Politische Psychologie, 2018, Nr. 2, S. 267-283

Is the Flynn effect related to migration? Meta-analytic evidence for correlates of stagnation and reversal of generational IQ test score changes

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Abstract

Generational IQ test score gains in the general population (the Flynn effect) have been observed to diminish in strength in recent years, and there is evidence for a stagnation and even a reversal of the Flynn effect in a number of countries. Here, we show that there is only little evidence for effects of migration, fertility, and mortality as substantive correlates of IQ decreases. We argue that the stagnation of the Flynn effect may be explained by ceiling effects and diminishing returns of IQ-boosting factors, whilst its reversal can be attributed to negative associations with psychometric *g*.

Keywords: Flynn effect; intelligence; meta-analysis; migration

Gibt es einen Zusammenhang zwischen dem Flynn-Effekt und Migration? Meta-analytische Evidenz für Korrelate von Stagnation und Umkehr von kohortenspezifischen IQ-Testnormverschiebungen

Zusammenfassung

Die Stärke positiver IQ-Testnormverschiebungen der Allgemeinbevölkerung über die Zeit (der Flynn-Effekt) schwächte sich in den letzten Jahren deutlich ab. Neuere Studien zeigen Hinweise für Stagnation und sogar eine Umkehr in einigen Ländern. In der vorliegenden Studie demonstrieren wir, dass für Einflüsse von Migration, Fertilität und Sterblichkeit auf abnehmende IQ-Testleistung nur wenig überzeugende Evidenz vorliegt. Wir schlussfolgern, dass die Stagnation des Flynn-Effekts durch Deckeneffekte und abnehmende Erträge von IQ-steigernden Faktoren erklärt werden kann, während die Umkehr auf negative Zusammenhänge mit psychometrischem *g* beruht.

Schlüsselwörter: Flynn-Effekt, Intelligenz, Meta-Analyse, Migration

Zusammenfassung

Eines der illustrativsten Beispiele für den Stellenwert, der der kognitiven Leistungsfähigkeit in unserer Gesellschaft zugemessen wird, findet sich bereits in den 1930er Jahren im weithin rezipierten Buch von Raymond B. Cattell *„The Fight for our National Intelligence"* (1937). In diesem Werk drückte er seine Besorgnis über erwartbare sinkende IQ-Testleistungen der Allgemeinbevölkerung in Großbritannien aus. Moderne Beispiele für die gesellschaftliche Relevanz kognitiver Leistungen finden sich in internationalen Vergleichsstudien wie PISA, TIMMS oder PIRLS, deren Ergebnisse über nationale Medien weite Verbreitung finden und die mitunter beträchtlichen Einfluss auf bildungspolitische Entscheidungen ausüben.

Anders als von Cattell (1937) erwartet, ließ sich über einen großen Teil des 20. Jahrhunderts hinweg eine Zunahme der Intelligenztestleistung in einer großen Anzahl von Ländern feststellen. In rezenten Studien zeigte sich jedoch eine Abschwächung der IQ-Zuwächse und in einigen Ländern sogar eine Stagnation beziehungsweise eine Umkehr dieses als „Flynn-Effekt" bekannten Phänomens. Einer der Faktoren, der in der Literatur für die Erklärung dieser Umkehr des Flynn-Effekts vorgeschlagen wird, findet sich in der Form von Migrationseffekten. Diese Theorie basiert auf der Annahme, dass (hauptsächlich nicht-westliche) Populationen mit niedrigeren durchschnittlichen kognitiven Fähigkeiten in (hauptsächlich westliche) Länder mit höheren mittleren Fähigkeiten migrieren, wodurch es zu einer Abnahme des IQs in den Gastländern kommt. Weitere vorgeschlagene Ursachen machen negative Zusammenhänge zwischen Fertilität und IQ sowie positive Zusammenhänge zwischen Mortalität und IQ für die Umkehr des Flynn-Effekts verantwortlich.

Das Ziel der vorliegenden Studie ist die Untersuchung von Migration, Fertilität und Mortalität als mögliche Ursachen für die Stagnation und Umkehr des Flynn-Effekts. Zu diesem Zweck verwendeten wir zwei meta-analytische Datensätze, die in diesem Kontext noch nicht untersucht wurden: Der erste Datensatz basiert auf durchschnittlichen IQ-Testleistungen von 94 unabhängigen Stichproben (N = 13,108) eines wohletablierten Raumvorstellungstests (3DW; Gittler, 1990) über einen Zeitraum von 38 Jahren in Österreich (1977-2014; Pietschnig & Gittler, 2015). Der zweite Datensatz beinhaltet IQ-Testleistungsveränderungen auf Testinstrumenten zur Erfassung von fullscale, kristallisierter und fluider Intelligenz von 137 unabhängigen Stichproben verschiedener Länder (N = 2,410,759) über einen Zeitraum von 54 Jahren (1960-2013; Pietschnig & Voracek, 2015). Indizes für nationale Migrationszahlen, Fertilitäts- und Mortalitätsraten wurden aus zwei verschiedenen Quellen erfasst.

In einer Serie von gewichteten einfachen und multiplen Meta-Regressionen zeigten sich keine bedeutsamen Einflüsse von drei Indikatoren für Migration (Zahl von Asylwerbern, Netto-Migration, absolute Migrationszahlen) auf die Testleistung im 3DW in die erwartete Richtung (mit Ausnahme von einem kleinen negativen Effekt von absoluter Migration; dieses Vorzeichen drehte sich jedoch nach Berücksichtigung von Publikationsjahr um). Diese Ergebnisse sind interessant, weil der 3DW konzeptuell eng mit psychometrischem *g* (allgemeine kognitive Fähigkeit) verknüpft ist und auch robuste Korrelationen mit anderen hoch *g*-ladenden Tests wie zum Beispiel dem Mental Rotations Test bekannt sind. Daraus lässt sich folgern, dass Migrationseffekte keine bedeutsame Rolle für IQ-Abnahmen spielen sollten. Unsere Ergebnisse sind konsistent mit bereits publizierten Erkenntnissen, die zeigten, dass migrationsbedingte Veränderungen von nationalen IQs kurzlebig sind (te Nijenhuis, de Jong, Evers, & van der Flier, 2004).

Zusammenhänge mit Fertilitäts- und Mortalitätsraten zeigten ein erratisches Muster inkonsistenter Vorzeichen bei mehrheitlich kleinen und trivialen Effekten zwi-

schen und innerhalb beider Meta-Analysen. Solche inkonsistente Effektmuster zeigten sich auch, wenn eine zeitliche Verzögerung dieser Effekte angenommen wurde. Basierend auf diesen Ergebnissen lässt sich schwerlich ein inhaltlich bedeutsamer Effekt von Fertilität und Mortalität auf IQ-Testleistungsveränderungen ableiten.

Insgesamt zeigen wir in der vorliegenden Studie, dass es nur wenig Evidenz für Effekte von Migration, Fertilität und Mortalität auf IQ-Testleistungsveränderungen gibt. Basierend auf der verfügbaren Evidenz (Pietschnig & Voracek, 2015) argumentieren wir, dass die beobachtete Stagnation und Umkehr des Flynn-Effekts auf zwei distinkte Mechanismen zurückgeführt werden kann: Einerseits können geringere Stärke und die Stagnation des Flynn-Effekts auf Deckeneffekte und abnehmende Erträge von IQ-steigernden Faktoren (verbesserte Ernährung, geringerer pathogener Stress, bessere und längere Beschulung, Testrateverhalten, soziale Multiplikatoren, nationale Prosperität) erklärt werden. Andererseits lassen sich Abnahmen in der durchschnittlichen Testleistung auf einen negativen Zusammenhang des Flynn-Effekts mit psychometrischem *g* zurückführen.

1. Introduction

Perhaps one of the most illustrative examples of how much value the society places on cognitive abilities may be found in the widely-cited book of Raymond B. Cattell (1937) *The Fight for our National Intelligence*, who therein expressed his concerns about potentially decreasing IQ scores of the UK population. Based on his observation of selective population reproduction patterns (i.e., low-ability individuals reproducing earlier and quicker), he estimated that IQs of the British population will decrease at a rate of about one IQ point per decade. He argued that the resulting lower population cognitive abilities would, inter alia, detrimentally affect the quality of educational systems, social progress, or national prosperity and security (Cattell, 1937; pp.46-85).

Without a doubt, cognitive abilities are nowadays valued and deemed important for the functioning of contemporary societies. This is for instance reflected by the variety of international cognitive ability and achievement comparisons that have been established by the International Association for the Evaluation of Educational Achievement, such as the PISA (Programme for International Student Assessment), TIMSS (Trends in International Mathematics and Science Study), or PIRLS studies (Progress in International Reading Literacy Study). Although these findings are based an achievement data which are conceptually not identical with results from cognitive ability tests, achievement and cognitive ability tests have been shown to be strongly linked (for a discussion, see, Rindermann, 2007). Results of such studies receive frequently considerable attention within national news outlets and inform policy and reform decisions.

Importantly, contrary to Cattell's prediction (1937), decreases in population IQs did not emerge following his publication. Indeed, the first systematic accounts describing IQ test score changes in the general population indicated substantial increases of test scores over time (Flynn, 1984, 1987).

In the so far most comprehensive meta-analysis about this so-called Flynn effect, test performance changes have been shown to have been predominantly positive over the past century, yielding average performance increases of about 2.8 IQ points per decade (Pietschnig & Voracek, 2015). Typically, the Flynn effect is stronger for fluid than crystallized IQ and appears to be negatively associated with psychometric *g* (i.e., the general factor of intelligence, see, Must, Must, & Raudik, 2003; Woodley & Meisenberg, 2013; but see Colom, Juan-Espinosa, & Garcia, 2001, for different findings).

However, the strength of IQ gains has been observed to decrease in more recent decades (Pietschnig & Voracek, 2015) and evidence for stagnation (e.g., Sundet, Barlaug, & Torjussen, 2004) or even a reversal of the Flynn effect in a number of countries has as of late started to accumulate (for a review, see Dutton, van der Linden, & Lynn, 2016).

Whilst a considerable number of theories has been proposed to explain the observed IQ gains, citing environmental (e.g., improved education), biological (hybrid vigor), or hybrid causes (e.g., improved nutrition, less pathogen stress; for an overview see, Pietschnig & Voracek, 2015), potential causes for IQ decreases have only received comparatively little attention. This is unsurprising, because until recently (allowing for a few exceptions), there has been little evidence for decreasing IQ scores and therefore there has been no need for an explanatory framework for IQ decreases.

One of the factors which has been discussed in the wake of these novel findings relates to immigration patterns. Specifically, it has been proposed that migration of lower IQ populations into host populations with higher IQs may have led to decreasing averages in the (typically Western) host countries' IQs (e.g., Dutton & Lynn, 2013). Indeed, increases in immigration rates have been shown to be negatively associated with large-scale assessments of competences in reading, mathematics, and problem solving in adults of 93 nations (Rindermann & Thompson, 2014).

Other potential factors that have been discussed pertain to fertility (i.e., suggesting that higher fertility should be associated with lower IQ scores because of selective reproduction patterns; e.g., Dutton & Lynn, 2013; Lynn, 2011) and reduced mortality in Western countries due to the advances in modern medicine (i.e., thus relaxing the principle of Darwinian selection by enabling less fit individuals to reach the reproductive age; Nyborg, 2012).

In the present meta-analysis, we aim to clarify associations of migration, fertility, and mortality with IQ test score gains. To this end, we reanalyze two large meta-analytic data sets providing evidence for (i) IQ performance changes on a spatial perception test from 1977 to 2014 in Austria (Pietschnig & Gittler, 2015) and (ii) IQ test score changes from 1909 to 2013 in 21 different countries on a number of different cognitive ability measures (Pietschnig & Voracek, 2015). First, we used three different indices, namely numbers of asylum seekers, net migration, and absolute migration to assess influences of migration. Second, for the assessment of reproduction effects we obtained fertility rates. Finally, we used mortality rates under the age of 5 years for the investigation of mortality effects on population IQ changes.

2. Study 1 – Methods

In study 1, we examined influences of migration, fertility, and mortality on IQ test norm changes on a spatial ability test (the 3DC; Dreidimensionaler Würfeltest [three-dimensional cube test]; Gittler, 1990) by means of a cross-temporal fixed-effect meta-analytical approach. Data were obtained from Pietschnig and Gittler (2015) and included sample-specific test-scores of Austrian student, general population, and mixed samples from 1977 to 2014.

2.1 Literature search

We aimed at providing a comprehensive account of the available evidence instead of focusing on published accounts only because publication status does not seem to be a useful proxy for study quality, but may rather lead to dissemination bias-related artifacts (for a discussion, see, Borenstein, Hedges, Higgins, & Rothstein, 2009). To this end, we used cited reference searches in ISI Web of Knowledge for key papers, used keyword searches in databases for published accounts (Austrian library catalog) as well as for grey literature (Datenbank deutschsprachiger Diplomarbeiten in Psychologie [database of master's theses in German language in Psychology], and screened reference lists of obtained studies. Moreover, a number of unpublished data sets, as available from the second author of this meta-analysis [GG], was included (for a detailed description, refer to Pietschnig & Gittler, 2015).

2.2 Inclusion criteria

Only studies reporting mean scores and ability parameters of the 3DC for samples comprising healthy adults from Austria were included (samples from Germany as retained for the original analysis in Pietschnig & Gittler, 2015, were excluded from the present analysis). Data had to be independent (i.e., samples did not overlap between studies) and mean raw scores or person ability parameters had to be reported. In cases of data dependencies, more recent studies and larger data sets were preferred.

2.3 Coding

Data were coded twice independently by the same experienced researcher [JP] into categories and necessary parameters were recorded (see, Pietschnig & Gittler, 2015, for details). Publication years, average sample performance (percentage of correctly solved items and person ability parameters within studies), and sample type (general population vs. students vs. mixed samples) were recorded. Discrepancies in coding were resolved through discussion with a second independent coder [GG].

2.4 Migration, mortality, and fertility

We obtained fertility and mortality rates under the age of 5 years (henceforth: mortality < 5) expressed as births per 1000 women and deaths per 1000 persons from the worldbank database (1977-2014) and additionally retrieved annual numbers of asylum seekers (2000-2014), absolute immigrant numbers (i.e., annual influx of people from abroad; 1996-2014), and net migration numbers (i.e., number of people entering minus number of people leaving the country; 1996-2014) for Austria from the national statistical office (Statistik Austria, *www.statistik.at*). For the latter three indices, the number of includable samples was somewhat reduced because of the available data of our predictor variables (see section 2.6).

2.5 Data analysis

In all analyses, data points were weighted according to the respective sample sizes (i.e., thus accounting for higher precision of larger sample estimates). We used three different methods, to assess influences of migration, mortality, and fertility on IQ test performance. First, a series of single weighted meta-regressions were used to assess influences of migration, mortality, and fertility, separately. Second, we used multiple weighted meta-regressions to assess influences of these predictors when data collection year was accounted for (i.e., data collection year captures test score changes over time in cross-temporal meta-analyses). Significant differences of the explanatory value of single and multiple meta-regressions were compared in terms of changes in explained variance. Finally, we calculated nonlinear regressions by predicting mean performance based on migration, fertility, and mortality whilst introducing a quadratic term in our regression equation to investigate influences of our predictors under the assumption of curvilinearity (variables were *z*-standardized prior to the calculation of curvilinear models, see Aiken & West, 1996, pp. 62-65). This approach was deemed useful, because spatial IQ test score changes in Austria have been observed to be better explained by an inverse U-shaped, rather than a linear, relationship (Pietschnig & Gittler, 2015).

We interpret the meaningfulness of predictors mainly in terms of the strength of effect sizes (i.e., partial η^2 values of .01, .06, and .14 for single and .02, .13 and .26 for multiple regressions as lower thresholds for small, medium, and strong effects; see Cohen, 1988), rather than nominal significance statistics (for a discussion, see, Cumming, 2014), because effect sizes provide more meaningful interpretations of (meta-analytical) results (with the exception of nonlinear relationships, where R^2 and η_p^2 values cannot be meaningfully interpreted; e.g., Spiess & Neumeyer, 2010). Multicollinearity was assessed by inspection of variance inflation factors *(VIFs)*. Following common guidelines, we assumed collinearity to be unproblematic when *VIFs* were < 4 (e.g., Kleinbaum, Kupper, Muller, & Nizam, 1998), but indicate cases where this criterion was not met. We supplemented all our calculations for fertility and mortality with time-lagged analyses by lagging fertility and mortality rates by mean sample ages. This was deemed useful as a sensitivity analysis, because fertility and mortality rates may not have an immediate effect on population IQs. We did not apply this approach to migration analyses because (i) migration effects should manifest themselves quicker than fertility and mortality influences and (ii) annual migration statistics for Austria are only available since 1996 at best, which reduces the number of includable studies for time-lagged analyses virtually to zero.

2.6 Final sample

In all, k = 27, 60, 60, 94, and 94 independent samples were included, totaling N = 2,241, 5,907, 5,907, 13,108, and 13,108 participants for asylum seekers, immigration numbers, net migration numbers, mortality < 5, and fertility rates, respectively, covering timespans from 15 to 38 years. Participants comprised adult healthy participants from convenience samples that had been recruited from schools, universities, and the general population in Austria (study characteristics are detailed in Pietschnig & Gittler, 2015).

3. Study 1 – Results

None of the annual migration numbers (i.e., asylum seekers, net migration, absolute migration) were significantly related to mean 3DC test performance (results of percentage of correctly solved items and person parameters were virtually identical; we subsequently provide results for person parameters only). Whilst numbers of asylum seekers were moderately positively associated with mean test performance (η_p^2 = .070), net migration and absolute migration showed trivial-to-small negative relationships (see upper three single regression entries in Table 1; results of all single regressions are presented in Figure 1).

Examination of curvilinear regressions did not yield any significant influences of quadratic terms (*p*s ranged from .07 to .47; upper three blocks of Table 2), thus largely ruling out similar influences as previously observed for publication year on mean 3DC performance (Pietschnig & Gittler, 2015). When data collection year was added to the models, the explanatory value of the models only improved significantly for net migration and absolute migration, although data collection year emerged as the more meaningful (negative) predictor in all cases. Interestingly, in the multiple regressions, all migration predictors were consistently positive, yielding small effects, thus indicating higher test performance in presence of higher asylum seeker, net-migration, and absolute migration numbers (see upper three multiple regression blocks in Table 1).

Test performance was negatively, albeit non-significantly, associated with fertility rates, showing small influences of fertility

Table 1. Weighted regressions of asylum seeker numbers, net migration, migration, fertility, and mortality rates on mean 3DW person parameters of Austrian samples.

	Standard					**Time-lagged**				
	b	SE	β	p	η_p^2	b	SE	β	p	η_p^2
Model summary (single)	$k = 27$; $R^2 = .03$; $F(1, 25) = 1.891$									-
Asylum seekers (2000-2014)	<0.001	<0.001	.221	.181	.070	-	-	-	-	-
Model summary (multiple)	$k = 27$; $\Delta R^2 < .01$; $F(2, 24) = 1.183$									-
Data collection year	-0.024	0.03	.300	.481	.021	-	-	-	-	-
Asylum seekers (2000-2014)	<0.001	<0.01	.165	.369	.034	-	-	-	-	-
Model summary (single)	$k = 60$; $R^2 < .01$; $F(1, 58) = 0.149$									-
Net migration (1996-2014)	>0.001	<0.001	.043	.701	.003	-	-	-	-	-
Model summary (multiple)	$k = 60$; $\Delta R^2 = .08^{**}$; $F(2, 57) = 0.149^{*}$									-
Data collection year	-0.058	0.02	-.733	.009	.113	-	-	-	-	-
Net migration (1996-2014)	<0.001	<0.01	.328	.064	.059	-	-	-	-	-
Model summary (single)	$k = 60$; $R^2 = .01$; $F(1, 58) = 1.553$									-
Migration (1996-2014)	>-0.001	<.001	-.143	.218	.026	-	-	-	-	-
Model summary (multiple)	$k = 60$; $\Delta R^2 = .05^{*}$; $F(2, 57) = 3.010$									-
Data collection year	-0.073	0.037	-.978	.041	.071	-	-	-	-	-
Migration (1996-2014)	<0.001	<0.001	.463	.142	.038	-	-	-	-	-
Model summary (single)	$k = 94$; $R^2 = .01$; $F(1, 92) = 1.865$					$k = 86$; $R^2 = .01$; $F(1, 84) = 2.243$				
Fertility rates (1977-2014)	0.438	0.320	.063	.175	.020	0.214	0.143	.149	.138	.026
Model summary (multiple)	$k = 94$; $\Delta R^2 < .01$; $F(2,91) = 1.111$					$k = 86$; $\Delta R^2 = .11^{***}$; $F(2, 83) = 7.206^{**}$				
Data collection year	-0.006	0.01	-.079	.545	.004	0.034	0.010	.431	.001	.125
Fertility rates (1977-2014)	-0.653	0.48	-.094	.176	.020	0.702	0.195	.490	.001	.135
Model summary (single)	$k = 94$; $R^2 = .02$; $F(1, 92) = 2.508$					$k = 86$; $R^2 = .05$; $F(1, 84) = 5.669^{**}$				
Mortality rates (1977-2014)	0.025	0.016	.117	.117	.027	0.019	0.008	.255	.020	.063
Model summary (multiple)	$k = 94$; $\Delta R^2 = .05^{*}$; $F(2,91) = 4.730^{*}$					$k = 86$; $\Delta R^2 = .13^{***}$; $F(2, 83) = 10.55^{***}$				
Data collection year	-0.049	0.02	-.625	.011	.069	0.044	0.010	.415	<.001	.149
Mortality rates (1977-2014)	-0.133	0.04	-.619	.003	.091	0.033	0.009	.575	<.001	.190

Note. R^2 of multiple regressions are adjusted values; *VIFs* for multiple regressions of migration and mortality = 7.10 and 5.42, respectively; all other VIFs < 2.3. * = $p < .05$, ** = $p < .01$.

Table 2. Curvilinear associations between asylum seeker numbers, net migration, migration, fertility, and mortality rates and mean 3DW person parameters of Austrian samples for standard and time-lagged analyses.

	Standard				**Time-lagged**			
	β	p	β_1	p_1	β	p	β_1	p_1
Model summary	$k = 27$; $R^2 = .02$; $F(2, 24) = 1.200$							-
Asylum seekers (2000-2014)	-.005	.988	.109	.468	-	-	-	-
Model summary	$k = 60$; $R^2 = <.01$; $F(2, 57) = 0.576$							-
Net migration (1996-2014)	-.155	.331	.075	.321	-	-	-	-
Model summary	$k = 60$; $R^2 = .05$; $F(2, 57) = 2.522$							-
Migration (1996-2014)	-.334	.033	.174	.069	-	-	-	-
Model summary	$k = 94$; $R^2 = <.01$; $F(2, 91) = 0.945$				$k = 86$; $R^2 = .11$; $F(2, 83) = 6.283^{**}$			
Fertility rates (1977-2014)	-.028	.868	-.009	.833	.283	.008	-.511	.002
Model summary	$k = 94$; $R^2 = <.03$; $F(2, 91) = 2.675$				$k = 86$; $R^2 = .12$; $F(2, 83) = 6.892^{**}$			
Mortality rates <5 (1977-2014)	.078	.573	-.111	.098	.250	.018	-.221	.007

Note. All R^2 are adjusted values; β = standardized coefficient for linear term, p = associated significance value; β_1 = standardized coefficient for quadratic term, p_1 = associated significance value; ** = $p < .01$

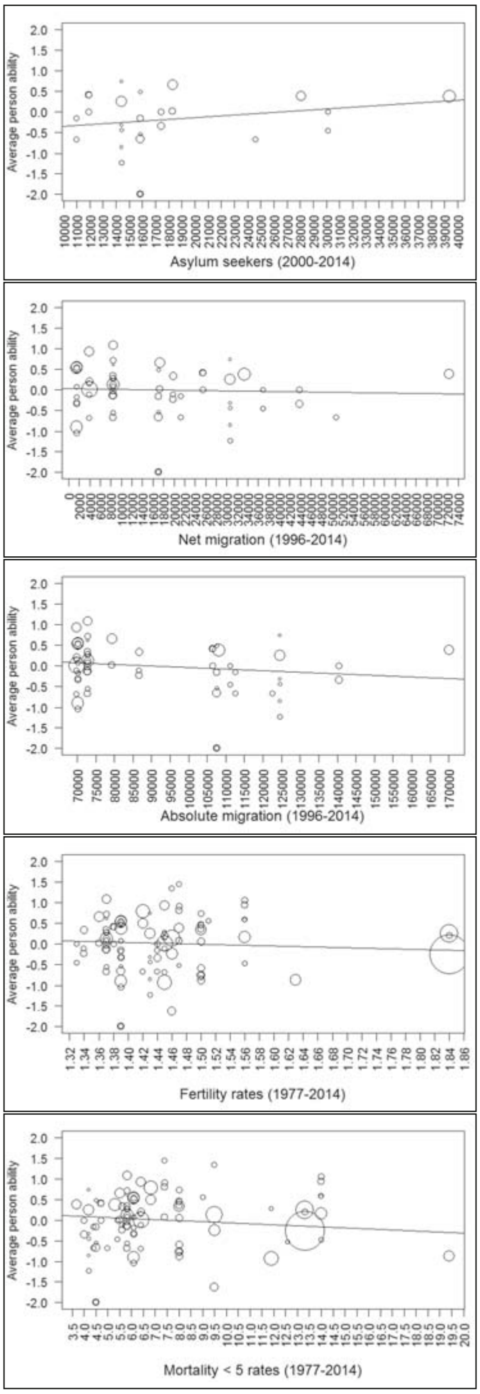

Figure 1. Bubble plots of single weighted regressions of asylum seeker numbers, net migration, absolute migration, fertility rates, and mortality rates on person ability parameters of Austrian samples.

Note. Symbol sizes represent accuracy of estimates (larger symbols are indicative of larger samples ns).

on person parameters. No significant curvilinear association was observed either (p = .83; penultimate block of Table 2). Associations between fertility and task performance remained non-trivial when data collection year was included in our multiple regression analysis (penultimate block of Table 1). Significant meaningful effects of time-lagged analyses yielded coefficient signs that are in contrast with the expected direction. Mortality < 5 was negatively associated with test performance, yielding a small effect. The subsequent multiple regression showed a consistent result, indicating negative influences of both mortality < 5 and data collection year, whilst time-lagged analyses indicated non-trivial positive effects of both predictors (bottom block of Table 1). No meaningful curvilinear relationship was observed for standard analyses. Interestingly however, significant curvilinear associations were found for time-lagged analyses, indicating positive linear associations that are negatively accelerated (bottom block of Table 2).

4. Study 2 – Methods

In study 2, we used the available data for IQ test norm changes from a comprehensive meta-analysis of test norm changes which provided evidence for potential causes of the Flynn effect, but which have not yet been investigated in relation to (inter-)national fertility and mortality patterns (Pietschnig & Voracek, 2015). IQ change data were available for fullscale, crystallized, and fluid IQ from 1909 to 2013 in 31 different countries (Pietschnig & Voracek, 2015). However, due to limited data availability of fertility and mortality estimates, analyses were restricted to data from 21 countries from 1960 to 2013 (see section 4.6). Of note, spatial IQ was also assessed in this publication, but has been excluded from the present analyses because the number of available data points was deemed too small for robust analysis (i.e., $k = 11$ eligible studies).

4.1 Literature search

We used a variety of different search strategies to obtain primary data from studies that were suited to provide evidence for generational IQ changes. Cited reference searches in ISI Web of Knowledge for key publications on the Flynn effect, keyword searches in scientific databases (Google Scholar, PubMed, ISI Web of Knowledge, Scopus), reference list screenings, and hand searches in available IQ test manuals were performed (for a detailed description, see Pietschnig & Voracek, 2015).

4.2 Inclusion criteria

Primary studies reporting test score changes of standardized psychometric ability measures without restrictions in terms of sample characteristics, such as age or health, were assessed (sample characteristics were included as moderators though, see below). Data had to be independent (i.e., samples did not overlap between studies) and sufficient statistical parameters had to be reported to allow calculation of gain scores. In cases of data dependencies, longer time spans and larger data sets were preferred.

4.3 Coding

Data were coded twice independently by the same experienced researcher [JP] into categories and necessary parameters were recorded (see, Pietschnig & Voracek, 2015, for details). This included recording of publication years, country, gain scores, sample type (healthy vs. patient samples), sample age, sex (percentage of men within samples), year of onset of IQ test score change (henceforth: year of onset), and type of cognitive measure (fullscale, crystallized, fluid, developmental, spatial IQ). Discrepancies in coding were resolved through discussion with a second independent coder [MV].

4.4 Mortality and fertility

National fertility and mortality rates under the age of 5 years were once again obtained from the worldbank database (*www.worldbank.org*). Data were available from 1960 to 2013, thus reducing the number of includable samples somewhat compared to the originally published account, because of the comparatively shorter timespan (see section 4.6). Migration numbers were not obtained for study 2, because the worldbank data provides only crude 5-year breakups (i.e., no individual years are available) which do not allow an accurate and meaningful inclusion in our regression models.

4.5 Data analysis

We followed an identical analytic approach as in study 1 (refer to section 2.5), with the following exceptions: (i) dependent variables were IQ change scores instead of mean performance, (ii) average national fertility and mortality < 5 rates for the respective timespans had to be used as predictors instead of mere rates (e.g., if an observed IQ increase covered ten years, the annual fertility rates over these ten years were averaged to obtain a meaningful predictor), (iii) curvilinearity was not modelled, and (iv) sample type, age, national GDP change, type of cognitive measure, covered timespan, and year of onset were used as moderating variables in multiple regressions, in accordance with previous evidence about meaningful predictors of the Flynn effect (Pietschnig & Voracek, 2015).

4.6 Final sample

In all, k = 137, 75, and 89 independent samples, totaling N = 2,410,759, 479,453, and 1,022,363 participants covering a timespan of 54 years (1960-2013) were included for fullscale IQ, crystallized IQ, and fluid IQ, respectively. Data from 21 countries (Argentina, Australia, Austria, Brazil, Canada, China, Finland, France, Germany, Israel, Kenya, Netherlands, Saudi Arabia, South Africa, South Korea, Spain, Sudan, Sweden, Turkey, United Kingdom, USA) were included in the present analyses. Samples comprised predominantly healthy participants and included both children and adults (study characteristics are detailed in the online supplementary materials S1 from Pietschnig & Voracek, 2015).

5. Study 2 – Results

No significant effects emerged for fertility rates. Although observed effects were nontrivial for fullscale and fluid IQ, the observed signs were positive, thus suggesting somewhat larger gains when fertility rates were higher (upper half of Table 3). The results for this predictor (i.e., signs and effect direction) remained virtually unchanged when better fitting multiple regression models were calculated (i.e., when including sample type, age, national GDP change, type of cognitive measure, covered timespan, and year of onset; all ps < .001 for changes in R^2). For fullscale IQ, observed gains were mainly driven by GDP growth and shorter timespans (i.e., indicating decreasing scores in more recent years; the sign for year of onset indicated an opposite direction), although interestingly fertility showed a meaningful, but positive relationship with IQ gains (η_p^2 = .041). For crystallized IQ gains (nonsignificant) associations with fertility rates were small at best and increases were most strongly related to decreasing scores in more recent years and gains, whilst fluid IQ gains were strongly associated with fertility (η_p^2 = .256; the coefficient sign indicated a positive relationship though) and decreasing gains in more recent years (see online Supplement S5 of Pietschnig & Voracek, 2015, for details). These results remained virtually identical in our sensitivity analyses when timelag was accounted for (see Table 3; upper third of Table 4).

Similar results emerged when using mortality < 5 as a predictor (detailed results are provided in the two bottom blocks of Table 4). Again, no significant (and mostly trivial, with the exception of a small positive

Table 3. Weighted single regressions of fertility and mortality < 5 rates on fullscale, crystallized, and fluid IQ gains (1960-2013) in 21 countries in standard and time-lagged analyses.

	Fullscale IQ		Crystallized IQ		Fluid IQ	
	standard	time-lagged	standard	time-lagged	standard	time-lagged
	Fertility					
k	137	89	75	46	89	57
F ($df1$, $df2$)	1.866 (1, 135)	6.472* (1, 88)	0.094 (1, 73)	1.335 (1, 44)	3.119 (1, 87)	6.622* (1, 55)
R^2	.006	.059	<.001	.007	.024	.091
b	0.044	0.104	-0.009	0.054	0.062	0.104
SE	0.032	0.041	0.031	0.046	0.035	0.040
p	.174	.013	.760	.254	.081	.013
η_p^2	.014	.069	.001	.029	.035	.107

Table 3: to be continued on next page →.

(cont'd) Table 3

	Fullscale IQ		Crystallized IQ		Fluid IQ	
	standard	**time-lagged**	**standard**	**time-lagged**	**standard**	**time-lagged**
	Mortality < 5					
k	137	87	75	46	89	56
F (df1, df2)	0.755 (1, 135)	0.470 (1, 85)	0.210 (1, 75)	0.737 (1, 44)	1.182 (1, 87)	0.595 (1, 54)
R^2	<.001	<.001	<.001	<.001	.002	<.001
b	0.001	0.001	-0.001	0.002	0.002	0.002
SE	0.001	0.002	0.001	0.002	0.002	0.002
p	.386	.495	.648	.395	.280	.444
η_p^2	.006	.005	.003	.016	.013	.011

Note. k = number of samples; Results of multiple meta-regressions for fertility are available from Supplement S5 of Pietschnig & Voracek (2015); * = $p < .05$.

effect on fluid IQ) effects of mortality < 5 on IQ gains were observed (bottom half of Table 3). When including moderating variables (see above) in multiple regressions, model fit improved; however, influences of mortality < 5 remained largely trivial and inconsistent in terms of coefficient signs. Fullscale IQ was mainly driven by type of cognitive measure, GDP growth, and decreasing strength of IQ gains over time (once more, the sign of year of onset was inconsistent with timespan). Crystallized and fluid IQ changes were meaningfully predicted by decreasing IQ gains over time, but fluid IQ showed a positive moderate association with mortality < 5 (η_p^2 = .148). In our sensitivity analyses, time-lagged mortality did not show meaningful influences on fullscale IQ, but was positively moderately-to-strongly associated with crystallized and fluid IQ.

Table 4. Multiple regressions of fertility and mortality < 5 rates on fullscale, crystallized, and fluid IQ gains (1960-2013) in 21 countries for standard (mortality only) and time-lagged analyses.

	Fullscale IQ			Crystallized IQ			Fluid IQ		
	b	p	η_p^2	b	p	η_p^2	b	p	η_p^2
	Fertility time-lagged								
Model summary	k = 89; R^2 = .19; F(7, 81) = 4.00***			k = 64; R^2 = .78; F(6, 67) = 43.61***			k = 56; R^2 = .14; F(5, 50) = 2.85*		
Fertility	0.157	.203	.020	-0.037	.211	.023	0.067	.021	.101
Children (0) vs. adult sample (1)	0.076	.772	.001	0.008	.882	<.001	-	-	-
Growth in GDP per capita	3.422	.731	.001	1.475	.571	.005	-0.042	.985	<.001
Medium g (1)	-0.120	.532	.005	-	-	-	-	-	-
High g (1)	-	-	-	-	-	-	-	-	-
Patient-based (0) vs. healthy sample (1)	-0.214	.695	.002	-0.011	.909	<.001	-0.042	.765	.002
Timespan	-0.025	.101	.033	-0.026	<.001	.521	0.001	.827	.001
Year of onset	0.016	.078	.038	-0.018	<.001	.318	-0.001	.922	<.001

Table 4: to be continued on next page →.

(cont'd) Table 4

	Fullscale IQ			Crystallized IQ			Fluid IQ		
	b	*p*	η_p^2	*b*	*p*	η_p^2	*b*	*p*	η_p^2
	Mortality standard								
Model summary	k = 137; R^2 = .36; F(8, 128) = 9.18***			k = 74; R^2 = .78; F(6, 67) = 42.98***			k = 88; R^2 = .72; F(6, 81) = 38.47***		
Mortality < 5	0.004	.142	.017	-0.001	.376	.012	0.007	<.001	.148
Children (0) vs. adult sample (1)	-0.086	.327	.008	-0.028	.583	.005	0.124	.052	.045
Growth in GDP per capita	6.738	.073	.025	1.638	.537	.006	-0.557	.815	.001
Medium *g* (1)	-0.199	<.001	.096	-	-	-	-	-	-
High *g* (1)	-0.195	.713	.001	-	-	-	-	-	-
Patient-based (0) vs. healthy sample (1)	0.061	.846	<.001	-0.037	.691	.002	0.037	.836	.001
Timespan	-0.012	.003	.066	-0.024	<.001	.562	-0.014	<.001	.284
Year of onset	.010	<.001	.099	-0.017	<.001	.327	-	-	-
	Mortality time-lagged								
Model summary	k = 87; R^2 = .20; F(7, 79) = 4.03***			k = 45; R^2 = .61; F(4, 40) = 18.53***			k = 55; R^2 = .39; F(5, 49) = 7.81***		
Mortality < 5	0.009	.320	.015	0.009	.017	.134	0.010	<.001	.357
Children (0) vs. adult sample (1)	0.147	.619	.003	-	-	-	-	-	-
Growth in GDP per capita	-0.498	.967	<.001	-0.820	.845	.001	-9.356	<.001	.241
Medium *g* (1)	-0.164	.419	.008	-	-	-	-	-	-
High *g* (1)	-	-	-	-	-	-	-	-	-
Patient-based (0) vs. healthy sample (1)	-0.296	.594	.004	-0.055	.783	.002	-0.042	.723	.003
Timespan	-0.022	0.018	.019	-0.045	<.001	.447	0.023	.001	.193
Year of onset	0.007	0.012	.005	-	-	-	-0.009	.029	.093

Note. k = number of samples; Omitted entries are due to dropping of variables because of *VIF*s > 4; Medium and high *g* predictors were only available for fullscale IQ; the high *g* predictor was removed from time-lagged analyses because there were no high *g* entries in the reduced data; Results of standard multiple meta-regressions for fertility are available from Supplement S5 of Pietschnig & Voracek (2015); * = p < .05; *** = p < .001.

6. Discussion

In all, the present evidence does not seem to support substantive associations of migration, fertility, or mortality with IQ test score changes. Signs of observed effects were frequently contrasting theory-based expectations and effect strengths were weak at best.

Specifically, migration indices were not meaningfully negatively related with performance in the 3DC (with the exception of absolute migration numbers that showed a small negative effect in a single regression). In fact, when accounting for publication year, numbers of asylum seekers, net migration, and absolute migration revealed consistently positive signs and small effects, indicating a positive relationship between migration and IQ test performance. These findings are important, because spatial perception is conceptually closely related to psychometric *g* (i.e., the general factor of intelligence) and has shown robust correlations (r = .55; Vogler, 2015) with other highly *g*-loaded tests such as the Mental Rotations Test (Vandenberg & Kuse, 1978).

These findings contrast the expectations of the migration hypothesis, because conceptually, the number of asylum seekers should show the most pronounced association with IQ test score decreases. Because asylum seekers in Austria predominantly originate from countries with lower average population test performance (asylum seekers originate mainly from developing countries, such as Syria, Afghanistan, Iraq, according to the Austrian Federal Ministry of the Interior, www.bmi.gv.at/publikationen; for an overview of national IQ averages, see, Lynn, 2011), asylum seeker numbers should be most closely related to IQ declines.

Of note, we caution against interpreting these findings as evidence for larger migration numbers leading to higher national IQs. However, the observed effects are inconsistent with the idea that migration effects represent a meaningful cause for decreasing population IQ scores. Our results seem to be in line with evidence suggesting that migration effects on national IQ levels are short-lived and performance gaps between migrant and host populations diminish over time (te Nijenhuis, de Jong, Evers, & van der Flier, 2004).

Influences of fertility yielded somewhat inconsistent results in our two meta-analyses. Based on previous accounts, fertility should be negatively associated with IQ test score changes (i.e., representing larger IQ gains in countries and higher test scores at times when more births occur; Lynn, 2011). Whilst we found trivial-to-small effects in the expected direction for spatial perception scores in Austria, the results of our study 2 were inconsistent with this result. Fertility showed only for the prediction of crystallized IQ the expected negative sign, yielding a trivial effect in the single regression, but a barely non-trivial one when further predictors were included. For fullscale and fluid IQ though, non-trivial positive effects of fertility emerged in both single and multiple regressions, indicating larger IQ gains during times when more births were recorded. These findings present only weak, if any, evidence for negative fertility effects on IQ gains and render the assumption of differing fertility patterns as a suitable explanation for IQ test score changes questionable.

For mortality < 5, we observed a similar erratic pattern of hypothesis conforming and non-conforming results. Spatial perception scores in Austria were negatively predicted by mortality rates yielding small effects, thus indicating higher scores when fewer deaths occurred. However, in study 2, only crystallized IQ showed an effect in the same direction, whilst fullscale and fluid IQ were positively predicted by mortality rates, yielding small-to-moderate effects and even more so in time-lagged analyses. Once more, this inconsistent pattern of results appears to present only little evidence for mortality as a meaningful correlate of decreasing IQ scores in the general population (Nyborg, 2012), although based on our present data, this idea cannot be completely dismissed.

The results discussed above seem to indicate that the explanatory value of migration, fertility, and mortality for the stagnation and reversal of the Flynn effect is limited at best. However, other candidate theories may offer more suitable alternative explanations. On the one hand, the most likely causes for generational IQ gains have been identified in the form of improved nutrition (e.g., Lynn, 2009), better and longer education (Williams, 1998), reduced pathogen stress (Eppig, Fincher, & Thornhill, 2010), and changes in test-taking behavior (i.e., more test guessing; e.g., Brand, Freshwater, & Dockrell, 1989; Pietschnig, Tran, & Voracek, 2013), whilst social multiplier effects (i.e., environmental reinforcement of intelligent behavior; Dickens & Flynn, 2001) and national prosperity may account for domain-specific differences in gains (for a review, see Pietschnig & Voracek, 2015). However, most of these causes cannot be expected to increase IQs indefinitely, but are bound to either reach a ceiling (as for instance, increased test guessing) or yield diminishing returns (as for instance, longer schooling). Therefore, the slowing down and stagnation of the Flynn effect may be explained by the reduced effectiveness of IQ boosting factors.

On the other hand, the Flynn effect has been frequently observed to be negatively related to psychometric *g* (e.g., Must et al., 2003; Pietschnig & Voracek, 2015). Therefore, increases in specific abilities may have so far masked a *g*-based ability decrease. This idea is consistent with previously reported declines of reaction times (i.e., highly *g*-loaded measures) over the past century (e.g., Woodley, te Nijenhuis, & Murphy, 2013, 2014; Woodley of Menie, te Nijenhuis, & Murphy, 2015; but see Dodonova & Dodonov, 2013; Nettelbeck, 2014; Parker, 2014; Woods, Wyma, Yund, Herron, & Reed, 2015; for critical commentaries).

6.1 Limitations

Some limitations should be noted when interpreting the results from this study. First, no breakdown for specific origin countries of migrants was available, thus rendering absolute and net migration numbers rather crude proxies for non-Western migration. However, it should be noted that asylum seeker numbers (which most likely exclusively originate from non-Western populations, see, www.bmi.gv.at/publikationen) did not show negative associations with spatial perception scores either, thus corroborating our findings of no meaningful associations of migration and test performance.

Second, the data in study 1 did not permit assessment of actual immigrant numbers within samples (although it seems very likely that migrants have been included within these samples). However, in terms of the evaluation of migration as a driver of IQ declines, it is irrelevant whether or not migrants were represented within the data. Either way, in presence of IQ decreases and non-meaningful associations with migration numbers, migration may be largely ruled out as a correlate of IQ declines.

Third, we investigated influences of migration only in study 1, but not study 2, because of the unavailability of suitable estimates. However, we included three indices of migration in study 1 which allowed us to assess the consistency of observed results across different models. In this vein, it needs to be acknowledged, that the results from our migration-based analyses should be only considered as tentative evidence for global IQ test score changes because they were based on Austrian samples only. Future migration-related examinations of other countries that showed Flynn effect reversals (e.g., Denmark, Finland, or France; Dutton & Lynn, 2013; 2015; Teasdale & Owen, 2005) may be useful for an evaluation of the generalizability of our findings.

Finally, limited data availability of predictors necessitated us to reduce the available IQ change and IQ score observations somewhat, thus reducing the number of includable samples from the original meta-analytic accounts.

6.2 Concluding remarks

In all, we show that there is only little evidence for migration, fertility, and mortality as meaningful correlates of a reversal of the Flynn effect. We argue that the observed reduction in strength of IQ gains and stagnation in some countries are due to ceiling effects and diminishing returns of IQ boosting factors, whilst recently emerging IQ decreases may be attributed to negative associations of the Flynn effect with psychometric *g*.

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