Heritability of justice sensitivity

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Abstract

Justice is one of fundamental principles in human evolution, and justice sensitivity, both from the proself perspective (e.g., as victim) and the prosocial perspective (e.g., as observer, beneficiary, and perpetrator), matters in mental wellness and social interaction. However, it remains unclear to what extent individual difference in justice sensitivity is influenced by genetic versus environmental factors. Using a sample with 244 twin pairs, the present research was an attempt to determine what extent genetic factor plays a role in the inter-individual difference of justice sensitivity as well as whether different facets of justice sensitivity, namely, proself and prosocial perspective, share common genetic basis. Results showed that (1) all the four facets of justice sensitivity were moderately heritable (21%-33%) and that the non-shared environmental factors accounted for the rest variations (67%-79%); (2) associations between the prosocial facets of justice sensitivity were driven by common genetics (rg: .50-.65) and non-shared environmental (re: .24-.65) influences, whereas no strong evidence supported a genetic correlation between proself and prosocial justice sensitivity. The current findings provide novel evidence that sensitivity to injustice, especially to others' suffering, is fundamentally grounded upon genetic origin, thus shedding light on the nature and nurture aspects of justice behavior.

Full Text

Heritability of Justice Sensitivity

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Author Notes: Zhou and Wu developed the research proposal, Wang conducted the data analysis and wrote the first draft. All authors contributed to writing the full paper and its revisions. This study was not preregistered. The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request. For correspondence, please contact Dr. Michael Shengtao Wu at Xiamen University via email at commuagent@163.com or michaelstwu@xmu.edu.cn; or Dr. Yuan Zhou at the Chinese Academy of Sciences (CAS) via email at zhouyuan@psych.ac.cn. We are thankful to Dr. Jie Zhang and the other staff of the Beijing Twin Study (BeTwiSt) at the Institute of Psychology, CAS for their help with data collection, and to Dr. Manfred Schmitt for his insightful comments on the early draft. The completion of this research was partially supported by grants from the National Natural Science Foundation of China (Nos. 91432302, 81771473), the Youth Innovation Promotion Association of the Chinese Academy of Sciences (No. 2012075), and the Fundamental Research Funds to Central Universities (No. 20720181086).

Abstract

Justice is one of the fundamental principles in human evolution, and justice sensitivity—whether from the proself perspective (e.g., as victim) or the prosocial perspective (e.g., as observer, beneficiary, and perpetrator)—matters for mental wellness and social interaction. However, it remains unclear to what extent individual differences in justice sensitivity are influenced by genetic versus environmental factors. Using a sample of 244 twin pairs, the present research attempted to determine the extent to which genetic factors play a role in inter-individual differences in justice sensitivity and whether different facets of justice sensitivity, namely proself and prosocial perspectives, share a common genetic basis. Results showed that (1) all four facets of justice sensitivity were moderately heritable (21%-33%) and that non-shared environmental factors accounted for the remaining variation (67%-79%); (2) associations between the prosocial facets of justice sensitivity were driven by common genetic (rg: .50-.65) and non-shared environmental (re: .24-.65) influences, whereas no strong evidence supported a genetic correlation between proself and prosocial justice sensitivity. These findings provide novel evidence that sensitivity to injustice, especially to others' suffering, is fundamentally grounded in genetic origins, thus shedding light on the nature and nurture aspects of justice behavior.

Keywords: justice sensitivity, heritability, twin study, behavioral genetics

Introduction

Justice is a crucial force for social stability and has deep evolutionary roots [?, ?]. Given that justice matters to all people [?], individuals are sensitive to situations when they or others are treated unfairly [?, ?, ?, ?]. Justice sensitivity is essential for the mental health and subjective well-being of individuals [?]. Moreover, justice sensitivity has been identified as a potential factor in the emergence and maintenance of psychiatric disorders with heritable etiologies, such as attention deficit hyperactivity disorder [?], depression [?], and borderline personality disorder [?]. However, it remains arguable whether the dispositional nature of justice sensitivity is more important than situational and societal factors for understanding justice principles and behavior [?]. That is, understanding the origin of justice sensitivity is vital for research on justice behavior.

In the current work, our interest lies in assessing the extent to which genetic factors play a role in inter-individual differences in justice sensitivity and whether different facets of justice sensitivity—namely for oneself and for others—share common innate and genetic mechanisms.

Individual Differences in Justice Sensitivity

Recent theories assume that justice sensitivity involves a low perceptual threshold for incidents of injustice, strong emotional responses to injustice (such as anger, outrage, and guilt), a tendency to ruminate about injustice, and a motivation to reestablish justice [?]. Justice sensitivity divides concern for justice into four facets according to the role a person plays in an unjust situation: victim, observer or bystander, passive beneficiary, or active perpetrator [?]. The victim is the person who feels unjustly treated, the observer is one who perceives the incident without being directly involved, the beneficiary is the person who receives the benefit passively, and the perpetrator is the one who committed the critical action [?]. On the one hand, these four facets can be further distinguished as justice concerns for the self and for others, such that victim sensitivity (VS) involves proself concerns for one' s own interest, whereas observer sensitivity (OS), beneficiary sensitivity (BS), and perpetrator sensitivity (PS) involve prosocial concerns for others and public wellbeing. VS is a mixture of self-related concerns and a sense of justice, whereas the remaining three facets have no selfish component but indicate prosocial and genuine justice concerns [?]. On the other hand, the four facets appear to overlap, with correlation coefficients ranging from 0.3 to 0.8 [?], because they share concern for justice as a common element. Regarding characteristic emotional responses to injustice, BS and PS share clear similarity in terms of guilty reactions, whereas VS and OS induce outward-focused emotions, such as anger and moral outrage, respectively [?, ?].

Although individual justice sensitivity depends on adopted perspectives, all four facets show dispositional stability in relation to personality traits, behavioral consequences, and cultural values. For personality traits, the proself facet (VS) is primarily associated with self-related concerns, such as neuroticism, Machiavellianism, paranoia, suspiciousness, vengeance, and jealousy. By contrast, the prosocial facets (OS, BS, and PS) are primarily associated with others-related concerns, such as agreeableness, role taking, empathy, and social responsibility [?, ?]. For behavioral consequences, OS, BS, and PS positively correlate with positive behavioral reciprocity and negatively with negative behavioral reciprocity, whereas VS negatively correlates with positive behavioral reciprocity and positively correlates with negative behavioral reciprocity [?]. In particular, people with high (vs. low) OS contribute more to the public good regardless of past exploitation [?]. Finally, for cultural values, recent cross-cultural studies reveal that variations in the prosocial facets have a stable relation with collectivism at both the country-level and individual level [?, ?, ?].

Biological Origin of Justice Sensitivity

Developmental psychology and behavioral genetics suggest that human nature or genetic factors partly contribute to individual differences in justice sensitivity. Developmental studies found that children as young as two years demonstrated preferences for fairness in ultimatum games [?]. A general predisposition toward just evaluations was also observed in 6- and 10-month-old infants who chose and looked longer at an individual who helped another than at one who hindered another [?, ?]. Previous observational research suggested that animals also respond negatively to inequity. For example, chimpanzees responded with temper tantrums if they did not obtain what they desired, social canids refused to play with individuals who violated social rules, and ravens showed third-party intervention against norm violations [?, ?]. In summary, the appearance of fairness preference in early life and inequity responses in animals suggest that intuitive reactions to injustice have deep biological roots. Behavioral genetics studies on twins further suggest that genes moderately influence fairness-related decision-making behavior [?, ?] and morality-related traits, such as honesty-humility [?].

However, from the perspective of socialization theory, environmental factors also affect individual differences in justice sensitivity. For example, older and highly educated people showed lower levels of proself justice sensitivity and higher levels of prosocial justice sensitivity. In addition, compared with Western Germans (capitalism-oriented), Eastern Germans (socialism-oriented) showed higher levels of all facets of justice sensitivity [?]. People in collectivist cultures, such as the Chinese, revealed high BS and comparable OS when compared with individualist Germans, Russians, and North Americans [?, ?]. Moreover, individuals experimentally primed by collectivist (vs. individualistic) unscrambled-sentence tasks scored high on interdependent self (vs. independent self) and on all three prosocial facets of justice sensitivity [?]. Similarly, on prosocial facets of justice sensitivity, collectivist Filipinos scored higher than individualist Australians [?].

Despite ample experimental evidence, whether individual variation in justice sensitivity is affected by genetic factors or shaped by environmental experience remains unclear. Theoretically, genetic and environmental factors are both considered to account for inter-individual differences in personality and behaviors, producing the diversities and uniformities of human nature. However, it is unknown to what extent genetic and environmental factors contribute to inter-individual differences in justice sensitivity. Besides, given that justice sensitivity consists of four components that are positively correlated with each other, it is unknown whether common genetic or environmental factors influence the phenotypic correlations between different perspectives of justice sensitivity. Therefore, empirical investigation of the extent to which nature and nurture contribute to the course of human development in justice sensitivity is still necessary.

The Present Research

To summarize, the current study aims to answer two questions. First, we investigate the extent to which genetic and environmental factors play a role in inter-individual differences in justice sensitivity. Second, we investigate whether different perspectives of justice sensitivity share common genetic or environmental factors in terms of justice for self and for others. Behavioral genetic work, which is fundamentally about the study of human variation, could provide important clues as to the sources of individual differences [**?**]. Specifically, the twin methodology can be used to identify the extent to which individual differences in justice sensitivity are influenced by genetic and environmental factors and to further examine the pairwise genetic and environmental correlations between multiple variables. Therefore, a twin study was conducted to examine the genetic and environmental bases of justice sensitivity and the genetic and environmental associations between different facets.

Method

Participants

A total of 244 same-sex twins (133 females, aged 18 to 25, M = 19.72, SD = 1.77) were recruited to participate in this study, among which 151 pairs were monozygotic (MZ) and 93 pairs were dizygotic (DZ). The sample was derived from the decision-making-brain sub-database, which was built based on the participant pool of the Beijing Twin Study (BeTwiSt) [**?**, **?**]. This sub-database was established in 2012 and included psychological trait measures and functional magnetic resonance imaging (fMRI) data, consisting of 411 and 277 pairs of twins respectively. Some key findings based on this sub-database have been published [**?**, **?**, **?**, **?**]. In this study, we included all subjects who completed the Justice Sensitivity Inventory. The zygosity of the twin pairs was determined via DNA testing. The ethics committee provided approval for the study. Additionally, we obtained written informed consent from all participants prior to commencing the study.

Measures

The Chinese version of the Justice Sensitivity Inventory was used to assess participants' sensitivity to injustice [**?**, **?**]. Each subscale contains 10 items that measure a single facet: VS (e.g., "It makes me angry when I am undeservingly worse off than others"), OS (e.g., "I am upset when someone is undeservingly worse off than others"), BS (e.g., "I feel guilty when I am better off than others for no reason"), and PS (e.g., "I feel guilty when I enrich myself at the cost of others"). Participants responded to the items on a 0–5 Likert scale (0 = not at all, 5 = exactly), with high scores indicating high sensitivity to injustice from the victim, observer, beneficiary, and perpetrator perspectives. Individual scores were obtained by averaging the items of the relevant subscale. The estimated reliabilities (Cronbach' s α) of the four facets were .83 for VS, .90 for OS, .85 for BS, and .89 for PS, respectively.

Data Analysis

By comparing the resemblance of MZ and DZ twin pairs on observed trait(s), we can estimate additive genetic (A), shared environmental (C), and non-shared environmental (E) contributions to variance within a trait and covariance between traits [**?**]. MZ twins are 100% genetically identical, whereas DZ twins are, on average, 50% identical for additive genetic effects. In the usual case where twins are reared together, greater resemblance between MZ twins than between DZ twins indicates that the trait is heritable. The proportion of trait variance or covariance between traits explained by additive genetic effects is referred to as "heritability." A shared environment contributes to the similarity of twins growing up in the same family. A non-shared environment is unique to each individual, which likewise includes measurement error.

Twins are perfectly correlated for age and same-sex twins are perfectly correlated for sex. Thus, variation associated with age or sex would inflate the correlation between twins. We separately regressed each facet of justice sensitivity onto sex and age, and then saved the standardized residuals for genetic analyses. Participants who scored 3 SD beyond the mean value of the entire sample were excluded from further analyses. The numbers of excluded participants were three for VS, two for OS, one for BS, and four for PS, respectively. To increase the statistical power of genetic model-fitting, we used all available data, including those from several twin pairs who were not pairwise.

Univariate and bivariate models were implemented in the OpenMx package for R version 3.0.1 to estimate genetic and environmental effects. First, univariate models were used to partition the variance of each dimension into genetic (A) and environmental (C and E) effects. For each dimension, the full ACE model was examined first. Sub-models (AE, CE, and E) nested within the full model were then tested by systematically removing one or two variance component(s). Next, for the bivariate analyses of each paired facet, a correlated factors model was used [**?**] [Figure 1: see original paper], wherein each variable was separately decomposed into ACE components. Meanwhile, the correlations of these components across variables were estimated. The full ACE model and all sub-models were systematically tested.

Figure 1. Path diagram illustrating bivariate genetic model-fitting. Measured variables are in rectangles. Latent factors A (genetic factors), C (shared environmental factors) and E (non-shared environmental factors) are in circles. rg: genetic correlation; rc: shared environmental correlation; re: non-shared environmental correlation.

We used three model fit indices: the change in chi-square (^{2}), Akaike' s Information Criterion (AIC) [**?**], and Bayesian Information Criterion (BIC) [**?**]. Comparing the full model with a sub-model, a significant chi-square difference suggests that the nested model fits significantly worse than the full model, and thus the full model should be chosen; otherwise, the nested model with fewer parameters should be considered in terms of parsimony [**?**, **?**]. Both AIC and BIC are useful in model selection, with low values indicating better fit than high values. In model selection, Raftery (1993) suggested that a BIC difference of 5 indicates "strong evidence" that one model is superior to another, whereas a difference of 10 indicates "conclusive evidence" [**?**]. Ultimately, the better-fitting model received due consideration [**?**].

Statistical Power for Genetic Analyses

In order to gauge whether we had sufficient power to detect genetic or environmental effects, we estimated the minimum effect size that could be reliably observed within the current sample. We implemented the power analysis via the package "pwr" in R [**?**], which functions along the lines of Cohen (1988). Given a sample size of N = 241/243 (the total number of twin pairs; Table 1), level of significance at .10[1], degrees of freedom (df) at 1 (estimating one effect each time), and power at the conventional level of .80, we could detect effects whose size (w) was no less than .162. Put otherwise, if the standardized estimate of a path parameter in the genetic model (e.g., A in univariate model or a1 in bivariate model) were no less than .16, we would have sufficient power to examine the corresponding genetic or environmental effects. This method of estimating statistical power for genetic analyses has been successfully adopted by Luo et al. (2020).

Results

Table 1 showed mean scores and standard deviations for each facet of justice sensitivity. In addition, as shown in Table 1, the proself facet (VS) was significantly and positively correlated with the prosocial facets (OS and BS). The correlations between each pair of prosocial facets (OS, BS, and PS) were likewise positively significant. The correlation between VS and PS was positive but not significant. This correlation pattern replicates findings from previous studies. Typically, the correlation between BS and PS is the highest and that between

VS and PS is the lowest [?].

Table 1. Means for, zero-order correlations among, and twin intraclass correlations for all measures.

			Twin correlations			
Measure	Mean	Zero-Order Correlation	ICCMZ	NMZ	ICCDZ	NDZ
VS	.37***	.17***	.53***	.31***	.61***	.48***
OS	150	-.10	.42***	150	-.08	.51***
BS	151	.33*	.36***	150	.17	
PS						

Note. VS: Victim Sensitivity; OS: Observer Sensitivity; BS: Beneficiary Sensitivity; PS: Perpetrator Sensitivity; ICC: intraclass correlation; **$p < .001$, p < .05; MZ: monozygotic twins; DZ: dizygotic twins; N: number of twin pairs.

Univariate Model Fitting

For all four facets of justice sensitivity, MZ twin correlations were significantly higher than DZ correlations (Table 1), suggesting that genes substantially contribute to individual differences in sensitivity to injustice. Thereafter, the heritability of each facet was examined by fitting a series of univariate models. In comparison with the ACE model, the E model fit significantly worse for each facet (Δ ^{2}s $\geq$ 7.16, ps $\leq$ .03), the AE model fit equally well for VS, OS, and PS (Δ ^{2}s = 0.00, ps = 1.00), and the AE and CE models each fit equally well for BS (Δ ^{2}s $\leq$ 0.92, ps $\geq$ .34). Therefore, the nested model with fewer parameters (AE/CE) should be considered in terms of parsimony [?, ?]. Finally, the AE model was considered more desirable because its AIC and BIC values were smaller than those of the CE model for each facet (Table 2). As shown in Table 2, univariate model fitting revealed moderate heritability for each facet (27% for VS, 21% for OS, 33% for BS, and 23% for PS) and large non-shared environmental effects (73% for VS, 79% for OS, 67% for BS, and 77% for PS). Importantly, the magnitude of all genetic and non-shared environmental effects was above the minimal effect size (.16) that we can detect with sufficient power.

Table 2. Univariate genetic model-fitting.

Measure	Model	-2LL	df	Change from full model Δ ^{2}	Δdf	p	A	C	E
VS	ACE						.27 (.02, .40)	.00 (.00, .19)	.73 (.60, .88)
	AE			0.00	1	1.00	.27 (.12, .40)	–	.73 (.60, .88)

Measure	Model	-2LL	df	Change from full model Δ^{2}	Δdf	p	A	C	E
OS	ACE						.21 (.00, .36)	.00 (.00, .19)	.82 (.70, .94)
	AE			0.00	1	1.00	.21 (.06, .36)	–	.79 (.64, .94)
BS	ACE						.33 (.19, .45)	.18 (.06, .30)	.68 (.55, .82)
	AE			0.92	1	.34	.33 (.19, .45)	–	.67 (.55, .81)
	CE			0.92	1	.34	–	.28 (.16, .39)	.72 (.61, .84)
PS	ACE						.23 (.00, .37)	.00 (.00, .27)	.77 (.63, .93)
	AE			0.00	1	1.00	.23 (.07, .37)	–	.77 (.63, .93)

Note. VS: Victim Sensitivity; OS: Observer Sensitivity; BS: Beneficiary Sensitivity; PS: Perpetrator Sensitivity. The full ACE model and the best-fitting model are presented for each component. -2LL: twice the negative log-likelihood; AIC: Akaike information criterion; Δ^{2}: change in chi-square; Δdf: change in degrees of freedom (df); A: proportion of variance due to additive genetic effects; C: proportion of variance due to shared environmental effects; E: proportion of variance due to non-shared environmental effects; 95% confidence intervals are in parentheses. The best-fitting model is underlined.

Bivariate Model Fitting

Bivariate modeling analyses were conducted using correlated-factors models to explore the extent of covariation between each pair of justice sensitivity facets (OS-BS, OS-PS, BS-PS, VS-OS, and VS-BS) due to genetic and environmental factors.

OS and BS: We tested the full ACE model first and thereafter the AE, CE, and E models (Table 3). Compared with the ACE model, the AE and CE models each fit equally well (Δ^{2}s $\leq$ 3.44, ps $\geq$ .33) but the E model fit significantly worse (Δ^{2} = 27.80, p = .00). The AE model was deemed preferable because its AIC and BIC values were smaller than those of the CE model (Figure 2a

[Figure 2: see original paper]) [?, ?, ?]. In the AE model, genes that influenced OS also moderately influenced BS (rg = .65), whereas non-shared environments that affected OS also had a significant impact on BS (re = .49).

OS and PS: As shown in Table 3, the correlated-factors model with only genetic and non-shared environmental components (i.e., AE model, Figure 2b) provided the best fit for the data (Δ^2 = 0.55, p = .91). OS and PS shared moderate genetic (rg = .58) and non-shared environmental (re = .24) correlations.

BS and PS: As shown in Table 3, the correlated-factors model with only genetic and non-shared environmental components (i.e., AE model, Figure 2c) provided the best fit for the data (Δ^2 = 1.24, p = .74). In the AE model, BS and PS shared moderate genetic (rg = .50) and non-shared environmental (re = .65) correlations.

VS and OS: The same model analysis was conducted for VS and OS. As seen in Table 3, the AE model was optimal (Δ^2 = 0.00, p = 1.00). In the AE model, VS and OS shared modest genetic (rg = .21) and non-shared environmental (re = .42) correlations. Notably, the 95% confidence interval of the genetic correlation (-.45 to .58) included zero (Figure 2d). Thus, no sufficient evidence was found to support a genetic correlation between VS and OS.

VS and BS: As seen in Table 3, the AE model provided the best fit for the data (Δ^2 = 0.18, p = .98). In the AE model, VS and BS shared minimal genetic correlation (rg = .07) and modest non-shared environmental correlation (re = .21). Notably, the 95% confidence interval of the genetic correlation (-.35 to .41) included zero (Figure 2e). Thus, no sufficient evidence was observed to support a genetic correlation between VS and BS.

In summary, the prosocial facets of justice sensitivity correlated with each other through genetic and environmental factors, and the magnitude of all genetic and non-shared environmental effects was above the minimal effect size (.16) that we can detect with sufficient power. However, the genetic correlation between the proself and prosocial facets was not significant. This analysis provides further evidence for the distinction between justice sensitivity for one' s self and for others.

Table 3. Bivariate genetic model-fitting.

Measure	Model	-2LL	Change from full model Δ^2	Δdf	p
OS-BS	ACE	2388.19			
	AE		3.44	2	.33
OS-PS	ACE	2501.36			
	AE		0.55	2	.91
BS-PS	ACE	2494.58			
	AE		1.24	2	.74
VS-OS	ACE	2138.61			
	AE		0.00	2	1.00

Measure	Model	-2LL	Change from full model Δ ^{2}	Δdf	p
VS-BS	ACE	2370.37			
	AE		0.18	2	.98

Note: VS: Victim Sensitivity; OS: Observer Sensitivity; BS: Beneficiary Sensitivity; PS: Perpetrator Sensitivity. The full ACE model and the best-fitting model are presented for each component. -2LL: twice the negative log-likelihood; AIC: Akaike information criterion; Δ ^{2}: change in chi-square; Δdf: change in degrees of freedom (df); A: proportion of variance due to additive genetic effects; C: proportion of variance due to shared environmental effects; E: proportion of variance due to non-shared environmental effects; 95% confidence intervals are in parentheses. The best-fitting model is underlined.

Figure 2. Best-fitting bivariate genetic models: (a) best-fitting model for OS and BS; (b) best-fitting model for OS and PS; (c) best-fitting model for BS and PS; (d) best-fitting model for VS and OS; (e) best-fitting model for VS and BS. VS: Victim Sensitivity; OS: Observer Sensitivity; BS: Beneficiary Sensitivity; PS: Perpetrator Sensitivity. Measured variables are in rectangles. Latent factors A (additive genetic factors) and E (non-shared environmental factors) are in circles. rg: genetic correlation; re: non-shared environmental correlation. All path estimates (95% confidence intervals), standardized but unsquared, are obtained from the best-fitting model.

Discussion

Justice is a fundamental concern of human societies and a critical component of morality. From an early age, individuals are motivated by considerations of justice such as fairness and equity for both themselves and others. Despite robust evidence that the desire for justice may be universal, numerous studies have revealed that individuals differ in their reactions to injustices, especially from different perspectives. Hypersensitivity to injustice has been proposed to contribute to the emergence and maintenance of several common mental disorders [**?**, **?**, **?**]. With this consideration, we examined the genetic contribution to justice sensitivity variations and the genetic associations between different facets using twins. The current results identified modest genetic contributions (21%–33%) and large non-shared environmental contributions (67%–79%) to justice sensitivity. The shared environmental contribution to justice sensitivity was minimal.

More importantly, moderate genetic (.50–.65) and non-shared environmental (.24–.65) correlations were found among the prosocial facets (OS, BS, and PS), whereas no strong evidence supported a genetic correlation between proself and prosocial justice sensitivity. These findings thus provide novel evidence about the genetic basis of justice sensitivity and the associations between different facets of prosocial justice sensitivity.

The results support our hypothesis that both nurture and nature play important roles in the development of individual differences in justice sensitivity. Studies have uncovered the heritability of numerous attitudes [?] and various aspects of social behavior [?], such as fairness-related decisions [?, ?, ?]. In the current study, the identified heritability of justice sensitivity has implications for understanding individual differences in sensitivity to injustice. Individuals differ in how readily they perceive and how strongly they react to injustice. Several systematic examinations have focused on individual differences in the emotions and behaviors that result from experiencing or witnessing injustice [?, ?, ?, ?]. Building on such previous investigations, the present study moves a step forward by conducting a behavioral genetics study on twins and finds moderate justice sensitivity heritability and large non-shared environmental influence for all facets. These findings provide novel evidence that justice sensitivity is a fundamental trait with a reliable genetic basis and environmental influences, thereby shedding light on the nature and nurture aspects of justice and morality.

A series of studies have documented associations between the four facets of justice sensitivity [?, ?]. In line with previous findings, we observed significant correlations for each paired facet except for VS and PS. More importantly, the associations between each pair of prosocial justice sensitivity (OS, BS, and PS) were found to be partly due to genetic factors, although non-shared environments likewise play a role. This discovery implies an overlap of the genes and non-shared environments that influence the three facets of prosocial justice sensitivity and provides evidence for the inherent nature behind these links. These findings are consistent with the previous view that individuals with observer, beneficiary, and perpetrator sensitivities share a genuine concern for justice, whereas those with victim sensitivity have self-related concerns [?]. Based on the self-others distinction of justice sensitivity in terms of personality, behavior, and cultural values [?, ?, ?], our findings provide biological evidence for the homogeneity of prosocial justice sensitivity for others. Specifically, our findings indicate that exploring the common genetic influences underlying prosocial facets is important for understanding the links between justice and morality.

Furthermore, in the AE models, non-shared environmental factors contribute to all facets of justice sensitivity more than genetic factors. For BS and PS, the CE models (shared and non-shared environmental factors) are also workable. These findings suggest that, although genetic factors are significant in explaining justice sensitivity variations, shared and non-shared environmental factors should likewise be considered. On the one hand, in twin analysis, non-shared environmental factors are often related to macro-level societies, such as ecological environment, social structure, and cultural values, all of which play a significant role in the socialization of justice sensitivity. For example, social institutions and cultural values have been found to account for group differences in justice sensitivity among Eastern versus Western Germans [?], Chinese versus Germans, Russians, and North Americans [?, ?], and Filipinos versus Australians [?]. Even spontaneous priming of collectivism vs. individualism can promote prosocial justice sensitivity [?]. On the other hand, shared environmental factors that are often related to micro-level societies, such as family, were found to be predictable in the CE models of BS (28%) and PS (17%). Although the family effect on BS and PS has not been tested, a few studies suggested that parenting style (restrictive vs. nurturant) affects the development of inhibition-based moral orientations [?]. Given that BS and PS are inhibition-based [?], for which people should not take advantage of others (as a beneficiary) or do evil (as a perpetrator), further research is necessary to test the effects of restrictive parenting on the development of BS and PS. In addition, a more recent investigation revealed that compared with upper class, lower class (indicated by low family income) scored higher on prosocial justice sensitivity, especially for BS and PS [?].

This study has several limitations. First, the twin participants were young adults. Previous studies found that, in comparison, older participants scored significantly higher on justice sensitivity for others and lower on justice sensitivity for self [?, ?]. Thus, our young adult participants may not be a representative sample of the general population. Second, our study only included a Chinese sample. Recent cross-cultural studies compared justice sensitivity across countries in terms of collectivism-individualism and found that people in collectivist cultures scored higher on prosocial facets than those in individualist cultures [?, ?, ?]. Thus, our results from the Chinese sample may not necessarily be generalizable to other populations. Third, we used the classic ACE models, which treated genetic, shared, and non-shared environmental effects as independent. This ignores the possibility that genetic and environmental factors may correlate or interact with each other in complex ways [?]. Such correlations or interactions are critical for gaining nuanced knowledge about the origins of justice sensitivity. Future investigations might include measures of environments to test for potential interactions or correlations with genes. Lastly, our sample was moderate in size. This entailed wide confidence intervals for model parameters and limited statistical power to detect small genetic or environmental effects, especially shared environmental effects [?]. Indeed, the magnitude of several shared environmental effects (Table 2) was below the minimal effect size (.16) that we can detect with sufficient power. Thus, future studies must investigate and further verify the heritability of justice sensitivity by extending the sample size and the scope of participant pools.

Justice principles play a dominant role in social interaction and justice sensitivity is important for human well-being and mental health. The origin of individual differences in justice sensitivity and the links between different facets remain elusive. By using twin methodology, the present study is the first to partition genetic and environmental influences on justice sensitivity across the four facets (VS, OS, BS, and PS) and to comprehensively examine the genetic associations between them. Overall, the results highlight the roles of additive genetic and non-shared environmental factors in shaping individuals' sensitivity to injustice. Genetic overlaps among prosocial concerns for others are also revealed. As the first genetic study on justice sensitivity, we believe that our findings can shed light on the nature of justice sensitivity and provide additional evidence for understanding proself and prosocial facets of justice sensitivity.

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[1] For power analyses of twin models, Verhulst (2017) recommends setting Type I Error rate as .10 to address a complex situation involving multiple chi-square distributions with different dfs. Such a solution is adequate for 1 df test but may lead to an underestimate of power for multiple df test. Nevertheless, we adopted this conservative strategy in our power analyses.

[2] Cohen (1988) suggests that w is comparable to the conventional effect size r, and that w values of 0.1, 0.3, and 0.5 represent small, medium, and large effect sizes, respectively.

Note: Figure translations are in progress. See original paper for figures.

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