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Refractive state, intelligence, education, and Lord's paradox

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ABSTRACT

In a cohort of Swedish men ($N = 45.906$), we found that men with myopia had higher levels of intelligence and education than men with emmetropia and both these groups had higher levels than men with hyperopia. The educational advantage of myopia was reduced by 47–66 percent when adjusting for intelligence but still remained significant. When adjusting for intelligence hyperopes had a higher level of education than emmetropes. Hyperopes also had the highest level of education compared to their level of intelligence. The reversal in the difference between hyperopes and emmetropes when adjusting for intelligence could be seen as an example of Lord's paradox, possibly due to hyperopes having a higher level of intelligence than emmetropes with the same intelligence test score.

Earlier studies have found an association between myopia (= near-sightedness) and a high level of education (Rosner and Belkin, 1987; Teasdale et al., 1988; Konstantopoulos et al., 2008; Mirshahi et al., 2014). However, as these studies were cross-sectional, the found association could, according to Reichenbach's (1956) principle, be due to (i) a high degree of studying causing myopia, e.g. due to less time outdoors and possibly also due to more time spent doing near work, although this association is not always found (Rose et al., 2008; Mutti and Zadnik, 2009; Morgan et al., 2012); (ii) myopia causing a high degree of studying; (iii) both a high degree of studying and myopia being caused by a third confounding factor. Some longitudinal studies have found an increase in the prevalence of myopia among students during their education (Zadnik and Mutti, 1987; Lin et al., 1996; Kinge and Midelfart, 1999; Loman et al., 2002). However, as these studies have not included any non-student control group, it is unclear whether the increase is due to studying or some other factor, e.g. aging.

Assuming an association between myopia and wearing glasses, alternative (ii) could, for instance, be due to a combination of people wearing glasses being perceived as intelligent and successful (Thornton, 1943; Hellström and Tekle, 1994; Walline et al., 2008; Leder et al., 2011) and the fact that people sometimes behave in accordance with stereotypes they are subjected to, a phenomenon called stereotype threat or, in the case of a positive effect, stereotype boost (Steele and Aronson, 1995; Shih et al., 2002; Armenta, 2010). It is also possible that myopes prefer near visual tasks and that it is this preference that facilitates achievement of high levels of education (Hirsch, 1959; Rosner and Belkin, 1987).

When it comes to possible confounders, intelligence is a good candidate as it seems to have a positive association with both myopia (Hirsch, 1959; Rosner and Belkin, 1987; Teasdale et al., 1988; Saw et al., 2004; Verma and Verma, 2015) and level of education (von Stumm et al., 2010; Sorjonen et al., 2015). It has been hypothesized that the association between myopia and high intelligence might be due to an inclination for reading among people with a high intellectual capacity and that this reading increases the risk to acquire myopia. However, the association between myopia and high intelligence is found even after controlling for reading activity (Saw et al., 2004). Another suggested possibility is that some genetic mechanisms might facilitate both neuronal growth in the brain and growth of the eye ball (Karlsson, 1975; Miller, 1992). In this case myopia would be some kind of side effect of increased cognitive capacity. It has also been proposed that myopes might actually not be more intelligent, but that their eyes are more adapted to test situations involving near work with time pressure, especially compared with hyperopes (= farsighted people), and this would result in higher scores on intelligence tests (Hirsch, 1959; Young, 1963).

Although not very conclusive, some findings indicate lower levels of intelligence and education among people with hyperopia (Hirsch, 1959). Possible reasons could be the opposite of those suggested for the increased levels among myopes - less inclination for reading and academic work, genetic mechanisms obstructing neuronal growth in the

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brain and growth of the eye ball among people with hyperopia, and eyes less adapted to taking intelligence tests.

The objective of the present study was to (i) analyze the prospective effect of refractive state on achieved level of education; (ii) analyze if, and to what degree, this possible effect is accounted for by intelligence; (iii) analyze if the effect of intelligence on education can be assumed to be same for people with different refractive states; (iv) spread the word about Lord's paradox in the scientific community.

1. Methods

1.1. Ethics statement

The Stockholm Regional Ethical Review Board has in decisions according to minutes 2004/5:9 agreed to co-processing of the compulsory military service material. The inclusion of more recent data to the database has also been approved by the Review Board (Dnr 2008/323-32 and 2010/604-32). We have had at our disposal only non-identifying information. Due to the character of the data base and the anonymization of all data, the Review Board waived the normal requirement for written consent.

1.2. Participants

The present study was based on data from 45,906 Swedish males, born between 1949 and 1951. They were conscripted for compulsory military service in 1969/1970. At that time, only 2–3% of all Swedish men were exempted from conscription, in most cases owing to severe handicaps or congenital disorders. Of the participants, 7490 (16.3%) were myopes, 37,182 (81.0%) emmetropes (= people who are neither myopic nor hyperopic; rays of light are accurately focused on the retina), and 1234 (2.7%) hyperopes. Of the conscripts, 1983 were excluded from the present analyses due to not having the same refractive state on both eyes, and 1432 due to missing data.

1.3. Assessment of refractive state and intelligence

At the conscription, personnel measured diopters using lenses and registered if the participant needed plus (hyperopia) or minus (myopia) lenses for improved vision. Data for both the right and the left eye was collected and only those with the same refractive state on both eyes were included in the present analyses. In the present cohort, this measure of refractive state has been shown to predict the onset of rhegmatogenous retinal detachment, a condition that is known to be strongly associated with myopia presence and degree (Farioli et al., 2016).

Four separate intelligence tests were performed, mainly in order to assess the conscripts' suitability for education as officers (Ross, 1988). (1) In a test named instructions (IN), the conscripts were required to follow written instructions, e.g. “cross over the second number and encircle the number 4”.This test had a time limit of 12 min and consisted of 40 questions; (2) In a test named selection (SE), the conscripts had to mark the odd one out of five words. This test had a time limit of 7 min and consisted of 40 questions; (3) In a test named assembly (AS), the conscripts had to determine which of four groups of pieces could be arranged to match a given figure. This test had a time limit of 4 min and consisted of 25 questions; (4) A last test, named technical understanding (TE), consisted of diagrams requiring mechanical ability. This test had a time limit of 15 min and consisted of 52 questions (Ross, 1988). According to Ross (1988), “instructions” and “selection” measured logical inductive and verbal intelligence, while “assembly” measured spatial intelligence, and “technical understanding” measured technical understanding. All the tests were progressive, starting with relatively simple questions that gradually became more difficult (Carlstedt, 2000; Zammit et al., 2004; Hemmingsson et al., 2006). The raw scores on all four tests were standardized to a scale from one to nine by the conscription personnel who then summed these four scores and standardized it to a normally distributed (Fig. 1) total intelligence test score ranging from one to nine (Ross, 1988; Carlstedt, 2000).

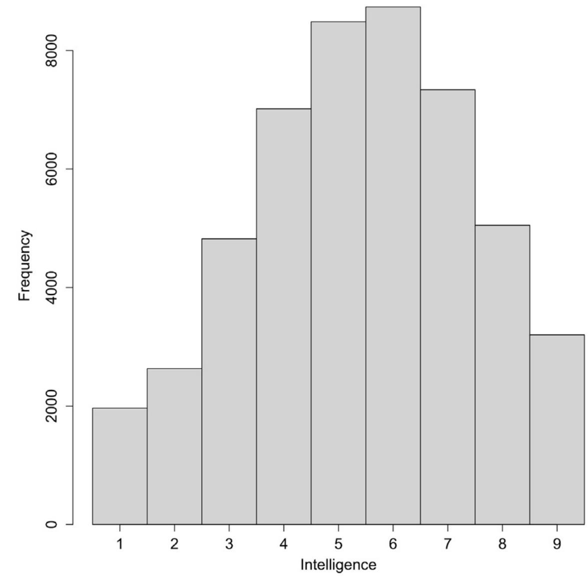

Fig. 1. Frequency distribution of intelligence in the present cohort of conscripts.

1.4. Data on attained level of education

The subjects' highest achieved level of education in 1990, when the subjects were between 39 and 41 years old, was available through national registers covering the entire population. The seven levels of education were: 1 = primary school less than nine years, 2 = primary school nine to ten years, 3 = upper secondary school up to two years, 4 = upper secondary school more than two but not more than three years, 5 = college or university less than three years, 6 = college or university three years or more, 7 = postgraduate studies. Level 4 versus 3 differentiates those who have achieved a more extensive upper secondary education that was usually mandatory for admittance to college or university. Level 6 versus 5 differentiates those who have achieved one of the requirements for an undergraduate degree. The classification was performed by Statistics Sweden (2000) in accordance with the Swedish education nomenclature (SUN).

1.5. Statistical analyses

Most analyses were conducted with R 3.2.2 (R Core Team, 2015). Intelligence and level of education were z-standardized. Group differences between refractive states were analyzed with linear regression using dummy-coded group variables as predictors. How much of the association between refractive state and level of education was accounted for by intelligence was analyzed with the mediation package (Tingley et al., 2014). Both level of education and the education minus intelligence difference were used as outcome measures. This latter measure indicates what level of education a person has achieved as compared to his level of intelligence. A value of 0.5, for example, would mean that he has achieved a level of education that is 0.5 standard deviation higher than his level of intelligence. Multigroup analyses were conducted, with Mplus 7.3 software, in order to evaluate how constrictions of the intercept (= predicted level of education, or education minus intelligence difference, for those of average intelligence) and of the slope (= standardized regression effect of intelligence on level of education, or on the education minus intelligence difference) between the three refractive states would affect model fit.

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