Heritability of Preferred Thinking Styles and a Genetic Link to Working Memory Capacity

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Genetic and environmental contributions to preferences for rational and experiential thinking were examined in 100 pairs of monozygotic and 73 pairs of same-sex dizygotic Australian twins. Univariate analyses for experiential thinking and working memory capacity (WMC) revealed genetic effects accounted for 44% and 39% of the variability respectively, with non-shared environmental effects accounting for the balance. For rational thinking, the univariate models produced ambiguous results about the relative roles of heritability and shared environment, but a subsequent Cholesky analysis suggested genetic effects accounted for 34%, with the balance, 66%, explained by the non-shared environment. The Cholesky analysis revealed that shared genetic effects accounted for 60%, and non-shared environment accounted for 40% of the relationship between preference for rational thinking and WMC.

∎ **Keywords:** working memory, dual-process theory, rationality, experientiality, twin study, heritability

Individuals differ with respect to how they prefer to think. Some like to methodically work through all the costs and benefits prior to making a decision, whereas others prefer to rely primarily on intuition. Some will use either approach depending on contextual factors such as time pressure and the perceived importance of the decision. Although it is widely accepted that individual differences stem from a combination of genetic endowment and environmental factors (Plomin et al., 2008), the extent to which each of these factors contributes to thinking style preferences has yet to be investigated. In this study, we adopt a behavioral genetics perspective to estimate the heritable and environmental components of two types of thinking styles (rational and experiential), based on dual process theories of cognition. We also investigate whether preference for rational thinking and working memory capacity (WMC) have a shared genetic basis.

According to dual process theories of cognition there are two distinct processing systems that guide human behavior (for a review, see Evans, 2008). The experiential system is automatic, fast, and is believed to be the primary and default mode of processing. It is consistently applied in response to environmental stimuli and involves the seemingly pre-conscious or automatic activation of memories, stereotypes, beliefs, and routine operations. It is strongly associated with emotions and affect and generally relies on cursory analyses of situations, often giving the sensation of rapid and effortless thought.

In contrast, the rational system relies on context-independent rules and the application of logical justification. By comparison, it can seem slower, deliberative and effortful (Evans, 2008; Stanovich et al., 2011). Some proponents of dual process theories suggest that preferences for rational and experiential thinking are relatively stable over time and contexts (Betsch et al., 2009; Harren, 1979; Marks et al., 2008; Pacini & Epstein, 1999).

The Rational Experiential Inventory (REI) is a well-established instrument developed to measure preferences for rational and experiential processing, using a combination of individuals' self-reported capacity (ability) and proclivity (engagement) in each thinking style (Pacini & Epstein, 1999). Studies using the REI have found that individuals with a strong rational style perform better than their less rationally inclined counterparts on a range judgment tasks, including: ratio-bias tasks (Pacini & Epstein, 1999), the famous 'Linda problem' (Toyosawa & Karasawa, 2004), proportion dominance problems (Bartels, 2006), estimating the probability of chance events (Shiloh et al.,

2002), framing effects and sunk cost tasks (Björklund & Bäckström, 2008; Carnevale et al., 2011) and in simulated real life decision-making (Lieberman, 2002; Shiloh & Shenhav-Sheffer, 2004). Across these studies, greater preference for experiential processing has been found to be positively associated with susceptibility to cognitive biases, superstitious beliefs and greater emotional expressivity. In studies using instruments other than the REI, experiential preference has been linked to superior performance in other areas, such as in emergency situations where previously learned routines have to be carried out immediately (Hogarth, 2008), and in problem-solving tasks with limited, high-quality information available (Kardes, 2006).

According to most dual process theorists, rational analysis is intimately tied to working memory processes (Evans, 2008). Rational processing requires attentional control to focus on relevant stimuli, to inhibit externally and internally generated irrelevant stimuli, and to apply rules, logic, calculations and adjustments necessitated by the judgment or decision-making context. Research suggests that individual differences in working memory capacity (WMC) may provide a critical platform for the attentional processes required for successful rational analysis (Evans, 2008; Kane et al., 2001).

Several researchers have proposed that WMC also may exert an important indirect effect on the *preference* for rational thinking (Barrett et al., 2004; Fletcher et al., 2011). Rational processing is often experienced as effortful and time consuming. Thus positive feedback, in the form of success on judgment and decision-making tasks, is believed to be important in encouraging continuing use of the rational system (Barrett et al., 2004). Given that individuals with higher WMC are more likely to succeed in tasks requiring rational analysis, they should be more inclined to engage in rational processing in the future. Conversely, individuals with lower WMC will be less likely to succeed in rational tasks, and therefore be more inclined to avoid this type of thinking. Such avoidance can prevent low WMC individuals from acquiring the necessary skills for rational problem solving, given that these skills are culturally transmitted through schooling and wider education (Epstein, 2003).

Preferences for experiential thinking, on the other hand, are believed to be unrelated to WMC. Experiential processing does not require attentional control or the conscious manipulation of symbols. It draws on previously learned and experienced thoughts, memories and beliefs that guide decision-making and behavior automatically, and largely outside the conscious control mechanisms operating within working memory (Barrett et al., 2004).

Given that thinking styles affect decision-making, sometimes to confer an advantage and sometimes to the detriment of the individual, it is important to understand the determinants of these traits. Knowledge of the factors that contribute to variability in rational preference and experiential preference could further our understanding about

selectively developing each preference for the individual's benefit. For example, if most of the variability in a particular trait is attributable to environmental factors, it might be beneficial to investigate which factors are responsible for the development of the trait. There might be large differences that ultimately could be identified as being due to home or school environments, or peer or family relationships, thereby indicating potential environmental factors for individuals to improve on or change. Similarly, if genetic factors account for substantial variability in a trait, we can attempt to discover the pathway from gene to trait (Plomin, et al., 2008). This could ultimately give rise to important information such as critical or peak periods for development in thinking styles, and potential interventions or enhancements of the environment to maximize the genetic potential of the individual.

Thinking styles are believed to share several fundamental features of personality traits in that they are believed to affect behavior, mood and cognitions, and because they are relatively stable over time and across different situations. Studies of different age groups (Marks et al., 2008; Pacini & Epstein, 1999) and across different cultures (Witteman et al., 2009) confirm the existence of the two thinking styles and their predictive validity. Therefore, it might be expected that preferred thinking styles may have a similar pattern of heritability to personality traits. According to a recent meta-analysis, genetic influences explained 40–50% of the variability in personality traits, including the Big Five (Bouchard & McGue, 2002). Shared environmental influences explained little, if any, of the variability in these personality dimensions.

The present study uses the classical twin design to investigate the factors contributing to variability in preferred thinking styles, and WMC. This design capitalizes on the fact that monozygotic (MZ) twins share the same genes and environment, while fraternal twins (dizygotic: DZ) share the same environment but only 50% of their genetic make-up, on average. With data from twins reared together (as in the current sample) the phenotypic variance can be partitioned into four sources of variance: additive genetic effects (A = genetic effects where the two alleles of each genotypes add equally in producing the phenotypic behavior (see Plomin et al., 2008, for details), dominance genetic effects (D = where one allele dominates the other in producing the phenotypic behavior), common environment (C = common environment: shared environmental factors that contribute to similarity in a behavior among twin pairs) and non-shared environment (E = non-shared environment: aspects that contribute to dissimilarity in a behavior among twin pairs).

This study investigated the genetic and environmental sources of individual variation in rational and experiential preference, as assessed by the REI. Using a sample of MZ and DZ twin pairs, we estimated the extent to which individual variation in scores on rational and experiential

preference were attributable to genetic and environmental factors. Consistent with the findings of previous studies on the genetic basis of personality traits, we predicted that the variability in experiential preference would be moderately heritable, in the order of 30–60% (Bouchard & McGue, 2002). For rationality, we expected that variability in the trait would be due to both genetics and common environmental factors. As with experiential preference, rational preference is expected to have a moderate genetic component, in line with other personality variables. However, skills that are used for rational processing (such as deductive and inductive reasoning and logical and critical analysis) are usually explicitly taught by parents and in schooling and higher education. Therefore, to the extent that these influences cause individuals to differ in their preferences for rationality, there should also be common environmental effects.

A second aim of the study was to investigate whether thinking styles and WMC have shared genetic origins. Thinking styles (personality factors) might lead individuals to systematically expose themselves to different learning environments, thereby ultimately affecting their cognitive abilities (Ackerman, 1996), but an absence of a genetic correlation between the two would preclude this. In previous studies, heritability estimates for working memory and executive functions were moderate at 43% to 49% (Ando et al., 2001), and heritability estimates for working memory speed and capacity across tasks ranged from 43% to 56% (Polderman et al., 2006). We expected to yield similar heritability estimates for the current WMC measure. Further, we expected to find a significant phenotypic correlation between WMC and rational preference, but not WMC and experientiality, and we used a Cholesky decomposition to quantify the extent of the genetic link.

Method

Participants

Participants were 476 individual twins, predominantly recruited by mail-out through the Australian Twin Registry. Twelve of the twin pairs were recruited at an ATR Twin Festival and six twin pairs were recruited through personal contacts of the primary researcher (friends and work colleagues). They were informed about the voluntary nature of the study and the estimated time required for completion. They were also provided with individual log-in codes for online participation. Participants were aged 18 to 67 years ($M = 37.1$, $SD = 6.5$). After coding, there were 100 MZ twin pairs (72 female and 28 male) and 73 DZ pairs (56 female and 17 male). Also, there were 69 MZ and 61 DZ individuals whose co-twin did not participate (77 females and 53 males). Data from all individuals were used to calculate descriptive statistics, but only twin pairs were used in modeling analyses.

Twin zygosity of all 480 respondents was confirmed by questions and coding guidelines taken from Nichols and Bilbro (1966) and Goldsmith (1991). The twins were initially asked their zygosity, responding to 'definitely identical', 'probably identical', 'probably fraternal', or 'definitely fraternal'. Further questions, such as whether the twins were confused as children by parents, teachers, and strangers, and whether the twins were 'as alike as two peas in a pod', and sameness of hair colour, complexion, and eye color were used to assess zygosity. These diagnoses were then compared to twin registry diagnoses of zygosity, which had been made prior to the current study using results from different combinations of parent's reports, self-reports, DNA testing and doctors' reports. Where information from participants did not agree with the twin registry, zygosity code supplied to the researcher, or with their co-twin, they were dropped from further analyses. The same rating was given for 99.2% of the participants and consequently two pairs of twins (four individuals) were dropped from all analyses, leaving a total of 476 individual participants.

Measures

All instruments were amalgamated into an on-line assessment battery as follows.

Working memory span tasks. There were two memory span tasks to assess working memory capacity (as recommended in Conway et al., 2005). The first task was an operation-word span task. This was adapted from Web-Ospan (Graf et al., 2005). Participants were required to respond by ticking a box *true* or *false* to 40 simple mathematical operations (e.g., $6/3 + 1 = 5$). Immediately following each arithmetic operation, participants were presented with a to-be-remembered word for 800 milliseconds (these were common monosyllabic English words). Each trial consisted of between two and six operation/word presentations, after which they were asked to recall and type the words in their order of presentation into boxes onscreen. There were ten trials overall: two each for 2, 3, 4, 5 or 6 operation/word pairs, resulting in a maximum score of 40 correct. These items were presented in a random order so that the participant did not know how many words they would each have to recall during each trial.

The second task was a sentence-letter span task (adapted from Kane et al., 2004). It was similar to the first task, but participants were presented with either logical or illogical sentences (instead of mathematical operations) that they responded to by ticking a box saying either *makes sense* or *doesn't make sense* (e.g., 'I was eating spaghetti under the blue news'). After responding, they viewed a to-be-remembered letter for 800 milliseconds. As with the first task, there were ten randomly presented trials overall that consisted of two each of 2, 3, 4, 5, and 6 pairings of sentence/letters (maximum score of 40). A score of 1 for each correctly recalled letter (in its correct place) was awarded

TABLE 1

Within-Person Correlations for Thinking Styles Variables and WMC

| Variable | Correlations | | |
	Experiential preference	Rational preference	WMC
Rational preference	.03	—	
WMC	-.02	.30**	—
Mean	3.47	3.64	.02
SD	.52	.52	.76

Note: MZ: *n* = 100 pairs; DZ: *n* = 73 pairs, Singletons: *n* = 130; *N* = 476.
 **p < .01; *p < .05.

and totaled for each of the two tasks. After standardization, the two tasks were averaged to give a total WMC score (α = .80). The reported reliabilities for the individually administered and computer-administered tests that Web-Ospan was based upon are between .50 and .81 (De Neys et al., 2002).

Rational-Experiential Inventory (REI). This 40-item self-report inventory (Pacini & Epstein, 1999) comprised 20 questions assessing participants' ability and proclivity to think rationally (e.g., 'I have a rational mind'; 'I enjoy intellectual challenges') and 20 questions assessing their ability and proclivity to operate experientially (e.g., 'I hardly ever go wrong when I listen to my deepest gut feelings to find an answer'; 'I like to rely on my intuitive impressions'). Items were rated on a 5-point scale, from 1 (*disagree strongly*) to 5 (*agree strongly*) and both scales exhibited excellent internal consistency for the current sample (rational preference α = .89, experiential preference α = .89). The REI has sound psychometric properties, with rational and experiential scales consistently exhibiting good internal consistency (Cronbach's α > .85) and test–retest reliability (*r* > .76) (Handley et al., 2000; Pacini & Epstein, 1999; Toyosawa & Karasawa, 2004).

Results

Preliminary Statistics

Within-person correlations for experiential preference, rational preference, and WMC are presented in Table 1, together with sample means and standard deviations. All variables were standardized by age and sex. This is common practice in behavior genetics to prevent shared environmental estimates from being inflated. As predicted, there was a moderate positive correlation between rational preference and WMC, and no associations between: (1) WMC and experiential preference, and (2) rational preference and experiential preference.

Univariate Genetic Analyses

Model fitting using MX (Neale et al., 2003) was applied to the raw twin data to estimate the proportions of variance in thinking styles and WMC due to genetic and environmental factors. A summary of these analyses is presented in Table 2.

For the analysis involving experiential preference, we estimated the proportion of variance attributable to additive genetic (A), dominance genetic (D), and non-shared environmental factors (E), given that the MZ twin correlations were more than twice the size of the DZ twin correlations, indicating negligible shared environment effects and possible genetic dominance effects (Plomin, et al., 2008). The fit of the ADE model was contrasted with the nested AE and E models.[1] The contrasts indicated that there was no significant deterioration in fit associated with dropping D from the ADE model, and also that the AE model fit the data significantly better than the E model, suggesting that the AE model represented the most parsimonious model to interpret. The model indicated 44% of the variability in experiential preference was attributable to additive genetic factors and 56% was due to non-shared environment.

For rational preference and WMC, there was no evidence of genetic dominance in the within-person correlations, thus the standard A (additive genetic) C (shared environment) E (non-shared environment) model was tested. For rational preference, there was no significant deterioration of fit associated with either the AE and CE nested models relative to the full ACE model. Examination of the -2LL and AIC fit indices indicated that AE and CE models produced very similar fits, making it difficult to choose between them. This pattern of results indicates that the additive genetic component of rational preference likely lies between zero (the assumed genetic component associated with the CE model) and .48 (the upper bound of the 95% CI for A from the AE model). Using the same logic, the shared environmental component for rational preference likely falls between zero and .41, and the non-shared environmental component between .52 (the lower bound of the 95% CI for the AE model) and .85 (the upper bound for the 95% CI for the CE model). More precise estimates for genetic and environmental contributions to rational preference are presented in the next section, where the bivariate Cholesky decomposition is reported. This subsequent analysis has greater statistical power to detect genetic and environmental effects than the univariate analyses reported here.

For WMC, the AE model did not differ significantly from the full ACE model (Δ *–2LL* = .00, *p* = 1.00), indicating that dropping shared environment (C) from the model did not result in a significant decrease in fit. Thus, the AE model represented the most parsimonious choice for interpretation and indicated that 39% was heritable and the remaining 61% was due to non-shared environment effects.

The Genetic Link Between WMC and Rational Preference

To investigate the possibility that there may be a shared genetic basis for rational preference and WMC, we conducted a bivariate Cholesky decomposition of the variables using MX (Neale et al., 2003). As with the univariate anal-

Jennifer M. Fletcher, Anthony D. G. Marks, Donald W. Hine and William L. Coventry

TABLE 2

Intra-class Correlations (ICCs) and Univariate Model-fit Statistics (95% Confidence Intervals) for Experiential Preference, Rational Preference and WMC

Measure	MZ ICCs	DZ ICCs	Model	A	D/C	E	-2LL	df	Δ-2LL p	AIC
Experiential preference	.47**	.19	ADE	.28 (.00–.57)	.17 (.00–.58)	.55 (.42–.71)	1330.62	472	—	—
			AE	**.44 (.29–.57)**	**—**	**.56 (.43–.71)**	1330.77	473	.71	-1.86
			E	—	—	1.00 (1.00–1.00)	1357.44	474	<.001***	22.82
Rational preference	.33**	.28*	ACE	.12 (.00–.47)	.19 (.00–.41)	.69 (.53–.85)	1335.13	472	—	—
			CE	**—**	**.28 (.15–.41)**	**.72 (.59–.85)**	1335.35	473	.641	-1.78
			AE	.34 (.17–.48)	—	.66 (.52–.83)	1335.82	473	.406	-1.31
			E	—	—	1.00 (1.00–1.00)	1350.64	474	<.001***	11.51
WMC	.32**	.21	ACE	.39 (.00–.54)	.00 (.00–.37)	.61 (.46–.82)	1347.00	472	—	—
			CE	—	.29 (.13–.42)	.71 (.58–.87)	1349.07	473	.150	.07
			AE	**.39 (.21–.54)**	**—**	**.61 (.46–.80)**	1347.00	473	1.00	-2.00
			E	—	—	1.00 (1.00–1.00)	1361.75	474	<.001**	10.76

Note: N (MZ) = 100 pairs, N (DZ) = 73 pairs. A, D, C, and E = additive genetic, dominance genetic, shared environment, and nonshared environmental variances. Model of best fit is in bold. -2LL = minus 2 times log likelihood of data. Δ-2LL = Difference in 2LL between the full model and nested model. Low p indicates poor fit of nested model compared with full model * p < .05, ** p < .01, *** p < .001. AIC = Akaike's Information Criterion (more negative values indicate better fit compared with full model).

TABLE 3

The Model Fits and Standardized Path Coefficients for Full and Nested of a Cholesky Bivariate Decomposition of WMC and Rational Preference

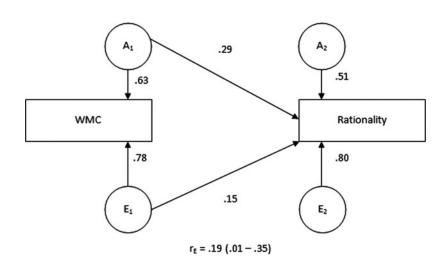|	Source of variability (95% CIs)		
Variable	A	C	E
ACE (-2LL = 2639.73, df = 941)			
Working memory capacity	.62 (.00–.74)	.09 (.00–.61)	.78 (.67–.90)
Shared paths	.08 (.00–.62)	.01 (.00–.59)	.81 (.72–.89)
Rational preference	.36 (.00–.67)	-.43 (-.63–.00)	.14 (.00–.30)
CE (-2LL = 2642.34, df = 944, Δ-2LL = 2.62, p = .45, AIC = -3.39)			
Working memory capacity	—	.54 (.37–.65)	.84 (.75–.93)
Shared paths	—	.24 (.04–.43)	.20 (.08–.32)
Rational preference	—	.48 (.31–.59)	.82 (.74–.90)
AE (-2LL = 2640.76, df = 944, Δ-2LL = 1.04, p = .79, AIC = -4.97)			
Working memory capacity	**.63 (.46–.74)**	**—**	**.78 (.67–.89)**
Shared paths	**.29 (.08–.47)**	**—**	**.15 (.01–.30)**
Rational preference	**.51 (.32–.63)**	**—**	**.80 (.71–.89)**

Note: Model of best fit is in bold. N (MZ) = 100 pairs, N (DZ) = 73 pairs A, C, and E = additive genetic, shared environment, and nonshared environmental standardized path coefficients respectively. -2LL = minus 2 times log likelihood of data. Δ-2LL = Difference in 2LL between the full model and submodel. p < .05 indicates poor fit of submodel compared with full model. AIC = Akaike's Information Criterion (more negative values indicate better fit compared with full model).

yses, we conducted decomposition analyses of the full ACE model, then the nested models, where we fixed the common environment to zero (AE) and the additive genetic effects to zero (CE). There was no significant deterioration in model fit associated with either the AE or CE nested models relative to the full ACE model. However, the AIC was substantially smaller for the AE model, indicating that it was the model of best fit. Table 3 shows the model fit statistics and the comparison of models for best fit.

Table 3 shows the standardized path coefficients estimated from each model for the latent genetic (A), common environment (C) and unique environment (E) factors for the following: WMC, rational preference, and the shared paths between WMC and rational preference. The standardized path coefficients for the Cholesky decomposition of the AE model are presented in Figure 1. A_1 and E_1 represent the

latent genetic and latent non-shared environmental factors affecting WMC. The diagonal pathways from A_1 and E_1 to rational preference represent shared variability for genetic and non-shared environment between the two traits. A_2 and E_2 represent the latent genetic and latent non-shared environmental factors that are specific to rationality (not shared with WMC).

The bivariate decomposition analysis also provided estimates for the genetic and non-shared environmental correlations. The genetic correlation (r_G) between WMC and rational preference was estimated at .49 (95% CIs = .16–.80). The shared genetic factor was 60% of the observable correlation between WMC and rational preference. There was a non-shared environmental correlation (r_E) of .19 (95% CIs = .01–.35), accounting for the remaining 40% of the correlation between WMC and rational preference.

FIGURE 1

Path diagram of a reduced (AE) Cholesky decomposition of WMC and rational preference showing standardized path coefficients for the latent genetic (A_1, A_2) and nonshared environment (E_1, E_2) effects.
r_G = genetic correlation, r_E = nonshared environmental correlation.

From the Cholesky AE model, we obtained estimates for rational preference of 34% for genetic effects (95% CIs = .18–.48) and 66% for nonshared environmental effects (95% CIs = .52–.82). We interpreted these as our best estimates for rational preference, given that the bivariate decomposition has greater power than the univariate test to detect genetic and shared environmental effects (Gillespie & Martin, 2005).

Discussion

This study provided several new and potentially important findings concerning the heritability of thinking style preferences and WMC. The results suggest that both experiential preference and rational preference are moderately heritable, as is commonly found for personality variables. In addition, the Cholesky decomposition analysis revealed that WMC and rational preference appear to share a substantial amount of common genetic variance. Each finding is discussed further below.

The univariate analyses for experiential preference yielded estimates broadly in line with other personality variables (Bouchard & McGue, 2002). Almost half (44%) of the variability in experiential preference was attributable to genetic effects, which is in accord with current conceptions of thinking styles as habitual and relatively stable within individuals (Epstein et al., 1996). This substantial genetic component is also consistent with the current understanding of experiential processing being reflexive, automatic, and a form of innate cognition that is shared with non-human animals (for a review, see Evans, 2008).

The parameter estimates also indicate that the shared environment has uniform effects on individuals with regard to experiential preference, and that the environmental effects that influence variability are primarily unique to each person. This could be because the training of students to rely on intuition is generally not emphasized in Western traditional pedagogy, and any encouragement given to individuals in enhancing intuitive thinking is usually more individually, idiosyncratically or spontaneously administered, and thereby attributable to one's unique environment.

For rational preference, the univariate estimates showed that familial factors (genetic and shared environment) account for around a third of the variability in individual differences. The estimates provided by the bivariate Cholesky decomposition analysis indicate that these effects are due to additive genetics (34%). As with experiential preference, these results are the same order of magnitude as genetic effects found for many personality variables (Bouchard & McGue, 2002). The remaining two thirds of rational preference were due to non-shared environmental effects, substantially more than any other factor. This was an unexpected finding, and runs counter to our prediction that shared environmental factors related to family and schooling would be the most important determinants of variability in rational preference.

Our finding that non-shared environmental factors accounted for the lion's share of variability in experiential and rational preference suggests the greatest determinant of variability in thinking styles is variation in experiences unique to the individual. It also highlights the importance of keeping 'the individual' firmly in perspective when studying individual differences and, where possible, attempting

Jennifer M. Fletcher, Anthony D. G. Marks, Donald W. Hine and William L. Coventry

to identify unique life experiences during key developmental stages that contribute to the adoption of, and preference for, different thinking styles. These unique environmental effects may include peer influences, accidents, health status, and mental health problems such as anxiety or depression. Future research is required to identify such environmental determinants, and the mechanisms through which they might influence thinking style preference.

Preference for rational and/or experiential cognition has previously been linked to a number of personality traits and psychological interests, including the Big Five (Pacini & Epstein, 1999), superstitious thinking (Fletcher et al., 2011), and beliefs in the paranormal, astrology, feng shui, and religiousness (Lindeman & Aarnio, 2007). Many of these variables, together with other similar traits, are known to be moderately to highly heritable (Bouchard, 2004). Future research should also assess shared genetic and environmental sources of variation with variables such as these in order to give a better picture of how preferences for rational and/or experiential thinking develop. Ultimately, these types of studies, along with research into unique environmental determinants, could be informative in discovering interventions or enhancements of the environment to assist in maximizing the genetic potential of individual thinking styles.

According to Evans (2011), one common thread among most dual process theories of cognition is that rational analysis is subject to the limitations of a working memory system, whereas experiential processing is not. Our findings support this view, providing evidence that a substantial amount of the shared phenotypic variability between WMC and rational preference is likely attributable to shared genes. The bivariate decomposition of WMC and rational preference indicated that shared genes accounted for 60% of the correlation between the two variables. The current study did not afford enough statistical power for direction of causation testing. However, further research in this area could help to infer if cognitive capacities drive individuals to develop personal thinking preferences, or if, as some personality theorists suggest, personality factors (such as thinking preferences) promote learning behaviors that in turn affect cognitive gains (Ackerman, 1996). Alternatively, important bidirectional relations between personality and cognition may account for the genetic correlation (Marsh & O'Mara, 2008). In terms of practical applications, the significant genetic correlation between WMC and rational preference is promising. Already, studies are looking at possible candidate genes for WMC and related variables (Parasuraman et al., 2005; Söderqvist et al., 2010).

In addition, several studies indicate that WMC can be trained, and improvements can generalize to other cognitive tasks as well (Klingberg et al., 2002). Given the demonstrated link between WMC and preference for rational processing, such WMC training may also have positive flow-on effects for generating increased proclivity for rational analysis. Although we recognize that rational analysis is not necessarily the optimal processing strategy in all situations, we believe it is preferable to possess this capacity and apply it when appropriate, than to rely exclusively or primarily on the experiential system.

As expected, there was no phenotypic correlation found between WMC and experiential preference. On the surface, this suggests it would be very unlikely these variables have shared genetic or environmental origins. Nevertheless, it is theoretically possible that genetic and environmental influences may be present, but operating in opposition to each other, essentially cancelling each other out, and resulting in a net phenotypic correlation of zero.

Limitations of the Present Study

The current study was based on a voluntary sample of adult twins, predominantly recruited by the Australian Twin Registry. Participants were required to have access to a computer and to be able to log in and run a simple online application. These results might not be generalizable to other age groups such as children or adolescents, and there could be some sampling bias favoring respondents who are more adept at using computers.

In addition, the estimate of the non-shared environment in all models also contains any measurement error from the study design. As mentioned, the REI is a well-established and reliable measure, the tests for WMC were designed to be analogous to the original measures, and all measures had high internal reliability. However, the tests were administered online so there might be unknown variables that have not been controlled for in the study. The extent to which there is measurement error will be reflected in the non-shared environmental component of all models, inflating the attribution of unique individual factors to the variability.

Finally, most of our interpretations in this study are based on variance estimates derived from nested univariate and bivariate models. In all instances, these nested models were not associated with a significant deterioration of fit relative to their corresponding fully saturated counterparts, so the nested models provided a more parsimonious account of observed effects. However, this also affirmed the low power, on account of our small sample size. Furthermore, some argue nested models generate more biased estimates for genetic and shared environment effects, rendering the saturated estimates more appropriate (Keller & Coventry, 2005). Future research with larger samples of twins is required to replicate our findings and produce more precise estimates.

Conclusion

This study investigated thinking styles from the perspective of behavioral genetics by providing estimates of genetic and environmental factors for rational preference and experiential preference. About half of the variability in experiential preference was attributable to genetic factors. Our best

estimates for the variability in rational preference (obtained from the bivariate model) indicated that around a third of its variability was attributable to additive genetic factors. The study also provided evidence that over half of the phenotypic correlation between WMC and rational preference was due to shared genetic influence. These shared genetic influences suggest that interventions aimed at increasing WMC may also improve individuals' capacities and preferences for rational analysis.

Acknowledgments

Endnote

1 The DE model was not tested because a model that has non-additive genetic variance without additive genetic variance is biologically implausible (see Neale & Cardon, 1992).

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