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Intelligence and Fitness: The Mediating Role of Educational Level

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Abstract

The evolutionary status of intelligence is not clear: It is positively related to various indicators of fitness but negatively to reproductive success as the most important fitness marker. In the present research, we explored the links between intelligence and three fitness indicators: number of children (short-term reproductive success), number of grandchildren (long-term reproductive success), and age at first birth. Participants were individuals in a postreproductive stage ($N = 191$; mean age = 66.5 years). Intelligence had a positive correlation with short-term reproductive success and age at first birth but a negative correlation with long-term reproductive success. Participants' education turned out to be a significant mediator of the link between intelligence and criterion measures. The results showed that intelligence can elevate short-term reproductive success. Furthermore, individuals with higher intellectual abilities tended to delay reproduction, which negatively affected their long-term reproductive success. Education was revealed as a very important resource which affects the link between cognitive abilities and fitness, thus proving its evolutionary role in contemporary populations.

Keywords

intelligence, reproductive success, age at first birth, education

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Intelligence and Fitness

Intelligence is frequently defined as the ability for problem-solving and adaptation of the individual to the environment (Sternberg & Detterman, 1986). The very definition of intelligence makes it plausible to assume that it can represent adaptation in an evolutionary sense: the trait which can enhance human fitness. Indeed, empirical data showed that intelligence is positively related to various indicators of fitness. Perhaps the most important link could be the one between intelligence and physical health (Gottfredson, & Deary, 2004) as well as longevity (Calvin et al., 2011) because they are important fitness markers. Furthermore, intelligence is positively related to sperm quality (Arden, Gottfredson, Miller, & Pierce, 2009) and decreased fluctuating asymmetry (Banks, Batchelor, & McDaniel, 2010), of which both can be seen as fitness indicators. It is possible that heightened cognitive abilities not only serve to enhance adaptation directly (by elevated learning from experience and successful problem-solving), they could be attractive to potential mates as costly signals revealing high fitness (Klasios, 2013).

However, the relations between intelligence and fitness become much more ambiguous when it comes to reproductive success, probably the crucial fitness component (Williams, 1996). Research frequently shows that intelligence is negatively related to fertility, measured by the number of children (e.g. Reeve, Lyerly, & Peach, 2013; Shatz, 2008). If individuals with heightened cognitive abilities have lower number of children, it may lead to a decrease in genetic potential for intelligence across generations in a process called dysgenic fertility (Lynn & Harvey, 2008).

A possible way to explain the negative relation between intelligence and reproductive success comes from life history theory. It represents a theoretical framework aimed at explaining evolutionary trade-offs regarding reproductive strategies (Del Giudice, Gangestad, & Kaplan, 2016). The theory identifies two major reproductive strategies with both costs and benefits regarding fitness. The fast life history strategy is based on early reproduction followed by a large number of offspring and

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low parental investment, whereas slow or K strategy is related to a later age of reproduction and smaller number of offspring with high parental effort. Since intelligence is robustly related to a higher educational level and socioeconomic success (Strenze, 2007), it is reasonable to assume that individuals with higher intellectual abilities delay reproduction in order to obtain these resources. This would mean that intelligence is a trait related to slow life history strategy (Rushton, 2004). However, when life history is measured psychometrically using self-report inventories instead of biological markers of maturation or reproduction, results show that intelligence is orthogonal to slow life history strategy (Woodley, 2011). This finding implies that intellectual capacities are not markers of either life history strategy, which suggests that the associations between intelligence and life history are heterogeneous in the empirical literature.

Goals of the Present Study

If there is a possibility that more intelligent individuals delay reproduction in order to gain resources (as the theory of intelligence as a part of slow life history strategy predicts), then the only valid measure of fitness would be lifetime reproductive success. For example, if we measure reproductive success in individuals in their 30s, we wouldn't make a proper estimate with respect to more intelligent individuals because it is possible that they might reproduce later in their lifetime. However, previous research on the intelligence–fertility link was not based on lifetime reproductive success. This is why we explored this relation in individuals in a postreproductive stage (females who were older than 50 years and males older than 55 years). This sample structure enabled us to estimate not only the number of children (short-term reproductive success) but also the number of grandchildren as an additional measure of fitness (long-term reproductive success). If intelligence is differently related to short- and long-term RS, it could indicate adaptive trade-offs (Penke & Jokela, 2016) as possible mechanisms that maintain genetic variance in intelligence. Finally, as a third fitness-related measure, we used age at first birth. It represents one of the key life history variables because a lower age at first birth indicates early reproduction as an indicator of fast life history strategy, and conversely, a higher age at first birth indicates postponement of reproduction, which leads to slow life history strategy. Since previous results regarding the link between intelligence and life history are inconsistent, we wanted to make additional insights into this relation.

Previous research has shown that participants' education is related to both short- and long-term reproductive success (Goodman & Koupil, 2010) as well as to a higher age at first birth (Rodgers, et al., 2008). Earlier studies usually considered education as a mediator of the link between intelligence and fitness-related measures (Wrulich, et al., 2013). The mediating role of education was specified in the "chain reaction" model (Gottfredson, 2002), which proposes that early intelligence represents a potential for greater educational achievement later in life. We used this model as a conceptual background, even though the present research is based on a cross-sectional study.

Method

Sample

We sampled females older than 50 years and males older than 55 years who have finished their reproductive stage. The total number of participants was 191, with a mean age of 66.5 years (65% female). The sample was convenient and all the subjects participated on a voluntary basis. Data were collected in several homes for elderly people in Serbia but also in the private homes of the participants. All participants had elementary reading skills. None of the subjects had diagnosed psychiatric disturbances at the time of data collection. Most of the participants were born and raised in larger urban areas in Serbia (62%). The data presented in this article are a part of a larger research project.

Measures

The Advanced Progressive Matrices-18 (APM-18; Pallier, et al., 2002) is an 18-item measure of general intelligence adapted from the Raven's Advanced Progressive Matrices–36 item version (Raven, Raven, & Court, 1993). Participants are asked to complete 18 visual patterns by choosing one of the eight possible answers. Items are arranged in order of increasing difficulty with a time limit of 8 min. The advantage of this APM version is the shortened time required for the test administration. The measure was validated in a Serbian sample by showing its systematic positive correlations with other measures of cognitive abilities (Teovanović, Knežević, & Stankov, 2015). Scale reliability in the present research was high ($\alpha = .83$).

Participants also provided the number of their children and grandchildren, together with the age when they had their first child. Education was measured by the number of completed years of formal education. The average duration of education in the sample was 13 years, which is equivalent to completed second year of faculty, which means that participants were more educated than the average citizen of Serbia, according to the last census.

Results

Descriptive Statistics and Normality Tests

The descriptive statistics of the examined variables are shown in Table 1. This table contains normality tests as well, which reveal that the distributions of all variables deviate significantly from the normal one (with the distribution of intelligence being close to the formal level of statistical significance).

Relations Between Examined Variables

Since the distribution of all variables turned out to be significantly different than normal, we calculated Spearman's correlation coefficients because it is more robust with regard to the shape of the variables' distribution. In addition, we calculated the Pearson's correlation coefficients as standard statistic of

Table 1. Descriptive Statistics and Normality Tests of the Examined Variables.

Variable	*M*	*SD*	Min.	Max.	Skewness	Kurtosis	K-S z
Age	66.49	12.00	50	95	0.34	−1.20	1.87**
Education	12.91	3.70	1	23	−0.64	1.18	2.28**
Intelligence	6.57	4.01	1	17	0.19	−0.81	1.25†
Number of children	1.60	0.94	0	4	−0.05	0.15	4.08**
Number of grandchildren	1.03	1.52	0	7	1.48	1.39	4.59**
Age at first birth	26.26	3.75	17	40	0.78	1.57	1.70**

Note. K-S z = Kolmogorov–Smirnov z statistic.
$^{**}p < .01$. $^{\dagger}p = .09$.

Table 2. Correlations Between the Examined Variables.

Variable	Age	Education	Intelligence	Number of Children	Number of Grandchildren	Age at First Birth
Age	/	−.36**	−.53**	−.24**	.44**	−.15*
Education	−.29**	/	.36**	.25**	−.05	.23**
Intelligence	−.55**	.35**	/	.22**	−.30**	.18*
No. of children	−.27**	.25**	.23**	/	.31**	−.29**
No. of grandchildren	.48**	−.13	−.34**	.33**	/	−.36**
Age at first birth	−.21**	.32**	.17*	−.20*	−.44**	/

Note. Spearman's correlation coefficients are shown below the diagonal; Pearson's coefficients of linear correlation are shown above the diagonal.
$^{**}p < .01$. $^{*}p < .05$.

bivariate correlations. Correlations between the variables are shown in Table 2. Nonparametric correlations (Spearman's) are shown below, while parametric correlations (Pearson's) are presented above the diagonal.

The most important information regarding the research goals is the relations between intelligence and the measures of fitness. The score on APM correlates positively with the number of children and age at first birth but negatively with the number of grandchildren. Furthermore, younger participants are more educated, show higher levels of intellectual abilities, have more children, and have a lower average age at first birth. Older subjects have more grand offspring. Education is positively related to intellectual capacities, number of children, and age at first birth. It is also interesting to mention that the number of children and grandchildren is positively associated, but the effect size of this relation is moderate.

Education as a Mediator of the Link Between Intelligence and Fitness

Education was analyzed as a mediator of the link between intelligence and fitness-related outcomes in the previous research (Gottfredson, 2002; Wrulich, et al., 2013). We tested a similar structural model, with education set as a mediator of intelligence's influence on fitness. Inspection of the residuals showed that they are not normally distributed. This is the reason why we presented results obtained both on original and normalized measures (normalization was performed via Blom's algorithm). Since all variables are modeled as observable ones, the fit of the model was high: $\chi^2 = 1.08(2)$, $p > .05$, normed fit index (NFI) = .99, comparative fit index (CFI) = .99, root mean square error of approximation (RMSEA) = .00 and $\chi^2 = 1.07(2)$, $p > .05$, NFI = .99, CFI = 1, RMSEA = .00 for the model with normalized measures. The structural model is shown in Figure 1.

The structural model revealed several interesting findings about the relations between the examined measures. Expectedly, the pathway between intelligence and education was significant; education fully mediates the relation between the intelligence score and age at first birth and partially mediates its link with the number of children. However, besides education, intelligence retains its influence on short-term reproductive success, and it is the sole predictor of long-term reproductive success, since there is no significant relation between education and this criterion. Moreover, education has a positive relation with age at first birth and short-term reproductive success. The estimations for original and normalized measures were very similar for the path coefficients. Larger differences are obtained on correlation coefficients: The model with normalized measures estimated lower correlations between the fitness measures.

Discussion

Intelligence, Education, and the Fitness-Related Outcomes

Data from the present research showed that intelligence is positively related to age at first birth, with a higher score on APM indicating a higher age at first reproduction. Individuals with higher intellectual abilities seem to delay reproduction, which is in accordance with the view of intelligence as a slow

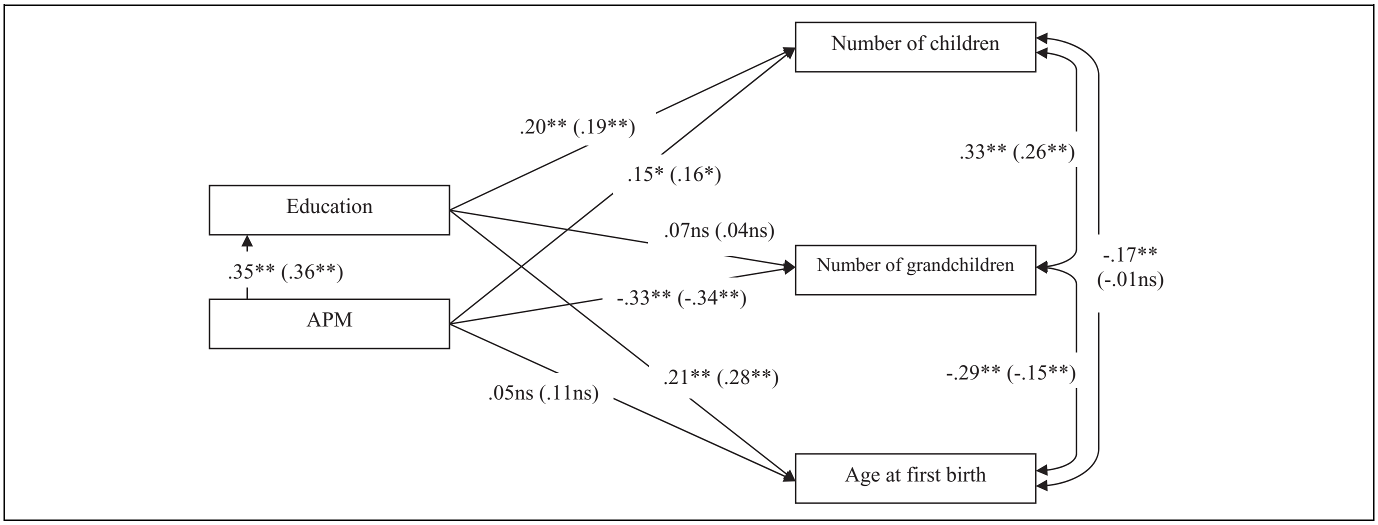

Figure 1. Education as a mediator of the link between intelligence and fitness. One-sided arrows represent causal pathways; double arrows represent correlations; coefficients for normalized measures are shown in the brackets; *$p < .05$. **$p < .01$. *ns* = nonsignificant.

life history trait (Rushton, 2004). However, other studies did not find relations between intelligence and slow life history strategy (Woodley, 2011). This discrepancy could be attributed to the previous operationalization of life history, which included mostly psychometrical measures of life history strategy. Our data suggest that more intelligent individuals might delay reproduction primarily to gain education as an important fitness-related resource. This conclusion is derived from the finding that the path between intelligence and age at first birth was not significant in the mediation model, while education was a significant predictor of this criterion measure. The present finding suggests that education completely mediates the link between intelligence and age at first birth, which was obtained in previous studies too (Rodgers et al., 2008).

Individuals with elevated intellectual abilities delay reproduction, however, that does not affect their short-term reproductive success. In fact, they finish their reproductive stage with a higher number of children. This finding is in line with the previous data on intelligence being positively related to various indicators of fitness, such as physical health (Gottfredson, & Deary, 2004), longevity (Calvin et al., 2011), decreased fluctuating asymmetry (Banks et al., 2010), and so on. This link is only partially mediated by education: Both intelligence and education have independent contributions to the prediction of short-term reproductive success. Previous research also found a positive link between education and the number of children (Goodman & Koupil, 2010). Since intelligence is related to a higher age at first birth, it is not surprising that previous studies found negative relations between intellectual abilities and fertility (Reeve et al., 2013; Shatz, 2008). Because of the slow life history strategy of individuals with higher cognitive abilities, lifetime reproductive success is potentially a more valid indicator of fitness.

Although intelligence may enhance human fitness in the short term, it could also decrease it in the long run. Present data indicate that intelligence is negatively related to the number of grandchildren. However, it must be emphasized that, unlike the number of children, the observed number of grandchildren is not the total one: Since the children of our participants have not passed their reproductive stage, it is possible that some of them could have more children of their own. In fact, this could partially explain the negative association between intelligence and long-term reproductive success: Since both intelligence and life history strategy are partially heritable (Figueredo, Vásquez, Brumbach, & Schneider, 2004; Trzaskowski, Yang, Visscher, & Plomin, 2014), it could be assumed that the children of more intelligent individuals would also delay reproduction and get their offspring later in the ontogeny.

The finding that intelligence has different relations to short- and long-term reproductive success has at least two important theoretical implications. Firstly, it suggests that the dysgenic effect described by some authors (Lynn & Harvey, 2008) is not so robust and stable. Several scholars proposed that the dysgenic effect has existed since the end of the 19th century (Woodley, te Nijenhuis, & Murphy, 2013). The positive correlation between intelligence and the number of children obtained in the present research is not congruent with the concept of dysgenic fertility. The data regarding the association between intellectual abilities and long-term reproductive success suggest that the dysgenic trend in intelligence could exist; however, it may not be a long-lasting but a relatively contemporary phenomenon.

Secondly, the findings from the current research show that there could be adaptive trade-offs in intelligence, as Penke & Jokela (2016) recently suggested. The trade-offs emerge when a trait acts both costly and beneficially on fitness. Higher intellectual abilities could be beneficial in regard to short-term reproductive success, however, it may decrease long-term reproductive success. Still, we should be cautious in interpreting this relation because the number of grandchildren measures in this study was not a total one. If these results are replicated with the total number of grand offspring, it would be a more straightforward finding of the adaptive trade-off associated with intelligence. In that case, these data could help scholars to explain the maintenance of genetic variance in intelligence (Arslan & Penke, 2015).

Limitations and Future Directions

The main limitation of this study is its sample size. This especially refers to the inability of exploring sex differences in relations between intelligence and fitness. This question should not be neglected because the existing literature implies that sex differences could be an important mediator in the intelligence–fitness link (Greengross & Miller, 2011). Another limitation refers to the causal nature of examined relations, especially since intelligence is measured after the criterion events (reproductive success) occurred. The data that show a moderately high stability of intelligence during the life span (Deary, Pattie, & Starr, 2013) encourage the inference of intelligence's effects on fitness, but not vice versa; however, the latter possibility cannot be rejected completely.

There is one more important limitation of the study related to all of the studies aiming to explore the evolutionary status of some psychological construct: The sample of examined individuals is certainly distinctive in its sociocultural characteristics. Our participants were selected from a post–World War 2 generation, which was faced with specific adaptive challenges that can be related both to intelligence and education. Associations between intelligence and fitness need to be explored in various samples with a careful notation of the environmental differences between the samples.

Concluding Remarks

The association between a given trait and fitness represents a potential window into its evolutionary relevance and status. If significant relations are found, then the trait is possibly affected by natural selection. Empirical data on the link between intelligence and fitness are inconsistent. Intelligence is positively related to various fitness indicators, but it has negative associations with the most important fitness marker—reproductive success. The present findings have the potential to reconcile previous data by measuring lifetime reproductive success and age at first birth. Results confirmed that more intelligent individuals delay reproduction in order to obtain resources like education, but this does not decrease their short-term reproductive success. In fact, they have a higher number of children. However, their long-term reproductive success is reduced. Differential associations of intelligence with short- and long-term reproductive success could emerge due to the slow life history strategy of more intelligent individuals' offspring. The other possibility for explaining these results is the adaptive trade-offs associated with intelligence. Results highlight the necessity of measuring lifetime reproductive success, especially in individuals with a slow life history strategy who tend to postpone their first reproduction.

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