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Genetic and experiential influences on behavior: Twins reunited at seventy-eight years

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Abstract

Twins living in different countries offer opportunities to explore associations between observed differences and experiential effects. This report compared the life histories, cognitive abilities, personality traits, psychomotor skills, medical characteristics, job satisfaction, social support and social relations of dizygotic (DZ) female twins reunited at 78, the world's longest separated set. The twins' advanced age also enabled a study of how co-twin differences in aging may be associated with current behavioral and social differences. Consistent with previous studies, these dizygotic reared apart (DZA) twins showed discordance across some, but not all, traits. Their different rearing situations and life histories may explain current differences in their responses to meeting their twin. This case highlights the importance of both genetic and rearing factors on behavior, but does not allow firm conclusions regarding the extent to which these sources explain individual developmental differences. However, such data contribute to the growing number of cross-culturally separated twins, generating novel hypotheses that may be assessed using larger samples.

Keywords

Twins; Reared-apart; Adoption; Intelligence; Personality; Health; Job satisfaction

1. Introduction

Twins reared apart help identify genetic and environmental influences on behavioral development (Segal, 2012). Monozygotic twins reared apart (MZA) allow direct estimates of genetic effects on behavior and health, because they share all their genes, but differ in their environments. Dizygotic twins reared apart (DZA) differ in their environments, but share only half their genes, on average. Greater MZA than DZA resemblance demonstrates genetic influence on measured traits (Martin, Boomsma, & Machin, 1997). Inclusion of DZA twins also allows tests of interactions between genes and environments. Unfortunately, past reared-apart twin studies did not recruit DZA twins (Juel-Nielsen, 1965; Newman, Freeman, & Holzinger, 1937; Shields, 1962), although Shields provided limited data on 11

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pairs. The Minnesota Study of Twins Reared Apart (MISTRA) was the first to accept participants without reference to zygosity (Tellegen et al., 1988).

A criticism of reared-apart twin research is that co-twins are generally raised or living in similar cultures. It is reasoned that twins' common circumstances limit the range of behavioral expression resulting from possible gene $\times$ environment interactions, obscuring environmental effects on behavior. Studies including twins raised in different countries were the MISTRA (12/137 pairs) and an ongoing study of young separated Chinese twins (2/15 pairs; Segal, Stohs, & Evans, 2011). However, confidentiality generally mandates that data from these pairs be part of group findings.

Recently, due largely to Internet searches, some twins reared in different countries have been identified and studied, with results published as case studies (Segal & Cortez, 2014; Segal & Hur, 2008). Data from accumulated cases can be pooled and examined for trends.

1.1. Current study

Most reunited twins are MZA, because their matched appearance eases identification, or leads to unexpected discovery of twin-ship. Most recently reunited pairs are young adults, perhaps because younger individuals use the Internet more frequently and skillfully than older individuals (Pew, 2014). Consequently, DZA and older twins are less likely to be reunited and studied than MZA and younger twins. The current report bridges these gaps via a behavioral assessment of DZA female twins reunited at age seventy-eight. Both were raised in England, although one relocated to the United States in her late twenties. Both twins live in small cities outside urban areas.

1.2. Identification of the twins

The twins came to the attention of the first author in June 2013 via e-mail from the son (S) of the twin in the United States (US). US received a letter in April 2013 from her twin sister's (UK) daughter (D) inquiring about US's maternal family. US and S called D and it was determined that D had located her mother's twin. Raised by her biological mother, US knew she was a twin. UK knew she was adopted, but was unaware of her twinship. The twins were reunited at seventy-eight, in May 2014, in California. They and their adult children participated in a two-day assessment at a nearby university. The twins are shown in Figure 1.

2. Methods

2.1. Materials and measures

Following informed consent procedures, the twins separately completed interviews and tasks described below. Protocol evaluation was completed by two individuals blind to the other rater's scores for consistency. D and S completed modified versions of the assessment.

Given the twins' advanced age and UK's reading difficulties, many items were read to both twins and recorded by an examiner. UK remembers having a severe illness at about age five which impaired her reading skills. This may have affected other cognitive functions. D assisted in some administrations of her mother's interviews.

The twins were DZ based on discordance for five/fifteen short tandem repeat (STR) markers. DNA analysis was performed by *Affiliated Genetics*, in Salt Lake City, Utah.

2.1.1. Life History Interview—The Life History Interview covered the twins' separation and subsequent life experiences. It was adapted from the MISTRA Life History Form.

2.1.2. Cognitive and general intelligence tests—Twins were administered the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) to assess basic cognitive status, such as awareness of dates/places. They also completed the Stroop Color and Color Word Tasks (Trenerry, Crosson, DeBoe, & Lever, 1989), Word List Memory Task (immediate/delayed recall and recognition) from the Consortium to Establish a Registry for Alzheimer's Disease (CERAD: Morris, Mohs, Rogers, Fillenbaum, & Heyman, 1989) and Trail Making Tasks A and B (Army Individual Test Battery, 1944).

The Wechsler Adult Intelligence Scale (WAIS-IV) was administered to each twin by different outside examiners (Pearson Education, 2008). Cognitive tasks from the Hawaii Ability Battery (DeFries et al., 1979) and Kit of Factor-Referenced Cognitive Tests (Ekstrom, French, Harman, & Dermen, 1976) included Visual Memory (immediate/delayed), Different Uses (spontaneous flexibility), Thing Categories (ideational fluency), and Word Beginnings and Endings (word fluency). UK could not complete the Word Beginnings and Endings test.

2.1.3. Personality inventories—The twins completed the 300-item Adjective Checklist (ACL), indicating which were self-descriptive (Gough & Heilbrun, 1983). The adult children used the ACL to describe their mother. Other questionnaires included the Personality Mini-Markers (Saucier, 1994) and 60-item NEO-PI-R (McCrae & Costa, 2004), yielding scores on the Big Five personality traits.

2.1.4. Medical health—The twins' heights and weights were measured. They also completed a detailed medical questionnaire.

2.1.5. Psychomotor skills—Handedness was classified using the Crovitz and Zener (1962) Group Test for Assessing Hand and Eye Dominance. All fourteen items were administered behaviorally. Eye dominance was assessed by having twins focus on an object, then narrow their field of vision until using one eye.

Psychomotor skills were evaluated with the Grooved Pegboard Test (Trites, 2002), assessing dexterity and complex visual-motor coordination. Participants match the groove of 25 pegs with the grooves of the board. Participants use their dominant hand to place the pegs in a left to right direction (Trial 1); participants use the non-dominant hand in the opposite direction (Trial 2).

2.1.6. Job satisfaction—Twins completed the 20-item form of the Minnesota Job Satisfaction Questionnaire (Weiss, Dawis, England, & Lofquist, 1967). The questionnaire yields scores for Extrinsic, Intrinsic and Overall Job Satisfaction. A separate overall job satisfaction item was included.

2.1.7. Perceived social support—The Medical Outcomes Study Social Support Scale (MOS-SSS; Sherbourne & Stewart, 1991) assessed the availability of overall functional support and four functional support indices: emotional, tangible, affectionate, and positive social interaction.

2.1.8. Twin relationship—The psychological significance of meeting their twin was assessed via individual and joint videotaped interviews.

3. Results

3.1. Results presented by assessment

3.1.1. Life History Interview—The twins were born on February 28, 1936 to a thirty-three-year-old mother in a small town near London. Given financial challenges and societal views toward single mothers, their mother attempted to relinquish one twin for adoption. UK was adopted quickly; US considered to be “less adoptable” due to scoliosis was not. The twins were separated by age 5 months, with no contact until their telephone call at age seventy-seven.

US was raised in England by the twins’ biological mother (domestic servant), living in approximately three different London area homes. Her mother married when US was fifteen. Her fifty-one-year-old stepfather (transport signalman) worked for the railway system. His grown biological son and two grown stepdaughters from a previous marriage did not live with US.

US's favorite school subject was English composition and her least favorite was algebra. She considered her school ranking to be in the bottom third. US left school at fifteen, and was employed in various office positions before joining the Women's Royal Navy (WRENs) at twenty-five. (UK never considered joining the WRENs.) While stationed in Malta she met her husband, a thirty-four-year-old serviceman with an A.A. degree in real estate appraisal, and married at twenty-eight. They moved to Sicily for one year before moving to the United States. US delivered two sons eighteen months apart, in 1965 and 1967. She worked with her husband managing rental homes before retiring at age fifty-seven, then provided volunteer counseling for young pregnant women.

US has engaged regularly in religious activities (Church of England). At thirty-six, she became a born-again Christian (Grace Bible Fellowship), pursuing religious activities two to three times per day.

UK was adopted by a thirty-year-old mother (housewife, until UK's teenage years when she became a catering services manager) and thirty-four-year-old father (bus driver and conductor, later chauffeur). Following her parents’ separation when UK was under six, she was raised as an only child by her adoptive mother. She had little contact with her adoptive father until her late-twenties. UK moved seven times between ages six and twenty-six, until marrying.

UK reports being an average student who enjoyed geography, but disliked reading. She left school at fifteen and worked at a printers’ shop binding books by hand. She stopped working

at twenty-five to marry; her three daughters were born in 1962, 1966 and 1970. Her husband (a builder) was six months younger and had also left school at age fifteen. Over the years UK held several part-time jobs, most recently in a plant nursery. She engaged in daily religious activities (Church of England) from childhood through young adulthood. She was baptized at age forty-nine and engages regularly in religious activities (Mormon Church; Church of Jesus Christ of Latter-day Saints, known as Mormons).

3.1.2. Cognitive tests

3.1.2.1. Mental status: Both twins scored relatively low on the MMSE. US scored 22/30 and UK scored 19/30. Scores below 25 suggest possible dementia, but this finding should be interpreted cautiously as will be discussed.

3.1.2.2. Stroop C and CW: The twins differed substantially in their completion times for the Stroop C (reading color words; a measure of processing speed) and Stroop CW (naming the font color of words written in different colors; a measure of inhibition). As expected, both twins performed better on the Stroop C than the Stroop CW. US had substantially faster times for both measures; completion times (in seconds) for US and UK were 74.7 vs. 219.0 (Stroop C) and 155.6 vs. 222.0 (Stroop CW), respectively. US also completed both tasks with fewer errors (0 and 2) than UK (7 and 3).

3.1.2.3. Verbal memory: Three episodic memory scores were derived from the CERAD 10-item word test. The sum of correctly recalled items (three trials) provides a measure of immediate recall. Delayed recall and delayed recognition of the 10 items were also assessed approximately 15 min later. Immediate recall scores were low for US (13/30 correctly recalled) and in the normal range for UK (16/30 correctly recalled). UK recalled more words than her sister, even though UK could not read 5/10 words during the initial trial, requiring interviewer assistance. Delayed recall was within the normal range for both twins. US recalled 4/10 words and UK recalled 5/10. Both twins scored a perfect 20/20 on delayed recognition.

3.1.2.4. Trails A and B: The Trail Making Task assessed psychomotor speed (Trails A) and set-shifting/complex sequencing (Trails B). As expected, both twins performed better on Trails A than B, but US completed both tasks faster than UK. Completion times (in seconds) for US and UK were 41.3 vs. 54.4 (Trails A) and 131.4 and 158.2 (Trails B), respectively.

3.1.2.5. WAIS-IV: The twins scored eleven points apart on the WAIS-IV, with scores of 93 (US) and 82 (UK). Their scores are, respectively, 0.47 SD and 1.20 SD below the test's mean (100 ± 15). More informative are the twins' IQ subtest profiles, indicating differing patterns of strengths and weaknesses. When comparing profiles, it may be most effective to examine shape (Pearson r), elevation (absolute mean difference) and scatter (absolute variance difference) separately (Furr, 2010), depicted in Fig.2. The double-entry intraclass correlation (ICC) was .02, but should be interpreted cautiously given negative average covariance among items. Shape similarity was negligible, while scatter showed slight dissimilarity.

3.1.2.6. Additional cognitive tests: Complete data were available for only four special cognitive ability tasks (see Fig. 3), so profile statistics were not calculated. The profiles appear concordant with the exception of the Things test, a measure of ideational fluency, on which UK excelled.

3.1.3. Personality—An ICC of .98 ($p < .001$) indicated remarkable profile similarity for the twins across 39 ACL scales. The shape and elevation were quite similar, although slight dissimilarity in scatter was detected (see Fig. 4).

Each twins' reliability on the ACL was assessed by comparing her responses with those of her adult child who described her. The ICCs and Pearson correlations indicated agreement, with some differences in elevation and scatter (see Table 1).

The twins' profiles for the Personality Mini-Markers and NEO are shown in Figs. 5 and 6, respectively. The Mini-Markers indicates little systematic resemblance between the twins, while the NEO reveals generally similar shape, but different positioning. Discrepancies as to the higher scoring twin were noted for Neuroticism and Agreeableness.

3.1.4. Medical health—US was 146 lb and 63.35 in. tall; UK was 143 lb and 61.63 in. tall. Their body mass indices were 25.7 and 26.5, respectively.

Menarche occurred at sixteen for US and at ten for UK. This difference exceeds that for twins reared apart (MZA: 1.07, DZA: 1.67) and together (MZ: 0.64, DZ: 1.43; Segal & Stohs, 2007). Both twins recalled fairly regular menses. UK delivered children at twenty-six, thirty and thirty-four; US delivered children at twenty-eight and thirty-one. UK possibly lost one twin early during her third pregnancy. Both were diagnosed with a prolapsed womb and both underwent hysterectomies, US in her fifties and UK at age forty-five.

US was diagnosed with non-Hodgkins lymphoma at seventy-four, but has been in remission following chemotherapy. US also experiences hearing difficulties, partially alleviated by a hearing aid. However, UK listed nearly twice as many physical complaints across her lifetime (55) than US (31). Their common symptoms include penicillin allergy, cataracts, glaucoma and heart problems, although only US received a pacemaker (2014). UK never smoked, while US smoked under ten cigarettes/day from fourteen to her mid-thirties.

US has engaged in more frequent and strenuous activities, whereas UK has preferred mild activities. Both twins first participated in synchronized swimming in mid-life. After age fifty, both twins have pursued fairly constant, albeit different, physical activity levels.

3.1.5. Psychomotor skills—Handedness and Eye Dominance. US was right-handed (score = 15), while UK showed mixed handedness (score = 34). UK, originally right-handed, had broken her right wrist in 2010 and used her left hand during recovery. However, she used her right hand to place pegs in the dominant hand condition. UK showed mixed eye dominance, but preferred her right eye, while US favored her left eye consistently.

Both twins correctly placed 25 pegs during both trials. However, UK completed the task nearly twice as quickly (trial 1: 1 min, 20 s; trial 2: 1 min, 43 s) as US (trial 1: 2 min, 9 s; trial 2: 2 min, 15 s). The twins had four peg drops, distributed differently across trials.

3.1.6. Job satisfaction—Both twins were very satisfied with their primary occupations (US: Navy WRENs, 2.50 years; UK: Printer's Shop, 15.00 years), although overall US was “very satisfied” and UK was “satisfied.” Their intrinsic, extrinsic and general satisfaction scores were 54, 26 and 88 (US) and 54, 22 and 84 (UK), respectively. These scores exceeded those of participants in the general reference group (47.14, 19.98 and 74.85) and MISTRA (49.37, 21.23 and 78.64; Arvey, Bouchard, Segal, & Abraham, 1989).

3.1.7. Perceived social support—US had higher scores than UK for overall support and the four subscales. However, neither appeared at risk for deficient social support. The lowest response on any item for both twins was 3/5, signifying support available some of the time for each item. Both endorsed a score of 5/5 (support available all the time) for several items, suggesting they are supported across multiple domains.

3.1.8. Twin relationship—US believed that finding her twin would be difficult and was contented with her life, so did not wish to jeopardize her situation. Had the opportunity arisen when she was younger she admits she would have been less cautious. However, she was excited when D found her, especially by the prospect of research participation. US viewed meeting her twin as an opportunity from God.

UK was uninterested in locating biological kin while her adoptive mother was alive. However, despite her satisfaction with life, at age sixty-five UK requested her birth certificate and asked D to research her family history. She was “delighted” to find a sister, and “speechlessly joyful” to learn that this sister was a twin. She was eager to establish contact and to continue the relationship. UK and D spent six days with her sister's family when the study concluded. The twins experienced some communication difficulties, given US's hearing problem and UK's strong British accent.

4. Discussion

4.1. A discussion of results across assessment areas

4.1.1. Life history—The twins' life histories differed despite both being raised by single mothers, and leaving school at fifteen to work. US traveled and lived abroad in her twenties while in the WRENs, relocating to the United States as a young adult. UK remained in her hometown after age eighteen, but traveled extensively within England, and took several trips abroad in her fifties. UK's relatively later foreign travel is consistent with her considerably higher score on Openness to Experience, although US scored higher on Extraversion.

4.1.2. Cognition and General Intelligence—Both twins' relatively low MMSE scores may underestimate their mental status. Questions regarding name and/or address of the location may have been inaccessible to many visitors. Their visit was planned over many months, yet the twins did not make their own travel plans and were closely supervised during the visit, so did not need to attend closely to their surroundings. US lost points

spelling *world* backwards, suggesting some working memory loss. UK was unable to spell *world* forwards or backwards; her lower score could reflect literacy deficiencies rather than working memory loss. Both twins had difficulty repeating “no if’s, and’s or but’s,” a language measure (Chopra, Cavalieri, & Libon, 2007).

Both twins performed within the normal range on the immediate and delayed recall tasks for their age and IQ level (Beeri et al., 2006; Jones, Greer, & Cox, 2011). Although US had stronger reading skills, UK performed better on episodic memory measures; perhaps UK’s reading problems heightened other abilities. As expected, most of UK’s errors occurred during the Stroop C, a test requiring word reading. In addition, UK’s time did not increase on the Stroop CW, suggesting that the words themselves were not as much of a distraction to her as they may have been to US, who is a stronger reader. In fact, better readers show more Stroop interference (Protopapas, Archonti, & Skaloumbakas, 2007).

The twins’ IQ scores of 93 (US) and 82 (UK) were in the average and low average ranges, respectively. These scores may partly reflect both twins’ lack of formal education. US’s higher score may be variously explained by her participation in a book club at the time of assessment, as well as UK’s reading difficulties. The twins’ IQ discrepancy is consistent with the mean ten-point DZT co-twin difference (Plomin & DeFries, 1980), while slightly exceeding that of the MISTRA DZA co-twins (8.78, $SD = 7.09$, range 0–25 points; Segal, 2012). Their only marked difference in cognitive abilities concerned ideational fluency (Things test) on which UK excelled. Interview sessions with UK revealed considerable imaginative processes; she also scored higher than US on Openness to Experience.

4.1.3. Personality—Despite the similar shape and elevation of the ACL scale scores, the scatter may be most reflective of these twins’ personality profiles. This conclusion is corroborated by their lack of resemblance on the Mini-Markers and NEO. US scored higher on Dominance/Extraversion across all three personality inventories, consistent with the twins’ self-reports during individual and joint interviews.

The children’s ACL ratings of their respective parent showed good agreement with the twins’ self-ratings in shape and elevation, although some scatter was noted. Not surprisingly, the parental ratings done by each child showed less concordance than those between each child and parent, except for the difference in elevation.

4.1.4. Medical health—The twins’ shared some medical complaints, but UK indicated more problems than US. It is difficult to pinpoint the source of this difference other than genetically based differences in aging. However, UK’s access to free national health care may have prompted her to seek assistance more readily than US who has private health insurance.

4.1.5. Psychomotor skills—UK was interested in crafts and had many opportunities to exercise fine motor skills, possibly explaining her faster times on the Grooved Pegboard. Typically, motor skills are positively associated with mental processing speed (see Kochunov et al., 2010). In the present case, however, US was faster than her twin on both the Stroop and Trail Making tasks.

UK's mixed handedness and eye dominance are consistent with the elevated frequency of left-handedness in twin versus non-twin populations (Boklage, 2010). UK was right-handed, but switched hands easily following injury to her right hand.

4.1.6. Job satisfaction—The twins' similarly high job satisfaction scores show that each was quite content with their employment. Both felt able to apply their creative talents and viewed their working conditions favorably. Their job satisfaction may be associated with their positive view of life and family, although these factors are most likely bidirectional.

4.1.7. Social support—US reported more available support overall, yet both perceived available support across all measured domains. Social support is strongly linked to mental and physical health; the twins' perceived support may have more strongly influenced their physical and psychosocial well-being than their received support (Uchino, 2009).

4.1.8. Twin relationship—Most reared apart twins are pleased to have met their co-twin. US welcomed the meeting and research participation, while UK felt that her life was “complete” following reunion. The prospect of meeting her twin had excited UK who was disinterested in biological kin. Regardless, sudden interest in a newly found twin, beyond that of biological parents, has been observed in other separated pairs (Segal, 2000). This response highlights the significance of twinship in the hierarchy of human social relationships.

DZA twins, on average, experience less closeness and less familiarity than MZA twins, upon meeting and subsequently (Segal, Hershberger, & Arad, 2003). Perceptions of behavioral similarities may be the “social glue” that attract and maintain social relationships (Segal, Graham, & Ettinger, 2013). In interviews, neither twin identified striking behavioral resemblances between them, but named selected similarities (e.g., husbands' name: Jim; arm positioning). Thus, it is difficult to predict the future of these twins' relationship, given their advanced age and the considerable physical distance between them.

5. Conclusions

Overall, the twins' differences were more frequent than their similarities. Differences were most apparent in general intelligence, Stroop completion times, ideational fluency, psychomotor completion times and medical health. Similarities included mental status, job satisfaction and social support. The personality data yielded mixed findings. The twins approached their relationship with one another from different perspectives, but were pleased to have met. In general, behavioral and physical differences between the twins appear linked to genetic factors and to UK's childhood illness. Their separated residences in the United States and England, beginning in young adulthood, did not appear to play key roles in their development. Continued study of US and UK will cover other domains, e.g., leisure activities, dietary preferences and evolving relationship.

Studies of DZA twins complement those of MZA twins whose genetic identity more clearly reveals the effects of different environments on development. DZA twins differ for both genetic and environmental reasons, such that predominance of one cannot be decided from

DZA twins alone, nor from a single case. Nevertheless, findings from DZA pairs, when evaluated against the backdrop of the reared-apart twin literature, can suggest new hypotheses and research directions. Future reared-apart twin studies should consider factors affecting personality changes and cognitive decline.

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Fig. 1.
US (left) and UK. Photo credit: Matthew Gush.

Fig. 2.
WAIS-IV profiles. Shape: $r = .07$; elevation: 2.17; standardized mean difference: 1.10;
scatter: 4.85; variance ratio: 1.37.

Fig. 3.
Special cognitive ability profiles.

Fig. 4.

ACL profiles. Shape: $r = .98$, $p < .001$, elevation: 0.53; standardized mean difference: $-.15$; scatter: 9.37; variance ratio: 1.06.

Fig. 5.
Personality Mini-Markers.

Fig. 6.
NEO profiles (*T*-scores).

Table 1

Twins' and children's ACL profiles compared.

	US-S	UK-D	S-D (for parent)
Shape	.96 ***	.94 ***	.82 ***
ICC	.91 ***	.96 ***	.83 ***
Elevation	4.28	3.05	1.51
Scatter	410.83	189.45	457.62
Variance ratio	2.74	1.27	2.95

 $p < .001$.