Beyond Test Scores: the Rank Effect and Non-Cognitive Skills

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The rank effect

The **rank effect** *is the impact of within-group ordinal ranking on future outcomes*:

- It affects future test scores, years of education (Murphy and Weinhardt, 2020; Carneiro et al., 2023), and future earnings (Denning et al., 2023)
- Several studies hint at non-cognitive skills related to self-concept as its drivers (Murphy and Weinhardt, 2020; Pagani et al., 2021; Carneiro et al., 2023)
- Evidence that developing non-cognitive skills is important for future achievement (Heckman and Kautz, 2012; Attanasio et al., 2020; Sorrenti et al., 2024)

Our research questions:

- **Can we find further proof of a rank effect on non-cognitive skills?**
- **Are there long-term effects?**

Our study

We use a population survey of children enrolled in primary school in Aberdeen (Scotland) in 1962:

- Collect demographic, primary school, and medical information
- A follow-up survey was run in 2001 covering 60% of the sample

We exploit quasi-random assignment to school-cohort groups. We find:

- Positive rank effect on **future test scores** and **attained education**
- Positive rank effect on **internalizing skills**, limited impact on **externalizing skills**
- No rank effect on mental health and socioeconomic status 40 years later

Data and Institutional Setting

The Aberdeen Children of the 1950s Survey

Different surveys are linked together:

- Reading Survey 1962-1967
- 2001 Follow-up

In particular, we use the data on:

- Standardized tests at age 9, and age 11
- In March 1964 the Rutter Questionnaire for teachers was administered

In the dataset, we have:

- All the children in primary school in Aberdeen (Scotland) in December 1962 (roughly 12,000)
- We exclude those in special and private schools (roughly 10,000 remain)
- Two intakes per year, August and January, give us two cohorts table

Non-cognitive Skills

Deriving non-cognitive skills

We use common factor analysis on the items of the Rutter Questionnaire:

- Variation is explained by a two-factor solution (screeplot loadings): these factors are **externalizing** and **internalizing skills**
- The solution aligns with psychological and economic research (Boyle and Jones, 1985; Klein et al., 2009; Narusyte et al., 2017; Attanasio et al., 2020)
- The distributions do not differ by cohort distribution

Empirical Strategy

Our model

$$Y_{isc} = \alpha R_{isc} + \beta f(A_{isc}) + \gamma g(\overline{A}_{sc-i}) + X_i\delta + \lambda_{sc} + \epsilon_{isc}$$

- Y_{isc} is the outcome of the 11-plus test distribution, externalizing/internalizing skills distribution, or long-term outcomes
- R_{isc} is the percentile school-cohort rank formula
- $f(A_{isc})$ is a quadratic polynomial of individual cognitive skills distribution
- $g(\overline{A}_{sc-i})$ controls for mean and standard deviation of peers' cognitive skills
- X_i is a vector of individual characteristics (Sex, Socioeconomic Status, Height, Weight, Birth Weight, and Number of Siblings)
- λ_{sc} are school-cohort fixed effects

Addressing passive sorting

Not having random assignment to schools, we need to make sure rank is not related to individual characteristics:

$$X_i = \delta R_{isc} + f(A_{isc}) + \gamma g(\overline{A}_{sc-i}) + \lambda_{sc} + \epsilon_{isc}$$

X_i are the individual characteristics listed before:

Balance checks

Variables	**Woman**	**High SES**	**Height**	**Weight**	**Birth Weight**	**Siblings**
Percentile Rank	0.052	0.012	0.135	0.119	-0.093	-0.070
	(0.061)	(0.032)	(0.108)	(0.114)	(0.151)	(0.078)
Observations	9,698	9,698	9,465	9,458	9,698	9,698

Results

Results - the rank effect on future test scores is meaningful

Rank effect: Verbal Reasoning and 11-plus Tests

Outcome Variable	Verbal Reasoning Test			11-plus Test		
Percentile Rank	0.586***	0.610***	0.606***	0.541***	0.577***	0.577***
	(0.068)	(0.068)	(0.069)	(0.072)	(0.073)	(0.074)
Observations	9,443	9,441	9,239	7,577	7,575	7,401
Group Fixed Effects	X	X	X	X	X	X
Cognitive Skills	X	X	X	X	X	X
Peer Quality		X	X		X	X
Individual Characteristics			X			X

- Ranking 4 positions higher in a group of 40 causes a 6% of a unit of standard deviation increase in subsequent test scores
- Estimates are similar to those of other studies (Murphy and Weinhardt, 2020; Elsner et al., 2021)
- Effect is linear graph

Results - there is a positive rank effect on internalizing skills

Rank effect: externalizing and internalizing skills

Outcome Variable	Externalizing Skills				Internalizing Skills			
Percentile Rank	0.288*	0.299*	0.286*	0.269*	0.508***	0.492***	0.483***	0.493***
	(0.162)	(0.164)	(0.161)	(0.160)	(0.150)	(0.151)	(0.154)	(0.154)
Observations	6,633	6,631	6,516	6,516	6,633	6,631	6,516	6,516
Group Fixed Effects	X	X	X	X	X	X	X	X
Cognitive Skills	X	X	X	X	X	X	X	X
Peer Quality		X	X	X		X	X	X
Individual Characteristics				X				X

- The same jump in the ranking improves internalizing skills by almost 5% of a unit of standard deviation
- The effect on internalizing skills is robust to the exclusion of extreme values robustness
- Also effect on non-cognitive skills follows a linear path graph
- Boys drive the overall small rank effect on externalizing skills results

The 2001 follow-up survey

In 2001 the children who participated in the survey were mailed a follow-up questionnaire. 59% of them replied. We find:

- No rank effect on 2001 Survey response
- Positive rank effect on the probability of achieving O-level and A-level education results
- No rank effect on socioeconomic status results
- No rank effect on mental health results

Conclusions

We find:

- Positive rank effect on future test scores and further education
- Positive rank effect on internalizing skills

We contribute mainly to two different streams of literature:

- We provide evidence that there is a direct effect of rank on non-cognitive skills tied to self-confidence
- We show the impact of non-cognitive skills on learning outcomes, but not on those of other realms

Thank you!

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Descriptive statistics

	Mean	SD	Median	Max	Min	N
Group Characteristics						
School Size	362	157	307	750	168	28
Cohort Size	36	20	29	126	12	275
Inputs						
Age 9 Test	0	1	0.05	4.41	-3.93	9,698
Height (inches)	42.28	2.02	42	29	54	9,310
Birth Weight (lbs)	11.05	2.27	11	17	1	9,970
Outputs						
Verbal Reasoning Test	0	1	-0.03	3.46	-3.63	9,717
Externalizing Skills	0	1	0.47	0.92	-8.13	6,790
Internalizing Skills	0	1	0.49	1.61	-7.28	6,790
Others						
Female	0.48	-	-	-	-	9,970
Low SES	0.91	-	-	-	-	9,970
A-levels	0.33	-	-	-	-	5,875
Degree	0.15	-	-	-	-	5,875

Notes: Inputs and outputs are standardized at the cohort level.

Percentilized rank

We construct rank normalizing ordinal rank by group size (Murphy and Weinhardt, 2020):

$$RANK_{isc} = (n_{isgk} - 1)/(N_{sgk} - 1)$$

Where n_{isgk} is the ordinal rank of individual i enrolled in school s and cohort gk, while N_{sgk} is the size of the cohort to which the student belongs. When we have ties between students, the mean rank is assigned.

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Grade progression mechanism

Intake	Key Timings	Cohort: October 1951 - April 1952	April 1952 - October 1952	October 1952 - April 1953	April 1953 - October 1953
August 1956		-	-	-	-
January 1957		1st Grade	-	-	-
August 1957		1st Grade	1st Grade	-	-
January 1958		2nd Grade	1st Grade	1st Grade	-
August 1958	Age 7 Test ⟶	2nd Grade	2nd Grade	1st Grade	1st Grade
January 1959		3rd Grade	2nd Grade	2nd Grade	1st Grade
August 1959		3rd Grade	3rd Grade	2nd Grade	2nd Grade
January 1960		4th Grade	3rd Grade	3rd Grade	2nd Grade
August 1960	Age 9 Test ⟶	4th Grade	4th Grade	3rd Grade	3rd Grade
January 1961		5th Grade	4th Grade	4th Grade	3rd Grade
August 1961		5th Grade	5th Grade	4th Grade	4th Grade
January 1962		6th Grade	5th Grade	5th Grade	4th Grade
August 1962	1962 Reading Test ⟶	6th Grade	6th Grade	5th Grade	5th Grade
January 1963		7th Grade	6th Grade	6th Grade	5th Grade
August 1963		7th Grade	7th Grade	6th Grade	6th Grade
January 1964	Rutter (scale b) ⟶	Junior Secondary School	7th Grade	7th Grade	6th Grade
August 1964		November 1964: 11-plus Test		7th Grade	7th Grade
January 1965		-	-	Junior Secondary School	7th Grade
August 1965		-	-	November 1964: 11-plus Test	
January 1966		-	-	-	-

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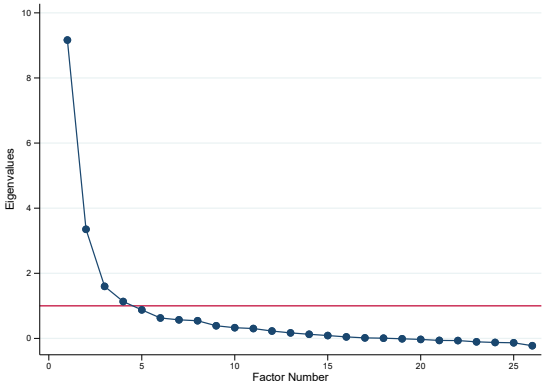
Common Factor Analysis: Screeplot

Figure: Screeplot of the Eigenvalues - Iteration 1



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Common factor analysis: factor loadings

Rotated (oblique) Factor Loadings for each iteration

	Iteration 1		Iteration 2	
Variable	Externalizing	Internalizing	Externalizing	Internalizing
Restless	**0.78**	0.00	**0.79**	-0.02
Truant	**0.68**	0.18	**0.67**	0.16
Fidgety	**0.77**	0.01	**0.76**	-0.01
Destroys Belongings	**0.89**	-0.07	**0.89**	-0.07
Fights Others	**0.87**	-0.04	**0.88**	-0.004
Disliked	**0.67**	0.33	**0.68**	0.33
Anxious	-0.16	**0.85**	-0.15	**0.86**
Solitary	0.11	**0.62**	0.12	**0.60**
Irritable	**0.75**	0.04	**0.76**	0.06
Often Unhappy and Miserable	0.22	**0.75**	0.24	**0.76**
Tics	0.39	0.32	-	-
Sucks Finger	0.26	0.25	-	-
Nail Biting	0.24	0.13	-	-
Trivial Absences	0.38	0.34	-	-
Disobedient	**0.87**	-0.12	**0.87**	-0.11
Poor Concentration	**0.57**	0.24	**0.56**	0.20
Afraid	-0.14	**0.85**	-0.12	**0.84**
Fussy over particular child	-0.18	**0.55**	-0.16	**0.58**
Often Lies	**0.86**	0.004	**0.86**	0.01
Stealing	**0.71**	-0.02	**0.70**	0.003
Wet/Soiled Themselves	0.26	0.29	-	-
Often Aching	0.16	**0.53**	0.17	**0.49**
Tearful	0.20	**0.63**	0.21	**0.65**
Stutters	0.20	0.29	-	-
Speech Difficulties	0.19	0.21	-	-
Bullies Others	**0.85**	-0.11	**0.85**	-0.09

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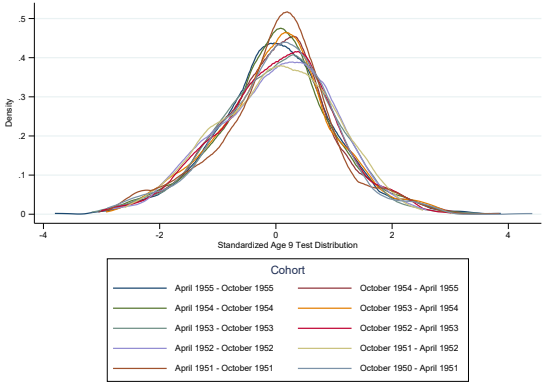
The distribution of the Age 9 Test

Figure: Distribution of the Age 9 Test by cohort, standardized at the cohort level



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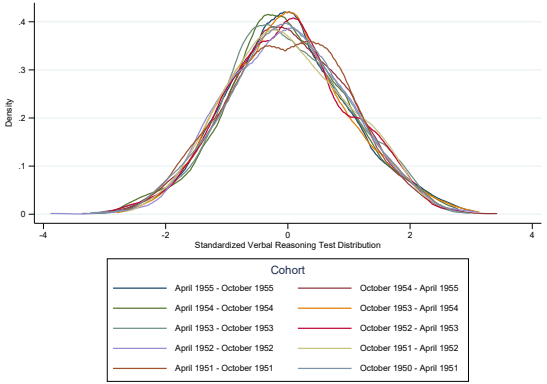
The distribution of Verbal Reasoning Test

Figure: Distribution of the 11-plus Test by cohort, standardized at the cohort level



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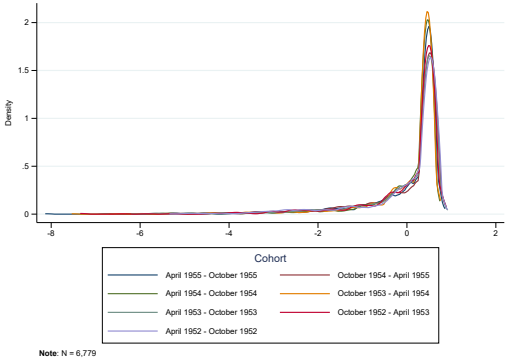
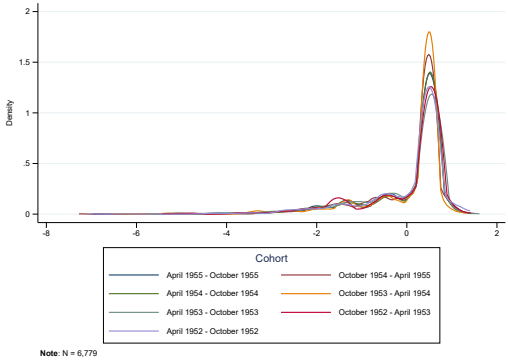
The distribution of externalizing and internalizing skills, by cohort

Figure: Distribution of Externalizing and Internalizing skills (standardized at the cohort level), by cohort





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Addressing passive sorting

Not having random assignment to schools, we need to make sure rank is not related to individual characteristics:

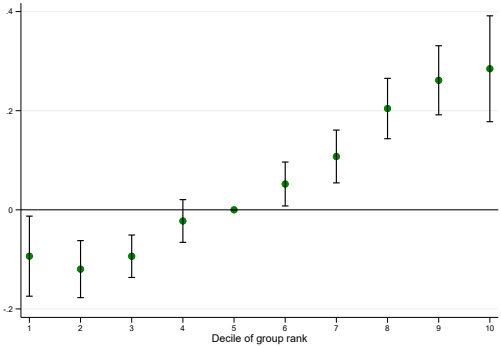
$$X_i = \delta R_{isc} + f(A_{isc}) + \lambda_{sc} + \epsilon_{isc}$$

X_i are individual characteristics such as Sex, Socioeconomic Status, Height, Weight, Birth Weight, and Number of Siblings.

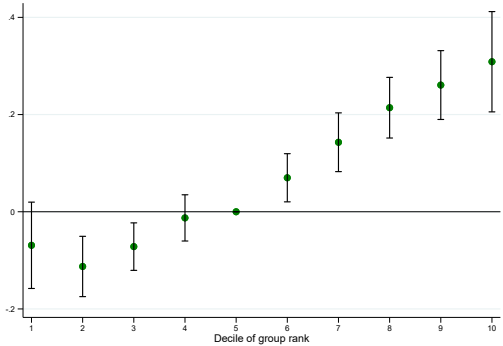
Variables	**Woman**	**High SES**	**Height**	**Weight**	**Birth Weight**	**Siblings**
Percentile Rank	0.052	0.012	0.135	0.119	-0.093	-0.070
	(0.061)	(0.032)	(0.108)	(0.114)	(0.151)	(0.078)
Observations	9,698	9,698	9,465	9,458	9,698	9,698

Results - performance nonlinearities

Figure: Rank effect on the (standardized) outcome of the Verbal Reasoning and 11-plus tests, by rank decile



Note: The dependent variable is the outcome of the Verbal Reasoning Test. N = 9,441.



Note: The dependent variable is the outcome of the 11-plus Test. N = 7,575.

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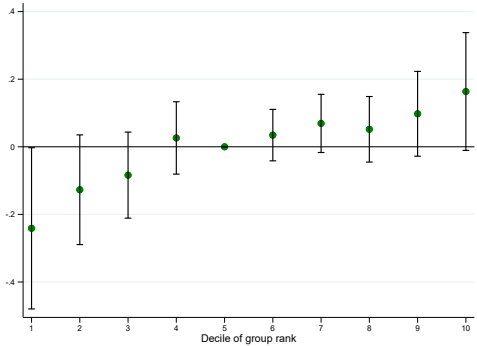
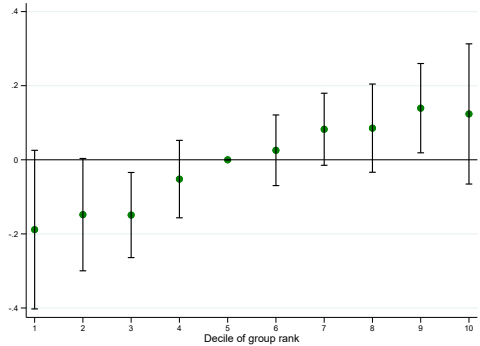
Results - non-cognitive skills nonlinearities

Figure: Rank effect on (standardized) externalizing and internalizing skills, by rank decile



Note: The dependent variable is Externalizing Skills. N = 6,516.



Note: The dependent variable is Internalizing Skills. N = 6,516.

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Heterogeneity - girls drive the change in internalizing skills

Heterogeneity by sex

Outcome Variable	VRT	11-plus Test	Externalizing Skills	Internalizing Skills
Percentile Rank # Male	0.530***	0.493***	0.425**	0.356**
	(0.072)	(0.076)	(0.175)	(0.164)
Percentile Rank # Female	0.683***	0.658***	0.141	0.605***
	(0.069)	(0.074)	(0.156)	(0.158)
T-test of the difference	0.153***	0.165***	-0.284***	0.249***
	(0.035)	(0.037)	(0.083)	(0.091)
Observations	9,441	7,575	6,516	6,516
Group Fixed Effects	X	X	X	X
Individual Characteristics	X	X	X	X
Cognitive Skills	X	X	X	X
Peer Quality	X	X	X	X

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Results - highly ranked children have better education outcomes

Rank effect: education

Outcome Variable	O-level	A-level	Degree
Percentile Rank	0.325***	0.419***	0.020
	(0.069)	(0.060)	(0.050)
Observations	5,744	5,744	5,744
Group Fixed Effects	X	X	X
Cognitive Skills	X	X	X
Peer Quality	X	X	X
Individual Characteristics	X	X	X

- Among the respondents, 15% have a degree, 33% have completed A-levels, and 60% have completed O-levels
- Educational attainment is affected, but not the probability of completing a degree

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Results - no solid evidence of a rank effect on socioeconomic status

Rank effect: socioeconomic status

Outcome Variable	Socioeconomic Status	log of Annual Income
Percentile Rank	0.034	0.080
	(0.054)	(0.112)
Observations	5,744	5,744
Group Fixed Effects	X	X
Cognitive Skills	X	X
Peer Quality	X	X
Individual Characteristics	X	X

- Roughly 17% of the respondents have a high socioeconomic status. The average annual income is £19,615
- No long-term impact on socioeconomic status and annual income

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Results - no rank effect on mental health

Rank effect: mental health

Outcome Variable	Probability of Enjoying Daily Life		Probability of Being Happy	
Percentile Rank	0.049	0.043	0.083	0.071
	(0.045)	(0.045)	(0.052)	(0.052)
Observations	5,744	5,744	5,744	5,744
Group Fixed Effects	X	X	X	X
Cognitive Skills	X	X	X	X
Peer Quality	X	X	X	X
Individual Characteristics	X	X	X	X
Education Level		X		X

- We use answers to the survey asking about current day-to-day life as indicators for mental health
- There does not seem to be a positive rank effect

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Robustness - the rank effect on internalizing skills is robust

Rank effect: externalizing and internalizing skills

Outcome Variable	Externalizing Skills				Internalizing Skills			
Cut bottom	-	3%	4%	5%	-	3%	4%	5%
Percentile Rank	0.269*	0.048	0.031	0.022	0.493***	0.340***	0.264***	0.257***
	(0.160)	(0.112)	(0.103)	(0.099)	(0.154)	(0.116)	(0.107)	(0.097)
Observations	6,516	6,313	6,250	6,179	6,516	6,313	6,250	6,179
Group Fixed Effects	X	X	X	X	X	X	X	X
Cognitive Skills	X	X	X	X	X	X	X	X
Peer Quality	X	X	X	X	X	X	X	X
Individual Characteristics	X	X	X	X	X	X	X	X

- We progressively exclude the bottom scorers for externalizing and internalizing skills
- Only rank effect on internalizing skills is robust

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Robustness - using school and cohort fixed effects

We also run a specification where we control for school and cohort fixed effects, λ_s and λ_c, separately:

$$Y_{isc} = \alpha R_{isc} + \beta f(A_{isc}) + \gamma g(\overline{A}_{sc-i}) + X_i\delta + \lambda_s + \lambda_c + \epsilon_{isc}$$

Running similar balancing checks as before, we see that:

Balance checks

Variables	Woman	High SES	Height	Weight	Birth Weight	Siblings
Percentile Rank	0.018	0.017	0.167	0.165*	0.052	-0.089
	(0.045)	(0.027)	(0.105)	(0.096)	(0.097)	(0.063)
Observations	9,698	9,698	9,465	9,458	9,698	9,698

Robustness - different identifying variation does not change the results

Rank effect: school and cohort fixed effects

Outcome Variable	Verbal Reasoning Test	11-plus Test	Externalizing Skills	Internalizing Skills
Percentile Rank	0.626***	0.644***	0.165	0.578***
	(0.062)	(0.061)	(0.140)	(0.154)
Observations	9,443	7,577	6,516	6,516
School Fixed Effects	X	X	X	X
Cohort Fixed Effects	X	X	X	X
Cognitive Skills	X	X	X	X
Peer Quality	X	X	X	X
Individual Characteristics	X	X	X	X

- The results are very similar when we exploit between-group variation
- Testament to the fact that group fixed effects do not capture a lot of the identifying variation