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A Flynn Effect in Khartoum, the Sudanese capital, 2004–2016

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ABSTRACT

Three recent studies have summarized evidence for Negative Flynn Effects (Dutton et al., 2016; Flynn & Shayer, 2018; Woodley of Menie, Peñaherrera-Aguirre, Fernandes, and Figueredo, 2017), that is secular deceases in IQ scores. To develop this important line of research, as many instances of this effect must be reported and understood as possible. Dutton, Bakhiet, Ziada, Essa, and Blahmar (2017) reported, in *Intelligence*, a Negative Flynn Effect in Khartoum, where education was voluntary for some cohorts. This study reports an increase in IQ, as assessed by the Colored Progressive Matrices, in Khartoum between 2004 and 2016. The increase in IQ amounted to 8 to 13 points, based on assessments of children between the ages of 6 and 9. Thus, the original negative Flynn Effect reflected schooling not being compulsory for some of the earlier sample.

1. Introduction

The Flynn Effect (e.g. Flynn, 2012) refers to the secular increase in IQ scores reported across the twentieth century, amounting to an increase of roughly 3 points per decade. This effect has been found to have occurred to the greatest extent on the less *g*-loaded subtests (e.g. te Nijenhuis & Van der Flier, 2013). Since the late 1990s, a Negative Flynn Effect has been being reported in European countries, amounting to an average IQ loss of 2.44 points per decade (see Dutton, Van der Linden, & Lynn, 2016). Woodley of Menie, Peñaherrera-Aguirre, Fernandes, and Figueredo (2017) have systematically analyzed the negative Flynn Effect and have found that it is greatest when the aggregate *g*-loading of the indicator class is lowest. Three recent studies have summarized evidence for Negative Flynn Effects (Dutton et al., 2016; Flynn & Shayer, 2018; Woodley of Menie, Peñaherrera-Aguirre, et al., 2017), two of them in *Intelligence*. To develop this important line of research as many instances of this effect must be reported and understood as possible.

Accordingly, where previous studies showing a Negative Flynn Effect have been reported and then are not replicated it is vital that this is disseminated to researchers in this area. In this regard, Dutton, Bakhiet, Ziada, Essa, and Blahmar (2017) found a Negative Flynn Effect, between 1999 and 2010, among children in Khartoum aged between 9 and 18, amounting to a loss of 2.13 IQ points per decade. They argued that both Kuwait (Dutton, Bakhiet, Essa, Blahmar, & Hakami, 2017) and Sudan has adopted a strongly religious curriculum and age and time related variation in the intensity of this paralleled age and cohort variation in the Negative Flynn Effect. In the case of Khartoum, they argued that this may also explain why the Negative Flynn Effect was stronger among school children aged 6, but then weakened. However, another explanation which they proposed was that compulsory schooling was only introduced in Sudan[1] *after* data were collected from the first sample in 1999. This could, of course, be cleared-up by comparing datasets which were both administered in a context of compulsory schooling. This would allow us to establish whether or not there really is a Negative Flynn Effect in Khartoum. This is what we will do in this extension of Dutton, Bakhiet, Ziada, et al. (2017). This is clearly important in permitting future meta-analyses of the Negative

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[1] It should be noted that "Sudan" refers to the Republic of Sudan. This is now only the northern part of the Sudan, of which the capital is Khartoum. The southern part broke away from the old Republic of Sudan in 2011 to form "South Sudan," the capital of which is Juba. Sudan is predominantly Sunni Muslim and Arab or Arab-African cline while South Sudan is mainly Christian or animist and Sub-Saharan African.

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Flynn Effect and in understanding the factors which might lead to it, including sampling errors, in different parts of the world.

2. Method

The Colored Progressive Matrices (Raven, 2008), a non-verbal reasoning test aimed primarily at children, was administered in 2004 to a sample of 1683 children aged between 6 and 9 years in Khartoum, the capital of Sudan. They were selected by the stratified sampling method to be representative of public and private schools and socio-economic status variation within the city. Stratified sampling is a type of sampling method in which the total population is divided into smaller groups or strata to complete the sampling process. The strata are formed based on common characteristics in the population data. After dividing the population into strata, the researcher randomly selects the sample proportionally. The classes we used in the current sample of 2016 are: by sex, by age, and by socio-economic level based on parental income (very low, low, medium, high). This matched the stratification of the 2004 sample. The children were group tested in classes in their schools by trained psychologists. This administration has been published in Arabic in Khatib, Mutwakkil, and Hussain (2006) and an English-language summary was presented in Bakhiet and Lynn (2014). In 2016, a similar study was carried out in Khartoum, using the same stratified sampling method, on a sample of 3015 children of comparable ages. This was conducted by three of the authors.

For the purpose of cross-national comparability we used British norms from 2007 (Raven, 2008, Table A1) to convert raw scores into IQ scores, but these norms are designed for use on individuals who can only have integer scores. Rounding fractional parts of raw-scores can lead to distortions. For this reason we created third order polynomial functions which describe the relationship between raw and IQ-scores within an age group with an accuracy of > 0.99 and used these functions for conversions (see Supplementary material for more detailed description). The advantage is an increase in the accuracy level of the conversions.

3. Results

Descriptive statistics and sex differences for CPM raw-scores are given in Table 1 separately for 2004 and 2016. In 2004, sex differences are mostly in favor of males (pos.) except in the group composed of seven years olds. Effect sizes are small with absolute Cohen's *d* between 0.16 and 0.31 but with a high significance in *t*-test for the total sample ($p < 0.001$). In 2016, sex differences are in favor of females (neg.), except in the group of six years olds, and effect sizes are non-significant to small with absolute Cohen's *d* between 0.05 and 0.20 but with a high significance on the *t*-test for the total sample ($p < 0.001$).

The changes in means and standard deviations of sex differences in CPM raw-scores between 2004 and 2016 are given in Table 2. A decrease of sex differences in all age groups due to a stronger increase in raw-scores for females than males (+4.90 vs. 2.92 in total samples) is recognizable. There is a robust increase in raw-scores from 2004 to 2016 across both sexes and all age groups with a moderate to strong effect size and moderate to high significance. The sample from 2016 shows consistently larger standard deviations with mostly highly significant differences to those from the 2004 sample, except for six and nine years old males.

Means of 2004 and 2016 as well as sex- and time-differences are given in Table 3 in British IQ scores according to the norms of 2007. The biggest sex differences are found among the seven years olds in 2004, with a difference of 3.67 IQ points in favor of males, and in 2016, with a difference of 4.18 in favor of females. By comparing sexes without separating them by age group, there was a sex-difference in 2004 of 2.75 points in favor of males but in 2016 of 2.43 points in favor of females. There was an increase in IQ scores, between 2004 and 2016, of 10.10 points (0.84 per year, 8.4 points per decade) for both sexes 7.52 (0.63 per year) for males only and 12.70 (1.06) for females. The strongest Flynn Effect could be found for nine years old females with an increase of 18.08 points (1.54 per year) and among the total cohort of nine year olds with an increase of 16.46 (1.37 per year), but these numbers must be taken with caution because of raw scores below the 1st British percentile, where CPM loses reliability. More credible top Flynn Effects are among the seven year olds with an increase of 11.82 (0.99 per year) for males and 8.91 (0.74 per year) for females. By contrast, the Flynn Effect markedly increases with age among girls and is stronger among girls than boys, apart from among 7 year olds, where the Flynn Effect appears to be anomalously high among boys.

4. Discussion

As noted above, the mean of the eight gains is .62*d*, equivalent to 10.10 IQ points over the twelve years and 8.42 IQ points per decade. Clearly, this is a very large effect and it may be wondered whether it is a result of measurement error. However, the average per decade Flynn Effect across the twentieth century is generally calculated using tests such as WAIS. Gains commensurate with that which we have observed have been found on Progressive Matrices tests. For example, between 1982 and 2007, the CPM score of a representative sample of British 8 year olds rose by 14.53 points (Flynn, 2012, p. 197). This amounts to an increase of 5.8 points in a decade.

As discussed, in Dutton, Bakhiet, Ziada, et al. (2017) a negative Flynn Effect was reported in a representative Khartoum sample of 9 to 18 year olds. They also found noticeable differences in the intensity of the effect by age-group. The possible explanations which they presented were: a negative intelligence-fertility nexus in Sudan, internal migration from the war torn parts of the country, age-group differences in the intensity of Sudan's "Muslim Curriculum" (a possibility broached in Flynn (2012) to explain anomalies in Sudan's Flynn Effect), and the fact

Table 1
Descriptive statistics and sex differences in raw-scores for CPM from Khartoum in 2004 and 2016.

Age (y)	Sex	2004						2016					
		N	*M*	*SD*	Dif. (m-f)	*D*	*T*	*N*	*M*	*SD*	Dif. (m-f)	*d*	*T*
6	M	92	13.50	5.30	1.00	0.21	−1.65	305	15.60	5.50	0.50	0.09	−1.07
	F	167	12.50	4.30				269	15.10	5.70			
7	M	167	13.00	4.80	−1.20	−0.26	2.65**	284	17.20	6.20	−0.30	−0.05	0.58
	F	293	14.20	4.60				294	17.50	6.20			
8	M	286	16.10	5.80	0.90	0.16	−2.00*	368	18.60	6.90	−1.40	−0.20	2.84**
	F	366	15.20	5.60				431	20.00	7.00			
9	M	183	17.60	7.30	2.10	0.32	−2.70**	505	20.50	7.40	−1.40	−0.19	3.04**
	F	129	15.50	5.90				559	21.90	7.60			
6–9	M	728	15.44	5.70	0.98	0.18	−3.69***	1462	18.36	6.92	−1.00	−0.14	3.86***
	F	955	14.46	5.10				1553	19.36	7.33			

m = male; f = female; *d* = Cohen's *d* for sex differences; *T* = *t*-values for sex differences; Significance (two-tailed): *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 2
Changes in *M* and *SD* in raw-scores for CPM from Khartoum between 2004 and 2016.

Age (*y*)	Sex	Changes between 2004 and 2016 in					
		M (raw-scores)				*SD* (raw-scores)	
		Dif. (2016–2004)	*d*	*T*	Dif. (m-f)	Dif. (2016–2004)	*F*
6	t	2.35	0.45	−5.85***	−0.50	0.80	1.35***
	m	2.10	0.39	−3.24**		0.20	1.08
	f	2.60	0.52	−5.07***		1.40	1.76***
7	t	3.75	0.69	−10.75***	0.90	1.50	1.74***
	m	4.20	0.76	−7.53***		1.40	1.67***
	f	3.30	0.61	−7.32***		1.60	1.82***
8	t	3.65	0.58	−10.77***	−2.30	1.25	1.49***
	m	2.50	0.39	−4.92***		1.10	1.42***
	f	4.80	0.76	−10.56***		1.40	1.56***
9	t	4.65	0.66	−9.89***	−3.50	0.90	1.28***
	m	2.90	0.39	−4.56***		0.10	1.03
	f	6.40	0.95	−8.96***		1.70	1.66***
6 to 9	t	3.91	0.62	−19.59***	−1.98	1.73	1.74***
	m	2.92	0.46	−9.85***		1.22	1.47***
	f	4.90	0.79	−18.14***		2.23	2.07***

t = both sexes (calculated as means of males and females); m = male; f = female; *d* = Cohen's *d* for time differences; *T* = *t*-values for time differences in *M*; *F* = *F*-values for time differences in *SD*. Significance: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 3
Test-results and differences in IQ-scores according to norms from the British standardization of 2007.

Age (y)	Sex	IQ-scores				
		M (2004)	*M* (2016)	Dif. (m-f) in 2004	Dif. (m-f) in 2016	Dif. (2016–2004)
6	t	76.54	83.72	3.29	1.43	7.18
	m	78.16	84.43			6.28
	f	74.87	83.01			8.14
7	t	67.50	77.84	−3.67	−0.76	10.33
	m	65.63	77.46			11.82
	f	69.30	78.21			8.91
8	t	63.74	71.29	1.55	−3.39	7.55
	m	64.53	69.64			5.11
	f	62.98	73.03			10.05
9	t	≤60.00[a]	76.46	3.28[a]	−4.18[a]	16.46[a]
	m	63.28	74.30			11.02
	f	≤60.00[a]	78.48			18.48[a]
6 to 9	t	71.46	81.56	2.75	−2.43	10.10
	m	72.81	80.34			7.52
	f	70.06	82.77			12.70

[a] Scores affected by the lower limit of 60.00 IQ-scores.

the compulsory primary education was only introduced in the year 2000, rendering the 1999 sample likely more elite than parts of the 2010 sample. This finding is, clearly, potentially inconsistent with the positive Flynn Effect in Khartoum between 2004 and 2016 which we report here. The most obvious variable between the two studies would appear to be compulsory primary education which, as already noted, did not exist in 1999 in Sudan. By 2004, primary education was compulsory, just as it was in 2016. As such, it would appear that the overall Negative Flynn Effect in Khartoum between 1999 and 2010 may be partly explicable in terms of the introduction of mandatory education only having occurred in the year 2000. In other words, changes in education policy clearly impact the extent of the recorded Flynn Effect. But we are then left asking, 'What is behind the positive Flynn Effect between 2004 and 2016?'

In terms of the Flynn Effect itself, two obvious candidates present themselves. The first is simply internal migration within Sudan. Studies from Western countries consistently find lower IQ in the countryside than in the cities. It has been found that intelligence predicts migration and that the more intelligent will tend to migrate to these cities in order to improve their lives and practice more skilled occupations (see Carl, 2015). This process of urbanization tends to increase as the country industrializes. As such it is possible that there is no Flynn Effect in Sudan itself, but merely one in Khartoum and that this is as a consequence of migratory factors. However, this is inconsistent with the studies we have already cited which reported a Flynn Effect in the northern part of Sudan more broadly.

As such, the explanation which would explain the most studies is simply that Sudan is in the process of undergoing a Flynn Effect, for the same reasons which Western countries have done previously. In other words, as Woodley (2012) argues, and as Pietschnig and Voracek (2015) show to be the most persuasive of the proposed explanations for the Flynn Effect, a slower Life History Speed (LHS) has led to greater specialization, increased education, and the increased use of analytical thinking. This has pushed the Sudanese further towards their genotypic limit on certain specialized abilities which are weakly correlated with g (see Dutton et al., 2016). Dutton et al. (2016) have argued that this environmentally induced increase has occurred in tandem with evidence – from assorted proxies, such as reaction times (for summary see Dutton & Charlton, 2015) – that general intelligence has been falling: the so-called Co-occurrence Model (Woodley of Menie, Figueredo, Sarraf, Hertler, Fernandes, and Peñaherrera-Aguirre, 2017; Woodley of Menie, Sarraf, Peñaherrera-Aguirre, Fernandes, and Becker, 2018). Until the 1990s, it was sufficient to cloak and overwhelm the genetic decrease at the level of Fullscale IQ. However, the Flynn Effect began to slow down, in the 1990s it reached its ceiling, and then a negative Flynn Effect began to be recorded. The best supported causal model for this is the negative cultural amplifier model of Meisenberg (2003). Immigration (and probably emigration too in the case of countries like Sudan) reduces IQ not only by virtue of biodemographic changes, but also by virtue of the impact of increased ethno-linguistic diversity on the host population. This degrades the environments sustaining the Flynn Effect (such as schooling), throwing it into reverse. This has been demonstrated, with regard to PISA tests, in Brunello and Rocco (2013). Accordingly, it can be reasonably proposed that Sudan's Flynn Effect can be explained by its being further behind in the process of industrialization than is Western Europe. Although there is a modest negative intelligence-fertility nexus in Sudan, the impact of this is still overwhelmed by the magnitude of the Flynn Effect, which is yet to reach its genotypic limit. In this sense, Sudan simply exemplifies what has been recorded in a variety of other developing countries, such as Kenya. As Flynn (2012, pp.62–63) has observed, it is likely that the war in Sudan and political instability have contributed to the Flynn Effect

hitting in relatively late.

Contra to this idea, it could be argued that Western countries and developing countries are very different and we should be cautious in assuming that the Flynn Effect is occurring in Sudan for the same reasons as it is the West. This is especially the case considering evidence already cited that the Negative Flynn Effect may not be occurring for the same reasons in Islamic countries as it is in the West. However, it can be countered that this makes an unwarranted division between the West and developing countries. If it is the case that Sudan is industrializing, then we would expect to find the beginnings of a Flynn Effect. This has been noted in the West across the twentieth century and at the beginning of that century the living standards of many European people were very much of a "developing country" nature (see Flynn, 2012). Moreover, we are not arguing that the Negative Flynn Effect in Islamic countries has a completely different cause. Indeed, it has been shown that part of the cause – in both cases – is likely dysgenic fertility. But we would expect different causes when comparing Western and non-Western countries; just as we might expect slight variation in causes when comparing Western countries to each other.

It could also be argued that our explanation is unlikely because Ravens is very strongly *g*-loaded and the explanation we have suggested is unlikely to elevate *g* to such an extent. However, it can be countered that a number of studies have now shown that Ravens is not as highly *g*-loaded as is commonly believed. It has been found that Ravens is, essentially, middling in its level of *g*-loadedness; around the region of 0.6 (Armstrong & Woodley, 2014; Johnson, Bouchard, Krueger, McGue, & Gottesman, 2004). There are a number of reasons for this. The multiple choice nature of the test means it is a prone to a "Brand Effect" (Brand, 1987) whereby every correctly guessed answer can boost IQ by 3 points. In older cohorts, subjects had to realize that a rule had to be developed to answer each questions, something which required general intelligence. Subjects are now taught about these rules, meaning they approach the test looking for these rules. This leads to aspects of abstract reasoning, such as looking for rules, increasingly decoupling from *g* and independently predicting the magnitude of the Flynn Effect (see Armstrong et al., 2016). In this regard, Fox and Mitchum (2013) have found that in later cohorts item response is much more strongly influenced by matters extrinsic to the Raven's test, meaning that Raven's is not measurement invariant between cohorts. On this basis, we would predict that the *g*-saturation (the loading of the items onto their item common factor) of Ravens items will be lower in our younger cohort, though we obviously require the raw data to test this.

In addition, we must ask, 'Why is the Flynn Effect in Sudan stronger for females?' It can be seen from Table 3 that, overall, the increase in IQ-scores is 7.52 for boys but 12.70 for girls. In this regard, a meta-analysis by Pietschnig et al. (2011, abstract) found, based on German studies, that there was 'only little evidence for sex differences regarding test score gains.' Overall, they concluded that there was no sex difference in magnitude worth speaking of. Ang, Rodgers, and Wänström (2010) likewise found in the USA that there was no sex difference in the magnitude of the Flynn Effect. That said, sex differences in the magnitude of the Flynn Effect were found on the SAT-V (see Wai & Putallaz, 2011, pp. 447–448). Also, there is evidence, from looking at the Flynn Effect among those with very high IQs, that the male over-representation has been decreasing over time (Wai, Putallaz, & Makel, 2012).

So, sex disparity is not unknown and we have found it again here. Table 1 reveals that at the ages of 8 and 9 the female Flynn Effect in Khartoum is more than double that of the male Flynn Effect. One possible explanation for this disparity is that there have been gradual changes in Sudan with regard to the perceived value of female education. It may have been the case that among girls born in 1995, for example, female education wasn't considered particularly important, something which would have changed to some extent by the time girls born in 2007 reached the same age. Thus, although the girls born in 1995 would have received compulsory schooling it may be that both this schooling and the home environment was less encouraging towards female education than was the case a decade later. Consistent with this is the fact that as the samples become younger there is a tendency for the sex difference in the magnitude of the Flynn Effect to decrease. The standard deviation increases between the two samples, possibly reflecting a larger and larger portion of society following the law and sending their children to school. As we have seen, it has been noted that the intensity of the "Muslim Curriculum" may be a factor in the reported Negative Flynn Effect in Kuwait, for example. In line with this, it may be speculated that Sudanese girls may have previously received a form of education that was much less analytically-focused than that of boys and this difference is now less pronounced, though this would be a matter for future research.

Further consistent with this interpretation is evidence of increasing equality of the sexes in Sudan. According to the United Nations Development Programme, although females are much less likely than males to attend secondary school, the proportion of females in primary education increased substantially between the years 2000 and 2015 and most regions of Sudan had gender parity in primary education by 2015. Between 1990 and 2015 women in the workforce (outside of agriculture) increased from 35% to 41% (UNDP United Nations Development Programme, 2015). In general, we would also expect that people that lived in the capital would hold less conservative political attitudes than those living elsewhere (see Carl, 2015) meaning that this change should be particularly pronounced in Khartoum. It may be the case, and for the same reasons, that in other developing countries the magnitude of the Flynn Effect has been stronger among females and becomes less pronounced as the cohorts become younger. This would certainly be worth investigating in a future study.

Finally, it can be seen from Table 3 that the IQ score (with reference to British norms) decreases as the children get older. This phenomenon has been observed in a meta-analysis of many Arab countries, as well as in other developing countries (Bakhiet et al., 2018). Bakhiet et al. (2018) argue that it reflects the way in which European schooling is more focused on analytical thinking than is the case in the Middle East. This leads to an amplification effect and the IQ difference between European and Arab children growing, until European children leave school and begin to create an environment reflective of their own innate intelligence.

5. Conclusions and limitations

Now that Sudan has become more stable, it appears to be undergoing the same kind of Flynn Effect as has been occurring in other developing nations, assuming that the process in Khartoum is broadly representative of the rest of the country. The fact that this Flynn Effect has been revealed – comparing two samples in which primary education was compulsory for all cohorts – would also help to explain why a Negative Flynn Effect was found in Khartoum in Dutton, Bakhiet, Ziada, et al. (2017). One point of considerable interest, however, is the fact that the intensity of the Flynn Effect was so much greater for girls. As stated, it would be informative to look back on many Western cohorts to see if there may have been a similar phenomenon.

In terms of limitations, we do not have access to the raw scores or item level results from the 2004 administration. If we did we could calculate whether or not this Khartoum Flynn Effect was occurring on general intelligence or not; whether or not it was a Jensen Effect. Based on other studies of the Flynn Effect we would not expect it to be a Jensen Effect (e.g. te Nijenhuis & Van der Flier, 2013; Woodley & Meisenberg, 2013; Woodley of Menie & Dunkel, 2015), but this remains to be proven.

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Appendix A. Supplementary data

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