Exposure To Heat and Student Cognitive Functioning

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Abstract

The number of extremely high temperature days has grown over time. Developing countries have less capacity to protect against the harm of extreme heat. It is important to understand how extreme heat affects productivity. There is a growing literature on the effects of extreme heat on productivity but very little empirical evidence in Africa. We contribute to this literature by examining the effect of extreme heat on children's test performance in Ghana. Test performance reflects skill and effort. Heat may affect test performance through changes in brain chemistry and functioning which results in decrease in attention, memory, information retention and processing. Using rich longitudinal data on children, including their attentiveness and performance on math and literacy tests, I estimate child fixed-effects models to obtain the effect of temperature on day of test on cognitive functioning. Including child fixed effects enables me to control for time-invariant characteristics of the child such as raw ability or parental attributes, enabling me to isolate the effect of temperature on the day of test. The results using data from southern Ghana suggest that exposure to high $(27-29°\mathrm{C})$ and very high temperatures (30° C or greater), relative to moderate temperatures in the $24-26°$ C range) significantly reduces attentiveness while weakly reducing listening and literacy scores. We find that the test performance of children from poor households is especially sensitive to exposure to extreme heat. That children are less attentive and score less under hot testing conditions has implications for how climate change will affect learning in classrooms.

JEL: Q54, I20, I21, I24, I25
Keywords: UTCI, Temperature, Student's Functioning, Student's Attentiveness

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1 Introduction

The number of extremely high temperature days has grown over time and developing countries suffer the most from it because they have less capacity to protect themselves against the harm of extreme heat. On one side, countries that are the hottest are also the poorest. On the other side, poor countries experience a learning crisis whereas by age 10, over half of the population in middle- and low-income countries cannot read or count (*(PDF) The Many Faces of the Learning Crisis* () *Quality* ()). The literature cites socio-economic background, teacher motivation and perception of efforts, school management, and also children's non readiness to school as determinants or drivers of low learning outcomes. One potential driver is extreme heat. Hot temperatures is proven to decrease children's productivity in the short run in developed countries. The setting of little to no adaptation strategies to extreme heat is also studied in countries such as China and India (Graff Zivin et al. (2020), Garg, Jagnani, and Taraz (2020)). However, all those studies focus the most on adults and how loss of productivity from heat could affect their long-term outcomes. Not much is known about how heat affect children productivity in a developing countries. Studies in the context of developed countries also show that there is no long run effect of heat on student outcomes. It could be the case because of post-strategies set up to counter the effect of heat on learning (Graff Zivin, Hsiang, and Neidell 2018). Those post strategies, however are costly and cannot be afforded by developing countries.

From studies in developing countries, we know much more about how students perform under high stakes exams. High stakes exams might require additional efforts from the students, which implies that the results might be an under-estimation of how heat affect the productivity of adults. In our context there is no stake and the assessments are irrelevant for the future of the interviewed children. Yet, the assessments are time consuming and cognitively demanding. Also, there is very little evidence in the context of African countries. We know more about the effect of heat on physical or labor productivity and agricultural productivity. LoPalo (2023) estimated the effects of temperature on physical labor, using DHS data and Emediegwu, Wossink, and Hall (2022) estimated how agricultural productivity is affected by high temperatures. While the importance of knowing about workers and agricultural productivity is not disputable, the importance of children's productivity in learning is more subtle but also as important. In this paper, we examine productivity in a cognitive activity using children's test performance and surveyor's assessment of students attentiveness in Ghana. The

dataset is a longitudinal data on children.

We linked temperature and panel survey data for children aged 3.5 to 6 years old in 2015. We link temperature data to an early childhood survey with similar survey instruments measuring cognitive and non-cognitive development outcomes for children—Quality Preschool for Ghana (QP4G). In particular, QP4G has a panel with 8 waves over 8 years. QP4G is a school based intervention aiming at improving children's school readiness in the Greater Accra region in Ghana. Children were 3-6 (in reality 2-10 years old), enrolled in pre-kindergarten at baseline in 2015 and were followed until 2022. Outcomes on literacy and math were regularly measured, as well as socio-emotional outcomes. For the first three years, the International Development and Early Learning Assessment (IDELA hereafter) was used to evaluate the children. For the last 5 data collections, various assessments were used including the Early Grade Reading Assessment (EGRA) and the International Social and Emotional Learning Assessment (ISELA). Each interviewer is trained to administer those tests and had to observe the students attentively in order to make a report at the end about their attentiveness, their dedication to the different tasks, whether they were focused or distracted and many other characteristics.

We identify the effects of temperature on child performance on survey instruments by exploiting variations within an individual. This is possible because of the longitudinal nature of the dataset. This methodology is rare in the literature.

Using data from all three survey-rounds jointly, on one side, preliminary findings show that, relative to the the estimates of literacy and math score, though negative, are not precise estimates. On the other side, attentiveness to the listening exercise is affected by hot temperature. Children's attentiveness to math exercise is affected by the cold bin relatively to the "comfortable" temperature bin (24°C and 26°C). When considering the attentiveness score on a scale of 1-4, the effects is U-shaped and shows that attention decreases by respectively 0.14 and 0.1 standard deviation as it gets hotter.

The rest of this paper is organized as follows. Section 2 describes data and construction of key measures. Section 3 presents summary statistics. Section 4 describes the estimation strategy. Section 5 presents and interprets the main results. Section 6 concludes. Tables and figures that are referenced with a prefix of a capital letter are in the online Appendix.

2 Data

To estimate the effects of exposure to heat on children functioning, we take advantage of a longitudinal data spanning eight (08) years in Ghana following a study called "Quality for Pre-school for Ghana" (hence, QP4G). We link QP4G to the fifth generation of the European Centre for Medium-Range Weather Forecasts (ECMWF) atmospheric reanalyses of the global climate, the ERA5-HEAT dataset. We particularly use the Universal Thermal Climate Index (hence, UTCI) to represent temperature.

2.1 UTCI Data

In our analysis, temperature is The Universal Thermal Climate Index. The UTCI is an index that combines air temperature, humidity, wind speed, and radiant heat and is a proxy of temperature felt by the body. The ERA5-HEAT dataset offers estimated hourly UTCI data expressed in degrees Celsius. The data is publicly available from January 1940 to near real-time. The precision is: $0.25° \times 0.25°$ spatial resolution (~31 Km). The UTCI is linked to three (03) waves of QP4G using on one side the longitude and latitude of each survey locations, and on the other side the date and time of the survey.

There are different thresholds that define different level of heat stress. From 26°C to 32°C the human body experience moderate heat stress. From 32°C to 38°C the human body experiences strong heat stress. From 38°C to 46°C the human body experiences very strong heat stress. UTCI above 46°C causes the human body to experience extreme heat stress. These thresholds do not account for acclimatization and do not say anything about acclimatization. Ghana is a tropical country and unlike northern countries, Ghana is in average hotter over the year. This raises the question of acclimatization and how this could change the UTCI heat stress thresholds for that side of the world.

2.2 QP4G Data

The data on children's outcomes and characteristics is from the QP4G intervention by Wolf et al. (2019). The intervention aims at improving classroom quality and develop of Ghanaian children's school readiness. The intervention was done in the Greater Accra region, in the southern part of Ghana. The intervention is school-based and included children aged 3.5 to 6.5 years old in the first year. The children were followed for 8 years, from 2015 to 2022. At

baseline, 3435 children were included in the study. There is attrition overtime of about 9% from the first survey year.

For the first three survey rounds, the surveys were done in school and include tests administered to kindergarten children. Fifteen (15) children were randomly selected in kindergarten class rosters and were individually surveyed. The date of the surveys are decided in advance given that it is a contract between the surveyors and the evaluator team. Therefore there is no selection of date by students.

To assess or measure children readiness, the International Development and Early Learning Assessment (IDELA) was used for the first three survey rounds. IDELA is a set of items, where each item test a different skill which could be cognitive or non cognitive. For example, the children reading comprehension and vocabulary skills were tested, as well as their ability to add, subtract, multiply and divide. Non cognitive tests include personal awareness. One specificity about the dataset is that there are surveyors' assessments of the student attentiveness related to some items or exercises (e.g.: listening comprehension exercise), as well as an overall assessment related to the whole test.

3 Sample and Summary Statistics

3.1 UTCI Measure

In 2.1, we highlighted that the the UTCI combines air temperature, humidity, wind speed, and radiant heat and is a measure of the perceived temperature. The human body experience heat stress starting from a UTCI of 26°C. There could be acclimatization for individuals living in a tropical area, meaning that, the human body could adapt and function relatively well, even under hotter temperatures. The human body in these areas could tolerate up to 3.5°C more than their counterpart in colder countries. The link between acclimatization and heat stress is not documented to the best of my knowledge, but believed threshold of heat stress could be different in the tropical countries such as Ghana. In our analysis, we define 2°C temperature bins following (Graff Zivin, Hsiang, and Neidell 2018). Using temperature bins allows for a non-linear relationship between UTCI and performance measures. Table 1 shows that while most children are exposed to a daily temperatures between 24°C and 29°C during the first and second survey-round, children are exposed to daily temperatures greater than 27°C during the third survey-round. Indeed, the second survey-round happened during colder days in

average compared to the first and third survey rounds [1]. In the first survey-round, children were interviewed in September, October and November[2]. The third survey-round took place in February and March. Few children are exposed to average daily temperatures below 23°C. Average daily temperature below 23°C are a deviation from the usual cold weather in Accra, Ghana [3]. Given that the human body experiences heat stress at 26°C and above, we define the "comfortable" temperature bin to be between 24°C and 26°C (included) and the effects of temperature will be relative to that temperature bin.

3.2 Sample

We use the first three survey rounds of QP4G spanning the years 2015 to 2017. There are 3435 students in 2015, 3500 in 2016 and 3126 students recorded in 2017. From 2015 to 2016, 367 students leave the study and were replaced by 432 students on the initial wait list of selected students. From 2015 to 2017, there was an attrition rate of about 9%. Table 2 shows that the average child age is 5.8 years for all 3 survey-rounds, but 5.2 years old for the first survey-round. The distribution of age is quite large, but concentrated around 3-6 years of age at the first survey-round. In fact, 87% of the children are aged 3-6 years old.

3.3 Outcomes

To assess student functioning, we use test scores. Firstly, we use the listening comprehension score, the number-sense (one-to-one correspondence) test score, and the surveyor's assessment of the student attentiveness associated with them. Secondly, we construct a math and literacy test score based on all questions related to math and literacy. Lastly, we construct the surveyor's assessment of child attentiveness based on overall assessment questions.

Listening Comprehension & Surveyor Assessment. The listening comprehension test assess the student's listening skills. A listening test requires to be focused and attentive and therefore is a good proxy to understanding children's functioning at the moment of the test. We measure the listening comprehension score as the percentage of correct answers provided by each individual. Graff Zivin, Hsiang, and Neidell (2018) uses reading comprehension and reading

1. Two thirds of the second survey-round happened during the coldest months of the year in Accra (June and July). The other third happened during the month of May which is hotter than June and July.

2. Only one child was interviewed in November

3. This link shows historical temperature variation (both air temperature and perceived temperature) in Accra, Ghana, from 2010 to 2020. Daily temperature variation is found by zooming into the graph and shows that temperatures below 24°C are colder than usual, even for the coldest months.

cognition tests as a measure of children's functioning. The reading comprehension exercise is a similar exercise to the listening comprehension exercise in our setting. For this first measure, missing answers were accounted for as non correct answers. Table 2 shows that the overall average listening score is 56%. The average is higher for the first survey-round and monotonically increases from the first survey-round to the last one.

Attentiveness to Listening. The surveyors were asked about the students attentiveness towards the listening test. The measure "Attentiveness to Listening" is obtained by computing the average of three dummy variables. Specifically, the surveyors were asked whether the child was motivated, concentrated and diligent towards the task. Table 2 shows that overall 88% of the children were reported to be attentive during the listening test. Similarly to the listening comprehension score, there is a monotonic increase in attentiveness to the listening exercise from the first survey round to the last one.

Literacy. The literacy score is the proportion of correct answers to all the literacy questions asked to the children. Table 2 shows that the average literacy score among children is 53% and is lower for children in the first survey-round and higher in the last survey-round. Indeed, the average literacy score in the first survey-round is 40% while it is 64% in the last one.

Number Sense (One-to-one Correspondence) & Surveyor Assessment. Number Sense (One-to-one Correspondence) Score. The Number sense test is a basis to all later math concepts. The number sense score is computed as the proportion of correct answers. The average number sense score is 94% according to Table 2. The score is increasing monotonically from a survey-round to the other.

Attentiveness to Number Sense. Similarly to the measure of attentiveness to listening, the attentiveness to number sense is also the average over three variables measuring whether children were attentive. Table **??** shows that overall 94% of the children were reported attentive to the number sense exercise. The average increases monotonically from the first survey-round to the last.

Math. The math score is the proportion of correct answers to all the math questions asked to the children. Table **??** shows that the average math score among all children from all survey-round is 50%. The score is higher for later waves.

Surveyor's Overall Assessment of the Child Attentiveness. Overall Surveyors' assessment of Attentiveness (1-4). At the end of each test, the surveyor is asked to answer seven questions

related to the overall performance of the children. Each question is on the scale 1-4 where 1 represents a bad performance while 4 represents the best performance. We average over the seven sub-questions to construct the overall measure of attentiveness of each child. Table 2 shows that children were attentive during the survey. There is little to no difference across waves.

Overall Surveyors' assessment of Attentiveness (0-1). Following the first overall measure of attentiveness, we construct a dummy version of the same outcome. To do so, we transform the original questions from a scale of 1-4 to a scale of 0-1 and we compute the average of those new dummy variables. Table 2 shows that children were attentive during the whole survey or test.

3.4 Other variables

Poverty Measure. We construct a dummy for poor using the house construction materials of the family of each child. While there is a lot of ways to construct a variable for poverty or wealth such as mother's education, income or a combination of assets, the construction materials allows for a clear cut where families who build their house with mud bricks are separated from families who build their house with cement. Table 2 shows that about 18% of the children have a poor socio-economic background.

4 Estimation Strategy

To estimate the effects of heat stress shock on child functioning on the day of the test, we mainly exploit two types of variations. The first one is a within survey-round variation in temperature. Indeed, in each survey-round individuals are assigned a daily average temperature. Also, kids are usually interviewed over a course of 2 months and some days. This implies that within a survey-round kids are exposed to different temperature. The second variation that we exploit is an across time variation (or a within child variation). Because of the longitudinal nature of our data, we observe the same individual multiple times, and while some individual might always be exposed to the same temperature bin throughout the three survey-rounds, some individuals will switch from a hotter temperature to a colder temperature or vice versa. Intuitively, the within child variation (or across time variation will compare the same individual taking the test at different point in time, one when the individual is exposed to hotter

temperature and one when the individual is not. Following the subsection 3.1 we define the omitted temperature bin as $24-26°C$. The specification used is:

$$y_{i,r(t)} = \sum_{c=1}^{4} \beta_c \mathbf{1}_{T_{L(i),t} \in [l_c, u_c]} + \delta_i + \delta_{r(t)} + \delta_a + \epsilon_{i,r(t)}, \tag{4.1}$$

where $[l_{\{c=1\}}, u_{\{c=1\}}] = [21°C, 23°C]$ is the first temperature bin. The omitted temperature bin in our analysis is $[l_{\{c=2\}}, u_{\{c=2\}}] = [24°C, 26°C]$. i represents a child, t represents a year and $r(t)$ stands for survey-round which embed the concept of time as a year and the concept of seasonality.Indeed, each survey round denotes a different seasons of the year. L represents location which is a cell of $2.5° \times 2.5°$. $y_{i,r(t)}$ is the outcome of child i interviewed in survey round $r(t)$.

The child FE, δ_i , in our specification solves omitted variable bias problems. It specifically allows to control for individual background characteristics such as innate skills or intrinsic ability, tolerance to stress, family wealth and parental support. We control for other yearly invariant characteristics, $\delta_{r(t)}$, such as seasonal variations, education policies, or the timing of the academic year [4]. We control for age, δ_a, because in our dataset, children are aged 2-11 years old, which is a wide range of age and each age implies different cognitive maturity as well as different adaptation to heat stress for example. There could be a correlation between age and heat if children take the test during a hot period when they are old and during a cold period when they are young and vice versa. We do not need to control for humidity because as discussed previously, the UTCI measures embeds humidity.

There is a third source of variation which is the spatial variation. Temperature is assigned at the cell level and individual are distributed across 6 cells in our dataset.

5 Temperature and Children Functioning

5.1 Temperature and Literacy Skills

The first three columns of Table 3 show the results from a regression of the three literacy variables over temperature without child FE, using the whole sample, including the singletons. The next three columns, that is columns 4, 5, and 6 show the results of the previous regres-

4. The survey-round FE is actually a survey-round $\times$ a dummy for intervention FE. The data used in this analysis is from a one year intervention done in 2015 in the Greater Accra region of Ghana. The objective of the intervention is to improve the readiness of kindergarten children for primary schools. The intervention was both at the teacher and at the parents level.

sion, with the sample that contains children interviewed at least two times during the three survey-rounds. The last three columns, that is, columns 7, 8 and 9 show the results from the estimation of Eq. (4.1). The three outcome variables are the listening comprehension score, the attentiveness to listening exercise, and the literacy score.

We notice that any deviation from the "comfortable" temperature bin 24°C - 26°C worsen the listening score of children but the estimates are not precise. This is consistent with the result in Graff Zivin, Hsiang, and Neidell (2018). Similarly to the listening score, a deviation from the comfortable bin worsen the attentiveness of children. Specifically, taking the test when the temperature is between 27°C - 30°C decreases the score by 0.08 standard deviation. Here the cold bin decreases the score of children by also about 0.08 standard deviation. The effect of temperature on the listening score has an inverted U-shape but the effect of temperature on children attentiveness as well as on the literacy score follows an increasing linear pattern whereas the coldest bin affects children the most and the hottest bin affects children the least.

5.2 Temperature and Math Skills

The first three columns of Table 4 show the results from a regression of the three math variables over temperature without child FE, using the whole sample, including the singletons. The next three columns, that is columns 4, 5, and 6 show the results of the previous regression, with the sample that contains children interviewed at least two times during the three survey-rounds. The last three columns, that is, columns 7, 8 and 9 show the results from the estimation of Eq. (4.1). The three outcome variables are the number sense score, the attentiveness to number sense exercise, and the math score.

The effects of temperature on the number sense score follows an inverted U-shape with the coldest bin decreasing significantly the number sense score by 0.11 standard deviation. Similarly to the number sense score, the coldest bin decreases children attentiveness related to the number sense exercise by about 0.16 standard deviation. The colder bin Here the cold bin decreases the score of children by also about 0.08 standard deviation. The effect of temperature on the number score also has an inverted U-shape but the effect of temperature on children attentiveness as well as on the math score follows an increasing pattern.

5.3 Temperature and Children's Attentiveness

The first two columns of Table 5 show the results from a regression of the two surveyor's measure of the child attentiveness variables over temperature without child FE, using the whole sample, including the singletons. The next two columns, that is columns 3 and 4 show the results of the previous regression, with the sample that contains children interviewed at least two times during the three survey-rounds. The last two columns, that is, columns 5 and 6 show the results from the estimation of Eq. (4.1). The two outcome variables are the two versions of the overall attentiveness of the children, where the first one is scaled from 1-4, while the second one is scaled 0-1.

Overall, a deviation from the comfortable bin decreases the attentiveness of children. When considering the attentiveness score on a scale of 1-4, the effects is U-shaped and shows that attention decreases by respectively 0.14 and 0.1 standard deviation as it gets hotter. On the other side, the cold bin decrease score, but the estimate is not precise. When considering the dummy version of children's attentiveness, we notice that the point estimate is the same for all temperature bin and represent a significant decrease of 0.13 standard deviation of attentiveness.

5.4 Heterogeneous Temperature Effects on Children's Attentiveness Across SES Background

The first two columns of Table 6 show the heterogeneity analysis results by socio-economic status background of children using the two surveyor's measure of the child attentiveness variables over temperature without child FE, using the whole sample, including the singletons. The next two columns, that is columns 3 and 4 show the results of the previous regression, with the sample that contains children interviewed at least two times during the three survey-rounds. The last two columns, that is, columns 5 and 6 show the results from the estimation of Eq. (4.1). The two outcome variables are the two versions of the overall attentiveness of the children, where the first one is scaled from 1-4, while the second one is scaled 0-1.

The results indicate that even though all children do not perform well when the temperature is not comfortable, poorer children perform worse. The score gap between both group disappears at really high temperature. This might implies that any adaptation capacity developed by richer kids over hotter temperature, might not work at really high temperature, here $> 30°C$

6 Conclusion

The number of extremely high temperature days has grown over time and developing countries suffer the most from it because they have less capacity to protect themselves against the harm of extreme heat. On one side, countries that are the hottest are also the poorest. On the other side, poor countries experience a learning crisis whereas by age 10, over half of the population in middle- and low-income countries cannot read or count. The literature cites socio-economic background, teacher motivation and perception of efforts, school management, and also children's non readiness to school as determinants or drivers of low learning outcomes. One potential driver is heat. Hot temperatures is proven to decrease children's productivity in the short run in developed countries. The setting of little to no adaptation strategies to extreme heat is also studied in countries such as China and India. However, all those studies focus the most on adults and how loss of productivity from heat could affect their long-term outcomes in the context of high stakes exams. Not much is known about how heat affect children productivity in a developing countries. In this paper, we examine productivity in a cognitive activity using children's test performance and surveyor's assessment of students attentiveness in Ghana. The dataset is a longitudinal data on children. We link temperature data to an early childhood survey with similar survey instruments measuring cognitive and non-cognitive development outcomes for children—Quality Preschool for Ghana (QP4G). In particular, QP4G has a panel with 8 waves over 8 years. QP4G is a school based intervention aiming at improving children's school readiness in the Greater Accra region in Ghana. Children were 3-6 (in reality 2-10 years old), enrolled in pre-kindergarten at baseline in 2015 and were followed until 2022. Outcomes on literacy and math were regularly measured, as well as socio-emotional outcomes. For the first three years, the International Development and Early Learning Assessment (IDELA hereafter) was used to evaluate the children. For the last 5 data collections, various assessments were used including the Early Grade Reading Assessment (EGRA) and the International Social and Emotional Learning Assessment (ISELA). Each interviewer is trained to administer those tests and had to observe the students attentively in order to make a report at the end about their attentiveness, their dedication to the different tasks, whether they were focused or distracted and many other characteristics.

We identify the effects of temperature on child performance on survey instruments by exploiting variations within an individual. This is possible because of the longitudinal nature

of the dataset. This methodology is rare in the literature.

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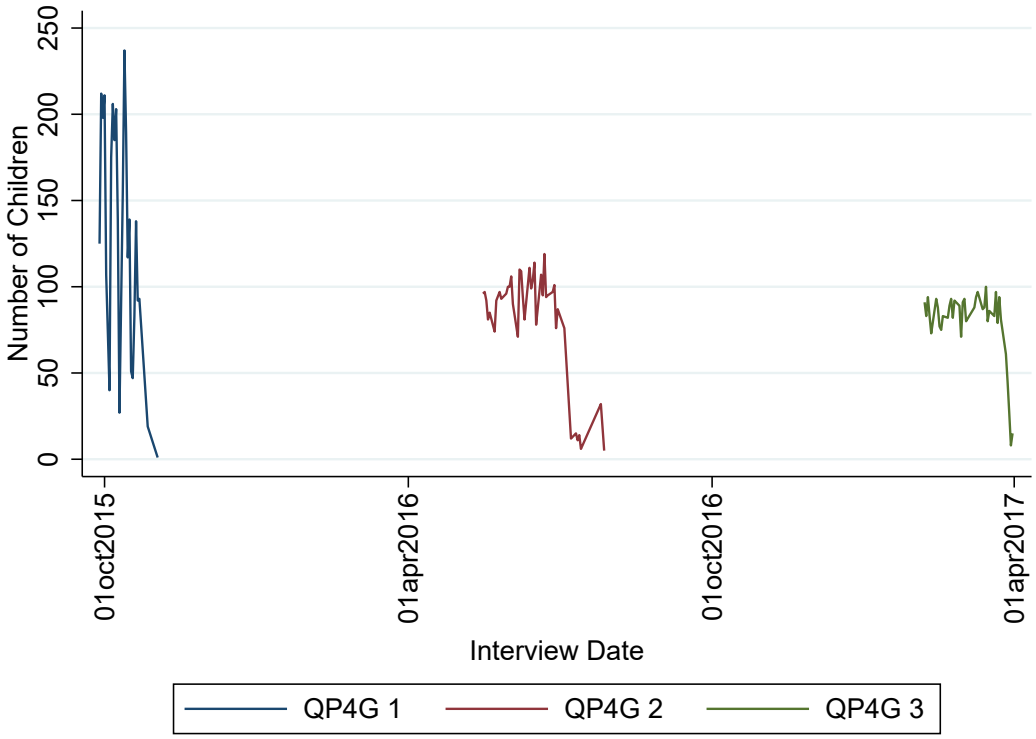
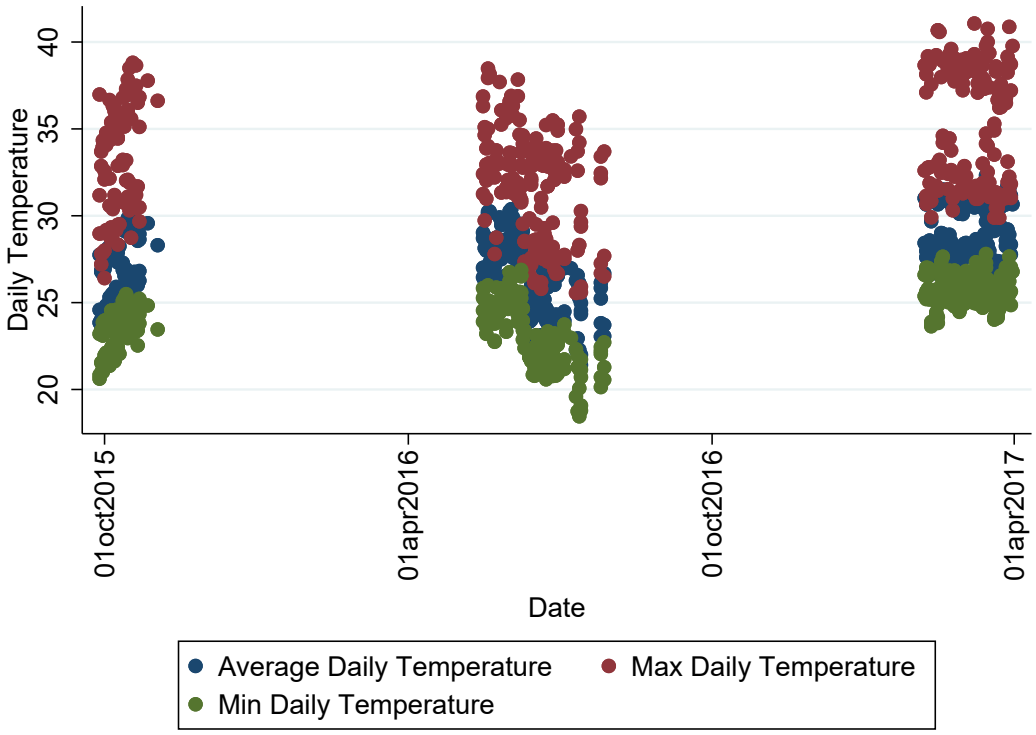
Tables and Figures

Fig. 1. Number of Students Interviewed per Day



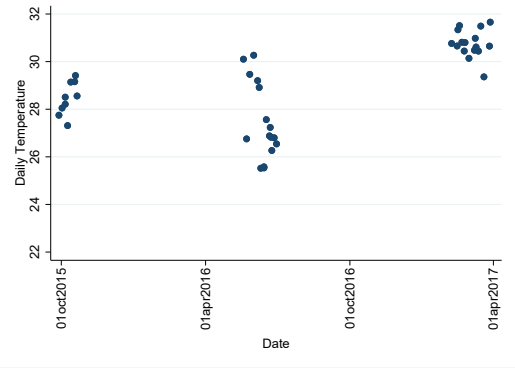
Note: The figure illustrates the daily variation in the number of interviews conducted during the three first survey-round.

Fig. 2. Temperature Variation by Wave

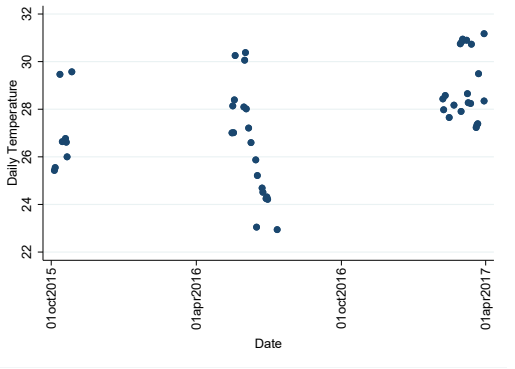


Note: The figure illustrates the temperature variation for each survey-round. The figure shows that the third survey-round is in average hotter than the first two survey-rounds. Temperature here stands for UTCI which is a proxy of the perceived temperature by the body.

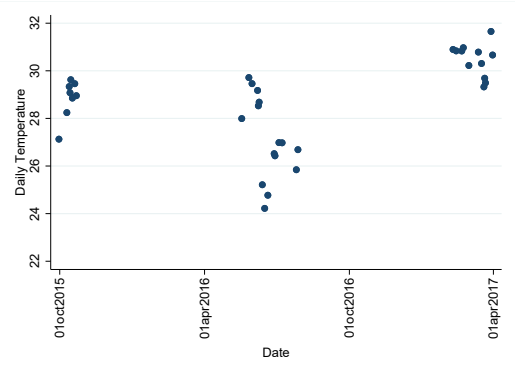
Fig. 3. Temperature Distribution by Districts



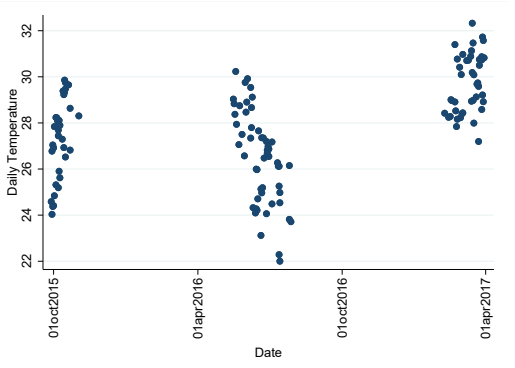
(a) Average temperature within a cell by



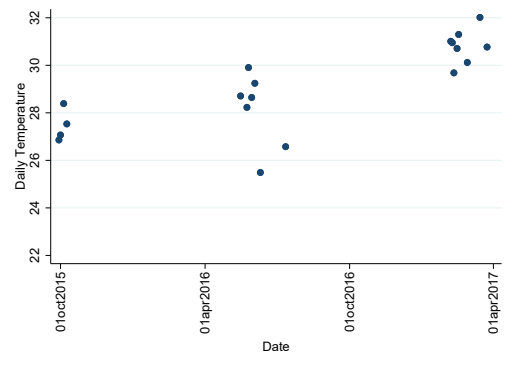
(b) Primary school consolidation–the closure of small community schools or their mergers into larger.



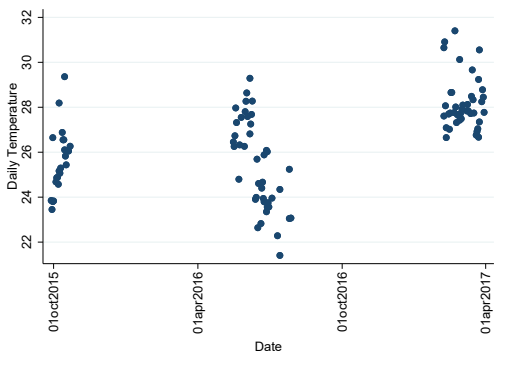
(c) We consider heterogeneous treatment effects across groups defined at the intersections of minority status.



(d) Compared to villages with schools, villages whose schools had closed reported that the schools students



(e) Duck number 5 from duckuments.



(f) Even more ducks.

Note: Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. $\sin^2(\alpha) + \cos^2(\beta) = 1$. If you read this text, you will get no information $E = mc^2$. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. This text should contain all letters of the alphabet and it should be written in of the original language. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. There is no need for special content, but the length of words should match the language. $a\sqrt[n]{b} = \sqrt[n]{a^n b}$.

Table 1: Summary Statistics: Temperature

	Proportion	SD	N
Wave 1			
Temperature $<$ 24°C	0.04	0.20	3,188
24°C $\leqslant$ Temp $<$ 27°C	0.41	0.49	3,188
27°C $\leqslant$ Temp $<$ 30°C	0.55	0.50	3,188
Temperature $\geqslant$ 30°C	0.00	0.00	3,188
Wave 2			
Temperature $<$ 24°C	0.09	0.29	3,312
24°C $\leqslant$ Temp $<$ 27°C	0.43	0.50	3,312
27°C $\leqslant$ Temp $<$ 30°C	0.42	0.49	3,312
Temperature $\geqslant$ 30°C	0.06	0.24	3,312
Wave 3			
Temperature $<$ 24°C	0.00	0.00	3,012
24°C $\leqslant$ Temp $<$ 27°C	0.03	0.16	3,012
27°C $\leqslant$ Temp $<$ 30°C	0.45	0.50	3,012
Temperature $\geqslant$ 30°C	0.52	0.50	3,012
Total			
Temperature $<$ 24°C	0.05	0.21	9,512
24°C $\leqslant$ Temp $<$ 27°C	0.30	0.46	9,512
27°C $\leqslant$ Temp $<$ 30°C	0.47	0.50	9,512
Temperature $\geqslant$ 30°C	0.19	0.39	9,512

Note: Summary statistics of the average daily temperature variable by wave/year. The mean column is showing the share of children exposed to the corresponding temperature bin. Calculations are made by authors using UTCI data.

Table 2: QP4G Overview and Key Statistics

	Mean	SD	Min	Max	N
Listening Score (0-1)	0.56	0.33	0.00	1.00	9512.00
Attentiveness to Listening (0-1)	0.88	0.27	0.00	1.00	9512.00
Literacy Score (0-1)	0.53	0.24	0.00	1.00	9512.00
Number Sense (One-to-one Correspondence) Score (0-1)	0.71	0.37	0.00	1.00	9512.00
Attentiveness to Number Sense (0-1)	0.94	0.19	0.00	1.00	9512.00
Math Score (0-1)	0.50	0.22	0.00	0.99	9512.00
Overall Surveyor's Assessment Score (1-4)	3.20	0.70	1.00	4.00	9473.00
Overall Surveyor Assessment Score (Dummy)	0.78	0.32	0.00	1.00	9473.00
Age	5.80	1.42	2.00	12.00	8266.00
Poor (Dummy)	0.18	0.38	0.00	1.00	7693.00

Note: This table shows summary statistics of the combined survey rounds sample on key outcomes variables. Calculations are made by authors using the three first waves of QP4G data.

Table 3: Literacy and Temperature

VARIABLES	(1) Listening Score	(2) Attentiveness to Listening	(3) Literacy Score
Temperature $< 24°C$	-0.0227	-0.0315	-0.0170*
	(0.0213)	(0.0193)	(0.00926)
$27°C \leqslant$ Temp $< 30°C$	-0.000503	-0.0207**	0.00392
	(0.00898)	(0.00933)	(0.00434)
Temperature $\geqslant 30°C$	-0.0160	-0.0149	-2.93e-05
	(0.0154)	(0.0144)	(0.00722)
Child FE	Yes	Yes	Yes
Survey Round FE	Yes	Yes	Yes
Age FE	Yes	Yes	Yes
Observations	7,940	7,940	7,940

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

Notes: Table shows regression results corresponding to equation 4.1. Specifically, the table is displaying three (03) outcomes, the listening comprehension score, how attentive the child was to the listening comprehension exercise, and the overall literacy score that pulls together all literacy related questions. All calculations are made by authors using the combined UTCI and QP4G data.

Table 4: Numeracy and Temperature.

VARIABLES	(1) Number Sense (One-to-one Correspondence) Score	(2) Attentiveness to Number Sense	(3) Math Score
Temperature $< 24°C$	-0.0408**	-0.0253*	-0.0107
	(0.0188)	(0.0141)	(0.00710)
$27°C \leqslant$ Temp $< 30°C$	0.00166	-0.000972	-0.00197
	(0.00885)	(0.00665)	(0.00301)
Temperature $\geqslant 30°C$	-0.00791	0.00140	9.26e-05
	(0.0146)	(0.0104)	(0.00502)
Child FE	Yes	Yes	Yes
Survey Round FE	Yes	Yes	Yes
Age FE	Yes	Yes	Yes
Observations	7,940	7,940	7,940

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

Note: Table shows regression results corresponding to equation 4.1. Specifically, the table is displaying three (03) outcomes, the number sense (one-to-one correspondence) score, how attentive the child was to the number sense exercise, and the overall math score that pulls together all math related questions. All calculations are made by authors using the combined UTCI and QP4G data.

Table 5: Overall Surveyor's Assessment of Child Attentiveness and Temperature

VARIABLES	(1) Overall Surveyor's Assessment Score (1-4)	(2) Overall Surveyor Assessment Score (Dummy)
Temperature $< 24°C$	-0.0176	-0.0418*
	(0.0417)	(0.0213)
$27°C \leqslant$ Temp $< 30°C$	-0.0968***	-0.0390***
	(0.0217)	(0.0104)
Temperature $\geqslant 30°C$	-0.0716**	-0.0370**
	(0.0351)	(0.0168)
Child FE	Yes	Yes
Survey Round FE	Yes	Yes
Age FE	Yes	Yes
Observations	7,900	7,900

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

Notes: Table shows regression results corresponding to equation 4.1. Specifically, the table is displaying three (03) outcomes, the listening comprehension score, how attentive the child was to the listening comprehension exercise, and the overall literacy score that pulls together all literacy related questions. All calculations are made by authors using the combined UTCI and QP4G data.

Table 6: Heterogeneity of Children's Attentiveness by Socio-Economic Background.

VARIABLES	(1) Overall Surveyor's Attentiveness Assessment (1-4)	(2) Overall Surveyor's Attentiveness Assessment (0-1)
Temperature $< 24°C$	-0.0167	-0.0418*
	(0.0467)	(0.0237)
$27°C \leqslant$ Temp $< 30°C$	-0.0857***	-0.0346***
	(0.0242)	(0.0114)
Temperature $\geqslant 30°C$	-0.0869**	-0.0473***
	(0.0381)	(0.0182)
Temperature $< 24°C \times$ Poor	0.000873	-0.0171
	(0.132)	(0.0717)
$27°C \leqslant$ Temp $< 30°C \times$ Poor	-0.0904*	-0.0398
	(0.0525)	(0.0267)
Temperature $\geqslant 30°C \times$ Poor	0.0157	0.0117
	(0.0603)	(0.0283)
Child FE	Yes	Yes
Survey Round FE	Yes	Yes
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

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