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Spurious heritability of ability tilts: A comment on Coyle et al. (2023)

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ABSTRACT

Ability tilts refer to within-individual differences between two abilities, e.g. math ability – verbal ability. Coyle et al. (2023) found ability tilts to be genetically heritable and concluded that ability tilts are genuine and, presumably, genetically coded individual characteristics. Moreover, Coyle et al. found a large portion of variance in ability tilts to be attributable to non-shared environmental factors (i.e. environmentability), which they interpreted to indicate that ability tilts are potentially generated by niche-picking. However, through simulations we show that heritability and environmentability of X-Y tilts are spurious consequences of heritability and environmentability of the constituent variables X and Y. Furthermore, we reanalyzed data used by Coyle et al. and show that the logic of their arguments would lead to the conclusions, for example, that the human genome codes for a difference between head circumference and verbal ability and that some individuals have picked a niche that includes a long nose at the expense of spatial ability. We do not find these conclusions tenable and propose, instead, that heritability and environmentability of tilts are spurious consequences of heritability and environmentability of the constituent variables.

1. Introduction

Ability tilts refer to within-individual differences between two abilities, e.g. math ability – verbal ability. In an extensive body of research, Coyle and colleagues have presented correlations between ability tilts and other measures of the constituent abilities, e.g. that a math ability – verbal ability difference tends to correlate positively with other measures of math ability, and negatively with other measures of verbal ability, than the ones used for calculating the tilt (Coyle, 2016, 2019, 2020, 2021, 2022; Coyle et al., 2014, 2015). Furthermore, Coyle and colleagues have argued that ability tilt correlations suggest that individuals have invested time and effort into cultivating one of the constituent abilities at the expense of the other ability, e.g. that a positive correlation between a math ability – verbal ability difference and another measure of math ability indicates that some individuals have invested more in math ability while others have invested more in verbal ability (Coyle, 2022; Coyle et al., 2014, 2015; Coyle & Greiff, 2021).

We have challenged the conclusions by Coyle and colleagues by pointing out that ability tilt correlations are a spurious consequence of the difference in correlations between measures of the same ability and measures of different abilities (Sorjonen et al., 2022, 2023). According to Eq. (1) (Guilford, 1965), the correlation between a X-Y difference and Z will be positive if the correlation between X and Z is more positive than the correlation between Y and Z, and negative if the correlation between X and Z is less positive than the correlation between Y and Z. This can probably explain, for example, a positive correlation between the birth rate – death rate difference and fertility across US states (Sorjonen et al., 2023). According to the logic of Coyle and colleagues, this correlation would, instead, indicate that some states have invested more in births while others have invested more in deaths, a conclusion we find untenable and which most researchers probably would be unwilling to accept.

$$E|r_{x-y,z}| = \frac{r_{xz} - r_{yz}}{\sqrt{2(1 - r_{xy})}} \quad (1)$$

In the latest development of this discussion, Coyle et al. (2023) showed, in analyses of twin data, that ability tilts were genetically heritable. They concluded that ability tilts, therefore, are genuine individual characteristics, presumably over and above the constituent abilities. This would mean that the human genome does not only code for various cognitive abilities, e.g. math and verbal ability, but also for their differences. Furthermore, Coyle et al. (2023) found a large portion of variance in ability tilts to be attributable to non-shared environmental factors, which they interpreted to indicate that ability tilts are

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potentially generated by niche-picking and experiences. We interpret this latter conclusion to be closely related to the conclusion by Coyle and colleagues that ability tilt correlations suggest that individuals have invested time and effort into cultivating one of the constituent abilities at the expense of the other ability (Coyle, 2022; Coyle et al., 2014, 2015; Coyle & Greiff, 2021).

Based on our previous findings that tilt correlations are a spurious consequence of correlations between the constituent variables, we predicted that heritability and environmentability of tilts may be spurious consequences of heritability and environmentability of the constituent characteristics. The objective of the present study was to assess this prediction, employing both simulations and reanalyses of data used by Coyle et al. (2023). Moreover, we estimated tilt correlations between head size, nose length, verbal ability, and a random variable that would be difficult to explain by differential investment. If these correlations are statistically significant, they challenge the interpretation by Coyle and colleagues that tilt correlations suggest differential investment.

2. Method

2.1. Simulations

A simulation was conducted through the following steps: (1) 5000 monozygotic and 5000 dizygotic twin couples, i.e. total $N = 20{,}000$, were allocated scores on two (X and Y) random, normal, standardized ($M = 0$, $SD = 1$) variables; (2) the correlation between monozygotic twins for X and Y was set to 0.1, 0.3, 0.5, 0.7, or 0.9 and to 0.5, 0.75, or 1.0 times that value among dizygotic twins. This resulted in $5 \times 5 \times 3 \times 3 = 225$ different combinations of correlations for X and Y among monozygotic and dizygotic twins; (3) we fitted an ACE model on each of the 225 datasets thus created and estimated heritability (i.e. variance due to additive genetic effects, A) and environmentability (i.e. variance due to non-shared environmental factors, E) of both X and Y as well as the X-Y difference, i.e. tilt.

2.2. Empirical analyses

Following Coyle et al. (2023), we used data from the Georgia Twin Study, described and made available by Osborne (1980). Data were collected from 108 monozygotic and 130 dizygotic twin couples (i.e. total $N = 476$) when they were between 12 and 18 years old. Biometric measures included: (1) Face length; (2) Head length; (3) Head breadth; (4) Head circumference; (5) Height; (6) Weight; (7) Nose length. Measures of cognitive abilities included the Primary Mental Abilities Tests: (1) Verbal meaning; (2) Number facility; (3) Reasoning; (4) Spatial relations. We added a random normal variable to the dataset. All measures were standardized ($M = 0$, $SD = 1$) before analyses. For each of the $(12 \times 11)/2 = 66$ pairwise combinations of these measures, heritability and environmentability of X and Y and the X-Y tilt were estimated with an ACE model while adjusting for the participants' sex, race, and age. Moreover, correlations between head circumference and the head length – nose length, head length – verbal ability, and head length – random variable tilts were estimated in two subsamples ($N = 238$) that randomly split the twin pairs. Simulations and analyses were conducted with R 4.1.3 statistical software (R Core Team, 2022) employing the MASS (Venables & Ripley, 2002) and mets (Scheike et al., 2014) packages. Data, an analytic script, and supplementary material are available at the Open Science Framework at https://osf.io/zwyg3/.

3. Results

3.1. Simulations

In the simulations, heritability and environmentability of a X-Y difference (i.e. tilt) was equal to the mean of the heritability and the environmentability of the constituent variables X and Y, respectively (Fig. 1). This suggests that heritability of the constituent variables X or Y is sufficient to cause an appearance of a heritable tilt, as defined by Coyle et al. (2023).

3.2. Empirical analyses

Heritability and environmentability of seven biometric and four cognitive measures in the Georgia Twin Study, and a random variable, are presented in Table 1. Heritability and environmentability of the 66 differences (i.e. tilts) between these measures are presented in Fig. 2 (and in the Supplementary Table S1 and in Supplementary, less cluttered, plots at https://osf.io/zwyg3/). In accordance with the simulations presented above, heritability and environmentability of tilts were to a high degree accounted for by the mean heritability and environmentability of the constituent variables. For example, mean heritability of head length (2) and spatial ability (11) was equal to $(0.66 + 0.44)/2 = 0.55$ while heritability of the head length – spatial ability tilt (2–11) was equal to 0.54 (95 % CI: 0.40; 0.68). Moreover, head circumference had a positive correlation with the head length – nose length tilt ($r = 0.54$ (95 % CI: 0.44; 0.62), $p < 0.001$ in subsample 1 and $r = 0.46$ (95 % CI: 0.35; 0.56), $p < 0.001$ in subsample 2, respectively), with the head length – verbal ability tilt ($r = 0.50$ (95 % CI: 0.39; 0.60), $p < 0.001$ in subsample 1 and $r = 0.57$ (95 % CI: 0.47; 0.66), $p < 0.001$ in subsample 2, respectively), and with the head length – random variable tilt ($r =$

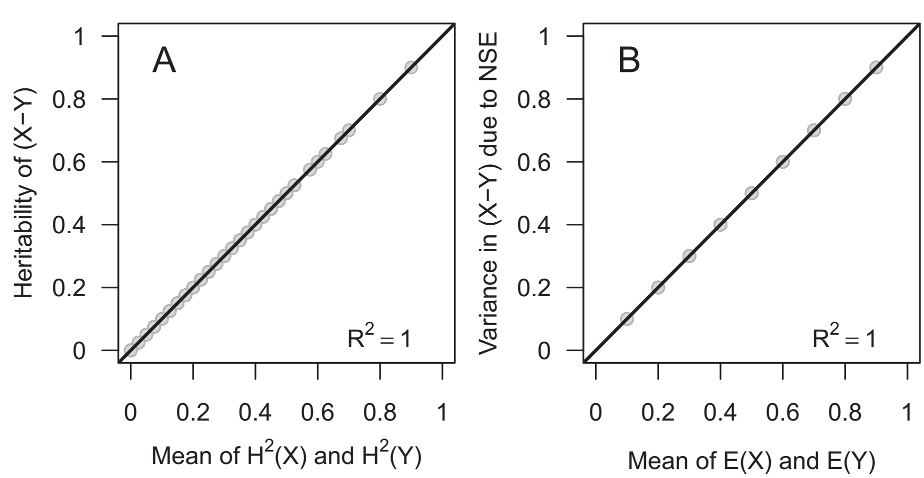

Fig. 1. (A) Heritability of a X-Y tilt as a function of the mean of the heritability of X and the heritability of Y; (B) variance in a X-Y tilt due to non-shared environmental factors (NSE, i.e. environmentability) as a function of the mean of the environmentability of X and the environmentability of Y.

Table 1
Heritability (H^2) and environmentability (E) of seven biometric measures and four cognitive abilities and a random variable (as well as 95 % confidence intervals). Estimates are adjusted for sex, race, and age.

Biometric			Cognitive ability		
Variable	H^2 (95% CI)	E (95 % CI)	Variable	H^2 (95% CI)	E (95 % CI)
1. Face.l	0.83 (0.56; 1.11)	0.14 (0.10; 0.18)	8. Verbal	0.27 (−0.14; 0.68)	0.47 (0.33; 0.62)
2. Head.l	0.66 (0.36; 0.97)	0.25 (0.18; 0.32)	9. Number	0.41 (0.05; 0.77)	0.37 (0.25; 0.49)
3. Head.b	0.35 (0.08; 0.61)	0.30 (0.21; 0.39)	10. Reasoning	0.53 (0.24; 0.81)	0.23 (0.15; 0.31)
4. Head.c	0.59 (0.36; 0.83)	0.14 (0.10; 0.19)	11. Spatial	0.44 (0.00; 0.88)	0.49 (0.33; 0.65)
5. Height	0.94 (0.92; 0.96)	0.06 (0.04; 0.08)			
6. Weight	0.96 (0.94; 0.97)	0.04 (0.03; 0.06)	12. Random	0.09 (−0.43; 0.61)	0.89 (0.68; 1.10)
7. Nose.l	0.65 (0.55; 0.74)	0.35 (0.26; 0.45)			

Note: .l = length, .b = breadth, .c = circumference.

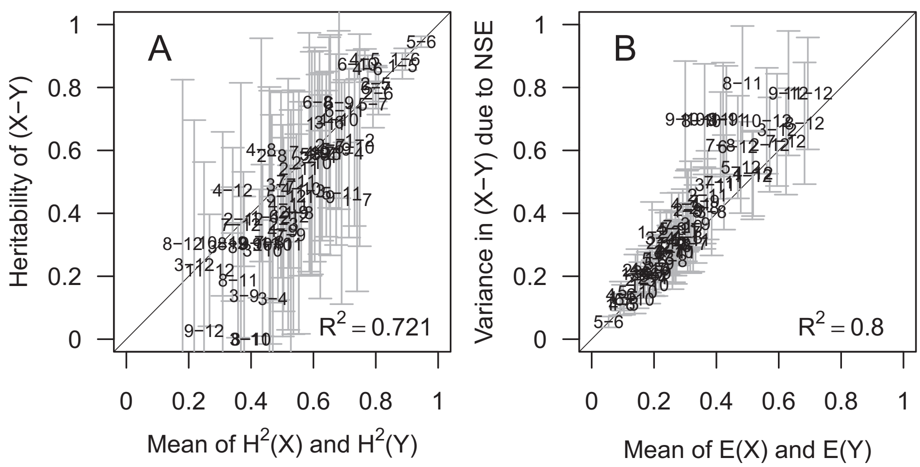

Fig. 2. (A) Heritability of a X-Y tilt as a function of the mean of the heritability of X and the heritability of Y; (B) variance in a X-Y tilt due to non-shared environmental factors (NSE, i.e. environmentability) as a function of the mean of the environmentability of X and the environmentability of Y. Numbers refer to measures in Table 1, e.g. 5–6 is the height – weight difference/tilt. Error bars denote the 95 % confidence interval. Data for the figure are available in Supplementary Table S1 at https://osf.io/zwyg3/.

0.43 (95 % CI: 0.32; 0.53), $p < 0.001$ in subsample 1 and $r = 0.43$ (95 % CI: 0.32; 0.53), $p < 0.001$ in subsample 2, respectively).

4. Discussion

The present study set out to evaluate two suggestions by Coyle et al. (2023): (1) heritability of ability tilts indicated that tilts are factual, and presumably genetically coded and heritable, traits over and above the constituent abilities; (2) the strong estimated dependence on non-shared environmental factors indicated that ability tilts are due to experiences, niche-picking, and, presumably, differential investment in one of the abilities at the expense of the other ability. It can be noted that the conclusion by Coyle and colleagues, that ability tilts are genuine and genetically coded and that they are, at the same time, due to niche-picking and differential investment, might appear somewhat paradoxical. If a characteristic is genetically coded it should be less modifiable by environmental factors, such as investment of effort. However, ability tilts would be far from alone in being affected by both genetic and environmental factors. It appears common to assume that genes set individual limits for characteristics, for example athletic aptitude, while environmental factors, for example amount of exercise, influence where within those limits individuals are located (Vecchi & Santos, 2023).

The first of Coyle et al.'s (2023) suggestions was challenged by the observation that our simulations found heritability of a X-Y tilt to be identical to the mean of the heritability of X and the heritability of Y. Hence, heritability of ability tilts appears to be a spurious consequence of the heritability of the constituent abilities. Furthermore, our empirical analyses found statistically significant heritability of various differences between biometric measures and ability scores, and even a random variable. According to the logic of the argument presented by Coyle et al. (2023), this would suggest that the human genome codes for, for example, differences between height and nose length ($H^2 = 0.75$), between head circumference and verbal ability ($H^2 = 0.60$), and between spatial ability and a random number allocated to the person several decades after birth ($H^2 = 0.22$). We find it very unlikely that the human genome would code for such tilts. Instead, we propose, again, that heritability of these, as well as other, tilts are spurious consequences of heritability of the constituent variables.

We turn to the conclusion by Coyle et al. (2023) that high degree of environmentability, i.e. phenotypic variance due to non-shared environmental factors, suggests niche-picking. Applied to the present empirical findings, this would mean that some participants had picked a niche that included a long head at the expense of a long nose and vice versa ($E = 0.34$), a long nose at the expense of verbal ability and vice versa ($E = 0.62$), and verbal ability at the expense of being allocated a high random number by us in 2023 and vice versa ($E = 0.69$). We do not believe that such niche-picking had taken place. Instead, we propose, in agreement with findings from our simulations, that environmentability of tilts are spurious consequences of environmentability of the constituent variables. And environmentability of the constituent variables are, in turn, a negative function of the correlation between monozygotic twins. This probably explains why many of the tilts with highest environmentability included the random variable.

Coyle et al.'s (2023) argument about niche-picking is reminiscent of the argument by Coyle and colleagues that tilt correlations support theories of differential investment (Coyle, 2022; Coyle et al., 2014, 2015; Coyle & Greiff, 2021). Using the same argument, the present findings indicated, for example, that some participants had invested time and effort into achieving a large head at the expense of a long nose, verbal ability, and a high random number, respectively. We do not find this conclusion tenable. We believe that tilt correlations are spurious consequences of differences in the strength of correlations between similar and dissimilar characteristics (see Eq. (1)), in agreement with what we have said before (Sorjonen et al., 2022, 2023).

It would be possible to argue that heritability of some tilts, e.g. between cognitive abilities, proves that they are genuine and genetically coded human characteristics while heritability of other tilts, e.g. involving a random variable, does not prove this. Similarly, it would be possible to claim that environmentability of some tilts, and some tilt correlations, proves that they are due to niche-picking and differential investment while environmentability and correlations of other tilts does not prove this. However, in order to be scientifically useful, such ad hoc "X proves Y except when it does not" modifications should specify when and why heritability, environmentability, and correlations of tilts proves that they are genuine, genetically coded, and due to niche-picking and differential investment, and when heritability, environmentability, and correlations of tilts do not prove this. Without such specifications, it would be just as justifiable to claim that "heritability and correlations of tilts prove genetic coding of and differential investment in a large head at the expense of verbal ability but they do not prove genetic coding of and differential investment in verbal ability at the expense of numerical ability" as to claim the opposite. Without any plausible modifying conditions, we should assume that heritability, environmentability, and correlations of all tilts are due to the same mechanisms. We propose that heritability, environmentability, and correlations of all tilts are spurious consequences of heritability, environmentability, and correlations of the constituent variables.

According to Coyle et al. (2023), their conclusions of the reality and relevance of ability tilts are validated by tilt effects being part of a nomological network. Although it is difficult to know exactly what they mean, one possible interpretation is that the claim only means that Coyle and colleagues have published many studies on tilts. However, spurious findings do not become less spurious just by being replicated. Besides, it could be argued that with the present and our previous studies (Sorjonen et al., 2022, 2023), we have established a competing nomological network in which tilt effects are spurious consequences of the effects of the constituent abilities.

4.1. Limitations

Measures used in the Georgia Twin Study, for example of cognitive abilities, may not have been optimal. However, we do not believe this to be a threat against our main conclusion that heritability, environmentability, and correlations of tilts are spurious consequences of heritability, environmentability, and correlations of the constituent variables. It is difficult to see how optimization of measures would unilaterally nullify heritability, environmentability, and correlations of nonsensical tilts between, for example, height and nose length while retaining heritability, environmentability, and correlations of tilts between cognitive abilities.

Our conclusion that heritability, environmentability, and correlations of all tilts are spurious consequences of heritability, environmentability, and correlations of the constituent variables is provisional. It is possible that future findings will falsify our conclusion.

5. Conclusions

In the present simulations and empirical analyses, we found heritability, environmentability and correlations of X-Y tilts to be spurious consequences of heritability, environmentability, and correlations of the constituent variables X and Y. This challenges claims by Coyle and colleagues that ability tilts are genuine and genetically coded human characteristics that are, at the same time, due to niche-picking and differential investment.

CRediT authorship contribution statement

Kimmo Sorjonen: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Bo Melin:** Conceptualization, Writing – review & editing, Supervision. **Gustav Nilsonne:** Conceptualization, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data, an analytic script, and supplementary material are available at the Open Science Framework at https://osf.io/zwyg3/.

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