Exposure To Heat and Student Cognitive Functioning

Yabo Gwladys Vidogbena

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Motivation

- The number of extremely high temperature days has grown over time ▸ Temp
  - Developing countries have less capacity to protect against harm of extreme heat
  - Important to understand how extreme heat affects productivity

- Very little evidence in Africa
  - Effect on physical labor *[LoPalo, 2023]*
  - Effect on agricultural productivity *[Emediegwu, Wossink and Hall, 2022]*

- Little evidence on Young children
  - Might explain learning loss

- I examine productivity in a cognitive activity
  - Students test performance, and surveyors' measure of students attentiveness in Ghana

Research Question

What is the effects of extreme heat on productivity?

- Novel data to analyze this question
  - Rich longitudinal data on children including their performance on math and literacy tests, surveyors' measure of students attentiveness

Literature Review

- Contemporaneous effect of heat exposure on student's performance:
  - *Suzuki, EL 2024* in Japan
  - *Park, JHR 2022* in NYC school district
  - *Li, EL 2021* in Brazil
  - *Zivin, et al., JEEM 2020* in China
  - *Zivin et al., JAERE 2018* using NLSY79

- Effect of accumulated exposure to heat on student's human capital:
  - *[Park, AER 2022]* in the US
  - *[Garg et al., JAERE 2020]* in India
  - *[Zivin et al., JAERE 2018]* using NLSY79

Conceptual Framework: How Does Heat Affect Performance?

- Potential mechanisms of heat exposure on productivity:
  - Changes in brain chemistry and functioning *[Hocking et al., 2001]*
  - Decrease in attention, memory, information retention and processing *[Hyde et al., 1997]*

Data: Temperature

- Data set is from: ERA5 by Copernicus Climate Change Service ▸ Temperature And Heat Stress
  - Estimated hourly temperature (UTCI) data expressed in degrees Celsius
  - Air temperature, humidity, wind speed, and radiant heat
  - Publicly available from January 1940 to near real-time
  - Precision is: $0.25^\circ \times 0.25^\circ$ spatial resolution ($\sim$31 Km)

- Summary Statistics:

	Mean	SD	Min	Max	N
Daily Temperature	27.84	2.13	21.41	32.33	9512.00
Temperature $< 24^\circ C$	0.05	0.21	0.00	1.00	9512.00
$24^\circ C \leq$ Temp $< 27^\circ C$	0.30	0.46	0.00	1.00	9512.00
$27^\circ C \leq$ Temp $< 30^\circ C$	0.47	0.50	0.00	1.00	9512.00
Temperature $\geq 30^\circ C$	0.19	0.39	0.00	1.00	9512.00

Data: Test Performance Measure

I use 3 rounds of a survey of 8 rounds on students in Ghana:

- Literacy and numeracy assessments:
  - International Development and Early Learning Assessment (IDELA)
  - Up to 29 items with sub-questions
    - From 2 to 20 sub-questions
- Surveyor's assessment of student's attentiveness
- Child are aged 2-10 years old at first survey

Today: Outcomes

Today:

- Child's listening score
- Surveyor's assessment of child's attentiveness to listening
- Child's number sense (one-to-one correspondence) score
- Surveyor's assessment of child's attentiveness to number sense
- Overall surveyor's assessment of child's attentiveness

Listening Comprehension & Surveyor Assessment

▸ Listening Question ▸ Cross-Tab Listening & Temperature ▸ Cross-Tab Attentiveness to Listening & Temperature

- Listening score
  - Test to assess listening skills
  - Requires concentration, attention, ability to make logical deductions
  - Score measured as the proportion of correct answers

- Surveyor assessment of child attentiveness to the listening activity
  - Average of three questions measured as dummy variables

	Mean	SD	Min	Max	N
Listening Score	0.56	0.33	0.00	1.00	9512.00
Attentiveness to Listening	0.88	0.27	0.00	1.00	9512.00

Number Sense & Surveyor Assessment

▸ Number Sense Question ▸ Cross-Tab Math & Temperature ▸ Cross-Tab Attentiveness to Math & Temperature

- Number sense (one-to-one correspondence) score
  - Includes matching one object with another one and counting
  - Score measured as the proportion of correct answers

- Surveyor assessment of child attentiveness to the Number sense activity
  - Average of three questions measured as dummy variables

	Mean	SD	Min	Max	N
Number Sense Score	0.71	0.37	0.00	1.00	9512.00
Attentiveness to Number Sense	0.94	0.19	0.00	1.00	9512.00

Surveyor's Overall Assessment of the Child Attentiveness

▸ Overall Assessment Questions

- 7 questions all on a scale of 1-4:
  - Attention to instructions, confidence, concentration on tasks, careful on tasks, pleasure on completing tasks, motivated to complete tasks, interested about the tasks

- Two measures:
  - Average of all 7 questions
  - Average of a dummy version of all 7 questions

	Mean	SD	Min	Max	N
Overall Assessment (1-4)	3.20	0.70	1.00	4.00	9473.00
Overall Assessment (0-1)	0.78	0.32	0.00	1.00	9473.00

Empirical Strategy

Intuition: Compare the same individual taking the test on different days, some hot, some not:

$$y_{i,r(t)} = f(\beta, T_{l(i),t}) + \delta_i + \delta_{r(t)} + \delta_a + \epsilon_{i,r(t)} \quad (1)$$

where:

- $y_{i,r(t)}$ is the outcome of child i interviewed in survey round $r(t)$
- $T_{l(i),t}$ are temperature bins
- l represents location
- δ_i is child FE
- $\delta_{r(t)}$ is a survey-round FE
- δ_a is age FE

Results (1/3)

VARIABLES	(1) Child's Listening Score	(2) Surveyor's Assessment of Attentiveness
Temperature $< 24°C$	-0.0227	-0.0315
	(0.0213)	(0.0193)
$27°C \leq$ Temp $< 30°C$	-0.000503	-0.0207**
	(0.00898)	(0.00933)
Temperature $\geq 30°C$	-0.0160	-0.0149
	(0.0154)	(0.0144)
Child FE	Yes	Yes
Survey Round FE	Yes	Yes
Age FE	Yes	Yes
Mean of Dependent Variable	0.56	0.88
SD of Dependent Variable	0.33	0.27
Observations	7,940	7,940

Robust standard errors clustered at individual level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Results (2/3)

VARIABLES	(1) Child's Number Sense Score	(2) Surveyor's Assessment of Attentiveness
Temperature $< 24^\circ C$	-0.0408**	-0.0253*
	(0.0188)	(0.0141)
$27^\circ C \leq$ Temp $< 30^\circ C$	0.00166	-0.000972
	(0.00885)	(0.00665)
Temperature $\geq 30^\circ C$	-0.00791	0.00140
	(0.0146)	(0.0104)
Child FE	Yes	Yes
Survey Round FE	Yes	Yes
Age FE	Yes	Yes
Mean of Dependent Variable	0.71	0.94
SD of Dependent Variable	0.37	0.19
Observations	7,940	7,940

Robust standard errors clustered at individual level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Results (3/3)

VARIABLES	(1) Overall Surveyor's Attentiveness Assessment (1-4)	(2) Overall Surveyor's Attentiveness Assessment (0-1)
Temperature $< 24^{\circ}C$	-0.0176	-0.0418*
	(0.0417)	(0.0213)
$27^{\circ}C \leq$ Temp $< 30^{\circ}C$	-0.0968***	-0.0390***
	(0.0217)	(0.0104)
Temperature $\geq 30^{\circ}C$	-0.0716**	-0.0370**
	(0.0351)	(0.0168)
Child FE	Yes	Yes
Survey Round FE	Yes	Yes
Age FE	Yes	Yes
Mean of Dependent Variable	3.20	0.78
SD of Dependent Variable	0.70	0.32
Observations	7,900	7,900

Robust standard errors clustered at individual level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Heterogeneity by SES Status (1/2)

- Effect may vary by SES status
- Children in high SES households may have developed mechanisms for functioning with heat
- Use home construction material as an indicator of SES ▸ Construction Material Category

Heterogeneity by SES Status (2/2)

VARIABLES	(1) Overall Surveyor's Attentiveness Assessment (1-4)	(2) Overall Surveyor's Attentiveness Assessment (0-1)
Temperature $< 24^{\circ}C$	-0.0167	-0.0418*
	(0.0467)	(0.0237)
$27^{\circ}C \leq$ Temp $< 30^{\circ}C$	-0.0857***	-0.0346***
	(0.0242)	(0.0114)
Temperature $\geq 30^{\circ}C$	-0.0869**	-0.0473***
	(0.0381)	(0.0182)
Temperature $< 24^{\circ}C \times$ Poor	0.000873	-0.0171
	(0.132)	(0.0717)
$27^{\circ}C \leq$ Temp $< 30^{\circ}C \times$ Poor	-0.0904*	-0.0398
	(0.0525)	(0.0267)
Temperature $\geq 30^{\circ}C \times$ Poor	0.0157	0.0117
	(0.0603)	(0.0283)
Child, Survey Round, Age FE	Yes	Yes
Observations	7,139	7,139

Robust standard errors clustered at individual level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Summary & Next Steps

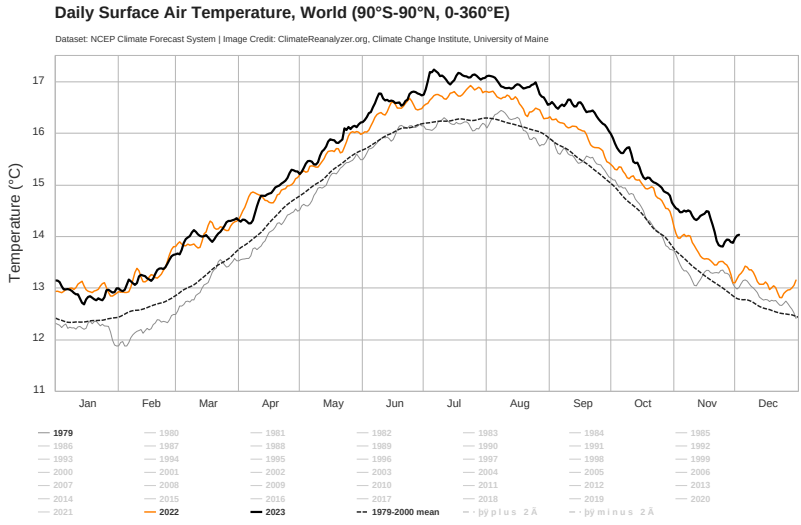
- Summary:
  - No evidence that listening score and number sense score are changing under heat
  - Evidence of a decrease in attentiveness when it gets hotter
  - Poorer are more affected when it is getting hotter but difference disappear when it gets really hot

- Next Steps:
  - Use all available 8 rounds, instead of 3, focusing on the overall surveyor's assessment of the child

Any Questions?

Temperature

▸ Motivation



Temperature And Heat Stress

▸ Extreme Heat

- Temperatures are associated with heat stress in the following way:
  - Moderate heat stress: 26°C to 32°C
  - Strong heat stress: 32°C to 38°C
  - Very strong heat stress: 38°C to 46°C
  - Extreme heat stress: above 46°C

Listening Question

Listening

The Mouse and the Cat

Once upon a time, there was a fat cat. He always wore a red hat. Once when he was sleeping, a small mouse came silently and stole the hat. The cat woke up to see his hat gone, he got very angry and started chasing the mouse. After a while, the mouse was trapped under a table and could not find any way to escape. So, the mouse said to the cat, "Please don't eat me, cat. If you let me live I will return your hat." After getting back his hat the cat said, "Please don't touch my hat again" and he went back to sleep in a happy mood.

Now I am going to ask you some questions about the story.

SCORING					
	Scoring categories	*Scoring options*			
Item No.	Comprehension	Correct (1)	Incorrect (0)	No response (-99)	Doesn't know (-88)
2401.	**"Who stole the cat's hat?"** (the mouse)	[ ]	[ ]	[ ]	[ ]
2402.	**"What is the color of the hat?"** (red)	[ ]	[ ]	[ ]	[ ]
2403.	**"Why did the cat chase the mouse?"** (because the mouse took/stole its hat)	[ ]	[ ]	[ ]	[ ]
2404.	**"Where did the mouse get trapped ?"** (under the table)	[ ]	[ ]	[ ]	[ ]
2405.	**"Why did the cat decide not to eat the mouse?"** (because the mouse gave back the hat)	[ ]	[ ]	[ ]	[ ]
	Persistence /Engagement	Yes (1)		No (0)	
2406.	Child stays concentrated on the task at hand; not easily distracted.	[ ]		[ ]	
2407.	Child is diligent/careful in their approach to the task.	[ ]		[ ]	
2408.	Child is motivated to complete task; does not want to stop the task.	[ ]		[ ]	

Cross-Tabulation: Listening and Temperature Bins

▸ Listening

Temperature Bin	Listening Score						
	0	.2	.4	.6	.8	1	Total
21-	92	59	46	66	111	62	436
24-	479	381	420	527	553	457	2,817
27-	619	570	683	858	998	771	4,499
30-	106	145	230	344	552	383	1,760
Total	1,296	1,155	1,379	1,795	2,214	1,673	9,512

Cross-Tabulation: Listening and Temperature Bins

▸ Listening

Temperature Bin	Attentiveness to Listening 0	.3333333	.6666667	1	Total
21-	29	33	46	328	436
24-	150	216	270	2,181	2,817
27-	243	305	444	3,507	4,499
30-	20	49	135	1,556	1,760
Total	442	603	895	7,572	9,512

Number Sense Question

Number Sense

SCORING					
	Scoring categories	*Scoring options*			
Item No.		Correct (1)	Incorrect (0)	No response (-99)	Doesn't know (-88)
	One to One correspondence				
601.	Child identifies 3 items	[ ]	[ ]	[ ]	[ ]
602.	Child identifies 8 items	[ ]	[ ]	[ ]	[ ]
603.	Child identifies 15 items	[ ]	[ ]	[ ]	[ ]
	Persistence / Engagement	Yes (1)		No (0)	
604.	Child stays concentrated on the task at hand; not easily distracted	[ ]		[ ]	
605.	Child diligent/careful in their approach to the task	[ ]		[ ]	
606.	Child is motivated to complete task; does not want to stop the task.	[ ]		[ ]	

Cross-Tabulation: Number Sense and Temperature Bins

▸ Number Sense

Temperature Bin	Number Sense (One-to-one Correspondence) Score				Total
	0	.3333333	.6666667	1	
21-	84	79	76	197	436
24-	530	426	576	1,285	2,817
27-	738	526	865	2,370	4,499
30-	78	106	287	1,289	1,760
Total	1,430	1,137	1,804	5,141	9,512

Cross-Tabulation: Number Sense and Temperature Bins

▸ Number Sense

Temperature Bin	Attentiveness to Number Sense				
	0	.3333333	.6666667	1	Total
21-	20	11	33	372	436
24-	75	99	198	2,445	2,817
27-	66	145	327	3,961	4,499
30-	6	21	59	1,674	1,760
Total	167	276	617	8,452	9,512

Overall Surveyor Assessment

▸ Overall Assessment

SCORING					
Item No.		*Almost never (1)*	*Sometimes (2)*	*Often (3)*	*Almost always (4)*
2901.	Did the child pay attention to the instructions and demonstrations throughout the assessment?	[ ]	[ ]	[ ]	[ ]
2902.	Did child show confidence when completing activities; did not show hesitation.	[ ]	[ ]	[ ]	[ ]
2903.	Did the child stay concentrated and on task during the activities and was not easily distracted?	[ ]	[ ]	[ ]	[ ]
2904.	Was child careful and diligent on tasks? Was child interested in accuracy?	[ ]	[ ]	[ ]	[ ]
2905.	Did child show pleasure in accomplishing specific tasks?	[ ]	[ ]	[ ]	[ ]
2906.	Was child motivated to complete tasks? Did not give up quickly and did not want to stop the task?	[ ]	[ ]	[ ]	[ ]
2907.	Was the child interested and curious about the tasks throughout the assessment?	[ ]	[ ]	[ ]	[ ]

Construction Material Question

▸ Heterogeneity

D04.	What is the main construction material used for the outer walls of your current dwelling?	1. [ ] Mud bricks/earth, wood, bamboo, metal sheet/slate/asbestos, palm leaves/thatch (grass/raffia etc.) 2. [ ] Cement/concrete blocks, landcrete, stone, or burnt bricks

DiD: Survey Round 1 & 2

▸ Results

Table: Difference-in-Differences: Survey-Round 1 & 2

VARIABLES	(1) DiD	(2) (1) & Sample with Age	(3) (1) + Age	(4) Ind FE	(5) (4) & Sample with Age	(6) (4) & Age
Treatment × After	-0.280	-0.248	-0.217	-0.280*	-0.256*	-0.241*
	(0.180)	(0.183)	(0.177)	(0.144)	(0.146)	(0.146)
Treatment	0.216*	0.178	0.166			
	(0.128)	(0.131)	(0.126)			
After	0.854***	0.836***	0.615***	0.854***	0.827***	0.722***
	(0.0449)	(0.0474)	(0.0473)	(0.0357)	(0.0378)	(0.0629)
Age			0.320***			0.157**
			(0.0168)			(0.0750)
Constant	2.091***	2.102***	0.454***	2.104***	2.118***	1.308***
	(0.0317)	(0.0340)	(0.0923)	(0.0245)	(0.0260)	(0.387)
Observations	5,692	5,114	5,114	5,692	5,114	5,114
R-squared	0.062	0.059	0.122	0.702	0.716	0.716

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

DiD: Survey Round 2 & 3

▸ Results

Table: Difference-in-Differences: Survey-Round 2 & 3

VARIABLES	(1) DiD	(2) (1) & Sample with Age	(3) (1) + Age	(4) Ind FE	(5) (4) & Sample with Age	(6) (4) & Age
Treatment × After	0.0236	0.00186	0.00683	0.0236	0.0275	0.0292
	(0.0816)	(0.0904)	(0.0884)	(0.0629)	(0.0717)	(0.0717)
Treatment	-0.115**	-0.123**	-0.0917			
	(0.0577)	(0.0618)	(0.0604)			
After	0.412***	0.455***	0.299***	0.412***	0.432***	0.344***
	(0.0573)	(0.0647)	(0.0641)	(0.0441)	(0.0515)	(0.0653)
Age			0.239***			0.135**
			(0.0164)			(0.0616)
Constant	2.994***	2.983***	1.581***	2.938***	2.924***	2.145***
	(0.0405)	(0.0440)	(0.105)	(0.0222)	(0.0241)	(0.358)
Observations	5,440	4,500	4,500	5,440	4,500	4,500
R-squared	0.021	0.024	0.068	0.709	0.731	0.732

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1