*Table S1: Summary of Regression Spline Estimates and Model Fit at Different Cut Points*

| Spline Cut Point (years) | Regression Estimates | | | | | | | | | Model Fit | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Younger Age | Older Age | Sex | ISCED | Sex *Educ | Younger *Sex | Older *Sex | Younger *Educ | Older *Educ | AIC | BIC | Log Likelihood |
| 50 | -0.01 | -0.19 | 0.43 | 1.04 | 0.15 | 0.08 | -0.02 | -0.03 | 0.01 | 130507 | 130618 | -65239 |
| 55 | -0.07 | -0.22 | 0.54 | 1.03 | 0.14 | 0.06 | -0.04 | -0.02 | 0.02 | 130465 | 130576 | -65219 |
| 60 | -0.10 | -0.26 | 0.55 | 1.05 | 0.14 | 0.04 | -0.05 | -0.01 | 0.02 | 130427 | 130538 | -65200 |
| 60.84 | -0.10 | -0.26 | 0.53 | 1.07 | 0.14 | 0.04 | -0.05 | -0.01 | 0.02 | 130422 | 130533 | -65197 |
| 65 | -0.12 | -0.31 | 0.39 | 1.11 | 0.15 | 0.02 | -0.05 | -0.01 | 0.01 | 130406 | 130517 | -65189 |
| **70** | **-0.13** | **-0.37** | **0.21** | **1.18** | **0.16** | **0.00** | **-0.04** | **0.00** | **0.00** | **130393** | **130504** | **-65183** |
| 75 | -0.14 | -0.47 | 0.06 | 1.25 | 0.17 | 0.00 | -0.01 | 0.00 | -0.02 | 130417 | 130528 | -65194 |

*Note:* Unstandardized estimates are presented here. Bold indicates the best-fitting model based on smallest Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and log likelihood values. All models were estimated using maximum likelihood and included random effects of country, sample, and twin pair. “Younger Age” and “Older Age” refer to the age regression slope below or above the regression spline cut point for that model (e.g., 50 in the first row). ISCED = Education score.

*Table S2: Model Estimates and Standard Errors for the Genetic Model*

| Parameter | Estimate | Standard Error | 95% CI Lower | 95% CI Upper |
|---|---|---|---|---|
| *A. ACE Paths - Females* | | | | |
| a11 Education | 0.564 | 0.043 | 0.475 | 0.642 |
| a12 Fluency | 0.296 | 0.050 | 0.198 | 0.391 |
| a22 Fluency | 0.493 | 0.036 | 0.397 | 0.551 |
| c11 Education | 0.454 | 0.047 | 0.362* | 0.537 |
| c12 Fluency | 0.057 | 0.051 | -0.044 | 0.156 |
| c22 Fluency | 0.050 | 0.079 | -0.105* | 0.208 |
| e11 Education | 0.546 | 0.012 | 0.524 | 0.570 |
| e12 Fluency | 0.014 | 0.020 | -0.026 | 0.053 |
| e22 Fluency | 0.657 | 0.013 | 0.631 | 0.683 |
| *B. ACE Paths - Males* | | | | |
| a11 Education | 0.653 | 0.034 | 0.587* | 0.711 |
| a12 Fluency | 0.099 | 0.055 | 0.000 | 0.244 |
| a22 Fluency | 0.469 | 0.041 | 0.388* | 0.536 |
| c11 Education | 0.337 | 0.045 | 0.248* | 0.429 |
| c12 Fluency | 0.213 | 0.054 | 0.108* | 0.308 |
| c22 Fluency | 0.098 | 0.084 | -0.253 | 0.170 |
| e11 Education | 0.566 | 0.012 | 0.543 | 0.590 |
| e12 Fluency | 0.046 | 0.027 | -0.014 | 0.096 |
| e22 Fluency | 0.650 | 0.013 | 0.625 | 0.677 |
| *C. ACE Moderation for Education - Females* | | | | |
| a12 Education Moderation | -0.080 | 0.036 | -0.140 | 0.036 |
| a22 Education Moderation | 0.050 | 0.034 | -0.053 | 0.121 |
| c12 Education Moderation | 0.085 | 0.034 | -0.029 | 0.143 |
| c22 Education Moderation | -0.008 | 0.096 | -0.176 | 0.160 |
| e12 Education Moderation | 0.010 | 0.024 | -0.041 | 0.056 |
| e22 Education Moderation | 0.016 | 0.017 | -0.016 | 0.048 |
| *D. ACE Moderation for Education - Males* | | | | |
| a12 Education Moderation | 0.007 | 0.035 | -0.092 | 0.076* |
| a22 Education Moderation | 0.031 | 0.046 | -0.062 | 0.117 |
| c12 Education Moderation | 0.031 | 0.040 | -0.060 | 0.148 |
| c22 Education Moderation | -0.191 | 0.031 | -0.246 | -0.130* |
| e12 Education Moderation | -0.016 | 0.029 | -0.080 | 0.052 |
| e22 Education Moderation | -0.053 | 0.014 | -0.080 | -0.025 |
| *E. ACE Moderation for Age - Females* | | | | |
| a11 Age Moderation | -0.036 | 0.022 | -0.082 | 0.008 |
| a12 Age Moderation | 0.007 | 0.048 | -0.084 | 0.102 |
| a22 Age Moderation | -0.014 | 0.034 | -0.088 | 0.055 |
| c11 Age Moderation | -0.044 | 0.025 | -0.095 | 0.006* |
| c12 Age Moderation | 0.065 | 0.051 | -0.029 | 0.165 |
| c22 Age Moderation | 0.078 | 0.063 | -0.172 | 0.162 |
| e11 Age Moderation | 0.011 | 0.010 | -0.008 | 0.031 |
| c12 Age Moderation | -0.012 | 0.019 | -0.049 | 0.026 |
| e22 Age Moderation | 0.012 | 0.014 | -0.015 | 0.039 |
| *F. ACE Moderation for Age - Males* | | | | |
| a11 Age Moderation | -0.080 | 0.036 | -0.151* | -0.009 |

| | | | | |
|---|---|---|---|---|
| a12 Age Moderation | -0.071 | 0.038 | -0.141 | 0.022 |
| a22 Age Moderation | -0.053 | 0.037 | -0.133 | 0.054 |
| c11 Age Moderation | 0.147 | 0.055 | 0.027 | 0.243 |
| c12 Age Moderation | 0.000 | 0.074 | -0.143 | 0.145* |
| c22 Age Moderation | -0.020 | 0.097 | -0.282 | 0.282 |
| e11 Age Moderation | 0.015 | 0.013 | -0.011 | 0.041 |
| e12 Age Moderation | 0.012 | 0.025 | -0.038 | 0.059 |
| e22 Age Moderation | 0.009 | 0.015 | -0.019 | 0.038 |
| *G. Mean Effects - Females* | | | | |
| Education Intercept | 0.161 | 0.029 | 0.104 | 0.217 |
| Fluency Intercept | -0.299 | 0.030 | -0.357 | -0.241 |
| Age on Education | 0.059 | 0.017 | 0.026 | 0.092 |
| Age on Fluency | -0.395 | 0.014 | -0.423 | -0.367 |
| Australia vs. USA (on Education) | -0.323 | 0.051 | -0.422 | -0.223 |
| Australia vs. USA (on Fluency) | 0.270 | 0.041 | 0.189 | 0.351 |
| Denmark vs Other (on Education) | -0.353 | 0.018 | -0.446 | -0.351 |
| Denmark vs Other (on Fluency) | 0.211 | 0.014 | 0.190 | 0.263 |
| *H. Mean Effects - Males* | | | | |
| Education Intercept | 0.290 | 0.040 | 0.212 | 0.367 |
| Fluency Intercept | -0.307 | 0.037 | -0.380 | -0.233 |
| Age on Education | 0.143 | 0.024 | 0.084 | 0.187 |
| Age on Fluency | -0.356 | 0.022 | -0.397 | -0.301 |
| Australia vs. USA (on Education) | -0.063 | 0.070 | -0.201 | 0.075 |
| Australia vs. USA (on Fluency) | 0.078 | 0.055 | -0.030 | 0.185 |
| Denmark vs Other (on Education) | -0.399 | 0.024 | -0.387 | -0.318 |
| Denmark vs Other (on Fluency) | 0.226 | 0.019 | 0.183 | 0.239 |

*Note:* Model estimates and standard errors from the full genetic model. Verbal fluency, age, and education variables were z-scored prior to analysis, and age was then re-centered at age 70 (i.e., z-score of .817). The a11 path refers to the genetic influences on education (in parts A and B) or the moderation of genetic influences on education by age (E and F). The a12 path refers to the genetic influences on semantic fluency shared with education (A and B) or the moderation of these influences by education (C and D) or age (E and F). The a22 path refers to the unique genetic influences on semantic fluency (A and B), or the moderation of these influences by education (C and D) or age (E and F). Similar paths were estimated for shared environmental influences (c11, c12, c22) and nonshared environmental influences (e11, e12, e22). The full model is displayed in Figure S5. * indicates that standard-error based confidence intervals (CIs) were used in the few cases where likelihood-based confidence intervals could not be estimated.

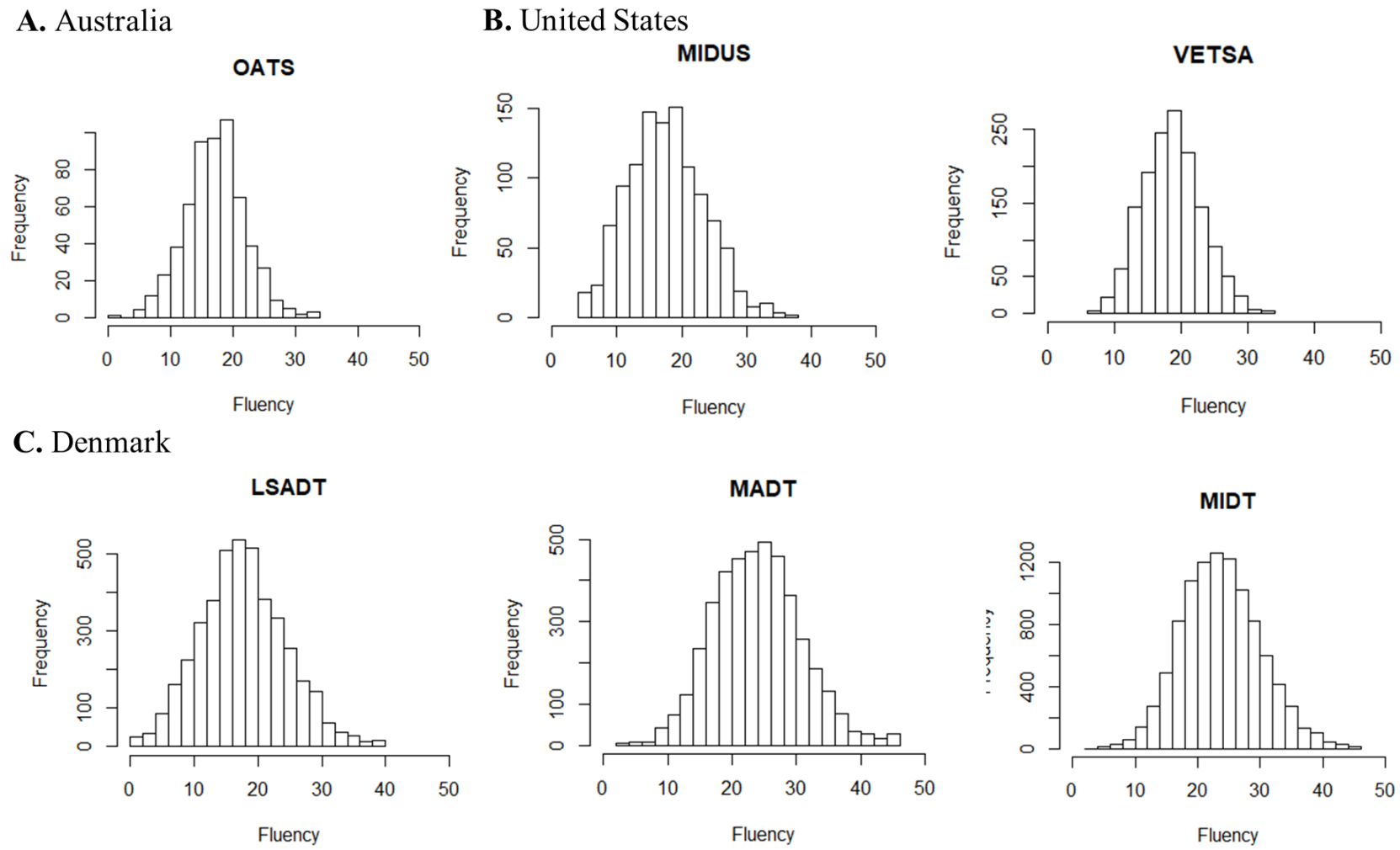



*Figure S1:* Histograms of winsorized verbal fluency scores in each sample (see Figure S4 for histogram of all studies combined). OATS = Older Australian Twins Study, MIDUS = Midlife in the United States, VETSA = Vietnam Era Twin Study of Aging, LSADT = Longitudinal Study of Aging Danish Twins, MIDT/MADT = Middle Age Danish Twin Studies.

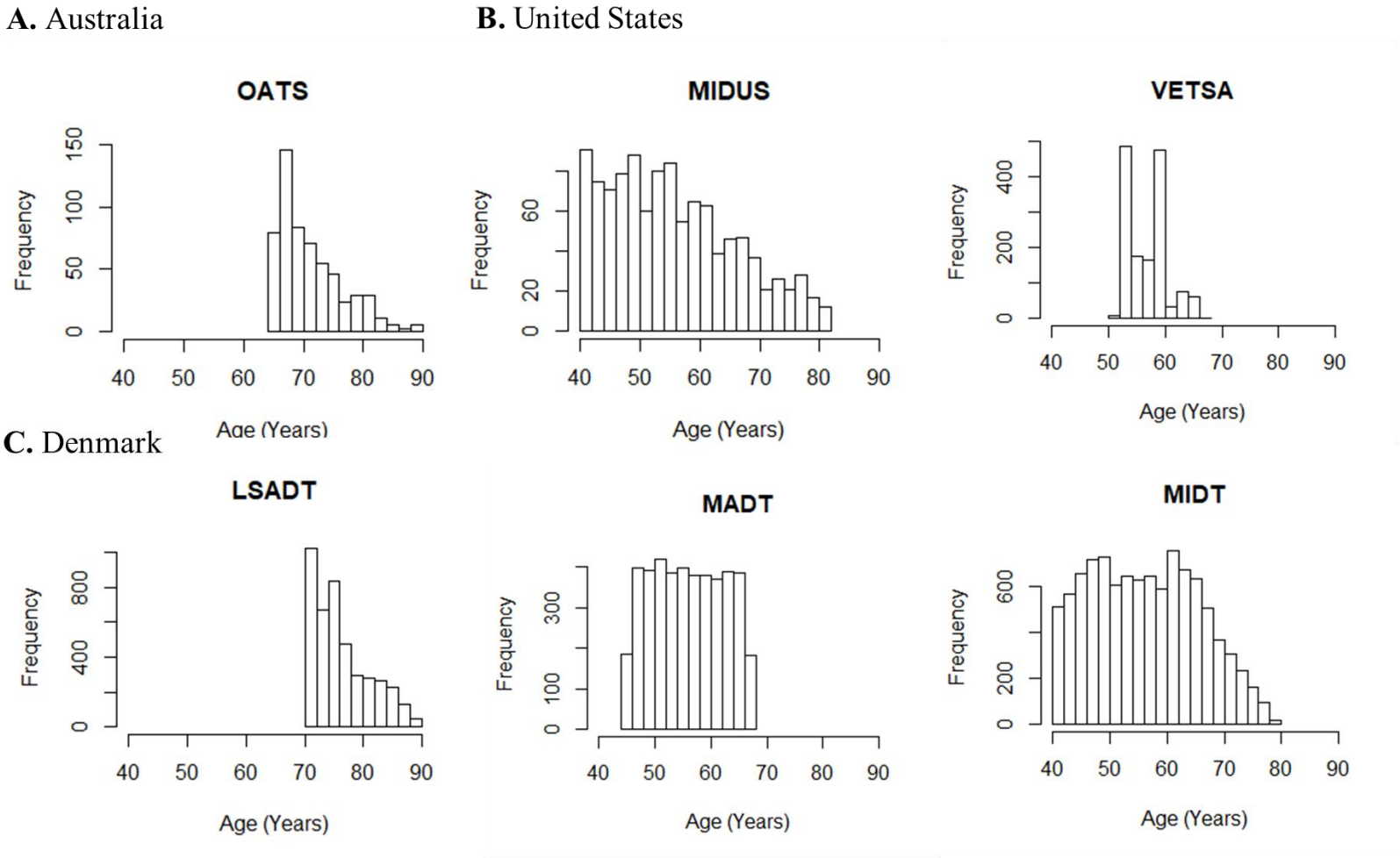



*Figure S2:* Histograms of age in each sample (see Figure S4 for histogram of all studies combined). OATS = Older Australian Twins Study, MIDUS = Midlife in the United States, VETSA = Vietnam Era Twin Study of Aging, LSADT = Longitudinal Study of Aging Danish Twins, MIDT/MADT = Middle Age Danish Twin Studies.

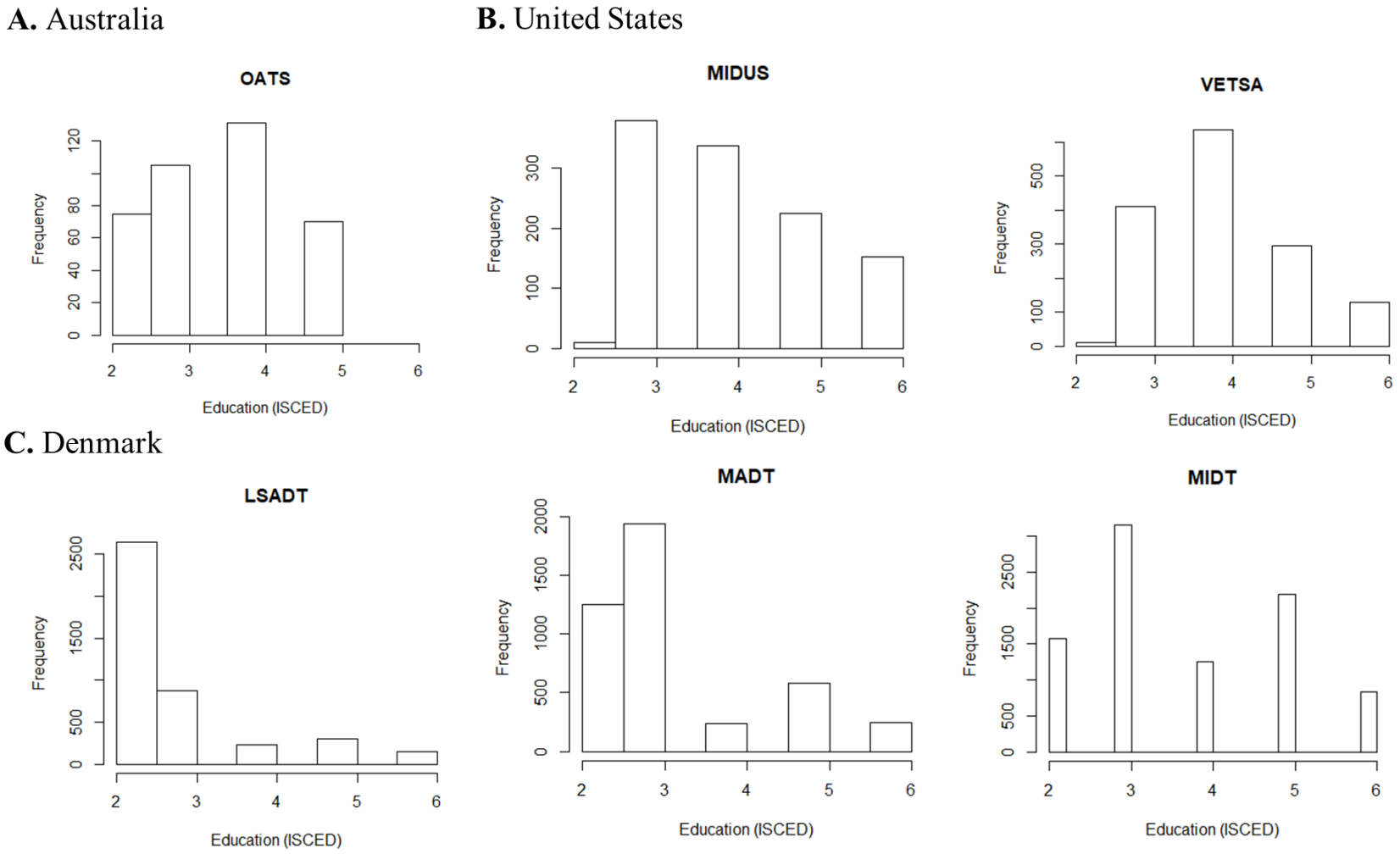
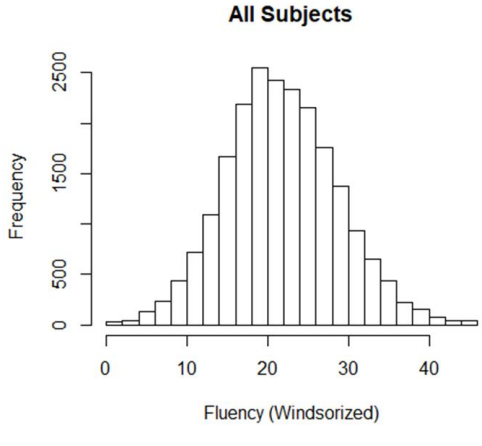
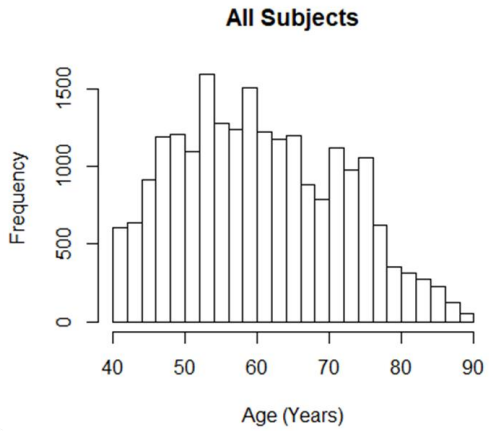



*Figure S3:* Histograms of education (ISCED bin) in each sample (see Figure S4 for histogram of all studies combined). OATS = Older Australian Twins Study, MIDUS = Midlife in the United States, VETSA = Vietnam Era Twin Study of Aging, LSADT = Longitudinal Study of Aging Danish Twins, MIDT/MADT = Middle Age Danish Twin Studies.

**A.** Fluency




**B.** Age




**C.** Education

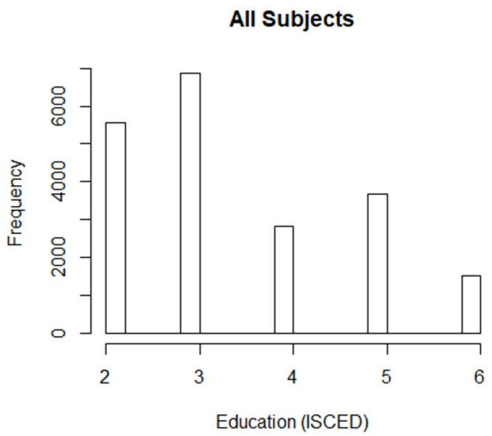



*Figure S4:* Histograms of fluency (windsorized score), age (years) and education (ISCED bin) in the full sample.

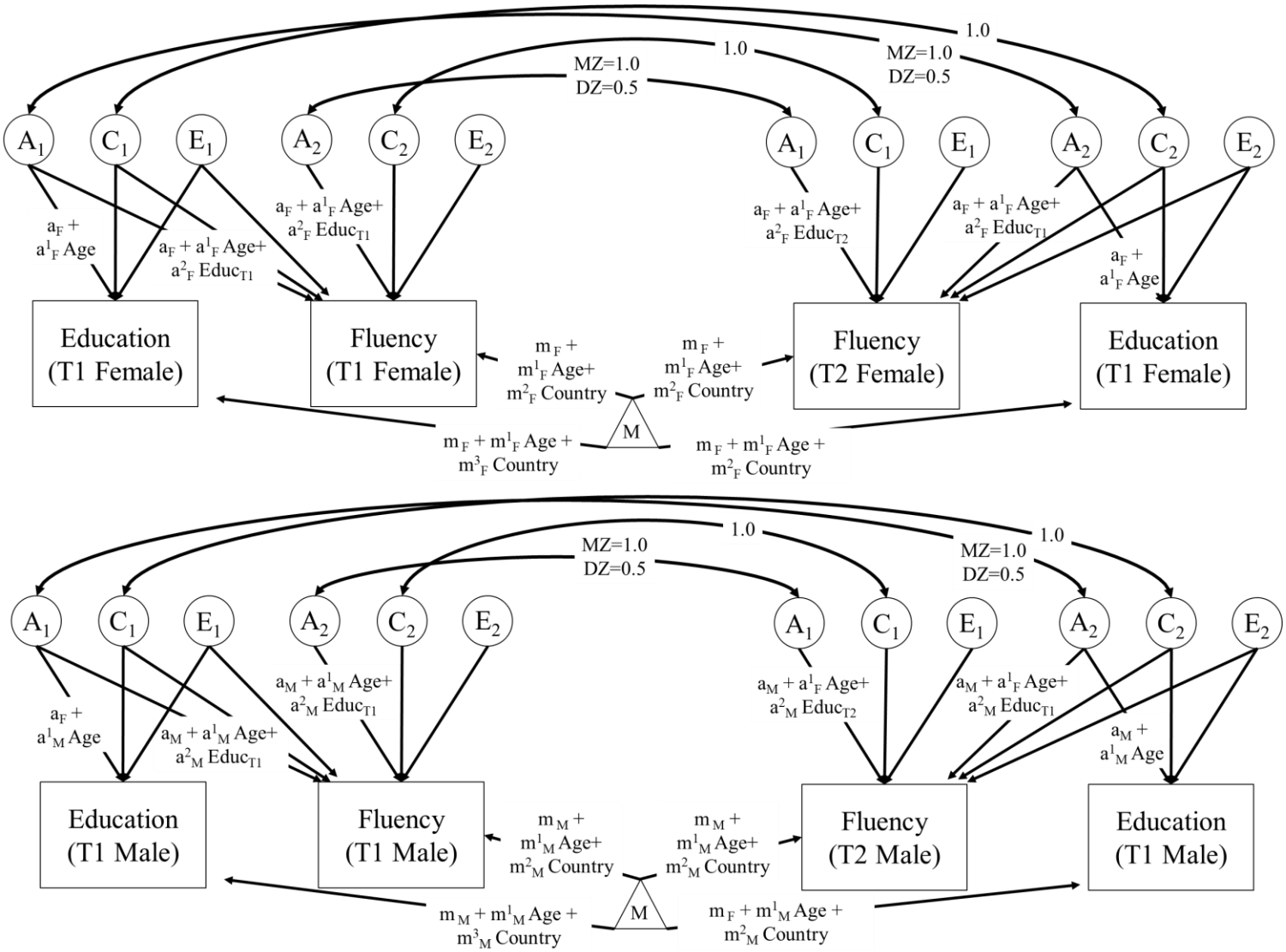



*Figure S5:* Path diagram of the biometric model involving moderation of genetic (A), shared environment (C), and nonshared environmental variance (E) by age, education, and sex, adapted from the univariate moderation model from Purcell (2002). Parameters

denoting genetic variance (a) are displayed, with $a^1$ representing the moderation of genetic variance by age of the twin and $a^2$ representing moderation of genetic variance by education. Similar paths were estimated for shared environment (c) and nonshared environment (e) but were omitted from this diagram for ease of viewing. Age was included as a family-level variable (i.e., the mean age for that twin pair) whereas education was included separately for each twin. Fixed-effects of country on the mean were estimated using two separate parameters (code 1: Australia = -1, Denmark = 0, USA = 1; code 2: Australia and USA = -1, Denmark = 2). Opposite sex twins were included in this analyses (twin 1 was always coded as male twin with the same estimates as the male same-sex twin 1s and twin 2 was always coded as the female twin with the same estimates as the female same-sex twin 2s). The m parameter corresponds to the intercept (standardized, then centered at age 70 and the mean ISCED value) and the $m^1$ and $m^2$ parameters reflect the regression coefficients on the mean. T1 = Twin 1; T2 = Twin 2; MZ = monozygotic; DZ = dizygotic.

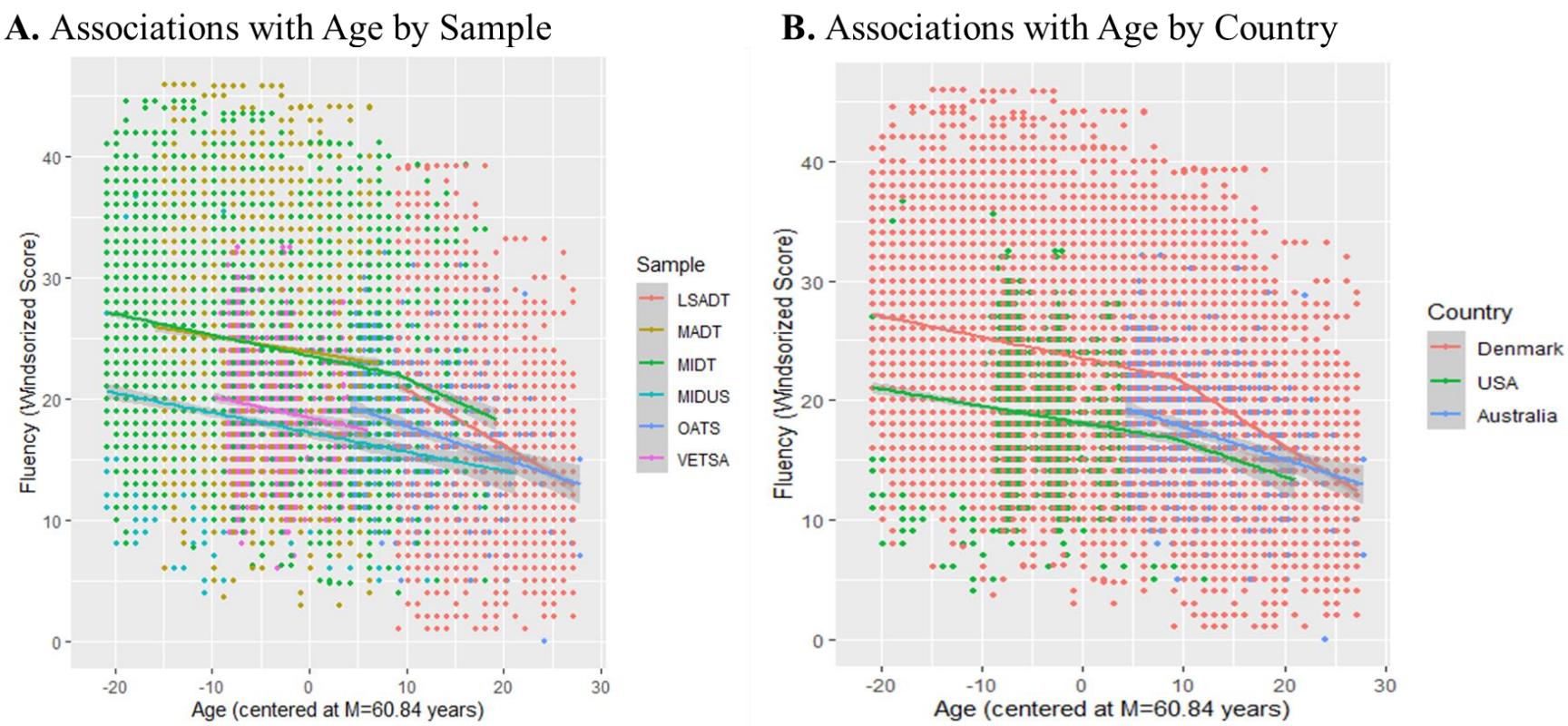



*Figure S6:* Associations between verbal fluency and age separated by sample (A) or country (B). Trend lines display correlations with age only (and the standard error of the effect) and do not control for education, sex, or the clustering of twins within families as described in the Results. The regression spline cut point of age 70 was based off the full phenotypic analyses. Standard errors for the Danish datasets are small because of the very large sample size.

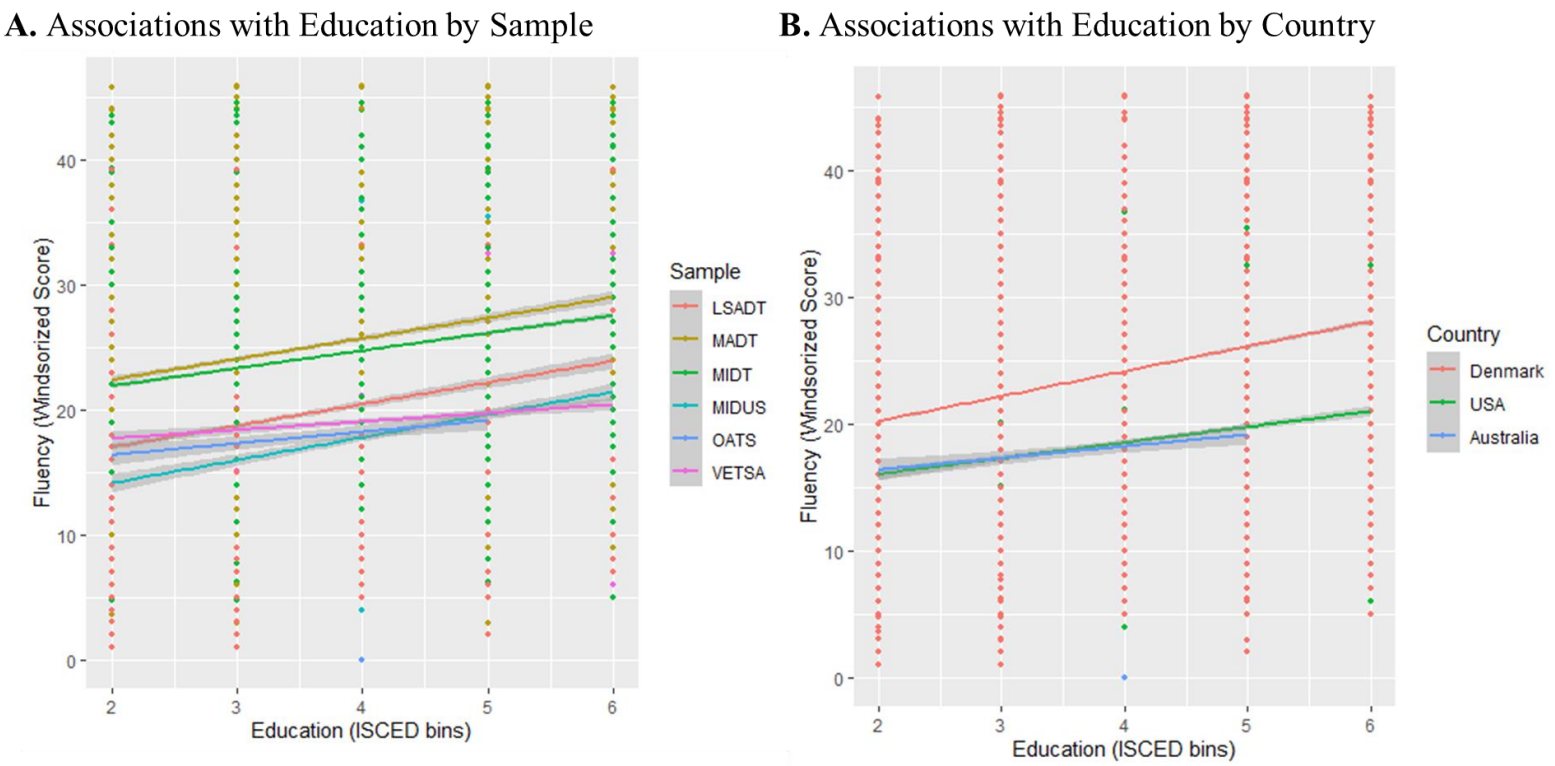



*Figure S7:* Associations between verbal fluency and education separated by sample (A) or country (B). Trend lines (with standard errors) do not control for age, sex, or the clustering of twins within families. Standard errors for the Danish datasets are small because of the very large sample size.