How geography influences complex cognitive ability

Abstract

Evolutionary explanations for geography's influence on complex cognitive ability (CCA) imply virtually immutable components of between-nation IQ differences. Their weight vis-à-vis the weight of situational components was evaluated through an analysis of a 194-country data set. Additive effects of absolute latitude (AL) and longitudinal distance from *Homo sapiens*' cradle (LDC) explain Northeastern Asian higher, Sub-Saharan African lower CCAs. AL exerts cognitive influence directly and through socioeconomic development and evolutionary genetics whereas LDC does through evolutionary genetics; however, this occurs differently in Africa-Near East-Europe and elsewhere. The findings are understood assuming supremacy of contemporary UV_B radiation→hormonal and climatic→socioeconomic mediators of the AL-CCA linkage whose effects are moderated by heterogeneous genetic and cultural adaptations to radiation and climate. Geography's cognitive effects are dynamic and public-policy actions may modify them.

Key words: geography, evolution, UV_B radiation, complex cognitive ability

1. Introduction

Geography influences complex cognitive ability (CCA), a variable measured by intelligence tests and/or student assessments in reading, math, and/or science (Rindermann, 2007): CCA increases with absolute latitude (AL) among nations (Lynn & Vanhanen, 2012) as well as within Italy (Lynn, 2010), Japan (Kura, 2013), Peru (León & Burga León, 2014), Spain (Lynn, 2012), and the United States (Pesta & Posnanski, 2014). In addition, two evolutionary theories predict variation of intelligence alongside longitude. The Negroid-Caucasoid-Mongoloid intellectual hierarchy (Rushton, 2000), which entails latitudinal (African-European) and longitudinal (European-East Asian) vectors, is contradicted by recent evidence showing that Mongoloids as a whole are not more intelligent than Caucasoids (Templer & Stephens, 2014). The other postulates that the challenges of cold, terrain ruggedness, and new species of flora and fauna demanded intellectual betterments of our species once modern humans left the African savanna (Kanazawa, 2008). There are theoretical problems with underlying assumptions of this concept (Dutton, 2013), yet also heuristic value: physical distance from possible cradles of *Homo sapiens* in Africa has been used as an indicator of the amount of evolutionary challenges encountered and it has been reported that latitude and longitude determine IQ additively (Kanazawa, 2008, Tables 2 and 3). Considering the criticism addressed to the empirical base (Wicherts, Borsboom, & Dolan, 2009), there is a need for an unbiased test of the longitudinal influence on CCA taking into account the direction of millenary human dispersals out of Africa (Fig. S1 in Online Supplementary Materials), excluding countries with current majority populations who were not aboriginal by 1500 AD (Putterman & Weil, 2011), and measuring longitudinal distance from *Homo sapiens*' cradle (LDC) under the light of evidence on earliest symbolic behavior (Henshilwood, d'Errico, Vanhaeren, van Niekerk, & Jacobs, 2004).

The evolutionary explanation for the AL-CCA connection is more specific and has prevailed during a quarter of a century. It assumes genetic imprints stemming from the evolvement of higher levels of intelligence in response to millenary cognitive demands for survival exerted on light-skinned humans by the cold winters of temperate regions; tropical, dark-skinned populations lacked such challenges or opportunities (Lynn, 1991; Nyborg, 2013). But this theory cannot explain findings in the United States (Pesta & Posnanaki, 2014) and Peru (León & Burga León, 2014), including the latter's megathermal *Amazonía*, where current populations present levels of CCA associated with gradients of AL despite that their ancestors were not necessarily exposed to gradients of cold. A novel situational theory accounts for the findings considering that UV_B radiation decays with AL. Decreasing UV_B photons and, consequently, vitamin D_3 cause diminished sexual hormones and, therefore, reduced family sizes which, in turn, produce positive cognitive effects by providing children with richer home intellectual environments and greater schooling opportunities (León, 2012). Moreover, a vitamin $D_3 \rightarrow$ dopamine linkage implies that, at lower ALs, a stronger positive mood skews children's play-study balance toward playing, with negative consequences for cognitive growth (León & Burga León, 2014).

This article presents results of testing the hypothesis on a cognitive influence of longitude and evaluates the relative strength of evolutionary and situational mediators of geography's cognitive effects. To differentiate ancient from present cognitive influences it was assumed that, in path models, millenary impacts would show up in the mediation of the AL-CCA and LDC-CCA relationships through evolutionary genetics whereas the situational effects predicted from UV_B radiation theory would be manifested in mediation of the AL-CCA linkage through a proxy for family size - total fertility rate (TFR) - plus an independent $AL \rightarrow CCA$ direct path reflecting effects of mood. In the tests of these

hypotheses evolutionary genetics was addressed by F_{ST} distance, an indicator of the time since two populations had a last common ancestor, that is, the time since they were in fact the same population; this variable reflects the way the world was settled by hunter-gatherer groups that, after colonizing a new habitat and expanding there, shed small groups that founded new colonies nearby (Henn, Cavalli-Sforza, & Feldman, 2012). Socioeconomic development was handled as another mediating variable.

Whereas evolutionary effects imply the virtual immutability of geography's impact on countries' CCA, the contemporary influence of UV_B radiation could be ameliorated through specific public-policy actions, such as family planning programs to reduce family size and the use of play in educational tasks to enhance the motivation of the learner. Hence, the study outcomes not only have scientific but social implications as well.

2. Method

2.1. Geophysical Data

The AL of each country's capital city was calculated; this measurement, implying a difference from the equatorial line, is strongly correlated with temperature (Kanazawa, 2008) and UV_B radiation (Engelsen, Brustad, Aksnes, & Lund, 2005). Since *Homo sapiens* emerged in a southern corner of Africa (Henn, Gignoux, Jobin, Granka, Macpherson, Kidd, et al., 2012; Tishkoff, Reed, Friedlaender, Eheret, Ranciaro, et al., 2009) and there is evidence of the earliest symbolic behavior at the Blombos Cave (Henshilwood, d'Errico, Vanhaeren, van Niekerk, & Jacobs, 2004), absolute longitudinal distance was calculated in geographic degrees from $21^{\circ} 13' E$ for African and European countries; yet, taking into account that millenary human dispersals elsewhere in the world were all in the west→east direction (Fig. S1), calculation of LDC in that direction was needed for nations beyond Africa-Europe. LDC for countries whose majority population was not aboriginal by 1500

AD (Putterman & Weil, 2011), regarded as meaningless, was not calculated. Average 1960-1990 monthly temperatures per country from the World Bank's (2014) Climate Change Knowledge Portal were utilized to classify as megathermal those Sub-Saharan African nations whose average temperature did not descend below 23° C in any month; only data for Gambia was unavailable.

2.2. *Cognitive Data*

Rindermann (2007), set to demonstrate that, across nations, student achievement assessments and intelligence tests primarily measure a common cognitive ability, extracted from them a *g* factor that explained 94-95% of the variance and called it “general complex cognitive ability”. The inputs he used were Lynn and Vanhanen's (2002, 2006) collection of IQ scores and student assessment scores from various sources. The Lynn-Vanhanen collection included published and unpublished results in 113 countries, mainly based on various forms of the Progressive Matrices Test and the Wechsler Intelligence Scale for Children. The student assessment scales involved mathematics, reading, and science tasks from various PISA (Program for International Student Assessment), TIMSS (Trends in International Mathematics and Science Study), and PIRLS (Progress in International Reading Literacy Study) rounds encompassing countries from all the continents. In the processing and integration of the data, Rindermann considered participation rates and conditions as well as age of participants and year of data collection and made adjustments and aggregations that produced standardized scores of general CCA per nation in IQ metrics. Thus, he improved the representativeness and comparability of data frequently used to support evolutionary theories of intelligence. For countries without cognitive data, Rindermann utilized IQ estimates derived from national indicators of school attendance.

Table S1 in Online Supplementary Materials lists the 194 countries of the Rindermann data set and Table S2 presents summary statistics.

2.3. Genetic Data

The research made use of F_{ST} distance or coancestor coefficient to evaluate genetic distance from the cradle of *Homo sapiens*. The measurements originated in Cavalli-Sforza, Menozzi, and Piazza's (1994) calculations of F_{ST} distances between 1,915 populations grouped by 9 continental sub-areas based on polymorphisms of 120 protein genes. Genetic distances with respect to South Africa were obtained for the present study from F_{ST} distances between countries calculated by Spolaore and Wacziarg (2009) considering each country's component populations and their sizes (weighted F_{ST}). These measurements are not at the cutting-edge of genetic research, but their results are similar to those of more recent technologies.

2.4. Social Data

The Human Development Index (UNDP, 2011) was used as the indicator of nations' socioeconomic status. This is a composite measure that considers income (real GNI per capita, PPP \$ In World Bank), education ($\frac{1}{2}$ mean years of schooling index Barro-Lee, $\frac{1}{2}$ expected years of schooling UNESCO), and life expectancy at birth (United Nations Population Division). While HDI increases with AL, poverty downgrades cognitive functioning (Mani, Mullainathan, Shafir, & Zhao, 2013). A concept essential to UV_B radiation theory as a proxy for family size is total fertility rate (TFR), which represents the number of children that would be born to a woman if she were to live to the end of her childbearing years and bear children in accordance with current age specific fertility. The study used country TFRs from the World Bank's (2012) World Development Indicators pertaining to 2004-2008.

2.5. Data Estimation

Whereas the 194 countries had CCA and geographic data, some lacked data entailing HDI, genetic distance, and/or TFR. One country (Bermuda) was excluded from the analysis and data was estimated for the others (see Online Supplementary Material).

3. Results

AL and LDC showed additive effects on CCA (Table S3): bootstrapped standardized regression coefficients for countries whose majority populations were aboriginal by 1500 AD were .87 ($p = .001$, two-tailed) for AL, .30 ($p = .084$, two-tailed) for LDC, and .08 ($p = .525$, two-tailed) for AL x LDC ($N = 102$). Northeastern Asian and Sub-Saharan African nations, respectively, produced most of the positive and negative outliers (Figure 1). This is so because Northeastern Asians are high in AL and high in LDC, whereas Sub-Saharan Africans are low in AL and low in LDC, which could have been predicted from Kanazawa's (2008) theory. Thus, the much discussed Northeastern Asian higher (e.g., Lynn, Chen, & Chen, 2011) and Sub-Saharan African lower CCAs (e.g., Wicherts, Dolan, & van der Maas, 2010) can be regarded as outcomes of additive effects of AL and LDC and this also is why Oceanic CCAs fall above those of Sub-Saharan Africans despite their similar ALs (Lynn & Vanhanen, 2012; Rindermann, 2007). The gist of the findings was not altered when other countries were added in the regression analyses (Figs. S2, S3).

The cognitive influence of genetic distance from South Africa, an evolutionary variable, was weaker than the independent cognitive influence of HDI, a contemporary variable, whatever the country sample (Table 1). It can be noticed that the genetic distance x HDI interaction became stronger and the impact of HDI became weaker as the quality of the data decayed. In the path analyses, upholding UV_B radiation theory, AL determined

CCA directly and through TFR and, consistent with evolutionary postulates, LDC and AL influenced CCA through F_{ST} distance from South Africa (Figure 2A; also see Fig. S4). As expected, HDI was strongly influenced by AL and less strongly but significantly by genetic distance from South Africa whereas it strongly influenced CCA (Figure 2B; see also Fig. S5). On the other hand, its inclusion weakened the TFR→CCA path, suggesting that a large part of the cognitive effects of TFR are associated with the women's desire for smaller families, domestic power, and use of contraception that come with socioeconomic development (León, 2013). The effect of TFR on CCA that is independent of HDI could have reached statistical significance under a more powerful research design (e.g., provinces of the 193 countries as units of analysis), as it did in Peru (León & Burga León, 2014).

The findings were submitted to various robustness tests. First, we considered the high correlation between genetic distance and LDC; the effects replicated when LDC was removed and the other retained and the coefficients increased when genetic distance was removed and LDC retained (Fig. S6). We also included in the model in Fig. 2 an AL x LDC interaction term which had no major impact on the results except for substantially increasing the direct impact of AL on CCA (Table S4). Finally, we separately analyzed the data for countries between 30° W and 60° E (Africa-Near East-Europe, ANEE), whose millenary dispersals were northbound, and countries of the remainder of the world, who migrated in a west-east direction from the Near East (Fig. S1). The AL-CCA r reached .92 ($p < .001$, $N = 72$) in ANEE and only .47 ($p = .009$, $N = 30$) elsewhere, a significant difference ($z = 4.64$, $p < .001$) which was reflected in a significant AL x Regional Dichotomy interaction (Table S5). In path analyses, the significant AL→CCA direct path emerged stronger in ANEE (Figure 3A) but it weakened, and the AL→HDI path vanished, elsewhere (Figure 3B). The influence of LDC diminished in ANEE and disappeared

elsewhere. Inclusion of more countries did not modify the essential thrust of the findings (Figs. S7-S10).

4. Discussion

The coexistence of mutually independent and significant $AL \rightarrow CCA$ and $AL \rightarrow F_{ST} \rightarrow CCA$ paths in Figures 2A and 2B plus an $AL \rightarrow TFR \rightarrow CCA$ path in Figure 2A can be understood assuming that the contemporary cognitive influences postulated by UV_B radiation theory coincide with cognitive effects of ancient genetic and cultural adaptations to the wintery scarcity of vitamin D_3 , sexual hormones, and dopamine at higher ALs. For example, as AL increased, the decaying availability of dopamine could have made adaptive mutations which augmented dopamine brain receptors and generated new neural circuits; dopamine is involved in the regulation of attention that contributes to anticipatory processes necessary for preparing voluntary action consequent upon intention (Nieoullon, 2002). Decayed sexual interest with higher AL left more free time for other endeavors, probably strengthening parental child-care and related cultural norms favorable to the enhancement of CCA. Furthermore, cold induces adults staying indoors, closer to children. Climatic factors may have strengthened human capital directly, too. As humans reached higher ALs they encountered better health conditions; whereas the high temperature of the tropics promotes the growth of human pests, the winter frost of temperate regions kills pathogens and parasites (Masters & McMillan, 2001). Further production implications emerged during the Neolithic; agricultural yields for all major crops are higher in temperate than tropical ecological zones because the former are not exposed to the high temperature and humidity of the tropics, which cause organic matter in the soil to break down quickly, robbing the soil of nutrients and the structure needed to slow down erosion (Bloom &

Sachs, 1998; Easterly & Levine, 2004). These factors may have contributed to millenary and contemporary socioeconomic development as depicted in Figure 4.

The weakened cognitive impacts of geography beyond ANEE (Figure 3B versus Figure 3A) can be interpreted considering that the AL-UV_B radiation r at Earth's surface is moderated by such variables as altitude, ozone layer thinning, clouds, pollution, water, and vegetation, and the moderators could be stronger beyond ANEE. A notable inconsistency is seen in China, receptor of less solar radiation than any other country of the world at similar AL and, consequently, above all of them in CCA (Fig. S11). Nonetheless, inconsistencies also occur within ANEE, mainly in Sub-Saharan Africa. Thus, the AL-CCA r was .53 ($p = .002$) in North Africa-Near East and .51 ($p = .001$) in Europe vis-à-vis only .28 ($p = .130$) in Sub-Saharan Africa, whereas it increased to .65 ($p = .059$) when the analyses were limited to the megathermal countries of this sub-continent (Fig. S12). That is, the differences in latitudinal reversals of radiation between ANEE and non-ANEE regions do not appear to be enough to account for the large regional differences observed in geography's cognitive effects. Therefore, there is a need for interpreting the observed differences in a different perspective.

It is proposed here that the results are due to moderating effects of millenary migration routes. Whereas the ancestors of most current populations of ANEE steadily travelled from south to north during the past 100,000 to 45,000 years, occasionally moving longitudinally along constant climate zones, this was not the case for the significant number of populations elsewhere in the world who returned to the tropics after achieving diverse levels of adaptation to lower UV_B radiation at the Near East or northerner settings. For example, ancestors of Amerindians who now reside in Ecuador were gathering, hunting, and parenting in Siberia 20 millennia ago; their dopamine receptors and child-rearing

practices, stabilized at 60° N, are likely to have survived to an important extent under the equatorial climates they encountered later at 0°. Thus, similar tropical environments now affect differently populations such as Papua New Guineans and Kenyans. An extreme case is that of Singaporeans, who exhibit one of the highest CCAs of the world despite living near the equatorial line; most of them descend from recently immigrated Chinese. More generally, the longevity and homogeneity of dermatological (Jablonski & Chaplin, 2010), brain, and cultural adaptations to AL are considerably greater in ANEE than elsewhere. Only non-ANEE populations who dispersed straight longitudinally from the Near East, such as present Chinese, Japanese, and Koreans, have a similar evolutionary stability. The study findings do not suggest explanations for the higher CCAs of Northeastern Asians than Europeans other than the concept of additive effects of AL and LDC on CCA (Kanazawa, 2008). But the complicated history of adaptations to AL outside the 30° W and 60° E range explain the weaker AL-CCA link found outside ANEE: current AL is contaminated by ancient AL beyond ANEE; within ANEE, current AL is more representative of ancient AL. In conclusion, our findings suggest contemporary UV_B radiation→hormonal and climatic→socioeconomic mediators of the AL-CCA *r* whose effects are moderated by different levels of adaptation to radiation and climate achieved by modern humans along their heterogeneous dispersal paths.

A key question of the research pertained to the relative extent of evolutionary and contemporary cognitive influences of geography. The country CCA variance accounted for is to a greater extent non-evolutionarily than evolutionarily determined (Table 1, Figure 2). Moreover, it can be assumed that only part of the evolutionary effects are genetic. Since non-genetic effects are more amenable to human control than genetic influences, our findings place tropical, dark-skinned populations in a zone of hope for intellectual

improvement. This could be achieved through strengthened family planning programs and school methodologies that incorporate playing as part of the learning process. On the other hand, since light skin is more sensitive to UV_B radiation (Jablonsky & Chaplin, 2010), ozone layer thinning can be expected to downgrade to a greater measure the CCA of light-skinned populations. That is, geography-determined cognitive differences between countries are far from immutable. That they can interact with specific social developments is shown by the fact that the rhythm of IQ gains (Flynn effect) is slowing down in temperate nations while it accelerates in tropical nations (Wongupparaj, Kumari, & Morris, 2015); temperate countries started their fertility transition toward smaller families earlier and are ending the transition now while, in the tropics, increasingly available contraceptive techniques are shrinking family size (Bongaarts, 2008).

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Table 1. *Standardized coefficients (betas) from the linear regression of country complex cognitive ability (CCA) score on three variables, and corrected proportion of variance accounted for (R^2), per analytic model and country inclusion criterion.*

Variable	Model I		Model II		Model III	
	Beta	R^2	Beta	R^2	Beta	R^2
Majority population aboriginal by 1500 AD, with measured CCA						
Genetic distance from S. Africa	.653***	.426	.319***	.831	.131	.833
Human Development Index			.719***		.620***	
Genetic distance x HDI					.254	
Majority population aboriginal by 1500 AD, with measured or estimated CCA						
Genetic distance from S. Africa	.708***	.497	.366***	.834	.067	.838
Human Development Index			.673***		.521***	
Genetic distance x HDI					.404*	
Majority population aboriginal or not by 1500 AD, with measured or estimated CCA						
Genetic distance from S. Africa	.719***	.515	.438***	.790	-.140	.808
Human Development Index			.595***		.331**	
Genetic distance x HDI					.753**	

+ $p = .10$, * $p = .05$, ** $p = .01$, *** $p = .001$, two-tailed.

Figure captions

Figure. 1. *Regression of complex cognitive ability on absolute latitude of capital city among countries whose current majority populations were aboriginal by 1500 AD, per continent.*

We excluded countries which only had CCA estimates based on national school attendance rates (1). Green = Africa, purple = Europe, yellow = Asia, orange = Oceania, and black = Americas-Caribbean. N = 102. Parallels to the regression line represent 80% confidence intervals.

Figure 2. *Bootstrapped standardized coefficients from saturated path models linking study variables.* (A) Human Development Index absent in the model. (B) Human Development Index present in the model. N = 102. * $p = .05$, ** $p = .01$, *** $p = .001$, two-tailed.

Figure 3. *Bootstrapped standardized coefficients from saturated path models linking study variables* (A) Africa-Near East-Europe. (B) Remainder of the world. * $p = .05$, ** $p = .01$, *** $p = .001$, two-tailed.

Figure 4. *Proposed theoretical framework.*

Figure 1.

Figure 2.

Figure 3.

Figure 4.