MANKIND QUARTERLY 2018 58:4 673-685

Boundary Conditions and New Directions for UVR Theory: Reply to Comments

Federico R. León*
Escuela de Postgrado, Universidad San Ignacio de Loyola, Lima, Perú

*Address for correspondence: federicorleone@gmail.com

Dedicated to Richard Lynn

Lynn's (2010) genetic interpretation of the increasing IQ observed from the South to the North of Italy and the debate that followed prompted León and Antonelli-Ponti (this issue) to undertake a study of Italian data in the perspective of UV radiation (UVR) theory (Study 1). The results suggested that UVR degrades intelligence by inhibiting socioeconomic development, which may account for the cognitive North-South divide in that country. The findings contradicted tenets of the cognitive capitalism perspective according to which it is intelligence that increases wealth. In a second study, León and Antonelli-Ponti (this issue, Study 2) found similar relationships among white children of the United States. Unlike in the Italian case, these cannot be attributed to latitudinal genetic variation confounded with UVR's contemporary effects. A third study in Brazil differentiated the socioeconomic and cognitive impacts of UVR from those of race (León & Antonelli-Ponti, this issue, Study 3). Overall, the findings suggested that increased UV radiation impairs socio-economic development, perhaps by reducing industriousness through oxidative stress, and the ensuing less-developed social environments exert negative influences on individuals' cognition. Yet, ancestry appeared to add latitudinal socioeconomic variance in Italy.

Carl's, Daniele's and Meisenberg's comments on the target article in this issue come with empirical and/or theoretical challenges to UVR Theory. Since their sets of evidence are beyond objection on empirical grounds, I respond here reinterpreting them and generating further observations that may help to contextualize the commentators' contributions. Finally, I propose refinements of UVR Theory capable of assimilating the new findings and theoretical insights. The reformulation specifies boundary conditions, and new directions for the theory are delineated.

Physical boundaries

Carl (this issue) mentioned Lynn's (1979) and Carl's (2015) reports of higher average IQ in the South of the United Kingdom, especially the South-East, than in the North, which is the opposite of what UVR Theory would predict considering latitude alone. Actually, the theory could explain these findings taking into account the difference in altitude above sea level observed between the North and the South of the UK. Altitude may also explain the cognitive difference between the Southwest and the Southeast reported by Carl (2015). Whereas the North of the main island has been rising during millennia, the Southeast has been sinking. The rationale is that exposure to UVR is higher with greater altitude; moreover, economic activity is made difficult by rugged terrain (León & Avilés, 2016), and both factors combined could have had stronger cognitive effects than those of UVR associated with latitude.

This explanation, however, would not apply to a parallel case of Germany not noticed in the specialized literature. Schoof et al. (2011) report greater accomplishments in regional educational outcomes for southern than northern Germany, yet altitude above sea level decreases from south to north in this country. This deviation could be attributed to the northerly location of the former communist states that now are part of reunited Germany. On the other hand, using data from twelve regions of the United Kingdom, Carl (this issue) showed that IQ among white British increases with UVR. Since measurements of UVR take altitude into account, the positive UVR-IQ relationship reported by Carl (this issue) presents a serious challenge to UVR Theory.

The challenge should be addressed in the proper context. Whereas the British and German cases are inconsistent with UVR Theory, those of Italy (Lynn, 2010), Japan (Kura, 2013), Peru (León & Burga León, 2014), Russia (Grigoriev, Lapteva & Lynn, 2016), Spain (Lynn, 2012), Sudan (Bakhiet & Lynn, 2015), and the USA (Eppig, Fincher & Thornhill, 2011; León, 2015, 2016; León & Burga-León, 2018; Pesta & Posnanski, 2014; Ryan, Bartels & Townsend, 2010) are not. Turkey (Lynn, Sakar & Cheng, 2015) and India (Lynn & Yadav, 2015) also present deviations from the theory's predictions but these cases are explained by the limited latitudinal extension of the former and the fact that Muslims, who present lower IQs than followers of other faiths (Lynn, 2008; Templer, 2010), are more concentrated in the northern than in the southern regions of India (Basant & Shariff, 2010).

Why should UVR Theory be upheld in Italy, Japan, Peru, Russia, Sudan, and the United States and contradicted in the United Kingdom and Germany? The difference between the two sets of countries is one of latitude and this suggests a boundary condition. I tested this hypothesis in a re-analysis of León's (2018a)

data which yielded the results plotted in Figure 1. Complex cognitive ability (CCA) scores came from Rindermann's (2007) standardization of IQ test scores and/or scores from standardized student evaluations across 194 countries. CCA is a *g* factor which accounted for 94-95% of the variance in such scores. The significant linear ($F = 12.31$, $p = .001$, two-tailed, bootstrapped) and quadratic trends ($F = 6.11$, $p = .006$, two tailed, bootstrapped) suggest that the increase of cognitive ability with decreasing UVR occurs up to a point in the UVR scale, where differences are so small that they become irrelevant and the linear increase begins to get reversed by virtue of likely negative effects of extreme cold.

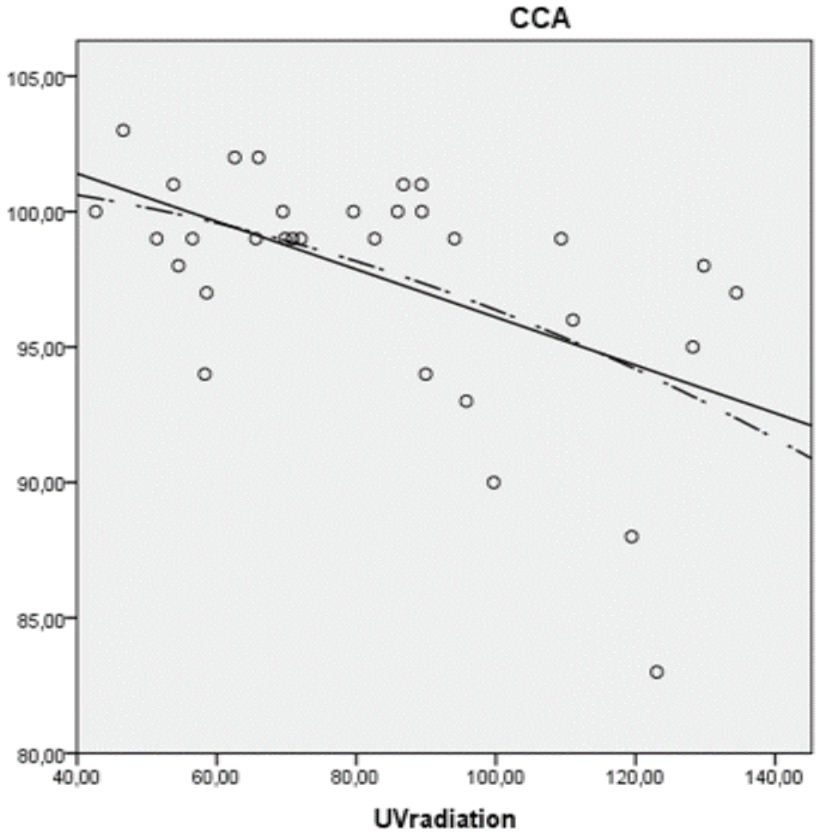

Figure 1. *Linear and quadratic trends for the regression of cognitive ability on UV radiation across 32 European countries.*

This suggests a need for adapting the theory to the evidence. To be consistent with the British and German data and my interpretive hypothesis, I propose a reformulation of UVR Theory stating that the increasing cognitive ability with absolute latitude predicted by the theory does not apply beyond 52° N or S.

Historical boundaries

Daniele (this issue) reported evidence showing that the current greater wealth of northern than southern Italy is a relatively recent phenomenon. Southern Italy was culturally more developed than northern Italy in the 8th century BC as well as in the Middle Ages. In the 1861-91 period, however, the two regions were equal in wealth and life expectancy while the North already exhibited greater literacy than the South. "The north-south divide became evident at the end of the 19th century, when the northern and western regions of Italy started the process of industrialization." A similar case would be evident at the continental level. Daniele showed that whereas now, UVR is negatively related to wealth across 36 European countries, it was positively related to population density, a proxy for wealth, in 1500 AD. According to him, the Industrial Revolution, which started in England in the second half of the 18th century and spread to continental Europe in the 19th century, was responsible for the latitudinal reversal of fortune. As a result, Portugal and Spain, which were richer than Germany, Sweden and Finland in 1600, would now be poorer than them. And in Italy, the North would have overcome the South because of the differential adoption of the Industrial Revolution. In Daniele's view, if UVR Theory were valid, such latitudinal reversals of fortune would not have occurred.

The argument entailing the Industrial Revolution, however, is weak. Why should Germany, Sweden, and Finland adopt industrialization more strongly than Portugal and Spain? Why northern more than southern Italy? Because of their greater proximity to England? Spain is much closer to England than Finland, both geographically and historically. Moreover, Spain and Portugal lagged behind England and France economically long before the start of the Industrial Revolution. Actually, the cultural and economic differences between northern and southern Europe did not undergo an abrupt change in the 19th century. The change was slow and evolved over at least 20 centuries. In Italy, by the time of the Renaissance political and cultural dynamism had moved entirely from the South to the North. The most important merchant cities, for example, were Venice, Genoa and Pisa, not Naples and Palermo. A research report in *Science* has shown this process worldwide from year 0 to the present on the basis of a reconstruction of the aggregate intellectual mobility through the birth and death locations of more than 150,000 notable individuals (Schich et al., 2014). A

majority of these individuals living two millennia ago were in Rome, but the cultural center of Europe steadily migrated from south to north within Italy and only then reached Vienna, Paris, Berlin, and London. The Industrial Revolution was just one step in this latitude-wise process of cultural evolution. The question that follows is, what happened with UVR during this process? Evidently, the UVR differences between countries and between regions remained more or less stable. What changed was the population as part of a south-to-north adaptation to the environment, a process that started long before year 0. The historical process of cultural development was clearly from South to North in Europe, as shown by Schich et al. (2014).

The erroneous assumption made by Daniele (this issue) is that climate in general and UVR in particular should affect equally all populations regardless of their level of technological development. This is obviously false. Whereas the backward societies of equatorial Africa still suffer the devastating effects of tropical diseases (Sachs & Mellany, 2002), the overwhelmingly Chinese inhabitants of Singapore, at 1.3° N, are capable of defending themselves against microbes thanks to their advanced civilization. Similarly, access to contraceptive methods reduces the size of families in modern societies, regardless of the level of sexual hormones which depend on UVR through vitamin D.

In a long-term perspective, at each step of the trajectory of *Homo sapiens* from equatorial Africa to Scandinavia, the migrant populations first adapted to the southern, then the northern reaches of Europe. Each step ahead required centuries or millennia of adaptation to the new environments. I assume that only when the arriving populations were duly settled, the socioeconomic and cognitive differences predicted by UVR Theory with respect to their southern neighbors became evident. This points to a historical boundary condition. To be consistent with the economic and cognitive historical evidence, I propose a reformulation of UVR Theory stating that the increasing cognitive ability with absolute latitude predicted by the theory does not necessarily apply before the 20th century.

Distance from Brussels

Daniele (this issue) posited a further challenge using distance from Brussels. "The distance from Brussels may be taken as a proxy of the 'peripherality' of a region with respect to the 'economic core' of Europe, an area composed of densely populated regions with high income per capita and per square kilometer. These geographically neighboring regions form a cluster that includes the South-East of the UK, the Benelux countries, West Germany, part of France and the north of Italy." He showed that distance from Brussels was not more strongly related to math scores and GDP than UVR across 21 regions/provinces of Italy,

but was the stronger correlate in a larger group of European territories that included the 21 regions/provinces of Italy and 14 Spanish regions. Since Spain's main axis would not present the North-South gradient of Italy, these results would indicate how, in the case of Italy, it is entirely possible that the link between UVR and economic development is spurious.

I do not agree. First, a north-south gradient of intelligence has been demonstrated in Spain (Lynn, 2012). Daniele's results only reflect the fact that the poorest regions of Spain (Extremadura, Andalucía, Castilla-La Mancha, Murcia) *as a whole* are to the west of the richest regions (Madrid, País Vasco, Navarra, Catalunia) *as a whole* which, in turn, are to the west of Brussels. Spain always tried to prevent the independence of its autonomous communities by giving them commercial facilities and later, in 1940-80, attempted to industrialize the country assigning 40% of its promotional funds to Catalunia, 20% to País Vasco, 20% to Madrid, and 20% to the remainder of the country (Payne, 1987).[1] Hence, Daniele's selection of Spain was compromised by its particularism. Why not selecting a larger geographic conglomerate such as the whole Mediterranean Basin? Using Daniele's rationale, I went further and tested his hypothesis across the 32 European countries of Figure 1, whose main axis does not present the North-South gradient of Italy. The results shown in Table 1 reveal stronger relationships between UVR than distance from Brussels both with complex cognitive ability (CCA) and with log GDP per capita. The latter was obtained from UNDP (2011). It refers to per capita national incomes per country with 2005 dollar purchasing power based on data from the World Bank, International Monetary Fund, United Nations Statistics Division, and United Nations Department of Economics and Social Affairs. Therefore, the Brussels challenge does not require specifying another boundary condition for UVR Theory.

Table 1. *Correlation coefficients, 32 European countries.*

	CCA	UVR	Distance from Brussels	Temperature
Log GDP per capita	0.69***	-0.37*	-0.31	-0.15
CCA	1	-0.54**	-0.49**	-0.37*
UVR		1	0.95***	0.70***
Distance from Brussels			1	0.80***

*p = .05, **p = .01, ***p = .001, two-tailed.

[1] The author is indebted to Héctor Roé for economic information on Spain and to Gerhard Meisenberg for his useful comments.

Challenges from genetics and history

Meisenberg (this issue) identified various mechanisms through which UVR could impact human behaviour: season of birth, vitamin D, folate, steroid hormones, and β-endorphin. Some of their effects are in directions not postulated by UVR Theory. On the other hand, UVR Theory could explain the Flynn effect through the secular decline in outdoor activities. Meisenberg considered that the plausibility of the theory should be judged vis-à-vis alternative theories: Lynn's (2010) genetic and Daniele and Malanima's (2011) historicist theories. He raised the issue of displaced populations, such as Chinese in Singapore (who are more intelligent than other Asian populations in the tropics and not less intelligent than Chinese who stayed in China despite the strength of UVR in Singapore), South Africans of European origin (whose light skin should make them especially susceptible to the negative effects of UVR but who nevertheless perform cognitively better than Bantus), and Africans in the United States (whose dark skin should protect them against the negative effects of UVR in the southern United States but are less intelligent than white Americans there).

León and Antonelli-Ponti (this issue) have already responded to this type of criticism (Study 2). In addition, weaknesses of the alternative theories can be highlighted. For example, Lynn's (2010) genetic theory cannot explain the positive relationship between absolute latitude and cognitive ability found in the Peruvian *Amazonia*, a region never exposed to cold (León & Burga-León, 2014), and the United States, where most families arrived a few generations ago (Pesta & Posnanski, 2014). Daniele and Malanima's (2011) historicist theory cannot explain the north-to-south declines in cognitive ability reported in Japan (Kura, 2013), Sudan (Bakhiet & Lynn, 2015), and the United States (Pesta & Posnanski, 2014), nor the south to north decline seen in Peru (León & Burga León, 2014) and Brazil (León & Antonelli-Ponti, this issue).

Meisenberg's criticism resembles the conception exposed by Woodley of Menie (see León & Antonelli-Ponti, this issue): an either/or paradigm according to which only one of the theories (UVR Theory or Lynn's theory, UVR Theory or Daniele and Malanima's theory) can be valid. Actually, each theory can account for a proportion of cognitive variance. What is needed to evaluate the relative strength of the theories is a comparative empirical test allowing for the emergence of relevant evidence. This was achieved to some extent in León and Burga-León's (2015) study across countries using genetic distance from South Africa, a direct measurement of a genetic variable, and absolute latitude as a proxy for UVR. The test confirmed both Kanazawa's (2008) implicit hypothesis of increased intelligence with longitudinal distance from the cradle of *Homo sapiens* (South Africa) through genetic distance from South Africa and León and Burga-León's

(2015) hypothesis that absolute latitude would affect cognitive ability independent of genetic distance from South Africa (León & Burga-León, 2015, Table 2).

New directions

UV radiation theory is usually treated as a single theory. Actually, four UVR theories are extant in the literature:

1. Less UVR → less vitamin D → less sexual hormones → smaller families → better child intellectual environments → greater cognitive ability (León & Burga León, 2014).
2. Less UVR → less vitamin D → less dopamine → more dopamine receptors → more neural linkages → greater cognitive ability (León & Burga-León, 2015), where the fourth and fifth components are evolutionary.
3. Less UVR → less oxidative stress → less fatigue → greater industriousness → greater wealth → greater cognitive ability (León & Hassall, 2017).
4. Less UVR → less oxidative stress → better health and education → greater cognitive ability (León, 2018).

A fifth UVR theory is suggested by evidence showing women's greater desire for children in equatorial than southern Peru regardless of age, education, income, number of children, marital status, and whether the women lived with the husband, which León (1984, 1986) attributed to a more patriarchal society in northern than southern Peru. Even within women's assumed natural domain, the household, their power to make decisions is weaker near the equator in Peru; furthermore, absolute latitude's effects on women's empowerment are observed independent of the degree of women's material/informational power (León, 2011). To explain these findings, León (2018b) stated that

> "Vitamin D is a hormone which activates genes that sustain the levels of estrogen in females and testosterone in males (Jones, Strungnell & DeLucca, 1998; Kinuta et al., 2000; Wang et al., 2015). Consequently, populations at higher absolute latitudes, where UV photons for fabrication of vitamin D are scarcer, present lower levels of sex hormones (Van Anders, Hampson & Watson, 2006; Wehr et al., 2009). In turn, testosterone and estrogen exhibit augmented scores at high altitude above sea level (Gonzales & Ortíz, 1994; Gonzales & Villena, 1997; Gonzales et al., 2011), where UV radiation is stronger (Engelsen et al., 2005). It was on this basis that León (2015) predicted and confirmed greater cognitive ability in the eastern than in the western United States;

> in Peru, León and Avilés (2016) were able to differentiate the cognitive and economic effects of altitude from those of rugged terrain. Results from a second stream of research ... (also suggest that) ... radiation is linked to gender inequality. The second to fourth digit ratio (2D:4D), a positive indicator of femininity and negative indicator of prenatal testosterone, increases with absolute latitude (Helle & Laaksonen, 2009; Hurd & van Anders, 2007; see also Fink et al., 2006, comparison of Germans and India's Mizos). The evidence is far from conclusive; there are issues of curvilinearity and the linkage is not found in China (Xu & Zheng, 2015). The latter could owe to the fact that this country is not latitudinally oriented... At any rate, the latitude-2D:4D ratio also suggests that exposure to UV radiation *may* enhance the masculinity of men and femininity of women; with greater physical and behavioral differentiation of the sexes, a society can be expected to present stronger gender inequality. ..... the diminished status of girls in societies with higher gender inequality limits their access to knowledge and, when they become mothers, (may) negatively affects their offspring's cognitive development. There is evidence that parents' language and education influence children's cognitive competence (e.g., Bradley et al., 1993; Hart & Risley, 1995; Phillips et al., 1998)."

Therefore, the fifth UVR Theory takes the following form:

5. Less UVR → weaker sexual differentiation of the genders → less gender inequality → more positive mother influence on the child → greater cognitive ability.

References

Bakhiet, S.F.A. & Lynn, R. (2015). Regional differences in intelligence in Sudan. *Intelligence* 50: 150-152.

Basant, R. & Shariff, A. (2010). *Handbook of Muslims in India: Empirical and Policy Perspectives*. Downloaded from https://ideas.repec.org/b/oxp/obooks/9780198062059.html.

Bradley, R.H., Whiteside, L., Caldwell, B., Casey, P.H., Kelleher, K., Pope, S., ... & Cross, D. (1993). Maternal IQ, the home environment, and child IQ in low birthweight premature children. *International Journal of Behavioral Development* 16: 61-74.

Carl, N. (2015). IQ and socio-economic development across regions of the UK. *Journal of Biosocial Science* 48: 406-417.

Daniele, V. & Malanima, P. (2011a). *Il divario Nord-Sud in Italia 1861-2011*. Soveria Mannelli: Rubbettino.

Engelsen, O., Brustad, M., Aksnes, L. & Lund, E. (2007). Daily duration of Vitamin D synthesis in human skin with relation to latitude, total ozone, altitude, ground cover, aerosols and cloud thickness. *Photochemistry and Photobiology* 81: 1287-1290.

Eppig, C., Fincher, C.L. & Thornhill, L. (2011). Parasite prevalence and the distribution of intelligence among states of the USA. *Intelligence* 39: 155-160.

Fink, B., Thanzami, V., Seydel, H. & Manning, J.T. (2006). Digit ratio and hand-grip strength in German and Mizos men: Cross-cultural evidence for an organizing effect of prenatal testosterone on strength. *American Journal of Human Biology* 18: 776-782.

Gonzales, G.F. & Ortíz, I. (1994). Age at menarche at sea level and high altitude in Peruvian women of different ethnic background. *American Journal of Human Biology* 6: 674-680.

Gonzales, G.F., Tapia, V., Gasco, M. & Gonzales-Castañeda, C. (2011). Serum testosterone levels and source of chronic mountain sickness in Peruvian natives at 4340 m. *Andrologia* 43: 189-195.

Gonzales, G.F. & Villena, A. (1997). Age at menopause in central Andean Peruvian women. *Menopause* 4: 32-38.

Grigoriev, A., Lapteva, E. & Lynn, R. (2016). Regional differences in intelligence, infant mortality, stature and fertility in European Russia in the late nineteenth century. *Intelligence* 55: 34-37.

Hart, B. & Risley, T.R. (1995). *Meaningful Differences in the Everyday Experience of Young American Children*. Baltimore: Paul Brookes.

Helle, S. & Laaksonen, T. (2009). Latitudinal gradient in 2D:4D. *Archives of Sexual Behavior* 38: 1-3.

Hurd, P.L. & van Anders, S.M. (2007). Latitude, digit ratios, and Allen's and Bermann's rules: A comment on Loehlin, McFadden, Medland, and Martin (2006). *Archives of Sexual Behavior* 36: 139-141.

Jones, G., Strungnell, S.A. & DeLuca, H.F. (1998). Current understanding of the molecular actions of vitamin D. *Physiology Review* 78: 1193-1231.

Kanazawa, S. (2008). Temperature and evolutionary novelty as forces behind the evolution of general intelligence. *Intelligence* 36: 99-108.

Kinuta, K., Tanaka, H., Morikawe, T., Aya, K., Kato, S. & Seino, Y. (2000). Vitamin D is an important factor in estrogen biosynthesis of both female and male gonads. *Endocrinology* 141: 1317-1324.

Kura, K. (2013). Japanese north-south gradient in IQ predicts differences in stature, skin color, income, and homicide rate. *Intelligence* 41: 512-516.

León F.R. (1984). El eje fecundatorio norte-sur del Perú: una interpretación psicológica. *Revista de Psicología* 2: 85-111.

León, F.R. (1986). Factores psicosociales, psicoeconómicos, y psicosexuales en el eje fecundatorio norte-sur del Perú. In: F.R. León (ed.), *Psicología y realidad peruana: El aporte objetivo.* Lima: Mosca Azul Editores.

León F.R. (2011). Latitud sur y control económico del hogar por la mujer peruana. *Revista de Psicología* 29: 361-388.

León, F.R. (2015). The east-to-west decay of math and reading scores in the United States: A prediction from UV_B radiation theory. *Personality and Individual Differences* 86: 287-290.

León, F.R. (2016). Race vis-à-vis latitude: Their influence on intelligence, infectious diseases, and income. *Mankind Quarterly* 56: 214-225.

León, F.R. (2018a). Diminished UV radiation enhances national cognitive ability, wealth, and institutions through health and education. *Personality and Individual Differences* 120: 52-57.

León, F.R. (2018b). Gender inequality mediates UV radiation's and Islam's effects on country development and cognitive ability. *Under review.*

León, F.R. & Avilés, E. (2016). How altitude above sea level affects intelligence. *Intelligence* 58: 33-41.

León, F.R. & Burga-León, A. (2014). Why complex cognitive ability increases with absolute latitude. *Intelligence* 46: 291-299.

León, F.R. & Burga-León, A. (2015). How geography influences complex cognitive ability. *Intelligence* 50: 221-227.

León, F.R. & Burga-León, A. (2018). UV radiation associates with state income through complex cognitive ability in the USA. *Journal of Individual Differences* 39: 18-26.

León, F.R. & Hassall, C. (2017). UV radiation is associated with latitudinal trends in cognitive ability of White children in the USA. *Journal of Individual Differences* 38: 155-162.

Lynn, R. (1979). The social ecology of intelligence in the British Isles. *British Journal of Social and Clinical Psychology* 18: 1-12.

Lynn, R. (2008). *The Global Bell Curve: Race, IQ, and Inequality Worldwide.* Augusta, GA: Washington Summit.

Lynn, R. (2010). In Italy, North-South differences in IQ predict differences in income, education, infant mortality, stature, and literacy. *Intelligence* 38: 93-100.

Lynn, R. (2012). North-south differences in Spain in IQ, educational attainment, per capita income, literacy, life expectancy and employment. *Mankind Quarterly* 52: 265-291.

Lynn, R., Sakar, C. & Cheng, H. (2015). Regional differences in intelligence, income, and other socioeconomic variables in Turkey. *Intelligence* 50: 144-149.

Lynn, R. & Yadav, P. (2015). Differences in cognitive ability, per capita income, infant mortality, fertility and latitude across states of India. *Intelligence* 49: 179-185.

Payne, S.G. (1987). *El régimen de Franco, 1936-1975.* Madrid: Alianza Editorial.

Pesta, B.J. & Posnanski, P.J. (2014). Only in America: Cold Winters theory, race, IQ and well-being. *Intelligence* 46: 271-274.

Phillips, M., Brooks-Gunn, J., Duncan, G.J., Klevanov, P.K. & Crane, J. (1998). Family background, parenting practices, and the Black-White test score gap. In: C. Jencks & M. Phillips (eds.), *The Black-White Test Score Gap.* Washington DC: Brookings Institution Press.

Rindermann, H. (2007). The *g*-factor of international cognitive ability comparisons: The homogeneity of results in PISA, TIMSS, PIRLS and IQ tests across nations. *European Journal of Personality* 21: 667-706.

Ryan, J.J., Bartels, J.M. & Townsend, J.M. (2010). Association between climate and IQ in the United States of America. *Psychological Reports* 107: 251-254.

Sachs, J.D. & Melaney, P. (2002). The economic and social burdens of malaria. *Nature* 415: 680-685.

Schich, M., Song, C., Ahn, Y.-Y., Mirsky, A., Martino, M., Barabási, A.L. & Helbing, D. (2014). A network framework of cultural history. *Science* 345: 558-562.

Schoof, U., Blinn, M., Schleiter, A., Ribbe, E. & Wiek, J. (2011). Deutscher Lernatlas: Ergebnisbericht 2011. Berlin: Bertelsmann Stiftung.

Templer, D.J. (2010). The comparison of mean IQ in Muslim and non-Muslim countries. *Mankind Quarterly* 50: 188-209.

UNDP (2011). *Human Development Report 2011.* New York: UN Development Program.

Van Anders, S.M., Hampson, E. & Watson, N.V. (2006). Seasonality, waist-to-hip ratio, and salivary testosterone. *Psychoneuroendocrinology* 31: 895-899.

Wang, N., Han, B., Li, Q., Chen, Y., Chen, Y., Xia, F., ... & Lu, Y. (2015). Vitamin D is associated with testosterone and hypogonadism in Chinese men: Results from a cross-sectional SPECT-China study. *Reproductive Biology and Endocrinology* 13(1): 74.

Wehr, E., Pitz, S., Boehm, B.O., März, W. & Obermayer-Pietsch, B. (2009). Association of vitamin D status with serum androgen levels in men. *Clinical Endocrinology* 73: 243-248.

Xu, Y. & Zheng, Y. (2015). The digit ratio (2D:4D) in China: A meta-analysis. *American Journal of Human Biology* 27: 304-309.