

Exposure To Heat and Student Cognitive Functioning

Yabo Gwladys Vidogbena
University of Houston

Sharon Wolf
University of Pennsylvania

KIEL-CEPR AEDC

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Table of Contents

Motivation & Research Question

Empirical Strategy

Data

Results

Summary

Motivation

- The number of high temperature days has grown over time ▶ Temp
 - Developing countries have less capacity to protect against harm of heat
- Despite increasing school enrollment, learning poverty remains high (*Evans, and Acosta, Journal of African Economies 2021*)
 - While 80% of primary school aged students are enrolled, less than 30% achieve the minimum proficiency level in reading (*Spotlight on basic education completion and foundational learning in Africa: born to learn, UNESCO 2022*)
 - Evidence of limited numeracy skills (*Bold et al., 2017; Adeniran et al., 2020*)
- What are the implications of more hot days on learning in developing country classrooms?

Research Question

What is the effect of heat on cognitive functioning?

- We study children in the southern region of Ghana
- Effect on child executive function behavior (*Araujo et al. 2016; Moffitt et al. 2011*)
- Effect on child test score

We use a novel data to analyze this question

- Longitudinal data on children allow using child fixed effects strategy
- Executive function behavior data made possible thanks to one-on-one testing

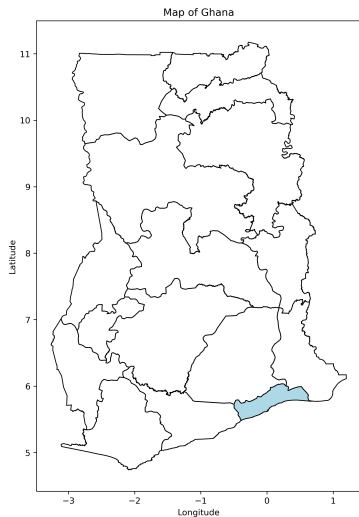
Related Literature

- Contemporaneous effect of heat exposure on student's test scores:
 - Zivin, Hsiang, and Neidell, *JAERE* 2018 using NLSY79
 - Zivin, Song, Tang, and Zhang, *JEEM* 2020 in China
 - Li, *Economics Letters* 2021 in Brazil
 - Park, *Journal of Human Resources* 2020 in NYC school district
- Effect of accumulated exposure to heat during childhood on student's human capital:
 - Zivin, Hsiang, and Neidell, *JAERE* 2018 using NLSY79
 - Garg, Jagtani, and Taraz, *JAERE* 2020 in India
- Our contribution
 - We look at executive function behavior which has not been done before
 - We examine African setting and younger children

Conceptual Framework: How Does Heat Affect Performance?

- Potential mechanisms of heat exposure on performance
 - Changes in brain chemistry and functioning (*Hocking et al. 2001*)
 - Decrease in attention, memory, information retention and processing (*Hyde et al. 1997*)
- Implications for students
 - Children might have worse executive function behavior
 - Children might get lower score on test or needs to exert higher effort to attain same score
- Effect could differ by socio-economic status (SES) and age group
 - Wealth might be protective because it offers better health and more cognitive activities practices
 - Young children could respond differently because their brains are at an early development stage

Background: Ghana



- Ghana is a western African country
- Tropical climate, with rising temperature over time [▶ Historical Temperature: West Africa](#)
- Concerns about low learning, educational inequality (*Spotlight on basic education completion and foundational learning: Ghana, UNESCO 2022*)
- We use data collected in the Greater Accra Region in Southern Ghana (*Wolf et al., 2018*)

Empirical Strategy

Intuition: Compare the same individual taking the test on different days, some days hotter than others:

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

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
- α_i is child FE
- $\delta_{r(t)}$ is a survey-round FE
- δ_a is age FE

Data: Children

Longitudinal data on children from *Wolf et al., (2018)* in the southern region of Ghana:

- Data from first 3 survey rounds:
 - Children are administered International Development and Early Learning Assessment (IDELA)
 - Test is administered one-on-one
 - 29 sections; each with 2 to 20 questions for the child
 - Information collected on children, families, schools, teachers
- In addition to question the child answers, assessor answers questions about child behavior
 - At end of survey, and at intermediate points

Overall Child Executive Function Behavior Rating by Assessor

SCORING					
<i>Item No.</i>		<i>Almost never (1)</i>	<i>Sometimes (2)</i>	<i>Often (3)</i>	<i>Almost always (4)</i>
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?	[]	[]	[]	[]

Overall Child Executive Function Behavior Rating by Assessor

- 7 questions, each on a scale of 1(Almost Never)- 4(Almost Always) [▶ Overall Assessment Questions](#)
- Assessors are educated and trained
- Main measures:
 - Average of all 7 questions
 - Average of dummy versions of all 7 questions

	Mean	SD	N
Overall Child EF Rating	3.21	0.70	8173
Dummy if Child Overall EF Rating is 2, 3, or 4	0.98	0.11	8173
Dummy if Overall Child EF Rating is 4	0.45	0.42	8173

Test Scores

- Math test score:
 - Fraction correct of answers to the math section
- Literacy test score:
 - Fraction correct of answers to the literacy section

	Mean	SD	N
Math Score	0.60	0.26	8173
Literacy Score	0.56	0.24	8173

Data: Universal Thermal Climate Index (UTCI)

- Data set is from Copernicus/Climate Change Service website
 - Accounts for air temperature, humidity, wind speed, radiant heat [▶ Temperature And Heat Stress](#)
 - Estimated hourly temperature (UTCI) data expressed in degrees Celsius
 - Publicly available from January 1940 to near real-time
 - Precision is: $0.25^{\circ} \times 0.25^{\circ}$ spatial resolution (~ 31 Km)
- We merge child data to UTCI data using school location and date of exam
 - We compute the daytime average temperature (8am-5pm)

Temperature Distribution by Survey Round

	Pooled	Survey Round 1 (May, Jun, Jul 2016)	Survey Round 2 (Feb, March 2017)	Survey Round 3 (Sep, Oct 2015)
Temperature $< 27^{\circ}C$	0.09	0.07	0.19	0.00
$27^{\circ}C \leq \text{Temp} < 30^{\circ}C$	0.23	0.32	0.28	0.07
$30^{\circ}C \leq \text{Temp} < 33^{\circ}C$	0.36	0.33	0.37	0.36
$33^{\circ}C \leq \text{Temp} < 36^{\circ}C$	0.28	0.27	0.16	0.43
Temperature $\geq 36^{\circ}C$	0.05	0.00	0.00	0.15

Impact of Heat on Overall Child Executive Function Behavior Rating

	Overall Child EF Rating
Omitted Bin: $< 27^{\circ}\text{C}$	
$27^{\circ}\text{C} \leq \text{Temp} < 30^{\circ}\text{C}$	-0.054* (0.031)
$30^{\circ}\text{C} \leq \text{Temp} < 33^{\circ}\text{C}$	-0.109*** (0.033)
$33^{\circ}\text{C} \leq \text{Temp} < 36^{\circ}\text{C}$	-0.182*** (0.042)
Temperature $\geq 36^{\circ}\text{C}$	-0.127** (0.057)
Child, Survey Round, Age FE	Y
Mean of Dependent Variable	3.21
SD of Dependent Variable	0.70
Observations	8173

→ Higher temperature decreases executive function behavior

► Overall Assessment Questions

Impact of Heat on Different Margins of Child Executive Function Behavior

	(1) Child EF Rating ≥ 2	(2) Child EF Rating = 4
Omitted Bin: $< 27^{\circ}C$		
$27^{\circ}C \leq \text{Temp} < 30^{\circ}C$	0.002 (0.005)	-0.059*** (0.019)
$30^{\circ}C \leq \text{Temp} < 33^{\circ}C$	-0.011** (0.005)	-0.077*** (0.020)
$33^{\circ}C \leq \text{Temp} < 36^{\circ}C$	-0.016** (0.007)	-0.107*** (0.026)
Temperature $\geq 36^{\circ}C$	0.007 (0.010)	-0.106*** (0.034)
Child, Survey-Round, Age FE	Y	Y
Mean of Dependent Variable	0.98	0.45
SD of Dependent Variable	0.11	0.42
Observations	8173	8173

Impact on Test Scores

	(1) Math Score (% Correct)	(2) Literacy Score (% Correct)
Omitted Bin: $< 27^{\circ}C$		
$27^{\circ}C \leq \text{Temp} < 30^{\circ}C$	-0.002 (0.005)	-0.007 (0.006)
$30^{\circ}C \leq \text{Temp} < 33^{\circ}C$	-0.003 (0.005)	-0.005 (0.007)
$33^{\circ}C \leq \text{Temp} < 36^{\circ}C$	-0.000 (0.007)	-0.005 (0.008)
Temperature $\geq 36^{\circ}C$	-0.003 (0.010)	-0.011 (0.011)
Child, Survey-Round, Age FE	Y	Y
Mean of Dependent Variable	0.60	0.56
SD of Dependent Variable	0.26	0.24
Observations	8173	8173

Heterogeneity by SES Status and by Age Group

- Heterogeneity by SES Status: [▶ Variable for Poverty](#) [▶ Heterogeneity by SES](#)
 - Overall, under heat rich children perform better than poor children
- Heterogeneity by age group: [▶ Heterogeneity by Age Group](#)
 - We find no difference between young (children younger than 6 years old) and old children in heat impact

Summary

- We found evidence that hotter temperatures decrease in EF behavior
 - Potential implications for learning in the classrooms on a regular school day
- We found no evidence that heat decreases test scores
 - Would like to investigate the role of students or assessor effort
- We find a significant difference between the poor and the rich in impact of heat
- We find no significant difference between older and younger kids in impact of heat

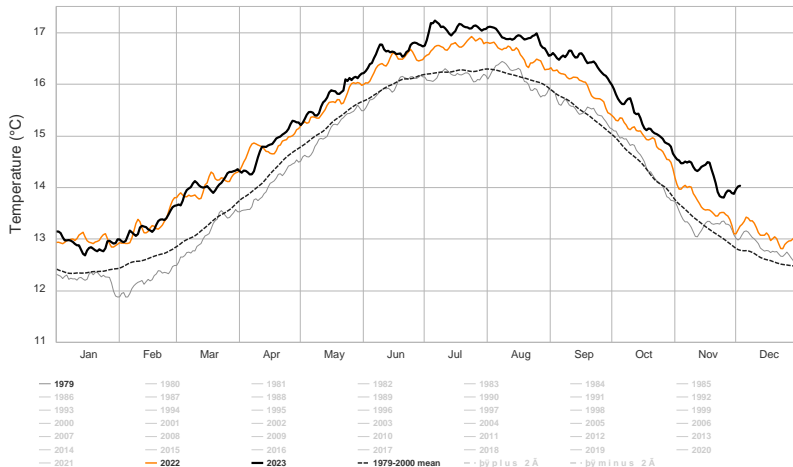
Thanks for your attention.

Temperature

► Motivation

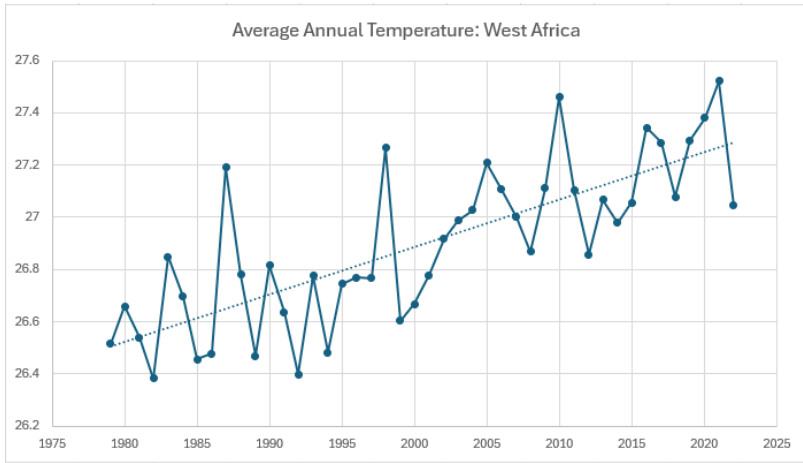
Daily Surface Air Temperature, World (90°S-90°N, 0-360°E)

Dataset: NCEP Climate Forecast System | Image Credit: ClimateReanalyzer.org, Climate Change Institute, University of Maine



Temperature

► Background: Ghana



Overall Surveyor Assessment

► Overall Assessment

► Main Result

SCORING					
<i>Item No.</i>		<i>Almost never (1)</i>	<i>Sometimes (2)</i>	<i>Often (3)</i>	<i>Almost always (4)</i>
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?	[]	[]	[]	[]

Listening Question

► Assessment Outcome

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					
Item No.	<i>Scoring categories</i>	<i>Scoring options</i>			
	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.	[]		[]	

Number Sense Question

► Assessment Outcome

SCORING					
	<i>Scoring categories</i>	<i>Scoring options</i>			
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.	[]		[]	

Intermediate Measures of Executive Function Behavior

SCORING					
	<i>Scoring categories</i>	<i>Scoring options</i>			
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.	[]		[]	

Intermediate Measures of Executive Function Behavior

- At two intermediate points during assessment, assessor rates child behavior
 - We use assessments after section 6 (number sense) and section 24 (oral comprehension)
 - ▶ [Assessment Questions for Number Sense](#)
 - ▶ [Assessment Questions for Listening](#)
- Measures:
 - Average of all 3 questions

	Mean	SD	N
Child EF Behavior For Number Sense	0.95	0.17	8173
Child EF Behavior For Listening	0.89	0.26	8173

UTCI And Heat Stress

► Extreme Heat

- UTCI 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

Impact on Earlier and Later Sections of Exam

► Results on other Outcomes

	(1) Child EF Dummy Number Sense (Earlier)	(2) Child EF Dummy Listening Comprehension (Later)
Omitted Bin: $< 27^{\circ}C$		
$27^{\circ}C \leq \text{Temp} < 30^{\circ}C$	-0.041 (0.026)	-0.010 (0.013)
$30^{\circ}C \leq \text{Temp} < 33^{\circ}C$	-0.035 (0.027)	-0.025* (0.014)
$33^{\circ}C \leq \text{Temp} < 36^{\circ}C$	-0.036 (0.035)	-0.057*** (0.018)
Temperature $\geq 36^{\circ}C$	-0.016 (0.046)	-0.007 (0.023)
Child, Survey-Round, Age FE	Y	Y
Mean of Dependent Variable	0.95	0.89
SD of Dependent Variable	0.17	0.26
Observations	8173	8173

Heterogeneity by SES Status

Heterogeneity

	(1) Overall Child EF Rating	(2) Child EF Rating ≥ 2	(3) Child EF Rating ≥ 3	(4) Child EF Rating = 4
Omitted Bin: $< 27^{\circ}\text{C}$				
$27^{\circ}\text{C} \leq \text{Temp} < 30^{\circ}\text{C}$	-0.085** (0.043)	-0.002 (0.006)	-0.035 (0.022)	-0.048* (0.027)
$30^{\circ}\text{C} \leq \text{Temp} < 33^{\circ}\text{C}$	-0.177*** (0.044)	-0.013** (0.006)	-0.070*** (0.023)	-0.095*** (0.028)
$33^{\circ}\text{C} \leq \text{Temp} < 36^{\circ}\text{C}$	-0.244*** (0.058)	-0.022*** (0.008)	-0.114*** (0.029)	-0.107*** (0.036)
Temperature $\geq 36^{\circ}\text{C}$	-0.267*** (0.080)	0.014 (0.012)	-0.129*** (0.041)	-0.152*** (0.047)
$27^{\circ}\text{C} \leq \text{Temp} < 30^{\circ}\text{C} \times \text{Poor}=0$	0.060 (0.063)	0.007 (0.009)	0.078** (0.031)	-0.026 (0.040)
$30^{\circ}\text{C} \leq \text{Temp} < 33^{\circ}\text{C} \times \text{Poor}=0$	0.123** (0.061)	0.004 (0.009)	0.093*** (0.030)	0.027 (0.038)
$33^{\circ}\text{C} \leq \text{Temp} < 36^{\circ}\text{C} \times \text{Poor}=0$	0.101 (0.070)	0.010 (0.010)	0.095*** (0.034)	-0.004 (0.045)
Temperature $\geq 36^{\circ}\text{C} \times \text{Poor}=0$	0.231** (0.094)	-0.014 (0.015)	0.169*** (0.046)	0.076 (0.057)
Child, Survey Round, Age FE	Yes	Yes	Yes	Yes
Mean of Dependent Variable: Poor	3.13	0.97	0.75	0.41
Mean of Dependent Variable: Rich	3.29	0.98	0.81	0.50
Observations	7419	7419	7419	7419

Heterogeneity by Age Group

Heterogeneity

	(1) Overall Child EF Rating	(2) Child EF Rating ≥ 2	(3) Child EF Rating ≥ 3	(4) Child EF Rating = 4
Omitted Bin: $< 27^{\circ}C$				
$27^{\circ}C \leq \text{Temp} < 30^{\circ}C$	-0.016 (0.047)	0.004 (0.009)	0.030 (0.024)	-0.050* (0.028)
$30^{\circ}C \leq \text{Temp} < 33^{\circ}C$	-0.116** (0.048)	-0.014 (0.010)	-0.024 (0.024)	-0.078*** (0.028)
$33^{\circ}C \leq \text{Temp} < 36^{\circ}C$	-0.225*** (0.055)	-0.024** (0.010)	-0.063** (0.027)	-0.139*** (0.033)
Temperature $\geq 36^{\circ}C$	-0.079 (0.097)	0.023 (0.018)	-0.017 (0.049)	-0.085 (0.054)
$27^{\circ}C \leq \text{Temp} < 30^{\circ}C \times \text{Young (Age} < 6) = 0$	-0.072 (0.061)	-0.004 (0.010)	-0.053* (0.030)	-0.015 (0.038)
$30^{\circ}C \leq \text{Temp} < 33^{\circ}C \times \text{Young (Age} < 6) = 0$	0.030 (0.061)	0.009 (0.011)	0.007 (0.030)	0.015 (0.037)
$33^{\circ}C \leq \text{Temp} < 36^{\circ}C \times \text{Young (Age} < 6) = 0$	0.097 (0.065)	0.018* (0.010)	0.006 (0.032)	0.073* (0.040)
Temperature $\geq 36^{\circ}C \times \text{Young (Age} < 6) = 0$	-0.037 (0.108)	-0.015 (0.019)	-0.018 (0.054)	-0.004 (0.061)
Child, Survey Round, Age FE	Yes	Yes	Yes	Yes
Mean of Dependent Variable: Young	3.08	0.96	0.73	0.39
Mean of Dependent Variable: Old	3.32	0.99	0.83	0.50
Observations	8173	8173	8173	8173

Toilet Type Question

► Heterogeneity

D05.	What type of toilet facility does the household usually use?	<div>1. <input type="checkbox"/> No toilet facility (bush, beach)</div> <div>2. <input type="checkbox"/> Pit latrine, bucket/pan</div> <div>3. <input type="checkbox"/> Public toilet (e.g., WC, KVIP, pit pan)</div> <div>4. <input type="checkbox"/> Private toilet (KVIP, or WC)</div>	
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