = 4.67$, $p < .05$
CTA > VT, $t(43.10) = 3.54$ $p < .001$
CTT > VT, $t(105.74) = 15.68$, $p < .001$
CTA > VT: CTT > VT, $F = 59.38$, $p < .001$

of one MZ pair from Taiwan and two MZ pairs from Vietnam. The twins were identified through the media (63.5%), referral by another (13.6%), self-referral (18.2%), and other means (4.7%).

Twins abandoned at orphanages and police stations in China are sometimes identified at different times and in different locations. Only 13.6% of the reared-apart twins had been found together. Background information about these infants is generally not provided, so birth dates are sometimes estimated by personnel based on infants' physical appearance. In this study, 10 pairs were assigned different dates of birth, ranging from 1 to 200 days. For purposes of the study, the age of each individual twin was determined as the interval spanning the date of IQ testing and the given date of birth; therefore, some co-twins differ slightly in age. The mean within-pair age difference (*n* [pairs] = 22) is 22.50 days (*SD* = 45.04, range = 0–219). With one exception, the twins in each pair had been reunited prior to IQ testing.

The twins' mean age at adoption was 1.53 years (*SD* = 2.60) and their mean age at reunion was 5.42 years (*SD* = 5.31). Their mean age at participation was 9.41 years (*SD* = 6.36). Mean contact time prior to IQ testing was 0.29 years (*SD* = 0.42). Twins in one pair had lived together for 11 months beginning at 17.92 years of age; one of these co-twins had been raised outside the United States. The reared-apart twins' contact data are summarized in Table 2.

The zygosity of 21 of the 22 twin pairs was confirmed by DNA analysis derived from buccal smears. The remaining pair was classified by results from a standard physical resemblance questionnaire completed by parents (Nichols & Bilbro, 1966). In every case but one, the questionnaire findings agreed with the DNA analysis; in this one case, zygosity was assigned by the DNA test result.

CTA families

The number of mothers and fathers in the following analyses vary somewhat depending upon data availability. A family that adopted their twin daughter's co-twin in late adolescence is counted once.

The reared-apart twins were adopted by mostly two-parent families (*n* = 39), but also by several single-mothers (*n* = 3) and single fathers (*n* = 1) in North America, Europe and Australia. Most mothers and fathers were Caucasian (88.1% and 85.0%, respectively), with the remainder of Hispanic (4.8%, 5.0%), Asian (2.4%, 5.0%) and mixed origin (4.8%, 5.0%). Several couples had divorced prior to or after participation in the study.

Table 2
Contact-related characteristics of reared-apart twins.

Measure	*M*	*SD*	Range
Time before separation (days)	114.14	174.10	1–563
Separation to first contact (years)	5.09	5.27	0.17–22.70
Separation to first contact (days)	1856.77	1922.75	62–8287
Reunion to IQ test (years)	4.28	5.62	0.01–23.14
Reunion to IQ test (days)	1562.19	2051.29	5–8445
Total contact: Time before separation + post-reunion (days)	148.53	183.14	2–569.50
Time apart: Age days − total contact	3286.22	2322.87	912.50–9062.50
% Lifetime apart	94.06	9.31	67–99.90

Note. N = 37–44

The twins' rearing parents were mostly older, well-educated and employed in high level occupations, as is characteristic of adoptive mothers and fathers (Stoolmiller, 1999). The mean age of the mothers was (n = 39, M = 48.08 years, SD = 7.98, 38 - 70) and the mean age of the fathers was (n = 37, M = 49.24 years, SD = 70.94, 38 - 69). Most mothers (n = 40, 90.0%) and fathers (n = 37, 89.02%) had completed at least one year of college/specialized training, had earned a Bachelor of Arts/Bachelor of Science degree or had received graduate school training. The majority of mothers (n = 42, 64.30%) and fathers (n = 38, 65.80%) were employed in professional, technical or managerial positions. Primary reasons for adopting (n = 38) included infertility (47.4%), desire for another child (26.3%), previous loss of a child (7.9%), humanitarian concerns (7.9%) and other circumstances (10.5%). Approximately one-fourth of the twins (27.09%) were being raised as only children, whereas nearly two-thirds had between 1 - 7 siblings, of which over half (54.80%) were the biological children of their adoptive parents.

CTT sample

The CTT sample included 97 individuals who were the members of 43 MZT twin pairs and 7 DZT twin pairs. One set of MZ triplets was organized into three twin pairs, and two sets of twins had been adopted by the same family, such that individual and pair level data were variously used where appropriate. All twins were female with the exception of one male in an opposite-sex twin pair, and all twins were Chinese. Following abandonment at police stations or orphanages, twins in 41 pairs and the triplets had been found together, whereas information was uncertain or did not apply in the remaining cases. The opposite-sex pair was adopted domestically in the United States.

The reared-together twins' mean age at adoption was 1.12 years (SD = 0.60), and their mean age at the time of participation was 7.32 years (SD = 2.58). The majority of these twins (90%) had been found together. The zygosity of 35 of the 50 reared-together twin pairs was confirmed by DNA analysis, whereas the remaining pairs were classified by results from a standard physical resemblance questionnaire. In every case but one, the DNA analysis agreed with the questionnaire findings (Nichols & Bilbro, 1966). Additional related data are displayed in Table 1.

CTT families

The reared-together twins were adopted by mostly two-parent families (n = 47) but also by one single divorced mother. The data presented here were adjusted such that the families with triplets and two adopted pairs were counted just once. All twins and their families resided in North America. Most mothers and fathers were Caucasian (87.2% and 85.1%, respectively), with the remainder being Hispanic (2.1% and 2.1%, respectively), Asian (8.5% and 12.8%, respectively), or of mixed ancestry (2.1% of mothers).

Families raising reared-together twins were identified by online twin groups (36.2%) and personal referrals (27.7%) but also via television programs, radio interviews and print media. Like the parents of other young adoptees, these twins' rearing parents were mostly older, well educated, and employed in high-level occupations. Mothers' mean age was 46.81 years (SD = 6.49, range = 35–64), and fathers' mean age was 48.77 years (SD = 7.44, range = 35–66). Graduate or professional training, a college degree, or college-level courses had been completed by 100% of both mothers and fathers. The

majority of mothers held professional, technical, or managerial positions (66.0%), whereas the remainder worked in clerical or sales areas (4.3%) or either were retired/unemployed with college/professional experience, had earned professional degrees but were working in other fields, or were homemakers (29.8%). Most fathers held professional, technical, or managerial positions (85.1%), whereas the remainder worked in clerical, sales, or service areas (10.7%), worked in machine trades (2.1%), or were retired/unemployed with college or professional experience (2.1%). Primary reasons for adopting included infertility (66.0%), wanting another child (17.0%), and humanitarian concerns (10.6%). Nearly two thirds of the twins were the only children in their family (63.8%), whereas the other pairs were raised with one to six siblings, of which 35.3% were the biological children of their rearing parents.

VT sample

The virtual twin sample included 325 individuals who comprised 169 VT pairs. A total of 10 participants belonged to two or three pairs due to sets of twins (7 cases) or triplets (3 cases) whose members were paired with an adoptee or a biological child. The 169 VT pairs were organized into 106 VT–AdAd) pairs (30 same-sex male pairs, 22 same-sex female pairs, and 54 opposite-sex pairs) and 63 VT–AdBi pairs (19 same-sex male pairs, 16 same-sex female pairs, and 28 opposite-sex pairs). The majority of the adopted VTs (51.9%) came immediately to their adoptive home after birth, whereas the remainder had lived in one (32.9%), two (12.8%), three or four (1.6%), or eight (0.8%) prior situations.

The VT sample included 261 adoptees whose mean age at adoption was 63.97 days (*SD* = 96.57, range = 0–373). This measure was entered as age home from the hospital for the 64 biological children (*M* = 6.78 days, *SD* = 10.64, range = 0–60). These data are compared with those of the CTA and CTT twins in Table 1. The mean age of the VTs at the time of intelligence testing was 8.73 years (*SD* = 9.18, range = 4.01–54.84). The median age of the sample was 5.04 years, with approximately 75% of the pairs younger than 7.60 years and approximately 90% of the pairs younger than 17.62 years. VTs' age at participation and age at adoption are also displayed in Table 1 for comparison with the CTA and CTT twin samples. The mean difference in VT pair age was 3.06 months (*SD* = 2.72, range = 0–9.23). Efforts were made to test pair members on the same day, but that was not always possible. The mean interval between test administrations was 4.58 days (*SD* = 23.91, range = 0–25.50), slightly increasing the mean difference in age at testing to 3.13 months (*SD* = 2.75, range = 0–9.87).

The majority of the 325 VTs were Caucasian (59.1%), with the remainder being distributed among Hispanic (12.3%), American Indian (0.3%), Black (4.0%), Asian (4.6%), South American Indian (4.6%), mixed (14.2%), and other backgrounds (0.9%). The members of most pairs (65.7%) were of similar ethnicity. As specified by the VT criteria, among the 150 VT pairs whose members attended school at the time of testing, both siblings were enrolled in the same school grade, 58% were in the same school class, and 97.3% attended the same school.

VT families

Families in the VT sample came to the attention of the principal investigator through media presence (53.3%), referral by another individual (28.2%), or a "like-twins" website (12.2%) that no longer appears to be active. Other sources included participation in a related study, self-referral, and the principal investigator's website. The virtual twins were members of mostly two-parent families living in the United States, although three pairs came from Canada, two pairs came from Colombia, and one pair came from Spain.

As was true of the Chinese twins' parents, most VT mothers and fathers were older and held relatively high-level occupations. Mothers' mean age at the time of their children's testing was 44.29 years (*SD* = 8.67, range = 32–82). Fathers' mean age at the time of testing was 46.02 years (SD = 8.67, range = 33–89).[2] The majority of mothers (60.6%) and fathers (84.6%) were engaged in professional, technical, or managerial positions. Other children in the family, ranging in number from one to six, were present in

[2] The older ages of some parents reflect the fact that several adult VT pairs were included in the study. The *ns* for age are for mothers (153) and fathers (142); the *ns* for occupation are for mothers (156) and fathers (144). In addition to occasional missing data, single-parent families, and divorces, these data were adjusted to account for the fact that some children were part of more than one pair.

51.4% of the homes. Slightly more than half of these children (56.5%) were the biological children of the VTs' rearing parents.

Materials

All three parent groups received a mailed informed consent letter and questionnaires after providing their interest in study participation. Questionnaires included a comprehensive life history form (e.g., parental age and occupation, religious affiliation, twins' adoption history, twins' educational background, contact frequency), Child Behavior Checklist (parent and teacher versions; Achenbach & Rescorla, 2001), medical and dental inventories, Pre-Adoption Adversity (PAA) Questionnaire (Tan & Marfo, 2006), Personality Mini-Markers Form (Saucier, 1994), Adjective Checklist (Gough & Heilbrun, 1983), and revised Runco Ideational Behavior Scale (parent and teacher forms; O'Neal, Paek, & Runco, 2015). The few twins aged 18 years and older completed several of these questionnaires, but the current article includes data provided by parents only. Three families with reared-apart twins did not return completed research packets, but relevant information was often provided by the co-twins' parents.

A key component of this study was completion of the age-appropriate Wechsler Intelligence Test by each individual twin (https://www.pearsonclinical.com). This test was administered by local examiners hired by the principal investigator who were blind to the aims of the investigation. Using different testers for each member of a pair ensured that protocol administration and scoring were completed without bias from halo effects (examiners' expectations of similar performance in co-twins, mostly MZ) or contrast effects (examiners' expectations of different performance between co-twins, mostly DZ or VT). However, when administration and scoring rules are followed precisely in research settings, bias is unlikely even when the same tester evaluates both co-twins in a pair (Segal & Russell, 1991).

Results

Demographic characteristics

The mean age and age variance of the reared-apart twins exceeded those of the reared-together twins, differences that were statistically significant, $F = 36.01$, $p < .001$, $t(49.55) = 2.10$, $p < .05$. This difference was explained by the presence of two reared-apart pairs who were in their early 20 s. Age at adoption and time in the orphanage did not differ between the reared-apart and reared-together pairs.

IQ testing

The mean interval between IQ testing for the reared-apart co-twins was M = 10.00 days ($SD = 7.10$, range = 0–26). All reared-together twins were tested on the same day and by different examiners. Every protocol was reviewed for scoring accuracy upon receipt.

The mean IQ score for the full reared-apart twin sample was 109.27 ($SD = 14.54$) and did not differ between MZA ($M = 109.63$, $SD = 13.99$) and DZA ($M = 108.50$, $SD = 16.18$) twin pairs. Both zygosity groups scored approximately half a standard deviation above the population test mean of 100 ($SD = 15$). The mean IQ score for the reared-together twins ($M = 106.23$, $SD = 13.65$) did not differ between the MZT ($M = 106.66$, $SD = 13.89$) and DZT ($M = 103.64$, $SD = 12.25$) twin pairs. More important, the Full Scale IQ scores of the reared-apart and reared-together twins, either as a whole or by zygosity groups, did not differ. The Verbal IQ score was, however, significantly higher among the reared-apart pairs than among the reared-together pairs, $t(139) = 2.41$, $p < .05$, Cohen's $d = 0.44$, and was higher among the reared-apart MZ pairs than among the reared-together MZ pairs, $t(111) = 2.28$, $p < .05$, Cohen's $d = 0.47$. This difference in direction was also observed between the two DZ twin groups, although both sample sizes were modest. The mean IQ scores and related data for both twin groups are displayed in Tables 3A and 3B.

Among the reared-apart twins, the three IQ scores yielded by the Wechsler test (Full Scale IQ, Verbal IQ, and Performance IQ) were unrelated to contact measures (i.e., days before separation, separation to first contact, time from reunion to IQ testing, and percentage of lifetime apart). However, longer total contact time was marginally associated with lower Performance IQ ($r = -.27$, $p < .08$). In addition, Younger age at adoption was significantly associated with a higher Full Scale IQ ($r = -.40$, $p < .01$), Verbal IQ ($r = -.41$, $p < .01$), and Performance IQ ($r = -.31$, $p < .05$) scores. The Full Scale and Verbal IQ correlations with age at adoption remained statistically significant, or approached significance, after exclusion of one older twin whose adoption occurred at 17 years of age, with the exception of the Performance IQ. In contrast, age at adoption was unrelated to the three IQ scores of the reared-together twins.

Intraclass correlations and confidence intervals for the Full Scale IQ, Verbal IQ, and Performance IQ scores are shown in Table 4. The Full Scale IQ ($r_i = .51$, $p < .05$) and Verbal IQ ($r_i = .56$, $p < .01$) intraclass correlations for the MZA pairs were statistically significant, whereas the Performance IQ correlation ($r_i = .35$) approached statistical significance. These analyses were not performed for the DZA or DZT twins given the small number of pairs. The correlations for the MZA twins are lower than the correlations based on other childhood and adult reared-together twin samples, which are typically $r_i = .85$ or .86 for MZT twins and $r_i = .60$ for DZT twins (Segal, 2012; Segal & Russell, 1991). In contrast, the MZT correlations for Full Scale IQ ($r_i = .75$, $p < .001$), Verbal IQ ($r_i = .83$, $p < .001$), and Performance IQ ($r_i = .54$, $p < .001$) are closer to the expected values for these twins, likely due to the larger sample size of 43 pairs, and all were statistically significant. None of the intraclass correlations differed significantly between the two twin groups, as shown in Table 4.

CTA twins: Within-pair differences

The Full Scale IQ score difference for the CTA–MZ twins ranged from 1 to 30 points ($M = 11.93$, $SD = 7.49$). The difference for the CTT–MZ twins was significantly less, ranging from 0 to 21 points ($M = 7.88$, $SD = 5.88$), $t(56) = 2.14$, $p < .05$. The following measures were unrelated to the IQ difference within the CTA–MZ pairs: days before separation, time in the orphanage, number of living situations, age at adoption, health at adoption (symptom count), age at reunion, lifetime contact, test interval, number of siblings, Hollingshead social status index, and current health (symptom count). The possibility that the differential effects of adverse birth events (e.g., twin-to-twin transfusion; premature delivery) could have played a role in some cases could not be determined.

In a further attempt to uncover reasons for IQ differences within pairs, examination of the rearing circumstances and educational backgrounds of the MZA pair with the largest score discrepancy (30 points) was undertaken. Both twins had been adopted at 1.41 years of age, and both twins were 3.54 years old at the time of testing. The higher-scoring twin had entered a preschool setting at 1.92 years of age, whereas her sister did not attend school until 4.5 years of age. Their families' Hollingshead social status indices were 2 and 3, respectively. A second IQ testing at 6 years of age, when both twins were in kindergarten, showed a 9-point increase for the first twin and a 19-point increase for the second twin, reducing their score discrepancy to 20 points. This effect is characteristic of regression to the mean, in which repeated testing usually yields lower scores for high-scoring individuals and higher scores for low-scoring individuals. In this case, the within-pair IQ difference most likely reflects the twins' young age at testing, their difference in school attendance, and the higher-scoring twin's rearing in a lively suburban area compared with her co-twin's rearing in a small remote village.

VTs versus MZA and MZT twins

The VTs as a group showed a mean Full Scale IQ score of 105.37, approximately one third of a standard deviation above the population mean. They were outperformed by both the CTA ($M = 109.27$) and CTA–MZ ($M = 109.63=3$) twins, a difference that approached statistical significance for the CTA versus VT comparison. The CTA twins did, however, score significantly higher than the VTs on Verbal IQ. The VTs' age at testing showed significant but extremely modest correlations with the Full Scale ($r = .14$, $p < .01$) and Performance IQ ($r = .16$, $p < .01$) scores. Age at adoption also showed significant but

Table 3
Wechsler IQ Scores for Reared-Apart Twins (CTA), Reared-Together Twins (CTT) and Virtual Twins (VTs).

A. Wechsler IQ scores for reared-apart twins.[a]			
Full sample (N = 44 individuals)	*M*	*SD*	Range
Full Scale IQ[b]	109.27	14.54	79–137
Verbal IQ[c]	109.84	16.23	74–147
Performance IQ	106.61	14.83	70–132
MZA (n = 30)	*M*	*SD*	Range
Full Scale IQ[b]	109.63	13.99	79–136
Verbal IQ[c]	110.83	16.08	74–147
Performance IQ	105.80	15.42	70–129
DZA (n = 14)	*M*	*SD*	Range
Full Scale IQ	108.50	16.18	89–137
Verbal IQ	107.71	16.93	86–140
Performance IQ	108.36	13.88	84–132

B. Wechsler IQ scores for reared-together twins[a]			
Full sample (N = 97 individuals)	*M*	*SD*	Range
Full Scale IQ	106.23	13.65	72–147
Verbal IQ[c]	103.33	14.18	73–140
Performance IQ	107.26	14.73	67–145
MZT (n = 83)	*M*	*SD*	Range
Full Scale IQ	106.66	13.89	77–147
Verbal IQ[c]	103.64	14.32	75–140
Performance IQ	107.33	14.93	67–145
DZT (n = 14)	*M*	*SD*	Range
Full Scale IQ	103.64	12.25	72–119
Verbal IQ	101.50	13.63	73–130
Performance IQ	106.86	13.98	86–127

C. Wechsler IQ scores for virtual twins (N = 325)			
Full sample (N = 325 individuals)	*M*	*SD*	Range
Full Scale IQ[b]	105.37	13.42	70–148
Verbal IQ[c]	105.05	14.32	62–150
Performance IQ	105.06	13.79	70–144
VT–AdAd (n = 209)	*M*	*SD*	Range
Full Scale IQ[b]	103.83	12.36	70–143
Verbal IQ	104.30	13.41	62–138
Performance IQ[d]	103.06	12.79	70–135
VT–AdBi (n = 116)	*M*	*SD*	Range
Full Scale IQ[b]	108.15	14.79	72–148
Verbal IQ	106.40	15.79	62–150
Performance IQ[d]	108.65	14.83	71–144

Note. MZA, monozygotic reared-apart twins; DZA, dizygotic reared-apart twins; MZT, monozygotic reared-together twins; DZT, dizygotic reared-together twins; VT, virtual twins; AdAd, adopted–adopted; AdBi, adopted–biological p <. 07.

[a] Recent versions of the Wechsler IQ test do not yield separate Verbal IQ and Performance IQ; verbal and perceptual reasoning scores were entered instead.

[b] Full Scale IQ:
CTA > VT, $t(367) = 1.79$, p <<, .07
VT–AdBi > VT–AdAd, $p < .01$

[c] Verbal IQ:
CTA > CTT, $p < .05$
MZA > MZT, $p < .05$
CTA > VT, $t(367) = 2.05$, $p < .05$

[d] Performance IQ:
VT–AdBi >VT–AdAd, $p < .001$.

modest associations with the Full Scale ($r = -.15$, $p < .01$) and Performance ($r = -.13$, $p < .05$) IQ scores. As such, older VTs performed somewhat better than younger VTs, and VTs who had entered their home at younger ages performed somewhat better than those who arrived later, Mean IQ scores, standard deviations, and ranges for the virtual twins are shown in Table 3C.

Table 4
IQ intraclass correlations and 95% confidence intervals for reared-apart and teared-together monozygotic twins and virtual twins.

IQ score[a]	CTA–MZA *N* (pairs) = 15	CTT–MZT *N* (pairs) = 43	VT *N* (pairs = 169)
Full Scale IQ[b]	.51*	.75***	.28***
[95% CI]	[.03, .80]	[.74, .92]	[.14, .41]
Verbal IQ[c]	.56**	.83***	.20**
[95% CI]	[.01, .82]	[.58, .86]	[.05, .34]
Performance IQ[d]	.35	.54***	.27**
[95% CI]	[−.17, .72]	[.29, .72]	[.12, .40]

Note. CTA, reared-apart Chinese twins; MZA, monozygotic reared-apart twins; CTT, reared-together Chinese twins; MZT, monozygotic reared-together twins; VT, virtual twins; CI, confidence interval.
*$p < .05$.
**$p < .01$.
***$p < .001$.
[a]Small sample sizes precluded calculation of intraclass correlations for dizygotic reared-apart and reared-together twin pairs.
[b]Full Scale IQ:
CTAr_i, CTTr_i, *ns*
CTAr_i, VTr_i, *ns*
CTTr_i > VTr_i (critical ratio = 4.56, $p < .001$).
[c]Verbal IQ:
CTAr_i, CTTr_i, *ns*
CTAr_i, VTr_i, *ns*
CTTr_i > VTr_i [critical ratio = 5.68, $p < .001$).
[d]Performance IQ:
CTAr_i, CTTr_i, *ns*
CTAr_i, VTr_i, *ns*
CTTr_i > VTr_i, *ns.*

Sex was unrelated to Full Scale IQ, Verbal IQ, and Performance IQ in the VT sample, yielding correlations of negligible magnitude. It was possible that some members of VT pairs differing in ethnicity were subjected to particular school events affecting their intellectual performance. VTs representing minority groups in their communities may have experienced lowered expectations by teachers or taunting by classmates. However, mean test score differences between members of VT pairs concordant (n = 217) and discordant (n = 108) for ethnicity were nonsignificant [Full Scale IQ: $t(323) = 1.17$, *ns*; Verbal IQ: $t(323) = -0.482$, *ns*; Performance IQ: $t(323) = -1.31$, *ns*]. Both twin groups were composed nearly exclusively of female twins and exclusively of Asian twins, precluding these analyses.

The VT intraclass correlations are displayed in Table 4 for comparative purposes with the two twin groups. As anticipated, the VTs' Full Scale IQ, Verbal IQ, and Performance IQ correlations fell below those of both MZ twin groups, consistent with the VTs' lack of genetic relatedness. However, a statistically significant difference was reached only between the CTT and VTs' Full Scale and Verbal IQs, likely an effect of the small CTA–MZ sample size.

The two twin groups included mostly female pairs, prompting examination of the mean scores and intraclass correlations for the 38 VT same-sex female pairs. The mean Full Scale IQ was higher for the 38 same-sex female CTA twins (M = 110.29, SD = 13.86) than for the 76 same-sex female VTs (M = 106.07, SD = 12.66), replicating the result for the full samples, although the difference was not statistically significant. Mean score differences were not observed between the 95 female same-sex CTT twins and 76 female same-sex VTs, as in the previous analysis. The VT intraclass correlation was reduced for the Full Scale IQ (r_i = .14 vs. .28) and Performance IQ (r_i = .03 vs. .27) scores, was essentially unchanged for the Verbal IQ score (r_i = .19 vs. .20), and none was significant. The lower intraclass IQ correlations would seem to reflect the lack of genetic relatedness between the VT same-sex female twins and reduced sample size (n [pairs] = 38); possible sex-based family socialization was not supported.

As indicated earlier, insightful comparisons observed in prior research concern the intelligence test performance of VT–AdBi and VT–AdAd pairs as well as of biological and adopted children. Most interesting, the Full Scale, Verbal, and Performance IQ correlations were statistically significant for the VT–AdBi pairs but not for the VT–AdAd pairs. Furthermore, the VT–AdBi pairs showed significantly greater

Full Scale IQ resemblance than the VT–AdAd pairs (r_i = .47 and .10, respectively). The correlational differences for the Verbal and Performance IQ scores showed the same pattern, as summarized in Table 5.

Consistent with expectations, the individual biological children (n = 64) significantly outperformed the individual adopted children (n = 261) in Full Scale IQ, $t(323) = -3.86$, $p < .001$, Verbal IQ, $t(84.06) = -2.36$, $p < .01$, and Performance IQ, $t(323) = -3.67$, $p < .001$.

These data were further examined by paired t tests using the VT–AdBi pairs only. As expected, the biological children obtained significantly higher scores across all three IQ measures than their same-age adopted siblings [Full Scale IQ: $t(61) = 4.04$, $p < .001$; Verbal IQ: $t(61) = 3.41$, $p = .001$; Performance IQ: $t(61) = 2.30$, $p < .01$].

Discussion

The first comprehensive report of a research program involving three novel sibships (CTA, CTT, and VT pairs) focused on family background and general intelligence. Key findings were as follows. First, the age, education, and occupational levels of the twins' parents, although superior to those of the general population, are characteristic of adoptive parents. These mothers and fathers were generally middle-aged, well educated, and employed in high-level positions. Given that fertility issues were their primary reason for adopting a child, it is expected that mothers and fathers would be older on average. Adoption agencies also screen prospective couples for financial security and other resources to ensure child well-being, thereby eliminating families incapable of providing such support.

Second, both the reared-apart and reared-together twins scored above the population mean in general intelligence. Above-average IQ scores are typical of volunteer twin samples because families whose children display learning problems and/or physical difficulties are less likely to seek out or accept research opportunities. Although healthier infants are often adopted sooner than less healthy infants and are more likely to succeed in academic tasks (Tan, 2009), it is worth noting that younger age at adoption was associated with higher Full Scale, Verbal, and Performance IQ scores *only* among the reared-apart twins, and the association was slight. The reasons for this are uncertain, especially given that age at adoption and time in the orphanage did not differ between the two twin groups. It is also the case that few reared-apart twins had been found together (13.6%), whereas nearly all the reared-together twins had been (90%). Some parents may have abandoned a healthier twin sooner (at a younger age), hoping that the infant would survive and have a favorable chance for adoption. Reasons for abandoning Chinese twins together may be more variable than those for abandoning singletons. For example, parents may be evaluating the social and financial consequences of keeping or raising two female twins.

Third, the mean Full Scale IQ score did not differ between reared-apart and reared-together twins. This finding supports the generalizability of the former to the larger young twin population, although the modest sample sizes urge caution. Worth noting is that the reared-apart twins scored significantly higher in Verbal IQ than the reared-together twins. Twins' early average language deficit, evidenced by private words, unusual gestures, and/or shared understandings, is well documented (Thorpe, Greenwood, Eivers, & Rutter, 2001). Such behaviors are believed to evolve from co-twins' constant companionship with a same-age child. The reasoning to support this explanation is that twins receive less language experience with adults than non-twin children, a situation that may partly explain their relatively lower verbal scores. Nearly two thirds of the reared-together twins were raised without other siblings, consistent with this view in that the twins probably spent considerable time together. Interestingly, the number of other children in the family correlated modestly, but *negatively,* with Verbal IQ in each sample both separately (CTA: $r = -.28$, $p < .07$; CTT: $r = -.23$, $p < .05$) and combined ($r = -.16$, $p < .05$), linking larger sibships to lower verbal scores. However, the presence of other children in the family may have different language implications for reared-apart and reared-together twins; reared-apart twins are not in competition with a same-age sibling for parental time and attention, whereas reared-together twins could be. Regardless, most reared-together twins' language skills improve as the twins acquire more varied social experiences (Thorpe et al., 2001).

Fourth, the magnitude of the three IQ intraclass correlations for the reared-together MZ twins was generally consistent with previous reports, indicating genetic effects. In contrast, the correlations were

Table 5
Full scale, verbal, and performance IQ scores and intraclass correlations for adoptees, biological children, VT–AdAd pairs, and VT–AdBi pairs.

	n (individuals)	*M*	(*SD*)
Full scale[a]			
VT–Ad	261	103.98	(12.55)
VT–Bi	64	111.05	(15.34)
Verbal[b]			
VT–Ad	261	104.00	(13.48)
VT–Bi	64	109.33	(16.76)
Performance[c]			
VT–Ad	261	103.69	(13.19)
VT–Bi	64	110.63	(14.89)

	n (pairs)[d]	*M*	(*SD*)	Difference	(*SD*)	r_i	95% CI
Full scale[e]							
VT–AdAd	106	103.94	(13.16)	7.03	(13.70)	.10	[−.09, .28]
VT–AdBi	62	110.97	(15.58)			.47***	[.25, .64]
Verbal							
VT–AdAd	106	102.56	(13.50)	7.03	(16.26)	.07	[.12, .26]
VT–AdBi	62	109.60	(16.84)			.36**	[.13, .56]
Performance							
VT–AdAd	106	105.56	(14.50)	4.77	(16.34)	.16*	[.03, .34]
VT–AdBi	62	110.34	(15.01)			.36**	[.13, .56]

Note. VT, virtual twins; Ad, adopted; Bi, biological.
*$p < .05$.
**$p < .01$.
***$p < .001$.
[a]$t(323) = -3.86$, $p < .001$.
[b]$t(84.1) = -2.36$, $p < .01$.
[c]$t(323) = -3.67$, $p < .001$.
[d]One pair was omitted from these analyses due to its unusual family structure; each member of a same-sex couple had conceived a biological child with a different partner.
[e]VT–AdBi r_i > VT–AdAd r_i, $p < .01$ (critical ratio = 2.54).

somewhat reduced for the reared-apart MZ twins but still statistically significant. The size of the MZA correlations was not unexpected because it most likely reflects the modest sample size and/or the twins' different educational and family experiences that have their greatest impact at a young age (Segal, 2012). (The effect size for the CTA–CTT correlational difference in Full Scale IQ was modest at ~ .40; sample sizes of 185 reared-apart and 64 reared-together pairs would be required to find a meaningful difference with an allocation ratio of 2.87, power of .80, and a significance level of .05.)

The young age of some of the twins may have also played a role in their IQ test performance given that IQ stability is generally not achieved until 6 or 7 years of age (Gottfried, Gottfried, & Guerin, 2006, 2009; Schneider, Niklas, & Schmiedeler, 2014). A somewhat higher percentage of MZT twins (56%) than of MZA twins (40%) were below 7 years of age, although the difference in their outcomes was slight except for the CTAs' superior Verbal IQ score. It will be of interest to revisit the intellectual development of the reared-apart twins to determine whether their scores show an expected convergence over time, indicative of genetic effects, as was shown for the single MZA pair with the largest score discrepancy and for MZ reared-together twins more generally. In contrast, DZ reared-together twins tend to show increased IQ divergence as they progress from childhood to adolescence (Bouchard, 2013; Wilson, 1978). Follow-up data in general ability and in other behavioral and physical domains are currently being collected.

Fifth, the VTs showed reduced intellectual resemblance relative to the two twin groups, as expected given their lack of genetic relatedness. A follow-up study of 43 VT pairs showed a decline in their Full Scale IQ correlation from .30 to .11 at the mean ages of 5.11 and 10.77 years, respectively. Not surprisingly, their within-pair difference increased from 10.74 to 14.12, respectively, at these time points (Segal, McGuire, Havlena, Gill, & Hershberger, 2007). These findings reflect the waning of shared environmental effects and/or the increased expression of trait-relevant genes as children

age. However, the most provocative finding was the greater intellectual resemblance of the VT–AdBi pairs than of the VT–AdAd pairs. This effect appears to be largely due to the correlation between the genotype of the biological child and the environment of the adoptee. Nevertheless, the adoptees in the VT–AdBi pairs did not perform as well as the biological children.

The reduced IQ scores of the VT adoptees, relative to the CTA and CTT twins, is important to consider. This reduction is most likely explained by their presumably heterogeneous biological family backgrounds. However, the twins were also adoptees, yet they scored significantly higher. The reasons for the twins' relinquishment would seem to be important. The twins were born to married couples who wanted children and were prepared to raise them but who were subject to both China's One-Child Policy and cultural preference for male children. Thus, the genetic backgrounds of the twins' parents would probably not include tendencies toward impulsivity (Eroğlu & Şahan, 2018), sexual promiscuity (Rodgers, Rowe, & Buster, 1999), and/or financial insecurity (Hodgkinson, Beers, Southammakosane, & Lewin, 2014) that characterize many, but not all, unwed couples confronting unwanted or unplanned pregnancies.

Limitations

Limitations to the current study are the relatively modest sample sizes, especially for the DZ twins, precluding calculation of IQ intraclass correlations for these twins. In addition, each pair was assessed at a somewhat different age, such that the developmental stages were not strictly uniform across pairs. A second measure of general intelligence would have also been desirable to include by way of within-sample replication. Fortunately, other behavioral domains to be reported on in the future (e.g., personality) were assessed with multiple measures and, as indicated, the general intelligence test is being administered a second time as the follow-up study proceeds.

In summary, data gathered from young reared-apart and reared-together twins appear to be applicable to the larger twin population. This conclusion is based on the general lack of difference between these two pair types in measured intelligence. An important exception concerns the Verbal IQ score, which was higher among the reared-apart twins than among the reared-together twins. However, the significant IQ intraclass correlations for the reared-apart twins, although somewhat below those of the reared-together twins, support the large number of both twin and adoption studies that find genetic effects on general intelligence and special mental abilities (Plomin, 2018). The extent to which findings from twin studies extend to the general population has been a matter of some debate, but the current consensus is that they do extend to the general population (Christensen, Vaupel, Holm, & Yashin, 1995; Munn-Chernoff et al., 2013). Exceptions include traits for which developmental effects may differ between twins and non-twins (e.g., cardiac conditions, midline abnormalities such as spina bifida) that more frequently affect multiple-birth children than singletons (Segal, 2017; Stanford Children's Health, 2020).

Applied and future directions

Applied directions of the current findings concern the rearing and educating of young twins and near-in-age children. Their importance is underlined by the generally high rate of twinning and blending of families in Western nations. Most significantly, none of the findings discussed above, such as the higher Verbal IQ of the reared-apart twins, should be interpreted as grounds for placing adopted twins with different families. In fact, the quality of parental verbal interaction with twins may successfully offset anticipated language delays in some cases (Rendle-Short, Skelt, & Bramley, 2015). This approach to raising twins also has relevance for educational administrators who often enforce mandatory separation of twins at school, fearing that these children will not develop a sense of individuality. However, such policies can cause anxiety and preoccupation with the co-twin in some cases (White et al., 2018). Special training for teachers and parents may facilitate twins' language abilities without imposing separation. However, opportunities to be apart from the twin, if introduced gradually and appropriately, may benefit twins' language skills. In fact, Webbink, Hay, and Visscher (2007) found that nonseparated twins did better at language and math than separated twins.

It is also critical to consider the significance of the twin relationship in cases of twin adoptions. Research shows that reunited adult twins indicate strong feelings of closeness and familiarity both upon meeting and at the time of research participation (Segal, Hershberger, & Arad, 2003). MZA twins' ratings exceeded those of DZA twins on average, mirroring what numerous investigators have reported regarding twin relations (Segal, 2013). Regret, anger, and sadness at not having known each other have been variously expressed by twins who have not grown up together. Thus, adoption agencies and families should make every effort to keep twins and siblings together. As indicated above, an early report of the Chinese twins' parents' observations of their child's initial meeting and departure indicated considerable happiness and sadness, respectively, especially among the older pairs (Segal et al., 2011). To their credit, the majority of CTA families arrange for twins to meet as often as possible, although this is sometimes difficult given the physical distance between them; in such cases, twins have relied on internet communications, which are not ideal. The development of within-pair relations as the CTA twins age is another key area for further study.

Other novel sibling groups, such as same-sex VTs with the same birthday and VTs who look very much alike, would refine and most likely reinforce the current findings. The pair members might feel more "twin-like" than others, but a genetic perspective and the current study predict a lack of intellectual resemblance between them. Classmates are sometimes born on the same day, yet it is hard to imagine how this shared feature would override genetically based individual differences in ability. A study of unrelated look-alikes found negligible within-pair similarities in personality and self-esteem (Segal, Hernandez, Graham, & Ettinger, 2018). Unrelated look-alikes parallel MZA twins in that they closely resemble one another physically and are not brought up together, but they share no genes in common by descent. As Rowe (1995) aptly put it, "Personality and temperament reside in the brain, not in a face" (p. 48). Evidence indicates that Rowe's words apply to intellect as well.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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