The male shortcut to math achievement

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Our study

- We study students' solutions to arithmetic tasks
  - Can they solve the task?
  - Can they choose an appropriate strategy for the task? (task-specific adaptivity)
- Example: 673 - 199 = ?

Standard algorithm:

$$\begin{array}{r} {}^{\not 6}\not{7}^{1}3 \\ -\,1\,9\,9 \\ \hline 4\,7\,4 \end{array}$$

Shortcut (compensation):

$$\begin{aligned} 673 - 199 &= 674 - 200 \\ &= 474 \end{aligned}$$

Hypothesis 1

- Male students more often use shortcut strategies than females
  - females follow rules (e.g. pedestrian rules), standard procedures (e.g. treatment guidelines), vaccination schedules etc. more often than males (e.g. Cullen et al. 2023, Rico-Ferreira et al. 2015)
  - female students are more conscientious than males (e.g. Brandes et al. 2021)
  - female students are behind males in comprehending the adaptive strategies already at school start (Sunde et al. 2020)
- H1: The gender gap in strategy use explains part of the gap in performance

Hypothesis 2

- Broad consensus among international education researchers:
  - Adaptivity is an important part of math proficiency (Baroody, 2003; Hickendorff, 2018; Sievert et al., 2019; Xu et al., 2017)
  - Adaptivity is positively associated with test performance (McMullen et al. 2016, 2017; Hästö, 2019)
- Danish math curriculum:
  - Teachers should "challenge and support individual students to develop arithmetic strategies based on their number understanding [...] the aim is not to practice standardised algorithms" (BUVM, 2019)
- H2: "Teacher adaptivity" affects males and females differently

Teacher adaptivity

- the *teacher's* teaching beliefs and teaching practices are aimed at developing the *student's* task-specific adaptivity
- the *teacher's* didactic approach favors *student* adaptivity
- A note of caution:
  - irrelevant whether the teacher him/herself possesses task-specific adaptivity
  - does not mean that the teacher adapts his/her didactic approach to the group of students or the situational context
- "teacher adaptivity" reflects a teacher's belief about adaptivity

Preview of results

1. Using shortcut strategies improves performance on arithmetic tasks
2. There is a large gender gap in use of shortcut strategies and it explains 30-50% of the gap in performance (H1)
3. Being assigned a teacher whose didactic approach favors adaptivity increases the gender gap in use of shortcut strategies and performance (H2)

Previous research: gender math gap

- Cultural influences at work before gaps show up (Cvencek et al. 2011):
  - Gender norms in the family (Dossi et al. 2021a,b) and in society (Machin & Pekkarinen 2008, Pope & Sydnor 2010)
  - Competitive environment around math (Niederle & Vesterlund 2010, Joensen & Nielsen 2016, 2018)
  - Math mindset/anxiety (Dweck 2006, Boaler 2015)
  - Mixed-gender composition (Booth & Nolen 2012)
- Demographic teacher-student match (Dee 2004/5/7 and many following):
  - Teachers' behavior (Lim and Meer 2017, 2021)
  - Teachers' beliefs about male and female ability (Sansone 2017)
  - Teachers' gender stereotypes (Carlana 2019)
  - Teacher adaptivity?

Data

- Gross sample
  - Grade 3 in school year 2020/21
  - 5 municipalities/19 schools/56 classes/864 students
- Data sources
  - Student assessment (728 students x 8 tasks)
    - 8 arithmetic tasks designed to elicit shortcut strategies
    - Shortcut: task solved by a shortcut strategy (0/1)
    - Accuracy: task solved correctly (0/1)
  - Teacher survey (21 teachers)
    - elicits belief about strategy choice
    - teacher background
  - Register data (830 students)
    - national test scores spring 2021
    - student background

TriFa Tasks Distribution

Summary statistics

Variable	All	Female	Male	Difference
Background				
Some College Mom	0.536	0.557	0.515	0.042
Some College Dad	0.420	0.427	0.413	0.014
Non-western	0.118	0.100	0.136	-0.036*
Observations	864	431	433	864
Outcome				
Shortcut Strategy	0.103	0.059	0.149	-0.089***
Accuracy	0.505	0.465	0.547	-0.083***
Observations	5,824	2,992	2,832	5,824
Test Score	0.095	-0.010	0.202	-0.213***
	(1.035)	(0.957)	(1.099)	(0.072)
Observations	830	418	412	830

Teacher adaptivity, factor loadings

	Questions	Loadings
1	The students should primarily be presented for one method of calculation	-.652
2	My students have learnt a standard algorithm for addition	-.664
3	My students and I have worked with alternative strategies for addition	.801
4	My students apply several different strategies for addition	.888
5	My students have learnt a standard algorithm for subtraction	-.728
6	My students and I have worked with alternative strategies for subtraction	.833
7	My students apply several different strategies for subtraction	.779
8	It's important that the students learn several different arithmetic strategies	.527
9	I spend much time talking about different arithmetic strategies for a given task	.845

Effects of using a shortcut strategy on accuracy

	Accuracy	Accuracy	Accuracy
Shortcut Strategy	0.316***	0.364***	0.256***
	(0.025)	(0.035)	(0.025)
Observations	5824	5824	5824
Mean Accuracy	0.505	0.505	0.505
Item fixed effects	X		X
Student fixed effects		X	X

Standard errors in parentheses

Clustering level: Class

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Gender gap in use of shortcut strategies

	Shortcut	Shortcut	Shortcut	Shortcut
Female	-0.088***	-0.088***	-0.083***	-0.083***
	(0.016)	(0.017)	(0.015)	(0.016)
Observations	5824	5824	5824	5824
Mean Shortcut	0.103	0.103	0.103	0.103
Item fixed effects	X	X	X	X
Class fixed effects			X	X
Parent controls		X		X

Standard errors in parentheses

Clustering level: Class

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Gender gap in accuracy

	Accuracy	Accuracy	Accuracy
Female	-0.082***	-0.056**	-0.048**
	(0.022)	(0.023)	(0.021)
Shortcut Strategy		0.303***	0.340***
		(0.026)	(0.020)
Observations	5824	5824	5824
Mean Accuracy	0.505	0.505	0.505
Item fixed effects	X	X	X
Class fixed effects			X

Standard errors in parentheses

Clustering level: Class

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Gender gap in test scores

	Test Score	Test Score	Test Score
Female	-0.203***	-0.100	-0.061
	(0.066)	(0.065)	(0.066)
Shortcut (student average)		1.756***	1.957***
		(0.249)	(0.268)
Observations	721	721	721
Mean Test Score	0.097	0.097	0.097
Class fixed effects			X

Standard errors in parentheses

Clustering level: Class

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Full

Correlation between teacher adaptivity and use of shortcut

	Shortcut	Shortcut	Shortcut	Shortcut
Teacher adaptivity	0.043**	0.043**	0.043**	0.035**
	(0.019)	(0.019)	(0.019)	(0.016)
Female		-0.063***	-0.061***	-0.058***
		(0.017)	(0.018)	(0.018)
Observations	3312	3312	3312	3312
Mean Shortcut	0.100	0.100	0.100	0.100
Item fixed effects	X	X	X	X
Parent controls			X	X
Teacher controls				X

Standard errors in parentheses

Clustering level: Class

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Empirical Strategy

- Study effect of teacher adaptivity (TA) on math outcome
- Exploit within-school-cohort-between-class variation in teacher adaptivity
- As an initial step, we estimate the following model:

$$y_{itcs} = \beta_0 + \beta_1 TA_c + \gamma_s + \theta_t + \varepsilon_{itcs}$$

- As a next step, we estimate the extended model:

$$y_{itcs} = \beta_0 + \beta_1 TA_c + \beta_2 Female_i + \beta_3 (Female_i \cdot TA_c) + \gamma_s + \theta_t + \mathbf{X}_i \beta_4 + (Female_i \cdot \mathbf{X}_i) \beta_5 + \mathbf{Z}_c \beta_6 + (Female_i \cdot \mathbf{Z}_c) \beta_7 + \varepsilon_{itcs}$$

Empirical Strategy

(Continued)

- Study effect of teacher adaptivity (TA) on **gender gap** in math outcomes
- Exploit within-class variation in outcomes between males and females
  - like Carlana (2019) who studies the impact of implicit stereotypes
- We estimate the following model:

$$y_{itc} = \alpha_0 + \alpha_1 \left(Female_i \cdot TA_c \right) + \alpha_2 Female_i + \gamma_c + \theta_t + \mathbf{X}_i \alpha_3 + \left(Female_i \cdot \mathbf{X}_i \right) \alpha_4 + \left(Female_i \cdot \mathbf{Z}_c \right) \alpha_5 + \varepsilon_{itc}$$

Empirical Strategy

(Continued)

- Assumptions
  - Students are not systematically assigned to classes where teachers have a certain teacher adaptivity
    - (weaker) Males and females are not systematically differently assigned to classes where ...
  - Teacher adaptivity does not reflect other gender-related behaviors or biases
- Identification checks
  - Analyse sorting and gender differences in sorting
  - Account for teacher gender and other teacher chars

Exogeneity of assignment of students to teachers I

	Female	Some College Mom	Some College Dad	Non-western
Teacher adaptivity	-0.114***	-0.044	0.042	0.047
	(0.032)	(0.042)	(0.047)	(0.103)
Observations	459	459	459	459
Mean of Independent Variable	0.501	0.458	0.397	0.148
School fixed effects	X	X	X	X

Standard errors in parentheses

Clustering level: School

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Exogeneity of assignment of students to teachers II

	Teacher Adaptivity	Teacher Adaptivity	Teacher Adaptivity	Teacher Adaptivity	Teacher Adaptivity
Female	-0.015	-0.152**	-0.002	0.019	-0.073
	(0.073)	(0.068)	(0.075)	(0.087)	(0.094)
Some College Mom		-0.195			-0.080
		(0.168)			(0.135)
Female × Some College Mom		0.300***			0.369**
		(0.102)			(0.158)
Some College Dad			-0.156		-0.038
			(0.160)		(0.120)
Female × Some College Dad			-0.018		-0.210
			(0.101)		(0.150)
Non-western				0.419**	0.373***
				(0.158)	(0.124)
Female × Non-western				0.030	0.093
				(0.144)	(0.147)
Observations	459	459	459	459	459
Mean Teacher Adaptivity	-0.035	-0.035	-0.035	-0.035	-0.035

Standard errors in parentheses

Clustering level: Class

Effects of teacher adaptivity on use of shortcut

	Shortcut	Shortcut	Shortcut	Shortcut	Shortcut	Shortcut
Teacher adaptivity	0.015		0.011	0.022	0.027	0.036
	(0.036)		(0.036)	(0.038)	(0.042)	(0.050)
Female		-0.071***	-0.071***	-0.072***	-0.073***	-0.035
		(0.016)	(0.016)	(0.014)	(0.022)	(0.028)
Female ×				-0.023*	-0.024*	-0.028
Teacher adaptivity				(0.013)	(0.013)	(0.017)
Observations	3312	3312	3312	3312	3312	3312
Mean Shortcut	0.100	0.100	0.100	0.100	0.100	0.100
Item fixed effects	X	X	X	X	X	X
School fixed effects	X	X	X	X	X	X
Parent controls, × Female					X	X
Teacher controls, × Female						X

Standard errors in parentheses

Clustering level: School

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Accuracy Test Scores

Effects of teacher adaptivity on gender gap in use of shortcut

	Shortcut	Shortcut	Shortcut	Shortcut
Female	-0.071***	-0.072***	-0.071***	-0.034
	(0.017)	(0.017)	(0.024)	(0.031)
Female ×		-0.024*	-0.025*	-0.029*
Teacher adaptivity		(0.013)	(0.014)	(0.017)
Observations	3312	3312	3312	3312
Mean Shortcut	0.100	0.100	0.100	0.100
Item fixed effects	X	X	X	X
Class fixed effects	X	X	X	X
Parent controls, × Female			X	X
Teacher controls × Female				X

Standard errors in parentheses

Clustering level: Class

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Effects of teacher adaptivity on gender gap in accuracy

	Accuracy	Accuracy	Accuracy	Accuracy
Female	-0.068**	-0.071**	-0.064	-0.100
	(0.028)	(0.026)	(0.057)	(0.096)
Female ×		-0.043*	-0.055*	-0.065**
Teacher adaptivity		(0.025)	(0.027)	(0.028)
Observations	3312	3312	3312	3312
Mean Accuracy	0.477	0.477	0.477	0.477
Item fixed effects	X	X	X	X
Class fixed effects	X	X	X	X
Parent controls, × Female			X	X
Teacher controls × Female				X

Standard errors in parentheses

Clustering level: Class

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

+Shortcut

Effects of teacher adaptivity on gender gap in test scores

	Test Score	Test Score	Test Score	Test Score
Female	-0.138*	-0.140*	-0.167	-0.250
	(0.075)	(0.075)	(0.158)	(0.222)
Female ×		-0.038	-0.057	-0.113*
Teacher adaptivity		(0.038)	(0.039)	(0.060)
Observations	448	448	448	448
Mean Test Score	-0.053	-0.053	-0.053	-0.053
Class fixed effects	X	X	X	X
Parent controls, × Female			X	X
Teacher controls × Female				X

Standard errors in parentheses

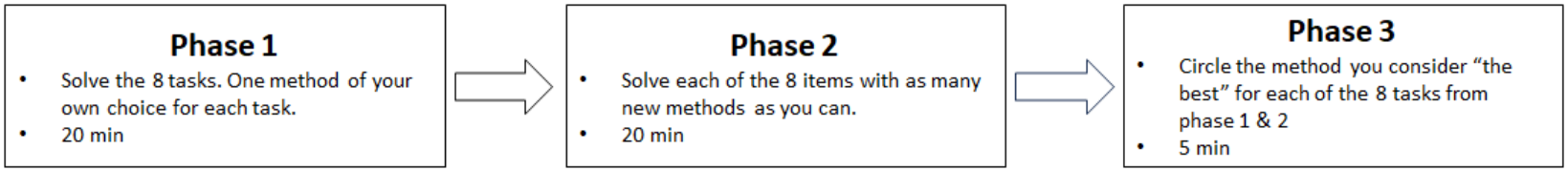
Clustering level: Class

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Conclusion

- The male-female gap in mathematics
  - ... is associated with use of shortcut strategies
  - ... increases with exposure to teachers whose didactic approach favors adaptivity
- Policy consequences
  - We might consider less discriminatory teaching practices/beliefs
  - If higher task-specific adaptivity is really key to deeper number understanding and math-intensive careers, we should figure out:
    - How do we develop the skill in females as well?
    - How is the skill related to other traits that vary by gender?

Tri-phase Flexibility Assessment (TriFA)



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Examples of tasks

	Item Number	Accuracy	Shortcut	Observations
77 + 19	1	0.78	0.18	370
482 + 218	2	0.71	0.16	370
153 + 249	3	0.61	0.14	370
298 + 483	4	0.53	0.10	370
84 - 19	9	0.44	0.12	370
103 - 98	10	0.36	0.12	370
963 - 499	11	0.09	n.a.	170
514 - 486	12	0.15	0.05	170
33 - 14	13	0.43	0.06	200
153 - 99	14	0.34	0.05	200
xxx	xxx	xxx	xxx	xxx
Observations		0.505	0.103	5824

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Association btw. teacher adaptivity and teacher characteristics

	Female Teacher	Male Teacher
Teacher adaptivity	-0.06	0.08
	(1.10)	(0.90)
Observations	12	9
	Age $\leq$ 50	Age $>$ 50
Teacher adaptivity	-0.01	0.01
	(1.12)	(0.79)
Observations	14	7
	Experience $<$ 6 years	Experience $\geq$ 6 years
Teacher adaptivity	0.32	-0.42
	(0.71)	(1.21)
Observations	12	9

Too few observations for math supervisors/specialization

Distribution of Shortcut and Accuracy

	Shortcut		Accuracy	
	Frequency	Fraction	Frequency	Fraction
0	510	70.05	60	8.24
1-2	118	16.21	153	21.02
3-4	62	8.52	210	28.85
+5	38	5.22	305	41.90
Observations	728	728	728	728
Mean	0.82		4.04	

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Gender gap in use of shortcut strategies

	Shortcut	Shortcut	Shortcut	Shortcut
Female	-0.088***	-0.088***	-0.083***	-0.083***
	(0.016)	(0.017)	(0.015)	(0.016)
Observations	5824	5824	5824	5824
Mean Shortcut	0.103	0.103	0.103	0.103
Item fixed effects	X	X	X	X
Class fixed effects			X	X
Parent controls		X		X

Standard errors in parentheses

Clustering level: Class

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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Gender gap in accuracy

	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
Female	-0.082***	-0.076***	-0.056**	-0.060***	-0.048**	-0.049**
	(0.022)	(0.020)	(0.023)	(0.022)	(0.021)	(0.020)
Shortcut Strategy			0.303***	0.290***	0.340***	0.335***
			(0.026)	(0.024)	(0.020)	(0.021)
Observations	5824	5824	5824	5824	5824	5824
Mean Accuracy	0.505	0.505	0.505	0.505	0.505	0.505
Item fixed effects	X	X	X	X	X	X
Class fixed effects		X			X	X
Parent controls				X		X

Standard errors in parentheses

Clustering level: Class

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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Gender gap in test scores

	Test Score	Test Score	Test Score	Test Score	Test Score	Test Score
Female	-0.203***	-0.169**	-0.100	-0.141**	-0.061	-0.070
	(0.066)	(0.068)	(0.065)	(0.063)	(0.066)	(0.068)
Shortcut (student average)			1.756***	1.562***	1.957***	1.863***
			(0.249)	(0.223)	(0.268)	(0.274)
Observations	721	721	721	721	721	721
Mean Test Score	0.097	0.097	0.097	0.097	0.097	0.097
Class fixed effects		X			X	X
Parent controls				X		X

Standard errors in parentheses

Clustering level: Class

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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Effects of teacher adaptivity on accuracy

	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy	Accuracy
Teacher adaptivity	0.005		0.001	0.023	0.032	0.072
	(0.063)		(0.064)	(0.062)	(0.055)	(0.071)
Female		-0.063***	-0.063***	-0.066***	-0.069*	-0.108
		(0.018)	(0.018)	(0.015)	(0.035)	(0.078)
Female ×				-0.047*	-0.057**	-0.067**
Teacher adaptivity				(0.023)	(0.025)	(0.029)
Observations	3312	3312	3312	3312	3312	3312
Mean Accuracy	0.477	0.477	0.477	0.477	0.477	0.477
Item fixed effects	X	X	X	X	X	X
School fixed effects	X	X	X	X	X	X
Parent controls, × Female					X	X
Teacher controls, × Female						X

Standard errors in parentheses

Clustering level: School

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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Effects of teacher adaptivity on test scores

	Test Score	Test Score	Test Score	Test Score	Test Score	Test Score
Teacher adaptivity	0.026		0.012	0.026	0.041	0.311
	(0.333)		(0.339)	(0.344)	(0.269)	(0.256)
Female		-0.115**	-0.114**	-0.116**	-0.149	-0.250
		(0.047)	(0.052)	(0.052)	(0.122)	(0.196)
Female ×				-0.035	-0.050	-0.117**
Teacher adaptivity				(0.022)	(0.033)	(0.050)
Observations	448	448	448	448	448	448
Mean Test Score	-0.053	-0.053	-0.053	-0.053	-0.053	-0.053
School fixed effects	X	X	X	X	X	X
Parent controls, × Female					X	X
Teacher controls, × Female						X

Standard errors in parentheses

Clustering level: School

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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Effects of teacher adaptivity on gender gap in accuracy, accounting for use for shortcut

	Accuracy	Accuracy	Accuracy	Accuracy
Female	-0.056*	-0.060**	-0.050	-0.085
	(0.028)	(0.026)	(0.056)	(0.096)
Female ×		-0.041	-0.052*	-0.059**
Teacher adaptivity		(0.024)	(0.026)	(0.028)
Observations	3312	3312	3312	3312
Mean Accuracy	0.477	0.477	0.477	0.477
Item fixed effects	X	X	X	X
Class fixed effects	X	X	X	X
Shortcut control, × Female	X	X	X	X
Parent controls, × Female			X	X
Teacher controls, × Female				X

Standard errors in parentheses

Clustering level: Class

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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