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The influence of nonshared environmental factors on number and word recall test performance

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ABSTRACT

A large body of research indicates that variation in intelligence is influenced by genetic and environmental factors. Despite this knowledge, much of the research examining environmental influences on intelligence is not conducted using genetically informative research designs. In order to address this gap in the literature, this study examines the potential association between nonshared environments and measures of intelligence (recall ability) in adulthood using monozygotic (MZ) difference scores analyses. Analysis of MZ twin pairs drawn from the National Longitudinal Study of Adolescent to Adult Health revealed that none of the nonshared environmental variables were consistently related to recall ability. One nonshared environmental variable, maternal disengagement, was found to be a significant predictor of recall ability in two of the four recall tasks. In addition, measures of maternal attachment and delinquent peers were found to be associated with only one test of word recall ability and none of the three other recall tests.

1. Introduction

Intelligence is a relatively stable trait that is characterized by a significant amount of variability in the population (Deary, Whalley, Lemmon, Crawford, & Starr, 2000). Of particular importance, intelligence has been found to be a predictor for an array of life outcomes. For instance, intelligence has been associated with increased educational outcomes, occupational status, and incomes in longitudinal studies (Strenze, 2007; Deary et al., 2005). In addition, intelligence as also been linked with health related outcomes including cardiovascular disease (Hart et al., 2004), obesity (Chandola, Deary, Blane, & Batty, 2006), stroke (Hart et al., 2004), and premature mortality (Batty, Deary, & Gottfredson, 2007). Overall, research indicates that intelligence has a broad influence that affects life factors in almost all domains of life.

Against this backdrop, it is not surprising that there is a significant amount of attention placed on identifying the etiology of intelligence and related cognitive abilities. Evidence from this body of research indicates that intelligence is under significant genetic influence with heritability estimates consistently above .50 (Plomin, 1999). The remaining variance tends to be accounted for by environmental influences that are unique to each child. Research has identified a host of specific environments that might be involved in the creation of variation in intelligence; however, a major limitation of most of this research is that it might be misspecified because of a failure to control for the potentially confounding effects of genetic influences.

2. Etiology of intelligence

There is a wealth of literature exploring the etiology of intelligence. Evidence from this line of research indicates that variation in intelligence is influenced by genetic and environmental factors (Nisbett et al., 2012). Studies on the heritability of intelligence indicate that genetic factors account for between 40% and 80% of the variance in intelligence (Nisbett et al., 2012; Deary, Johnson, & Houlihan, 2009). Moreover, findings from this area of research reveal an age-related pattern with low estimates of heritability during childhood and increasing estimates of heritability with age (Spinath, Ronald, Harlaar, Price, & Plomin, 2003; Haworth et al., 2010). Overall, findings from these studies indicate that genes account for approximately 80% of the variance in intelligence in adulthood (Gottfredson & Saklofske, 2009; Edmonds et al., 2008).[1] The remaining variance in intelligence is explained by environmental factors (and error).

Studies that examine the influence of genetic factors on intelligence frequently employ twin-based research designs. Twin-based research designs operate by comparing phenotypic similarity between monozygotic (MZ) and dizygotic (DZ) twin pairs which allows for phenotypic variance to be partitioned into genetic and environmental components. The logic of this approach is grounded in the fact that MZ twins share approximately 100% of their DNA and DZ twins share approximately

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[1] A reviewer pointed out that gene-environment interactions and active/evocative gene-environment correlations may help to explain the high estimates of heritability for intelligence. For an in-depth discussion of this issue see Plomin, DeFries and Loehlin (1977)

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50% of their distinguishing DNA.[2] As a result, if the assumptions of twin research designs are met, greater phenotypic similarity between MZ twins compared to DZ twins is interpreted as being the result of genetic influences, with the remaining variance being the result of environmental influences (and error). The environmental component is divided into a shared and a nonshared component.[3] Shared environmental influences make children who live in the same household similar to one another whereas nonshared environmental influences make children who live in the same household different from one another. In general, findings from twin-based research studies on the etiology of intelligence indicate that nonshared environments account for variation in adult intelligence scores, while shared environmental factors appear to have limited effects (Edmonds et al., 2008; McGue & Bouchard, 1998; Bouchard & McGue, 2003).

Aside from genetically informed studies on intelligence, there is a growing line of research examining specific environments that may account for variation in intelligence. For instance, previous research has identified family-level measures, such as parental involvement (Bradley et al., 1993; Fan & Chen, 2001), parental attachment (Guo & Harris, 2000), and parental encouragement (Koutsoulis & Campbell, 2001) as being related to intelligence and academic performance. In addition, findings from studies that incorporate natural experiments and reviews of the literature on the relationship between education and intelligence indicate that additional years of schooling are associated with intelligence scores in adulthood (Brinch & Galloway, 2012; Ceci, 1991). Most of the existing studies in this area, however, have examined the influence of environmental factors on intelligence using standard social science methodologies that examine only one child per family and do not estimate genetic effects. Furthermore, these studies are unable to distinguish between shared and nonshared environments.

3. Limitations of environmental research on intelligence

Despite the large body of research indicating that intelligence is genetically influenced, the majority of studies examining environmental effects on intelligence do not take into account genetic influences. As a result, the models used to examine the etiology of intelligence might be misspecified and thus produce incorrect or biased coefficients for environmental measures. Further complicating the matter is that a large review of the studies examining genetic influences on variation in environmental measures revealed that variability in parenting measures and other environments predicted to influence the development of intelligence is due to genetic influences (Kendler & Baker, 2007).[4] Findings from studies that have revealed that specific environmental measures are significantly related to variation in intelligence, therefore, may be confounded by unmeasured genetic influences as these studies usually do not attempt to control for genetic confounding. Importantly, studies that have examined the development of intelligence using genetically informative designs have revealed relatively small or even nonsignificant effects for specific environmental variables, including family- and parent-based measures (Beaver et al., 2014; Haworth et al., 2010; Bouchard & McGue, 2003).

4. Current study

There is a significant amount of research examining environmental influences on intelligence, but most of this research does not take into account the influence of genetics. As a consequence, it is not possible to determine the precise role that specific environmental factors have on measures of intelligence. In order to address this gap, the current study estimated the association between nonshared environmental factors and intelligence (as measured by number and word recall tasks). We use MZ difference scores analyses to examine these associations and, at the same time, take into account genetic confounding.

5. Methods

5.1. Data

This study uses data drawn from waves 1 and 4 of the National Longitudinal Study of Adolescent to Adult Health (Add Health). Add Health is a multi-wave longitudinal and nationally representative sample of adolescents in the United States (Udry, 2003). Data collection for the first wave of the Add Health survey was conducted during the 1994–1995 school year and included information from more than 90,000 students who were between the ages of 12 and 18. Questions in the first wave of the Add Health survey covered topics such as daily activities, relationships with parents and peers, and involvement with delinquency. The fourth wave of the survey was administered between 2007 and 2008 and was completed by more than 15,000 of the original participants from wave 1 (Harris et al., 2003). At wave 4, participants were young adults between the ages of 24 and 32 and were asked questions related to educational histories, employment status, and marital status.

The Add Health survey contains a subsample of siblings, twins, and cousins that can be used to conduct genetically informed analyses. During the first wave of the survey, kinship pairs were deliberately oversampled by asking respondents if they lived with a twin, sibling, cousin, or unrelated sibling. If the participants answered affirmatively, and the sibling, was between the ages of 11 and 20, then the sibling was added into the sample. The full sibling sample contains more than 3000 kinship pairs (Beaver, 2008). This study uses data from 289 pairs of monozygotic (MZ) twins with sample sizes ranging from 161 to 163 MZ twin pairs for the analyses of this study.

5.2. Measures

5.2.1. Outcome measures

5.2.1.1. Number recall. At wave 4 participants were asked to complete seven tasks that involved repeating a sequence of numbers backwards to the survey administrator. The length of the number sequences ranged from two to eight numbers. A total-number recall score was created by summing together how participants performed on each of these number recall tasks. Participants were awarded one point for correctly completing each of the number recall sequence tasks. For this analysis we use the total-number recall score and a mid-range (4 number) recall score to measure number recall ability. The total-number recall test measure has been used previously as a measure of short-term memory (Lundberg, 2015) and as a measure of neuropsychological deficits with Add Health data (Beaver, Vaughn, DeLisi, Barnes, & Boutwell, 2012).

5.2.1.2. Word recall. At wave 4 participants were asked to perform two word recall tasks where they were asked to repeat as many words off a list that they could remember in a set time period. In the first task, respondents were shown a word list and then immediately asked to repeat as many words off the list that they could remember in a 90-second time period. In the second task, administered later in the survey,

[2] Genetic differences may arise between MZ twins due to point mutations and epigenetic markers (Li et al., 2013; Fraga et al., 2005).

[3] Some researchers in this area further decompose environmental factors into effectively and objectively shared environments. For a thorough discussion of the difference between effectively and objectively shared/nonshared environments see Turkheimer and Waldron (2000).

[4] This phenomenon is referred to as a gene-environment correlation. Gene-environment correlations refer to the process through which genetic propensity can influence and structure environments. For a more thorough discussion on gene-environment correlations see Plomin, DeFries, and Loehlin (1977).

respondents were asked to recall as many words as possible from the list in the first recall task in a 60-second time period. Scores were calculated by adding up all of the correct words repeated off the list in each of the tasks. For this analysis we use the word recall scores from both the 60-second and 90-second word recall exercises. The word recall test has been used previously to measure short-term memory (90-second task), long-term memory (60-second task) (Lundberg, 2015), and neuropsychological deficits with Add Health data (Beaver et al., 2012).[5]

5.2.2. Trait-based measures

5.2.2.1. Verbal ability. Verbal ability was measured at wave 1 using the Picture Vocabulary Test (PVT). The PVT is an abbreviated version of the Peabody Picture Vocabulary Test (PPVT). PVT scores in the Add Health data are available in standardized, raw, and percentile rank forms. For this study, we employed the standardized PVT scores. The PVT has been used previously by researchers using Add Health data (Rowe, Jacobson, & Van den Oord, 1999). We included this measure in the analyses in order to control for the influence of adolescent verbal ability on recall ability in adulthood.

5.2.2.2. Low self-control. A low self-control scale was created at wave 1 in order to be able to control for the effects of low self-control in adolescence on later measures of intelligence and recall ability. Following the example of previous research (Perrone, Sullivan, Pratt, & Margaryan, 2004), a low self-control scale was created using answers to five items concerning respondent's ability to concentrate, focus, and get along with others. Respondents, for instance, were asked if they have trouble paying attention, difficulty staying focused, and if they get along with their teachers. Answers to these five questions were summed together in a low self-control scale ($\alpha = .664$). These items were coded so that higher values indicate lower levels of self-control. This low self-control scale is identical to low self-control scales used previously with Add Health data (Wright, Beaver, DeLisi, & Vaughn, 2008).

5.2.3. Environmental measures

5.2.3.1. Maternal attachment. A maternal attachment scale was created at wave 1 by summing together answers from two questions concerning respondent's emotional attachment to their mothers ($\alpha = .640$). This scale is similar to other maternal attachment scales that have been used previously with Add health data (Schreck, Fisher, & Miller, 2004; Haynie, 2001).

5.2.3.2. Maternal involvement. A maternal involvement scale was created at wave 1 using answers to 10 questions that were designed to assess what activities a respondent regularly participated in with their mother. For instance, respondents were asked if they went shopping or went to a movie with their mother over the last four weeks. Answers were coded so that 1 = yes and 0 = no. Answers to these questions were summed together in a maternal involvement scale ($\alpha = .553$). This scale is similar to maternal involvement scales that have been used previously with Add Health data (Crosnoe & Elder, 2004).

5.2.3.3. Maternal disengagement. A maternal disengagement scale was created at wave 1 using answers to five questions regarding respondent's relationships with their mothers. Respondents, for example, were asked to indicate how much they talked with their mother and how warm their mother was. Answers to these five questions were summed together in a maternal disengagement scale ($\alpha = .836$). This scale is coded so that higher values indicate higher levels of maternal disengagement. This maternal disengagement scale is identical to previous maternal disengagement scales that have been used with Add Health data (Beaver et al., 2009).

5.2.3.4. Parental permissiveness. A parental permissiveness scale was created at wave 1 using answers to seven questions where respondents were asked to indicate how permissive their parent's parenting practices were. For example, respondents were asked to indicate if their parents allowed them to make their own decisions regarding what they ate, curfews, and friends. Answers to these items are coded so that 1 = yes and 0 = no. Answers to these questions were summed together in a parental permissiveness scale ($\alpha = .631$). This scale is similar to parental permissiveness scales that have previously been used with Add Health data (Beaver et al., 2012).

5.2.3.5. Delinquent peers. A scale for delinquent peers was created at wave 1 by summing together answers to three questions concerning peer involvement in substance use. Specifically, respondents were asked to indicate how many of their closest friends drank alcohol at least once a month, smoked at least one cigarette a day, and smoked marijuana at least once a month. These items were coded so that higher values represent greater peer involvement in delinquency. These items were summed together in a delinquent peers scale ($\alpha = .756$). This delinquent peers scale is identical to previous delinquent peers scales that have been used with Add Health data (Beaver, Vaughn, & DeLisi, 2013).

5.3. Analytic strategy

This study employs monozygotic (MZ) difference scores analyses in order to estimate the influence of nonshared environmental factors in adolescence on recall ability in adulthood. MZ difference scores are considered one of the more ideal analytic strategies for establishing causation in research on nonshared environmental factors (Caspi et al., 2004; Asbury, Dunn, Pike, & Plomin, 2003; Pike, Reiss, Hetherington, & Plomin, 1996; Rovine, 1994). With the MZ difference approach, it is possible to take advantage of the fact that MZ twins share approximately 100% of their DNA. Since MZ twins are approximately genetic clones, differences between MZ twin's phenotypes are due to the influence of environmental factors that differ between them—that is, nonshared environmental factors. The MZ difference scores approach eliminates the possibility that the association between nonshared environments and phenotypes is due to genetic confounding. Furthermore, the MZ difference scores approach also isolates the effect of the nonshared environment from the shared environment allowing for the examination of nonshared environmental factors independently.[6]

For this study, the MZ difference scores analyses proceeded in three steps. First, one twin from each pair was randomly designated as Twin 1, and the other twin was designated as Twin 2. Second, in order to create the difference scores, Twin 2's scores on each variable were subtracted

[5] Previous research examining recall ability and intelligence demonstrates that recall tasks are able to measure a component of general intelligence (Unsworth & Engle, 2007). Serial recall tasks, for instance, are frequently employed as subtests on standardized tests of intelligence (Rosen & Engle, 1997). In addition, performance on serial recall tasks have been found to be correlated with measures of nine subtests of intelligence according to the Wechsler Adult Intelligence Scale (Matarazzo, 1972) along with scores on aptitude and achievement tests including the Scholastic Aptitude Test (SAT) (Rosen & Engle, 1997; Dempster & Cooney, 1982).

[6] Previous researchers have raised concerns that using difference scores analyses will exacerbate problems with reliability (Lord, 1958). This issue has been examined extensively and there is a body of research that indicates that using difference scores, along with MZ difference scores, can be a reliable analytic strategy (Asbury et al., 2003; Ragosa & Willett, 1983; Ragosa, Brandt & Zimowski, 1982). Furthermore, there is evidence to indicate that difference scores can still be a reliable analytic strategy when examining measures that have a significant level of measurement error (Ragosa, Brandt, & Zimowski, 1982; Asbury et al., 2003).

Table 1
Descriptive statistics.

	Mean	S. D.	MZ r	Range	N
Word recall 60 s	.032	2.354	.302*	−6.00–6.00	217
Word recall 90 s	−.203	2.529	.182*	−11.00–7.00	217
Number recall 4 numbers	−.075	.553	.065	−1.00–1.00	213
Number recall total score	.207	1.618	.376*	−4.00–4.00	217
Maternal attachment	−.128	1.837	.360*	−9.78–13.03	252
Maternal involvement	.076	4.705	.431*	−16.50–12.96	253
Maternal disengagement	.093	3.974	.394*	−22.30–8.86	251
Parental permissiveness	−.296	4.555	.413*	−15.09–13.14	269
Low self-control	.031	3.593	.399*	−12.50–10.08	274
Delinquent peers	−.035	2.030	.656*	−6.44–7.26	268
PVT W1	−.077	9.928	.778*	−37.00–32.00	260

* $p < .05$.

from Twin 1's scores. Difference scores were created for the recall outcome variables as well as all of the environmental and trait-based predictor variables.[7] Third, the MZ difference scores were analyzed using ordinary least squares (OLS) regression in order to test for associations between the environmental predictor variables, trait-based measures, and the recall outcomes.

6. Results

Table 2 displays the results of the MZ difference scores analysis examining the association between nonshared environmental factors, trait-based characteristics, and word recall ability. Table 2 includes two models for both of the word recall tasks. The first model contains the nonshared environmental factors and low self-control. The second model contains the same variables as the first model and includes wave 1 verbal intelligence scores. As can be seen in Table 2, maternal disengagement has a statistically significant and negative relationship with performance on the 60-second word recall task in the first model. This relationship, however, drops to a level of marginal significance ($p = .052$) after controlling for wave 1 verbal intelligence scores in the second model. This finding indicates that the twin who scored lower on maternal disengagement tended to score higher on the 60-second word recall task. Further examination of Table 2 reveals that maternal attachment is positively and significantly associated with performance on the 90-second recall task in both models. This finding indicates that the twin with a higher score on maternal attachment scored higher on the 90-second word recall task. In addition, delinquent peers have a significant negative relationship with the 90-second word recall task performance in both models. Furthermore, maternal disengagement has a negative association with performance on the 90-second word recall task that nears significance in model 1 ($p = .066$) and in model 2 ($p = .068$).[8]

Table 3 presents the results of the MZ difference scores analysis examining the association between nonshared environmental factors, trait-based characteristics, and number recall task performance. Table 3 employs the same two models used in Table 2 for both of the number recall tasks. Examination of Table 3 reveals that none of the nonshared environmental factors or trait-based characteristics are significantly associated with performance on the 4-number recall task. In contrast, findings for the total-number recall task indicate that only one of the nonshared environmental factors influences task performance. As can be seen in Table 3, maternal disengagement is positively and significantly associated with performance on the total-number recall task in both models. This finding indicates that the twin with a higher score on maternal disengagement scored higher on the total number recall task. Additionally, verbal intelligence is positively and significantly associated with total-number recall task performance in the second model.

7. Discussion

Findings from research studies examining the etiology of intelligence indicate that environmental factors in childhood influence intelligence scores in adulthood (Koutsoulis & Campbell, 2001; Guo & Harris, 2000). The majority of these studies, however, are not conducted using genetically informative research designs, resulting in a body of evidence that is difficult to interpret. The current study addressed this gap in the literature by examining the influence of nonshared environmental factors on a measure of intelligence using a genetically informative research design. The MZ difference scores analyses revealed two main findings.

First, maternal disengagement was found to be significantly associated with 60-second word recall ability and total-number recall score. Surprisingly, maternal disengagement appeared to have opposite effects on number recall and word recall ability. Maternal disengagement was found to be negatively associated with 60-second word recall ability, while it was positively associated with total-number recall ability. These results indicate that maternal disengagement has significant effects on recall ability, however, the effects are in opposite directions for word and number recall ability. The contradictory effects of maternal disengagement on measures of recall ability suggest the need for further examination of the relationship between maternal disengagement and recall ability in adulthood.

Second, maternal attachment was positively associated with performance on the 90-second word recall task. This finding is consistent with previous research that indicates that parental attachment is positively associated with intelligence (Guo & Harris, 2000). Keep in mind, however, that maternal attachment was not found to be associated with performance on any of the other recall tasks. Also of importance, none of the other nonshared parenting measures were found to be significantly related to recall ability in adulthood. The general absence of significant effects for parenting measures is in contrast with findings from several previous studies that have examined the influence of parenting behaviors on intelligence (Bradley et al., 1993; Fan & Chen, 2001). These findings, however, are consistent with findings from other studies that have employed genetically sensitive research designs to examine the influence of parenting behaviors on intelligence (Beaver et al., 2014). Taken together, these results indicate that nonshared parenting measures in adolescence do not have consistent effects on adult recall ability using a genetically informative research design.

The results of this study indicate that some environmental measures predicted to account for variation in intelligence are not statistically significant when examined using a genetically sensitive research design. These findings, however, need to be interpreted with caution because of a number of limitations. First, recall ability was used as an indicator for intelligence at wave 4. While there is a substantial quantity of research indicating that recall ability is a valid indicator of intelligence (Unsworth & Engle, 2007; Rosen & Engle, 1997), it is possible that a different pattern of findings may have been observed if another measure of intelligence had been available at wave 4. Second, many of the previous studies examining the influence of parenting behaviors on intelligence examined environmental factors in childhood as opposed to adolescence. As a result, it is possible that the parenting variables measured at wave 1 may have had less of an effect than if they had been measured at an earlier time point.

[7] In order for MZ difference scores to be meaningful there has to be variation within the MZ twin pairs on the predictor and outcome variables. We tested for variability between the MZ twins on all of the variables included in the analyses using intra-twin correlations. The correlations between the MZ twins are presented in Table 1. Examination of the correlations reveals that the twins are significantly correlated on most of the variables included in the analyses, however, the correlations also reveal that there is significant variation between the MZ twins on each of the measures.

[8] A reviewer pointed out that it would be interesting to examine the influence of the nonshared environmental factors on a composite measure of recall task performance. We reestimated our analysis using a composite measure for the recall scores and our findings reveal that none of the nonshared environmental factors are significantly associated with the composite recall measure.

Table 2
MZ difference scores for word recall.

	60 s						90 s					
	Model 1			Model 2			Model 1			Model 2		
	b	Beta	SE	b	Beta	SE	b	Beta	SE	b	Beta	SE
Maternal attachment	.137	.116	.093	.130	.110	.093	.202	.163	.096*	.198	.160	.096*
Maternal involvement	.020	.041	.038	.013	.028	.038	−.019	−.038	.039	−.023	−.046	.039
Maternal disengagement	−.090	−.158	.046*	−.089	−.156	.045ǂ	−.087	−.146	.047^	−.087	−.144	.047γ
Parental permissiveness	.027	.053	.041	.022	.042	.041	−.006	−.011	.042	−.009	−.017	.043
Delinquent peers	−.068	−.061	.088	−.059	−.053	.088	−.189	−.163	.091*	−.184	−.158	.092*
Low self-control	−.039	−.062	.051	−.038	−.060	.051	.019	.029	.053	.020	.030	.053
PVT W1				.023	.103	.018				.014	.060	.018
N	163			163			163			163		

* $p < .05$.
** $p < .01$.
ǂ $p = .052$.
^ $p = .066$.
γ $p = .068$.

Table 3
MZ difference scores for number recall.

	Four numbers						Total score					
	Model 1			Model 2			Model 1			Model 2		
	b	Beta	SE	b	Beta	SE	b	Beta	SE	b	Beta	SE
Maternal attachment	.026	.094	.022	.025	.090	.022	−.031	−.037	.067	−.042	−.049	.066
Maternal involvement	.009	.080	.009	.008	.072	.009	.020	.057	.027	.010	.028	.027
Maternal disengagement	.007	.052	.011	.007	.055	.011	.072	.175	.033*	.074	.179	.032*
Parental permissiveness	.001	.010	.010	.000	.003	.010	.017	.045	.030	.008	.021	.029
Delinquent peers	−.003	−.013	.021	−.002	−.006	.021	.006	.008	.064	.021	.026	.063
Low self-control	−.002	−.017	.012	−.003	−.018	.012	−.004	−.010	.037	−.003	−.007	.036
PVT W1				.004	.068	.004				.036	.226	.013*
N	161			161			163			163		

* $p < .05$.
** $p < .01$.

Third, the sample size for the analyses conducted in this study hovered around 160 MZ twin pairs leaving opening the possibility that the findings may be limited by sample size and thus statistical power. As a result, it is possible that some of the insignificant findings in this study may be the result of "false-negatives." Future studies examining these relationships will be needed to determine if the nonsignificant findings may be due to Type II error. Last, this analysis did not address the possibility of how gene–environment correlations might be involved in the creation of variation in the recall tasks. Future research is needed addressing these limitations in order to determine the robustness of the results that were reported here.

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Appendix A. Zero-order correlation matrix of variables included in the analyses

		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
Word recall 60 s	X1	1										
Word recall 90 s	X2	.67*	1									
Total number recall	X3	.32*	.32*	1								
Four number recall	X4	−.01	.00	.10*	1							
PVT W1	X5	.29*	.30*	.40*	.06	1						
Maternal attachment	X6	.08	.08	.02	−.08	.05	1					
Maternal involvement	X7	.17*	.15*	.09	.04	.14*	.11*	1				
Maternal disengagement	X8	−.03	−.04	.05	.11*	−.01	−.38*	−.17*	1			
Parental permissiveness	X9	.10*	.05	.21*	−.08	.18*	−.01	−.05	.01	1		
Delinquent peers	X10	−.03	−.10*	−.04	−.04	−.11*	−.11*	−.01	.12*	.10*	1	
Low self-control	X11	−.03	−.06	−.03	.07	−.10*	−.09*	−.03	.27*	−.04	.27*	1

N = 578.
* $p < .05$, two-tailed.

Correlation matrix of MZ difference scores included in the analyses.

		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
Word recall 60 s	X1	1										
Word recall 90 s	X2	.56*	1									
Total number recall	X3	.20	.06	1								
Four number recall	X4	−.07	.02	−.06	1							
PVT W1	X5	.10	.07	.03	.08	1						
Maternal attachment	X6	.12	.15*	.49	.09	.08	1					
Maternal involvement	X7	.07	.03	.03	.06	.12	.04	1				
Maternal disengagement	X8	−.16*	−.15*	−.36	.03	−.02	−.15*	−.04	1			
Parental permissiveness	X9	.09	−.00	−.11	.01	.14*	.07	−.03	−.01	1		
Delinquent peers	X10	−.05	−.16*	.23	−.04	−.12	−.05	.01	.07	−.01	1	
Low self-control	X11	−.11	−.04	.15	.04	−.05	−.01	.08	.23*	.07	.17*	1

N = 289 MZ twin pairs.
* $p < .05$, two-tailed.

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