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# Shared genetic and environmental influences on self-reported creative achievement in art and science

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ABSTRACT

Artists and scientists have been the most frequently investigated groups in the literature of creative achievement. We previously found that genetic influences on the artistic and the scientific creative achievement were substantial. Using a self-report measure of creative achievement, the present study estimated the phenotypic relationship between scientific and artistic creative achievements, and investigated shared genetic and environmental sources for the relationship between the two creative achievements. Three hundred and thirty-eight adult Italian twins [79 monozygotic (MZ) pairs & 90 same-sex dizygotic (DZ) pairs] completed the Artistic Creative Achievement (ACA) and the Scientific Creative Achievement (SCA) scales developed from the Creative Achievement Questionnaire. The mean age of the sample was 26.3 years. The phenotypic correlation between the ACA and the SCA was .54. Cross-twin cross-trait correlation was .45 for MZ and .15 for DZ twins. Bivariate Cholesky models were applied to the raw twin data. In the best-fitting model, the genetic and unique environmental correlations between ACA and SCA were .71 and .36, respectively. These results suggest that common sets of genes are largely responsible for the association between ACA and SCA.

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## 1. Introduction

Creativity plays a cardinal role in technological advance, in the social and behavioral sciences, and in the arts. To date, artists and scientists have been the most frequently investigated groups in the literature of creative achievement (Feist, 1998).

Researchers of creative accomplishment have long suggested that highly creative scientists and artists share some distinctive characteristics (Feist, 1998; Vernon, 1989). A meta-analysis of personality traits associated with creativity showed that creative individuals in the art and science domains were open to new experiences, self-confident, autonomous, self-accepting, ambitious, intrinsically motivated, dominant, and hostile (Feist, 1998). Especially, a high level of 'openness to experiences' was consistently linked with creativity in the field of art and science. Longitudinal studies yielded similar results. In a 44 year follow-up study of 80 male graduate students working in various fields of science, Feist and Barren (2003) found that openness, and the Psychological Mindedness and Tolerance scale of the California Psychological Inventory (Gough, 1987) at age 27 years significantly predicted creative lifetime achievement in terms of publication, citation, and award at age 72 years. The Tolerance scale measured the degree to which individuals are tolerant of other's beliefs and values, even when they are different from one's own. The Psychological Mindedness scale measured the extent to which individuals are insightful, intellectual, perceptive, and understanding. Creative scientists and artists do not always share personality traits, however. For example, Feist (1998) and Gelade (1997) reported that creative artists were more emotionally unstable and lower on conscientiousness as compared to creative scientists.

The relationship between IQ and creativity remains controversial. The threshold theory of intelligence and creativity (Torrance, 1962) proposes that IQ is necessary but not sufficient for creative achievement and that the relationship between IQ and creativity is not linear such that at lower IQ levels (<120), the correlations are strong and positive, whereas at higher IQ levels (⩾120), the correlations are negligible. The threshold theory has not been consistently supported, however (Jauk, Benedek, Dunst, & Neubauer, 2013; Nusbaum & Silvia, 2011; Preckel, Holling, & Wiese, 2006). Recent meta-analysis findings and reviews of the literature on the relationship between IQ and creativity showed that the two constructs were moderately related, with correlations being

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approximately in the range of $r = .20–.40$ (Batey & Furnham, 2006; Kim, 2005).

Overall, the results of creativity studies to date indicate that creative artists and scientists may share intellectual abilities and certain personality traits, suggesting existence of the phenotypic relationship between artistic and scientific creative achievements. The main goals of the present study were twofold: first, we aimed to establish the phenotypic relationship between artistic and scientific creative achievements. Secondly, we attempted to determine the extent to which common genetic and environmental factors explain the phenotypic relationship between the artistic and scientific creative achievement in a sample of adult twins.

Using the sample in the present study, we previously demonstrated that genetic and unique environmental factors were important for individual difference in self-reported artistic and scientific creative achievements (Piffer & Hur, 2014). Especially, heritability for artistic creative achievement was substantial and higher than that for the scientific creative achievement. Shared environmental influences were negligible in both creative achievements. These findings were consistent with the results of recent twin studies of creativity based on large adolescent and young adult twin samples (Penke, 2003; Vinkhuyzen, van der Sluis, Posthuma, & Boomsma, 2009). Given these findings, we expected that shared genetic and unique environmental factors would significantly contribute to the relationship between scientific and artistic creative achievements.

## 2. Material and methods

### 2.1. Subjects

Subjects comprised 338 twins (79 MZ pairs & 90 same-sex DZ pairs) who volunteered to participate in our creativity research in response to our invitation letter mailed in 2011 to the address of the same-sex twins born between 1980 and 1992 in different regions of Italy. We obtained mailing addresses of the twins from city councils. Incomplete twin pairs were excluded from data analyses. Zygosity of twins was determined by self-report questions. We removed twins who were not sure about their zygosity from our analysis. The mean age of the total sample was 26.3 years with a SD of 6.6 years. Sixty-two percent of the sample was female. As in most volunteer twin samples, this sample has an overrepresentation of females (Lykken, McGue, & Tellegen, 1988).

### 2.2. Measures

The Creative Achievement Questionnaire (CAQ; Carson, Peterson, & Higgins, 2005) is a self-report measure of creative achievement in various creative areas. As compared to other self-rating instruments of creativity that measure one's belief on his/her creativity, the CAQ has more objectivity as it measures one's observable, concrete creative achievements. In each creativity domain, the participant is asked to place a checkmark next to the item describing his or her accomplishments. Each creativity domain includes eight specifically written items of ascending achievement weighted with a score from 0 to 7 (e.g., for the Visual Arts domain; 0 = I have no training or recognized talent in this area, 1 = I have taken lessons in this area, 2 = People have commented on my talent in this area, 3 = I have won a prize or prizes at a juried art show, 4 = I have had a showing of my work in a gallery, 5 = I have sold a piece of my work, 6 = My work has been critiqued in local publications, and 7 = My work has been critiqued in national publications). The eight specific questions were written in a similar way across creativity domains in the CAQ. As creative products such as paintings, publications, and compositions can be easily quantified, judgments about these creative accomplishments can be more reliable. Test–retest and internal consistency reliabilities and other psychometric properties have been well established (Carson et al., 2005; Silvia, Wigert, Reiter-Palmon, & Kaufman, 2012). Especially, the CAQ has been shown to successfully discriminate between more and less creative persons (Vellante et al., 2011).

Twins completed the questions of the CAQ via Internet (URL: Freeonlinesurve.com platform). The CAQ includes two scales developed from factor analyses: Artistic Creative Achievement (ACA) and Scientific Creative Achievement (SCA) (Carson et al., 2005). The ACA assesses creative achievement in arts and includes the visual arts, music, humor, creative writing, dance, and theatre and film domains. An ACA score was computed by summing the scores across these six domains. The SCA assesses creative achievement in science, and consists of the scientific discovery, scientific invention, and culinary endeavors domains. An SCA score was generated by summing the scores of these three areas. As the distributions of ACA and SCA were highly positively skewed with skewness indices of 2.8 for ACA and 4.4 for SCA, prior to twin analyses, logarithmic transformations were performed, which resulted in the skewness indices of .45 for the former and .76 for the latter.

### 2.3. Statistical analysis

Just as the phenotypic variance of a single variable can be divided into additive genetic (A), shared environmental (C), and unique environmental variance plus measurement error (E), the covariance between two traits can be decomposed into A, C, and E components. A refers to the sum of the average effects of all genes that influence a trait. C includes those environmental effects shared by the two members of a twin pair and makes twins similar. E represents those environmental factors unique to each member of a twin pair and therefore, makes twins different from each other.

To determine common additive genetic and shared and unique environmental influences on the phenotypic relationship between ACA and SCA, we computed cross-twin cross-trait correlation (e.g., correlation of twin 1's ACA with twin 2's SCA) for MZ and DZ twins and carried out bivariate Cholesky model-fitting analyses (Neale & Cardon, 1992). Given that MZ twins share all their genes and DZ twins share, on average, 50% of their segregating genes, greater MZ than DZ cross-twin cross-trait correlation would suggest that additive genetic effects influence the phenotypic correlation between ACA and SCA. In contrast, similar MZ and DZ cross-twin cross-trait correlation indicates that shared environmental factors are important for the association between ACA and SCA. Finally, unique environmental influences are implicated if the MZ cross-twin cross-trait correlation is less than 1.00. To compute cross-twin cross-trait correlations, we used the double-entry method to remove the variance associated with the ordering of siblings within a twin pair.

Figure 1 shows a bivariate Cholesky model (for only one twin in the pair) where the paths from the common factors to the first phenotype, SCA ($a_{11}$, $c_{11}$, $e_{11}$) indicate the influences of $A_1$, $C_1$, and $E_1$ on SCA. The paths from the common factors to the second phenotype, ACA ($a_{21}$, $c_{21}$, $e_{21}$) indicate the extent to which influences of $A_1$, $C_1$, and $E_1$ are common between SCA and ACA. The paths from the factors specific to the second phenotype, ACA ($a_{22}$, $c_{22}$, $e_{22}$) represent $A_2$, $C_2$, and $E_2$ that are unique to ACA, and thus independent of the factors operating on the SCA.

Using the maximum likelihood estimation method in Mx (Neale, Boker, Xie, & Maes, 2003), we computed parameter estimates in the model. The raw data option in Mx calculates twice the negative log-likelihood ($-2LL$) of the data. Because the difference in $-2LL$ between the full and the nested model is distributed as a chi-square, it allows for a test of the difference in model-fit.

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