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Genetic and environmental influences on applied creativity: A reared-apart twin study

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Abstract

Applied creativity involves bringing innovation to real-life activities. The first reared-apart twin study assessing genetic and environmental origins of applied creativity, via Draw-a-House (*DAH*) and Draw-a-Person (*DAP*) tasks, is presented. Participants included 69 MZA and 53 DZA twin pairs from the Minnesota Study of Twins Reared Apart. Drawings were evaluated by four artists and four non-artists. Genetic effects were demonstrated for the *DAP* (.38–.47), but not for the *DAH*. Creative personality showed genetic effects (.50), and modest, but significant correlations with scores on the two drawings (*r*s = .17–.26). Both genetic and nonshared environmental influences underlie variance in applied creativity. Individuals concerned with enhancing creativity among students and others may better understand individual differences in performance and training.

Keywords

Twins; Creativity; Genetics

1. Introduction

> "The first step is imagination, the capacity that we all have to see something in the mind's eye. Creativity is then using that imagination to solve problems—call it applied imagination. Then innovation is putting that creativity into practice as applied creativity."
>
> [(Robinson, 2006).]

Defining creativity is challenging for psychologists, educators and artists. Originality and usefulness are often considered to characterize creativity; however, originality alone is insufficient because it might reflect random processes or lack of purpose (Runco & Jaeger, 2012; Sarkar & Chakrabarti, 2011). Another key issue is how much creativity is genetically or environmentally influenced. Applied creativity—"putting creativity into practice" (Robinson, 2006)— is the focus of the present report. Specifically, genetic and environmental factors underlying esthetic, artistic and novel qualities of reared-apart twins' paper and pencil drawings are examined.

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As Simonton notes (2012), Sir Frances Galton considered creativity in the context of nature and nurture in *English Men of Science* (1874). Galton concluded that heredity ("pre-efficients") contributed significantly to his subjects' eminence. However, the environmentalist perspective in the United States permeated much of psychological research in the 1930s–1970s. Many studies emphasized situational factors affecting creativity, e.g., educational practices (Biber, 1958) and freedom to pursue problems (Kaplan, 1960). By the 1960s cognitive psychology was gaining ground, emphasizing the acquisition/development of domain-specific skills, and in the 1980s behavioral-genetics became more mainstream. A more balanced view of creativity emerged, in which both genetic and environmental factors were acknowledged for achieving creative outcomes. However, environmental influences on creativity, such as sustained practice (Ericsson, 2014) and collaborative partnership (Shenk, 2014), are still emphasized.

Creativity can be enhanced following training. Cropley and Cropley (2000) increased the innovation/creativity of engineering students via lectures and counseling. *The Creative Project*, at the College Misericordia, in Dallas, TX, enhanced the creativity of student nurses regarding humanistic aspects of patient care (Pavill, 2011). A meta-analysis of 70 creativity studies showed that effective training programs focused on skill application using realistic exercises (Scott, Leritz, & Mumford, 2004). Regardless, how much training effects persist, and why they vary across individuals, remains uncertain. Resolving such debates requires genetically-informed research, e.g., twin/adoption studies. It is possible that genetically-based tendencies affect variation in the efficacy and persistence of creativity training.

A reared-apart twin study of applied tasks, in which ideas are expressed via activities, has never been undertaken. Findings from this analysis have implications for individuals dedicated to fostering creativity. To the extent that genetic factors affect applied creative activities, efforts toward individually tailored programs may be advised.

1.1. Intelligence and creativity

IQ has a genetic component (Johnson, Bouchard, Krueger, McGue, & Gottesman, 2004), but general intelligence differs from creativity (Bouchard & Lykken, 1999). Nusbaum and Silvia (2011) showed that openness predicted creativity, but not fluid intelligence, whereas intellect predicted fluid intelligence, but not creativity. As Simonton (1999) suggested, high intelligence may be necessary, but not sufficient, for extraordinary creative achievement. Similarly, low levels of intelligence may not support creative undertakings.

Recent work underlines the complexity of giftedness of which creativity is one form. Creativity may involve the ability to go beyond intelligence to synthesize unrelated associations among concepts. The relationship between intelligence and creative potential may be mediated by biologically-based executive mechanisms. Such mechanisms may include cognitive inhibition and task-switching (Benedek, Franz, Heene, & Neubauer, 2012).

1.2. Twin studies of creativity

Twin designs include identical (monozygotic or MZ) twins who share 100% of their genes and fraternal (dizygotic or DZ) twins who share, on average, 50% of their genes. Greater MZ than DZ resemblance demonstrates genetic influence on behavior. Twin studies of creative attributes have produced mixed findings regarding genetic effects. An early study of thirteen twin pairs suggested that creativity was not heritable, but was related to intelligence measures (Richmond, 1966). Another twin study found that environment plays a stronger role than heredity in shaping creativity (Vandenberg, 1968).

Additional research suggests that genetic contributions to creativity vary with construct and type of measure. Reznikoff, Domino, Bridges, and Honeyman (1973) found genetic effects on word association, but not on associational fluency in teenage twins. An Italian study of adolescent twins showed genetic effects on adaptive flexibility and esthetic judgment, but not on ideational or expressional fluency, findings replicated with an American sample (Barron, 1972). A subsequent study of young adult twins reported genetic effects on perceptual and esthetic abilities, but not on esthetic preferences (Barron & Parisi, 1976).

Summarizing ten creativity studies, average correlations were .61 for MZ twins and .50 for DZ twins, suggesting modest heritability (Nichols, 1978). However, Canter (1973) proposed that these correlations would have been more similar controlling for general cognitive ability. Accordingly, a recent survey failed to support genetic influence on creative behavior (Chávez-Eakle, 2007).

A recent study reported a .29 heritability on four-year-old twin children's human figure drawing, using the Draw-a-Child task (Arden, Trzaskowski, Garfield, & Plomin, 2014). This was not a creativity study, but an assessment of children's ability, based on the presence/correct number of body features. Creative attributes, such as esthetic quality and interesting features, were not examined. The generalizability of these findings to adults is unknown.

The relatively young age of the twin participants in some previous studies may have limited conclusions regarding genetic effects on creative expression. Specifically, genetic influence on many traits, e.g., general intelligence and exercise participation, increases with age as individuals gain greater control over their environments (McClearn et al., 1997; Stubbe et al., 2006). Lehman (1960) asserted that most creative products are generated during young adulthood and that 80% of significant creative contributions occur by age 50. Lifespan research on creativity suggests that creativity peaks in middle adulthood (Simonton, 1996).

Some limitations of extant twin research on creativity can be overcome using reared-apart adult twins. Adults exert greater control over their environments than children, allowing expression of genetically-based proclivities. Furthermore, MZA twins provide direct estimates of genetic effects on behavior given their shared genes and nonshared environments. Varied measures of creativity can also identify heritable features. It is anticipated that applied creative ability will show heritable individual differences, given the unstructured nature of the task with respect to time and direction. The possibility that creative behavior in an applied task is influenced by genetic and environmental factors to the same degree as creative personality will be assessed.

The Minnesota Study of Twins Reared Apart (MISTRA) is the only reared-apart twin study to have assessed creativity (Segal, 2012). Measures included the Creative Personality Scale (Gough, 1979) and Multidimensional Personality Questionnaire's Traditionalism scale (Tellegen et al., 1988). Heritabilities on these measures ranged between .40 and .50 (Bouchard & Lykken, 1999; Waller, Bouchard, Lykken, Tellegen, & Blacker, 1993). The scales used, while informative, did not assess applied creativity.

1.3. Artist and non-artist judges

Many studies assessing creativity report higher consistency among experts than non-experts (Kaufman, Baer, & Cole, 2009). It has been suggested that experts judge artifacts in comparison with others in the group, rather than with reference to an absolute standard (Kaufman et al., 2009). The current study offered an opportunity to compare the reliabilities of artist and non-artist raters.

1.4. Current study

The first analysis of applied creative ability using reared-apart twins is presented. It was hypothesized that (1) MZA twin pairs would receive more concordant creativity scores than DZA twin pairs, consistent with genetic effects, and (2) artists' scoring agreement would exceed that of non-artists.

2. Methods and materials

2.1. Participants

Participants included 18–77-year-old, reared-apart monozygotic (MZA, N = 69) and dizygotic (DZA, N = 53) twin pairs from the MISTRA. MZA twins consisted of 41 female and 28 male pairs; two individual female MZA twins were included in some analyses. DZA twins consisted of 36 same-sex pairs and 17 opposite-sex pairs. Mean ages of the MZA and DZA pairs were 42.31 years (*SD* 12.82) and 45.40 years (*SD* 13.12), respectively, and did not differ significantly. Mean age at reunion was 32.51 years (*SD* = 15.80, 0.25–64.67) for MZA twins and 41.79 years (*SD* = 13.60, 20.00– 74.58 years) for DZA twins. DZA twins were reunited later [$t(118) = -3.384$, $p < .001$], presumably due to difficulties locating one another (Segal, 2012). Relatives/friends accompanying twins completed the drawing tasks. Their data were used in the age-and sex-correction of the creativity ratings.

A subsample of twins returned for ten-year follow-up assessments, when some previously completed tasks were readministered. Data from three follow-up twin pairs were incorporated into the data set, because they did not complete the drawings initially. Data from the full sample and full twin sample were variously used to age- and sex-correct the data, according to the methods of McGue and Bouchard (1984).

2.2. Drawing tasks

The MISTRA assessment included an individual videotaped life history interview. During this session, each twin was asked to "draw a house" and to "draw a person" without time limits. These drawings were produced without the co-twin present and neither twin had access to the drawing of the other. A total of 289 Draw-a-House (*DAH*) images and 318

Draw-a-Person (*DAP*) images were created. Correlations between twins' scores on the Creative Personality Scale (Adjective Checklist) and associations of these scores with their creativity ratings on the drawings were examined.

2.3. Consensual Assessment Technique

Amabile's Consensual Assessment Technique (CAT) is a current method for measuring creativity. Amabile (1982) asserted that "a product or response is creative to the extent that appropriate observers independently agree it is creative" (p. 1001). This independent agreement is achieved by choosing raters with expertise in a particular field. The CAT's reliabilities range between .80 and .94 (Baer, 1994, 2003; Sternberg & Lubart, 1995). It helps solve the problem of defining creativity because it categorizes creative qualities characterizing a given product and is not restricted by a theoretical definition. The CAT was incorporated into the present study as the Artistic Quality Rating Scale (AQRS), developed for this project (Bouchard & Segal, unpublished).

The AQRS assesses one dimension of creativity (esthetic judgment), represented by a composite score. It includes three creative dimensions (esthetically pleasing, well-drawn and creatively done) rated as 0: "no quality", 1: "low quality", or 2: "high quality." Two additional points could be given based on raters' overall impression of the drawing. The total possible score range was 0–8 points, although this was modified following pilot testing.

2.4. Data analysis

2.4.1. Intraclass correlations—Intraclass correlations provide a preliminary indication of how much genes and environments affect the variance of a phenotype via biometric model fitting. If the MZ correlation exceeds the DZ correlation, genetic influence on the phenotype is suggested. Nonshared environmental contributions are implicated if the MZ correlation is less than 1.0. A reared-apart twin design is a variant of the classic MZ–DZ comparison as it only estimates genetic and nonshared environmental factors (Segal, 2012).

2.4.2. Biometric model fitting—Univariate biometric modeling was used to estimate simultaneously the relative additive genetic (A) and nonshared environmental (E) contributions to the phenotypes. An AE univariate biometric model, in which C was constrained to 0, was fit by maximum likelihood estimation of the raw data in Mx (Neale, Boker, Xie, & Maes, 2003). The correlation between the genetic (A) factors is constrained to 1.0 for MZ twins and 0.5 for DZ twins. Nonshared environmental (E) factors are uncorrelated between the twins. Genetic and nonshared environmental influences on a single measured variable are denoted by paths a_1 and e_1, respectively.

An AE model in which genetic and nonshared environmental paths were estimated was tested. The A path that was not significantly different from zero, as indicated by 95% confidence intervals, was systematically dropped. Model differences were explored using a nested model approach that compared the AE model and the E model. Differences in χ^2 values of the models ($\Delta\chi^2$) in relation to differences in their degrees of freedom were tested to determine whether the E model resulted in a significant decrement in model fit compared to the AE model. If the $\Delta\chi^2$ value for the E model to the full model is non-significant, the E model accurately represents the data and is, therefore, a preferable fit compared to the full model. Twin model assumptions, e.g., equal environments assumption are summarized in Johnson (2007) and Kendler, Neale, Kessler, Heath, and Eaves (1994).

3. Results

3.1. Pilot study

A pilot study assessed experimental procedures, rating scales and inter-rater reliabilities. Raters were three artists (two females, one male) and one male non-artist. Pilot rating sessions included a brief description of the study and instructions for completing the AQRS. Twenty “mock” drawings each of houses and people were created by research staff for this purpose. The four raters viewed the 40 drawings twice in one session.

Inter-rater reliabilities were good to excellent as indicated by intraclass correlations of .92 (house: first viewing), .93 (person, first viewing), .75 (house, second viewing) and .88 (person, second viewing). Based on raters’ feedbacks, the viewing time for the primary study (described below) was reduced from 30 to 18 s. The AQRS was modified to enable greater variability in the ratings: 0: “no flair or interesting features,” 1: “low quality, 2: “medium quality,” and 3: “high quality”, increasing the maximum score from 8 to 11. A decision was also made to begin each rating session with practice ratings of five drawings to familiarize judges with the form.

3.2. Primary study

The eight judges for the primary study were four artists and four non-artists, two males and two females each. Female artists were 35 and 23 years of age; male artists were both 24 years of age. Three were recruited via CSUF’s art department and one was located by personal referral. The non-artist females were an undergraduate psychology senior and a psychology graduate student, while the non-artist males were a counseling psychology graduate student and a Professor Emeritus of Philosophy. The non-artist female judges were 23 and 24 years of age and the non-artist males were 24 and 70 years of age, respectively. They were not informed of the age, rearing status or multiple birth status of the twins to avoid influencing their ratings.

3.2.1. Inter-rater reliability—The artists showed consistency in their creativity ratings for the *DAH*s (r_i = .742) and *DAP*s (r_i = .774). The non-artist values were moderate to high for the *DAH*s (r_i = .636) and *DAP*s (r_i = .774), respectively.

3.2.2. Creativity similarity—Intraclass correlations for the MZA and DZA twin pairs, organized by artist and drawings, are displayed in Table 1. Significant, but modest, MZA (r_i = .29, p < .01) and DZA correlations (r_i = .26, p < .05) were found for *DAH* as rated by artists. The *DAH* correlation based on ratings by non-artists for MZA twins was not significant (r_i = 10), whereas the DZA correlation was modest, but statistically significant (r_i = .25, p < .05). The relative magnitude of these correlations indicates an absence of genetic influence on the creativity of *DAH*s.

The MZA correlations for person drawings were significant for both artists ($r_i = .38$, $p < .001$) and non-artists ($r_i = .45$, $p < .001$), whereas only the DZA non-artist correlation reached statistical significance ($r_i = .23$, $p < .05$). Genetic effects were suggested, although the size of these correlations did not differ significantly between twin types.

A correlational analysis of the *DAH*s and *DAP*s for twins and non-twins ($n = 296–327$) was performed in relation to rater type. The *DAH–DAP*s correlated significantly for artists ($r = .46$, $p < .001$), and non-artists ($r = .53$, $p < .001$), using the age–sex corrected data. Correlating across rater type, but within drawing, also yielded significant correlations for *DAH* ($r = .83$, $p < .001$) and *DAP* ($r = .82$, $p < .001$).

The next analysis used the twin data only, combined across judges. Again, genetic influence was indicated for the person, but not for the house drawings; the difference between the intraclass correlations approached statistical significance ($z = 1.531$, $p < .06$). These data are summarized in Table 2.

3.2.3. Creative personality—Small, but significant correlations were obtained between the twins' ACL Creative Personality scale scores and the four *DAH*/*DAP*-artist/non-artist ratings (rs = .17–.26). Intraclass correlations for Creative Personality were $r_i = .52^{***}$, 95% CI: .30, −.69 (MZA: $n = 57$ pairs) and $r_i = .12$, 95% CI: −.17, − .40 (DZA: $n = 45$ pairs). The MZA correlation significantly exceeded the DZA correlation [$z = 2.25$, $p < .05$], indicating genetic influence on this measure.

3.2.4. Model fitting results—Both genetic and nonshared environmental influences explained the variance in the artists' and non-artists' ratings of the twins' *DAP* drawings. With respect to artists' ratings, A and E factors contributed 38% (95% CI: 20–52%) and 62% (95% CI: 47– 80%) of the variance, respectively. With respect to non-artists' ratings, A and E factors explained 47% (95% CI: 31–60%) and 53% (95% CI: 40–69%) of the variance, respectively.

In contrast, most of the variance in the *DAH*s, as rated by artists and non-artists, was ascribable to nonshared environmental effects. For *DAH*s rated by artists, genetic effects explained 26% (95% CI: 08–43%) of the variance, whereas nonshared environmental contributions accounted for 74% (95% CI: 57–92%) of the variance. Likewise, for *DAH*s rated by non-artists, 23% (95% CI: 04– 40%) of the variance was attributable to genetic factors, whereas 77% (95% CI: 60–96%) was explained by the nonshared environment. These results are summarized in Table 3.

Univariate biometric model fitting results were consistent with findings from the intraclass correlations for the Creative Personality scale. The results suggested that both genetic and nonshared environmental contributions contribute to individual differences in Creative Personality. Specifically, A and E factors explained 50% (95% CI: 32–64%) and 50% (95% CI: 36–68%), respectively, of the variance in Creativity Personality.

4. Discussion

4.1. Genetic and environmental influences on creativity

It was hypothesized that MZA twin pairs would receive more similar creativity scores than DZA twin pairs, indicative of genetic effects. Genetic influence was indicated for the *DAP*s, given the MZA and DZA intraclass correlations and model-fitting results, explaining 38–47% of the variance. This suggests that applied creativity on the *DAP* task is partly heritable, and also arises from individuals' unique experiences. In contrast, findings of genetic influence on *DAH* appeared somewhat contradictory. The intraclass correlations were fairly similar across twin types suggesting a lack of genetic effects. Model fitting also indicated that most of the variance was attributable to the nonshared environment, but suggested that 23–26% of the variance was explained by genetic factors. Given the similar magnitudes of the MZA and DZA intraclass correlations, the observed genetic effects on the *DAH* may reflect the lack of power to drop A. Thus, it appears that most of the variance in the house drawing ratings is explained by the nonshared environment.

It is informative to consider why *DAH* is more likely to show genetic influence than *DAP*. Person drawings enable greater variability across features, such as facial structure, hairstyle and gender, whereas house drawings uniformly include a door, windows and a chimney. Specifically, most people can bring more individual expression to drawing a person than a house. Supporting this view, decision-making freedom is considered a prerequisite for creativity in complex problem-solving (Skulimowski, 2011). This interpretation may characterize the MISTRA twins who were not professional artists, but artists might bring considerable creativity to their drawings of houses.

It is also important to consider the nature of nonshared environmental influences relevant to applied creativity drawing tasks. They may potentially include co-twin differences in art instruction, parental encouragement and/or available opportunities. Identifying such effects is beyond the scope of the present paper, but defines a direction for future research.

The Creative Personality scale showed genetic influence, evident by the significantly higher MZA than DZA intraclass correlation. Genetic influence on Creative Personality explained 50% of the variance, consistent with findings from the *DAP* task which most likely allowed greater freedom of expression than the *DAH* task. The low, but significant correlations of the Creative Personality scale with the drawing task ratings suggest that personality contributes somewhat to applied creativity, although the underlying mechanisms remain uncertain.

4.2. Raters

It was hypothesized that the artists' scoring agreement would exceed that of the non-artists. Both the artist and non-artists raters showed consistency in their judgments of *DAP*s, although the artists showed greater reliability for the *DAH*s than did the non-artists. This finding supported the expectation that individuals with artistic experience would show greater agreement than less practiced individuals.

4.3. Implications

The first reared-apart twin study of applied creative ability demonstrated genetic influence on one of two drawing tasks. A reason that the *DAP*, but not the *DAH*, showed genetic effects is speculative (greater freedom of expression), but suggestive. As such, given techniques may enhance or sustain creativity in some contexts, but not others. Tasks not conducive to individualized efforts are unlikely to show genetic effects.

Parents, teachers, coaches and others concerned with fostering creativity in children, students and athletes should pay closer attention to individual difference characteristics (e.g., personality, motivation) that may affect creativity in applied settings. Two children or two athletes exposed to similar training may show different outcomes. Appreciating that such differences may have a partial genetic basis can assist understanding of behavioral variation and provide guidance.

4.4. Limitations

The present study is not without limitations. In addition to the modest sample size, creativity was assessed on one occasion and in a somewhat limited manner. For example, the availability of colored pencils may have enhanced variation among twins, with some participants choosing to use them and others not. It is also likely that lack of creative expression in one area does not imply lack of creative expression in all areas. Assessing creativity using alternative tasks (e.g., decorating a cake or designing a home) would have been of interest. Nevertheless, a reared-apart twin study of applied creativity demonstrated genetic influence on the *DAP*, providing insight and informed thinking about the origins of this behavior.

4.5. Future directions

Genetically informed studies of applied creativity with larger samples would increase power. In addition to twin research, studies of unrelated siblings (especially virtual twins who are matched in age) would be revealing. The Fullerton Virtual Twin Study is currently obtaining creativity ratings of children from parents and teachers, so can strengthen discussion of factors affecting creative behavior.

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Table 1

Intraclass correlations for drawings: Zygosity and rater type.

	MZA		DZA	
	Artist	**Non-artists**	**Artist**	**Non-artists**
DAH	.29**	.10	.26*	.26*
N (pairs)	60	60	47	47
95% CI	[.05, .51]	[−.15, .34]	[−.02, −.51]	[−.02, −.51]
DAP	.38***	.45***	.15	.23*
N (pairs)	68	68	53	53
95% CI	[.16, .57]	[.24, .62]	[−.12, .40]	[−.04, .47]

Note. CI = confidence intervals. Analysis used age–sex corrected data.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 2

Intraclass correlations across judges: Artists and non-artists combined.

	MZA	DZA
DAH	.23*	.28*
N (pairs)	60	47
95% CI	[−.02, −.45]	[.00, −.52]
DAP	.46***	.21
N (pairs)	68	53
95% CI	[.25, −.63]	[−.06, −.45]

Note. CI = confidence interval.

* $p < .05$.

*** $p < .001$.

Table 3

AE univariate biometric model fitting results.

Variable	Proportion of variance explained		Fit statistics				
	A	**E**	***−2LL***	***AIC***	***df***	**$\Delta\chi^2$**	***p***
Creative personality	**.50 (.32, .64)**	**.50 (.36, .68)**	**1609.95**	**987.95**	**311**	–	–
	–	1.00	1635.85	1011.85	312	25.90	0.000
DAP (artist)	**.38 (.20, .52)**	**.62 (.47, .80)**	**2113.66**	**1491.66**	**311**	–	–
	–	1.00	2129.93	1505.93	312	16.27	0.000
DAP (non-artist)	**.47 (.31, .60)**	**.53 (.40, .69)**	**2065.81**	**1443.81**	**311**	–	–
	–	1.00	2092.53	1468.53	312	26.72	0.000
DAH (artist)	**.26 (.08, .43)**	**.74 (.57, .92)**	**2070.53**	**1448.53**	**311**	–	–
	–	1.00	2078.00	1454.00	312	7.46	0.006
DAH (non-artist)	**.23 (.04, .40)**	**.77 (.60, .96)**	**1902.30**	**1280.30**	**311**	–	–
	–	1.00	1907.95	1283.95	312	5.65	0.018

Note. A and E denote proportion of variance in each variable explained by genetic and nonshared environmental factors, respectively. −2LL = −2 × log likelihood; AIC = Akaike Information Criterion; df = degrees of freedom; $\Delta\chi^2$ = change in chi-square; p = p-value. Best-fitting model in bold.