

Genetic Influence on the Variance in Coincidence Timing and Its Covariance with IQ: A Twin Study

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Performance measures on a coincidence timing task have previously been associated with psychometric IQ suggesting that the ability of an individual to devote processing resources at the required time may account for some of intelligence test variance. Using the twin design, this study investigates whether genetic variability explains some of the variance in coincidence timing and whether common genetic factors account for the association with intellectual functioning. Fifty-five 16-year old twin pairs (28 MZ, 27 DZ) were tested. Individual differences in number of hits (HITS), mean absolute error (MAE), and intra-individual trial-to-trial consistency (*SD*) were significantly influenced by genetic factors, accounting for approximately 50 percent of the variance. The correlation between coincidence timing and psychometric IQ was confirmed and ranged from 0.11 to 0.53 with a mean correlation of 0.33. In the limited sample, the correlation between IQ and the coincidence timing measures appeared to be mediated largely by a unique environmental factor, with only a small loading of *SD* on the genetic factor influencing IQ. However, as the confidence intervals in the other genetic cross loadings are large, we cannot exclude the possibility of a much stronger genetic influence.

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INTRODUCTION

Individual differences in coincidence timing ability to predict a future event were demonstrated as early as the eighteenth century, when the German astronomer Bessel realized that variation in the timings of transits of astronomic bodies reflected individual differences between observers (Boring, 1950). Coincidence timing is the skill of predicting and reading that two events occur at the same point in time and requires attention and integration of information over time. Unlike the more familiar reaction time task, coincidence timing tasks do not depend exclusively on speed of processing but on abilities such as attention and estimation (Larson, 1989) involving the monitoring of moving inputs, anticipating when targets will coincide and a planned, discrete, and anticipatory response. While they show some features of pursuit rotor, coincidence timing tasks represent more basic processing, monitoring moving inputs and a discrete ungraded response. Skill at such tasks is thought to relate to everyday activities such as predicting a gap in the traffic to coincide with one's road crossing, stepping on and off an escalator, playing video games, and in earlier times, the ability to time one's aim to hit a moving animal (Kolakowski & Malina, 1974; Smith & McPhee, 1987).

Smith and McPhee (1987) first investigated whether timing performance measures on a computerized coincidence timing task correlated with standard psychometric measures of intelligence. In Grade 8 school children, they found a moderate negative correlation (-0.29) between the number of errors on a coincidence timing task and the standard progressive matrices scores (SPM), and between intra-individual consistency of coincidence performance and SPM scores (-0.40). This relationship between coincidence timing and psychometric intelligence was later confirmed by Larson (1989) who found a correlation (-0.20) between coincidence timing errors and the Armed Forces Qualifying Test in Naval recruits, and by Saccuzzo, Johnson, and Guertin (1994) who reported a correlation between SPM and both coincidence timing errors (-0.30) and consistency (-0.28) in gifted and non-gifted children. Larson (1989) suggested that differences in some biological mechanism such as working memory could underlie the relationship between coincidence timing and psychometric intelligence. Although limited data from Saccuzzo et al. (1994) did not support Larson's hypothesis, there is accumulating evidence for a significant association between various measures of working memory, information processing and intelligence (e.g., Fry & Hale, 1996; Jurden, 1995; Just & Carpenter, 1992; Kyllonen & Christal, 1990; Necka, 1992).

To date, there has been no investigation of possible genetic influences on individual differences in coincidence timing skills or the extent to which genetic influences account for the relationship between coincidence timing and psychometric intelligence. If the phenotypic association between coincidence timing and psychometric IQ were found to be due largely to correlated genetic effects this would provide support for the notion of some common biological mechanism subserving both psychometric IQ and coincidence timing skills. While individual differences in speed of processing and its relationship with psychometric IQ both appear to be significantly influenced by genetic factors (Baker, Vernon, & Ho, 1991; Boomsma & Somsen, 1991; Ho, Baker, & Decker, 1988; Petrill, Thompson, & Detterman, 1995; Petrill, Luo, Thompson, & Detterman, 1996; Rijdsdijk, Vernon, & Boomsma, 1998; Vernon, 1989), it is likely that individual differences in measures of information processing are not uniformly explained by genetic

variance and the relative importance of genetic and environmental influences varies across tasks.

The current investigation, therefore, uses the twin method to partition the variance in coincidence timing among individuals into genetic and environmental components, and examines the extent to which coincidence timing and psychometric intelligence are influenced by the same underlying factors. The twin design compares monozygotic (MZ) twin pairs who share 100 percent of their genes with dizygotic (DZ) twins who share, on average, only 50 percent of their genes, and makes the assumption that there are no differential experiences between MZ and DZ twins which significantly impact on behavior (e.g., Kendler et al., 1993). Thus, if the causes of familial similarity are primarily additive genetic in origin, the correlation in performance of MZ co-twins is expected to be twice the correlation observed between DZ co-twins.

The study is part of a larger ongoing study investigating genetic influences on memory, attention and problem solving abilities—the MAPS study which will eventually consist of 500 plus twin or sibling pairs. As the coincidence timing task was dropped from the protocol in order to make testing time for the study acceptable, the data for the coincidence timing measures are complete and no more data will be collected by us. Therefore, while we fully acknowledge that the data are based on a small sample and the analyses and interpretation of the results are limited, these preliminary findings of coincidence timing are also reported as a prodromus to the MAPS study.

METHOD

Participants

Fifty-five pairs of twins (28 MZ (10 female, 18 male), 27 DZ (eight female, five male, 14 opposite sex)) with a mean age of 16.5 years (range 16.2–17.3 years) participated. These are the first twin pairs tested in a large ongoing study using several information processing and physiological measures to study genetic influences on cognition. Zygosity was determined by ABO, MN and Rh blood groups as well as eight independent highly polymorphic DNA markers. The probability of concordance for all markers given dizygosity was less than 10^{-3} .

All participants lived in South East Queensland had normal or corrected vision (better than 6/12 Snellen equivalent) and had no history of head injuries, neurological or psychiatric conditions. Participants were instructed to avoid consuming caffeine-containing foods or drinks for 2 h before their visit and no participants were currently taking prescribed medication with central nervous system effects.

Each co-twin was tested in the morning on the same day, and within 2 h of each other. Psychometric IQ was assessed first followed by coincidence timing skills. Written, informed consent was obtained from the twins and their parents and all data were stored and analyzed by numbers rather than names, and treated confidentially.

Psychometric Intelligence

The Multidimensional Aptitude Battery (MAB) was chosen as a measure of general intelligence. This is a group test of intelligence involving multiple choice questions, and patterned after, and highly correlated with, the Wechsler Adult Intelligence Scale—

Revised (Jackson, 1984). Time constraints and the availability of a (partly) computerized version of the test that could easily be administered by a research nurse were important factors in our choice of test. In addition, the MAB has been used in other work relating information processing measures with intelligence (Baker et al., 1991; Vernon, 1989; Vernon & Kantor, 1986). The test was administered to each participant separately using the standard MAB instructions as specified in the manual. Three verbal (information, arithmetic, and vocabulary) and two performance (object and spatial) sub-tests were used. The computerized version was used for the verbal sub-tests and the pencil and paper version for the performance sub-tests. Participants were given 7 min for each sub-test and adequate time for reading instructions and practice of example questions was given prior to each sub-test. Performance was scored by the MAB computer program to yield a full-scale IQ (FSIQ) score normed on a Canadian sample (Jackson, 1984). Verbal and performance IQ were also scored but are not reported in this study.

Coincidence Timing Task

The task was a modified version of that used by Smith and McPhee (1987). Participants viewed a computer screen with a vertical white line (the wire) down the centre, and on which the target (a mosquito) moved back and forth across the screen. The task required participants to press the space bar of the keyboard with their preferred hand so that their key press coincided within ± 19 ms of the mosquito sting's transit of the wire. Feedback consisted of a beep when the mosquito was successfully hit. For every successful HIT, the mosquito's lost sting was added to the left-hand corner of the screen (n.b. the mosquito always got back its sting).

The mosquito followed one of two paths across the screen. The simpler one was straight horizontal motion from left to right and back again across the middle of the screen. The more complex was a pseudorandom path based on the horizontal path but instead of moving one position right (or left), the mosquito could also move diagonally one across and one up or down. The random path was restrained to return to the level of the horizontal path at the right and left edge of the screen. The horizontal speed of the mosquito was the same for all trials. A movement from right to left and back again was called a cycle. There was a brief random delay (100–1000 ms) between cycles to prevent participants picking up a rhythm and pressing the key at a regular interval without full attention to the screen. Each cycle was treated as two trials, one on the left-to-right (LTR) transit, the other on the right-to-left (RTL). For each trial, the position of the mosquito's sting when the participant responded, the "response position" was recorded. If the participant omitted a response or was too slow in responding (i.e., the mosquito had already transited the screen), that trial was treated as missing.

All participants received 50 trials (25 LTR, 25 RTL) in each of the two conditions (i.e., straight vs. pseudorandom path) in the same order. Five cycles of each condition were demonstrated immediately prior to testing with no response required. Total testing time for each participant was approximately 10 min.

Four measures were computed for the 100 trials (i.e., collapsed over conditions). The measures included: number of responses within ± 19 ms of the wire (HITS), mean absolute error (MAE) calculated by taking the response position from the position of the wire, discarding the sign and taking the mean, standard deviation (*SD*) of the distribution of response positions (about the mean response position, not about the wire), and the number

of omitted responses (MISSES). Although HITS, MAE, and *SD* are empirically related, they measure conceptually different aspects of performance. The MAE equates anticipations (when the response position is before the true position) and lags (response after the true position) and gives the average miss size or reflected value of the overall mean accuracy; *SD* measures intra-individual trial-by-trial consistency of response, whereas number of HITS provides a criterion based measure of performance accuracy. As higher values of MAE and *SD* indicate worse performance these measures were reflected so that for the four main measures higher values indicate better performance, thereby avoiding numerical problems in the model fitting analyses.

Statistical Analyses

Reliability (Cronbach's alpha, split half reliability), distributions and associations (Pearson product moment correlation) of measures were assessed using SPSS for Windows version 8.0 (SPSS Inc., 1997).

Maximum likelihood (ML) analysis of the individual observations in which hypotheses about the means, variances, and covariances are tested (Lange et al., 1976), was used to investigate effects of birth order, zygosity and sex using the structural equation modelling package, Mx (Neale, 1998). Each of the two twin groups (MZ and DZ) has two means (one each for twins 1 and 2), two variances, and one covariance, giving a total of four means, four variances, and two covariances, or 10 parameters in all. Sex differences were tested by specifying a female mean and male deviation from that mean but otherwise made no restrictions on the size of variances and covariances of twins (i.e., one additional parameter). Initially, a saturated model is fitted estimating all 11 parameters, followed by submodels incorporating successive simplifications. The fit of each model is tested by likelihood ratio chi-square test against the preceding, more complex model within which it is nested (Neale & Cardon, 1992).

To test whether the mean IQ and the variance in IQ of our sample was significantly different from a population mean IQ of 100 ± 15 *SD*, a model in which the four means (i.e., for each co-twin for each zygosity group) were constrained to 100 was tested against the unrestricted model. Similarly, for the variance, a model in which all four variances were constrained to 225 was specified and tested against the unrestricted model.

ML correlations for each zygosity group were computed with means constrained to be equal but with separate male and female means specified to account for any sex effects. To distinguish between the possible mechanisms by which familial likeness may arise, the empirical base model was constrained to include possible causes of variation. There are four broad causes of variation, three of which (additive genetic influences "A," genetic dominance "D," and common environment "C") make family members more alike than random pairs of individuals, and one of which (unique environmental experiences, including error, "E") makes MZ twins and siblings different. However, as D and C are negatively confounded only one of them can appear in a given model and, as we shall see, the correlations do not suggest dominance effects so models containing A, C, and E were fitted to the raw data.

To examine the sources and pattern of covariation among related measures, and specifically whether there are common genetic influences of IQ and the coincidence timing measures a Cholesky decomposition was used. Although the power of the study is limited due to the relatively small sample size, given the correlations between the coincidence

Table 1. Means \pm SD (Range) for Coincidence Timing and Psychometric IQ

	<i>Males, n = 60</i>	<i>Females, n = 50</i>	<i>Total, N = 110</i>
Percentage HITS	57.5 \pm 14.0	48.2 \pm 14.5 ^a	53.3 \pm 14.9 (16–89)
Percentage MISSES	1.1 \pm 1.8	3.5 \pm 8.2	2.2 \pm 5.8 (0–40)
Mean error (MAE) (ms) ^b	22.3 \pm 7.7	26.7 \pm 9.1	24.3 \pm 8.6 (10–59)
Consistency (SD) (ms) ^b	27.8 \pm 8.2	32.5 \pm 9.0 ^a	29.9 \pm 8.8 (12–53)
Psychometric IQ ^c	113.5 \pm 11.8	112.0 \pm 12.4	112.8 \pm 12.0 (81–140)

Notes: ^aMale and female means differ, $p < 0.05$.
^bHigher values indicate worse performance, MAE: $n = 59$ males (109 total); SD: $n = 59$ males, 48 females, (107 total).
^c $n = 59$ males (109 total).

timing measures are high (reported below) a considerable increase in power is gained through the use of multivariate analyses as illustrated by Schmitz, Cherny, and Fulker (1998). Each source of covariance between n variables was decomposed into a series of n factors, the first factor loading on all variables, the second factor loading on all but the first variable, the third factor loading on all but the first two variables, and so on until the last factor loads on only the n th variable. A complete decomposition for the three sources of variance—additive genes, shared environment, and individual environment was specified initially. This full model was then simplified by successive dropping of nonsignificant parameters, i.e., by seeing whether dropping a parameter resulted in a significant increase in the goodness-of-fit chi square. The same principles of parsimony were applied in arriving at the preferred model as described above (Neale & Cardon, 1992).

RESULTS

Preliminary Analyses

Cronbach’s alpha for the 100 coincidence timing responses (50×2 conditions) was 0.94 and split half reliability (i.e., comparison of the two conditions) was 0.80, consistent with previous findings (Saccuzzo et al., 1994; Smith & McPhee, 1987). Number of HITS and full-scale IQ was normally distributed, and similarly, MAE and SD after one or three participants respectively were removed. Although the three outliers had a reasonable number of HITS (27, 27 and 38) either both the average miss size was high (MAE = 73) and consistency of response low ($SD = 111$) or just the consistency of response was low ($SD = 58, 60$) compared to the sample mean. Number of MISSES required a log transformation ($\ln(x + 1)$ for MISSES) to improve normality.

Analysis of Means

Distributions for all measures are shown in Table 1. As the mean number of HITS was around 50, and 55 percent of the sample had zero MISSES and a further 42 percent fewer than nine (out of a total of 100 trials) the difficulty of the task seemed appropriate for the sample and within the capability of all participants. The mean IQ of our sample was significantly higher than the normal population mean IQ of 100 ($\Delta\chi^2_4 = 46.10$) but the

Table 2. Maximum Likelihood Correlations for MZ (Above Diagonal) and DZ (Below Diagonal) Pairs for Measures of Psychometric IQ (IQ), Percent HITS (HITS), Mean Absolute Error (MAE), and Consistency (SD), for Twin 1 and Twin 2

	Twin 1				Twin 2			
	<i>IQ-1</i>	<i>HITS-1</i>	<i>MAE-1</i>	<i>SD-1</i>	<i>IQ-2</i>	<i>HITS-2</i>	<i>MAE-2</i>	<i>SD-2</i>
IQ-1		0.53	0.35	0.48	0.78	0.22	0.08	0.26
HITS-1	0.11		0.84	0.64	0.35	0.63	0.57	0.51
MAE-1	0.16	0.95		0.78	0.29	0.69	0.65	0.51
SD-1	0.29	0.85	0.93		0.47	0.63	0.47	0.50
IQ-2	0.53	0.06	0.14	0.15		0.38	0.23	0.38
HITS-2	-0.07	0.23	0.21	0.20	0.42		0.93	0.84
MAE-2	-0.14	0.39	0.38	0.32	0.38	0.84		0.83
SD-2	-0.05	0.46	0.44	0.37	0.36	0.68	0.85	

Notes: Co-twin correlations for each measure are shown in bold. MAE and SD are reflected so higher values indicate better performance and therefore, in general, correlate positively with IQ and HITS.

Dizygotic twins ($n = 26-27$), monozygotic twins ($n = 26-28$). Sixty-eight percent confidence intervals for co-twin correlations for MZs: 0.69–0.84 (IQ), 0.50–0.73 (HITS), 0.52–0.75 (MAE), 0.37–0.64 (SD) and DZs: 0.37–0.66 (IQ), 0.04–0.41 (HITS), 0.20–0.53 (MAE), 0.18–0.52 (SD). Sixty-eight percent confidence intervals for correlation between IQ and each coincidence timing measure: MZ twin 1/twin 2: 0.39–0.65/0.21–0.53 (HITS), 0.18–0.51/0.05–0.41 (MAE), 0.37–0.65/0.21–0.53 (SD). DZ twin 1/twin 2: -0.10–0.29/0.26–0.58 (HITS), -0.05–0.33/0.21–0.53 (MAE), 0.07–0.43/0.18–0.51 (SD).

variance was not significantly different from that of the population norms (i.e., $SD = 15$) ($\Delta\chi^2_4 = 4.87$).

ML analysis showed there were no significant mean differences or differences in variance between co-twins or zygoty group for any of the measures. Significant sex effects were found for two of the four coincidence timing measures (HITS and SD), but no significant difference between males and females was found for psychometric IQ. Males performed better than females with a significantly better HIT rate (i.e., more accurate) and lower SD (i.e., more consistent). No significant difference was found between males and females in MAE or in the number of MISSES. In all further analyses, sex effects (sex differences in the means can inflate twin resemblance for same sex twins) were adjusted for with a multiple regression procedure which specifies a female mean and male deviation from that mean but otherwise makes no restrictions on the size of variances and covariances of twins.

Estimating Twin Correlations and Univariate Model Fitting

ML correlations are shown in Table 2 for both MZ and DZ twins. The twins 1–2 correlations for the key variables are highlighted in bold. It can be seen that for IQ, HITS, MAE and SD the MZ correlations are higher than their DZ counterparts indicating additive genetic control of familial aggregation for psychometric IQ and coincidence timing. For MISSES the MZ correlation was low (0.29), the DZ correlation being -0.11 so this variable was not included in further analyses.

An ACE model gave an identical fit to the empirical model of a common variance, and an MZ and DZ correlation for each of the measures (necessarily so, since each has three parameters and the same constraints). Dropping both A and C

from the model, resulted in a significantly worse fit for each measure ($\Delta\chi^2 = 37.24$ (IQ), 22.06 (HITS), 19.03 (MAE), 8.90 (*SD*)) confirming that there was significant familial aggregation. However, dropping only one of A ($\Delta\chi^2 = 2.98$ (IQ), 2.23 (HITS), 0.78 (MAE), 0.77 (*SD*)) or C ($\Delta\chi^2 = 1.87$ (IQ), 0.16 (HITS), 0.51 (MAE), 0.07 (*SD*)) from the ACE model resulted in a nonsignificant $\Delta\chi^2$ indicating that either, or both, could be the cause of the familial correlation. Under the AE model, heritability estimates are 77, 66, 60, and 57 percent for IQ, HITS, MAE, and *SD*, respectively, and under the ACE model, corresponding heritabilities are 40, 51, 32, and 35 percent.

Fitting Multivariate Genetic and Environmental Models

Phenotypic correlations among coincidence timing measures were all high (0.68–0.95) (Table 2). The correlation of HITS with both MAE and *SD* is interesting given that these measures are calculated from all trials with a response (i.e., excluding MISSES) of which only approximately half were classified as HITS. Most importantly, better performance on the task was correlated with higher IQ scores (0.23–0.53) as seen in Table 2 for both twins 1 and 2 of the MZs and twin 2 of the DZs. Although the correlations were lower (0.11–0.29) for twin 1 of the DZs.

To dissect the relative contributions of genes and environment to the covariation between measures (IQ, HITS, MAE, and *SD*) a Cholesky decomposition for three sources of variance—additive genes, shared environment, and individual environment (ACE model) was specified giving a fit of $-2LL_{507} = 2716.88$. Dropping the shared environment (AE model) worsened fit by only $\Delta\chi^2_{10} = 2.33$ (n.s.), whereas dropping genetic factors from the ACE model caused an increase of $\Delta\chi^2_{10} = 9.66$ (n.s.). Although either an AE or CE model is acceptable, the AE model provides the better fit to the data suggesting that additive genes are a more important source of variation and covariation between measures. Further simplification of the additive genetic factor structure by successive dropping of nonsignificant parameters results in the model shown in Fig. 1 ($-2LL_{522} = 2727.42$).

The principal genetic features of the model are as follows. First, there is a common genetic factor (G1) accounting for 76 percent (0.87^2) of the variance in IQ which also accounts for a small amount (4% (0.20^2)) of the variance in *SD*, such that genetic influences which increase IQ also reduce *SD* (i.e., increase the consistency of the response of an individual). Although none of the genetic variance in HITS or MAE is accounted for by G1 the confidence intervals in the cross loading are high, -0.07 , -0.40 and -0.11 – 0.36 on HITS and MAE, respectively. A second independent genetic factor (G2) accounted for 58 percent (0.76^2), 55 percent (0.74^2), and 48 percent (0.69^2) of the variance in HITS, MAE, and *SD*, respectively. A third (G3) and fourth (G4) genetic factor did not account for any of the genetic variance in MAE and *SD*. Thus, for HITS, MAE and *SD*, the genetic factor influencing one also influences the other.

As individual environmental variance also subsumes any errors of measurement, it is to be expected that the vertical paths from E1, E2, E3 and E4 to the corresponding first, second, third, and fourth variables, respectively (IQ, HITS, MAE, and *SD*) will be large. There is also significant cross loading of the E1 factor on the three coincidence timing measures suggesting that individual environment—either long-term developmental events such as childhood infection or trauma or idiosyncratic (e.g., short-term alertness or mood)

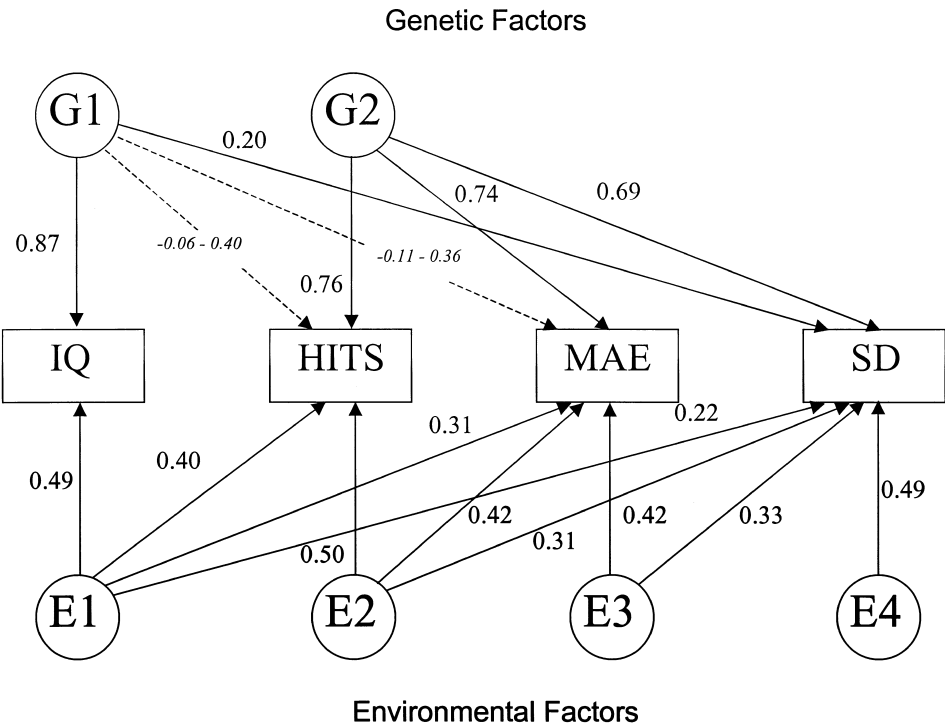


Figure 1. Path diagram showing latent genetic and environmental influences on measured phenotypes—psychometric IQ, percent HITS, mean absolute error (MAE) and consistency (*SD*). The loading on both HITS and MAE by G1 (shown as a dashed line) is not significant but the 95 percent CIs (shown in italics) are wide.

influence both coincidence timing and IQ, as well as cross loading of the E2 factors on MAE and *SD*, and E3 on *SD*.

DISCUSSION

Thus far, there has been no attempt to examine whether individual differences in coincidence timing skills exhibit familial aggregation. This study used twins to examine individual variation in coincidence timing skills and to attempt to partition the variation into genetic and environmental components. It also investigated whether there is a common genetic variance that accounts for the significant correlation between coincidence timing and psychometric intelligence that has previously been reported and which we replicate here.

Substantial individual variation in coincidence timing skills was found in our 16-year old twin sample with means and standard deviations similar to those found previously (Larson, 1989; Saccuzzo et al., 1994; Smith & McPhee, 1987). Three measures of coincidence timing—hit rate, mean error, and intra-individual trial-to-trial consistency

showed similar variability that was as large as that found for psychometric IQ from the same sample. Between individual variability was not related to birth order nor was zygosity, with MZ and DZ twin pairs performing similarly for all measures of coincidence timing and psychometric IQ. Males had a significantly better hit rate and were more consistent than females but there were no sex differences in mean error or psychometric IQ. Smith and McPhee (1987) previously reported sex differences for younger children in mean error but not trial-to-trial consistency. It may be that the better performance of males reflects their greater competitiveness at computer games compared to females, or spatial ability differences. Clearly, further study with a larger sample is required to examine this potential sex difference.

Twin correlations for the coincidence timing measures demonstrate significant familial aggregation. MZ co-twins showed considerable similarity with the correlation ranging from 0.50 to 0.63, the MZ correlation for HITS was approximately twice the DZ, and for MAE and *SD* the MZ correlation was higher than the DZ. However, the sample size was not large enough to distinguish A and C. A sizeable amount (57–66%) of the variance between individuals in coincidence timing may be accounted for by genetic factors in addition to nonshared environmental variance. A genetic factor loading on all coincidence timing measures was found suggesting that the strong phenotypic correlation between coincidence timing measures is substantially due to an underlying common genetic influence. Although parameter estimates must be interpreted with caution given the relatively small sample size of this study, they are in agreement with previous studies of cognitive ability (Baker et al., 1991; Boomsma & Somsen, 1991; Ho et al., 1988; Petrill et al., 1995, 1996; Rijdsdijk et al., 1998; Vernon, 1989). For a trait with a narrow heritability of 0.7 and no shared environmental variance, for a univariate analysis our sample would have 95 percent power to reject the hypothesis of no familial aggregation and approximately 40 percent power to reject the hypothesis that the familial aggregation is due to shared environment. For a wide range of cases, Schmitz et al. (1998) show that moving from a univariate to a quadrivariate analysis more than doubles the power to detect additive genetic variance so we may assume that our power to detect it in this study is at least 80 percent.

Confirming previous studies (Larson, 1989; Saccuzzo et al., 1994; Smith & McPhee, 1987), we found a significant correlation between coincidence timing and psychometric IQ, lending additional support to a relationship between these measures. Correlations of similar magnitude were also found with both verbal and performance measures of IQ and coincidence timing measures but are not reported in this study. Slightly stronger correlations are found for both HITS and *SD* with IQ than for MAE and IQ, following previous work showing that intra-individual trial-to-trial consistency correlates well with intelligence test scores (Jensen, 1982; Smith & Stanley, 1983). The multivariate analysis suggested that a small part of the covariance may be due to a common genetic factor. Partitioning the covariance of coincidence timing and IQ into genetic and environmental components showed that *SD* shared some of the genetic variance with psychometric IQ. However, the phenotypic associations of hit rate and IQ, and mean error with IQ could not be attributed to a common genetic variance. Given the strong inter-correlations between the coincidence timing measures it is not clear why *SD* should be influenced by a common genetic factor that underpins IQ, but not hit rate or mean error. It may be that *SD* is the only coincidence timing measure that (albeit indirectly) taps underlying physiological

processes such as the processing component of working memory that is shown, along with the storage function of working memory, to be important for predicting performance on cognitive tasks (Carpenter & Just, 1989; Daneman & Carpenter, 1980). Alternatively, the findings may simply be a reflection of our relatively small sample size such that our parameter estimates are unstable, and as the confidence intervals in the genetic cross loadings are large we cannot exclude the possibility of a much stronger genetic influence.

In conclusion, this study is the first attempt to investigate possible genetic influences on individual differences in coincidence timing skills and to examine the extent to which genetic influences account for the association with psychometric intelligence. It provides some potentially important information for the biological bases of the association between information processing and intelligence and future work will further the understanding of these preliminary results. The coincidence timing procedure is a psychophysiological task that assesses the consistency of an anticipation response of a participant and does not depend exclusively on speed of processing. While the genetic influence operating upon coincidence timing skills was found to be of similar magnitude to that of response time tasks, it is not known whether coincidence timing skills share the same target information and, if so, whether any shared variance among different information processing measures can be attributed to common genetic influences. It is possible that consistency of response and speed of response have different but equally important genetic contributions, and each contributes to the variance in human intellectual functioning.

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