Heat and Team Production: Experimental Evidence from Bangladesh

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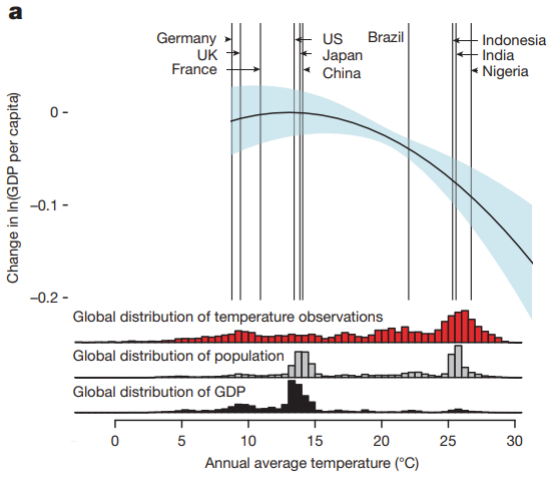
Higher temperatures are associated with decreased economic growth

(Dell, Jones, and Olken, 2012; Burke, Hsiang, and Miguel, 2015)



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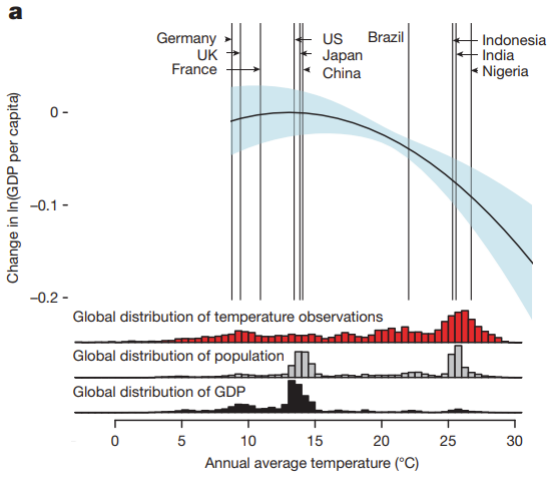

- Mechanisms include decrease in agricultural income, and increase in social conflict

What about the direct impact of heat stress on worker output?

Especially in lower-income countries as deployment of climate control in the workplace is limited

- Growing quasi-experimental evidence on the effects of heat on low-skilled worker output (e.g., manufacturing workers)
  - Typically physical, routine, or process-based tasks
- **Limited evidence on how heat affects high-skilled worker output (e.g., computer programmers)**
  - Typically mental, creative, or variable tasks
  - Share of employment in high-skilled occupations is 20% globally and increasing
  - Prior (somewhat related) evidence finds strongest effects from quasi-experimental studies on test scores (children) and judges decision-making
    - Weaker evidence from laboratory experiments on mental or cognitive processes for individual participants, with the exception of aggressive behavior (Almas et al, 2019)

Does the impact of heat on worker output change in team tasks?

High-skilled jobs increasingly require teamwork (Wuchty et al., 2007)

- High-skilled teamwork is increasingly being undertaken in warmer climates (Lan et al., 2014; Stocker et al., 2013; Thursby and Thursby, 2006)

Heat appears to alter mood (Almås et al., 2019; Taylor et al., 2016)

- Unclear if effects of heat on larger scale conflict translate into conflict in work teams

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The labor productivity impacts of heat could be larger than previously documented if impacts on team productivity are more than just sum of impacts on individual productivity.

The first field experiment on heat and high-skilled worker performance

Research design preview:

- Computer science students in Dhaka, Bangladesh, hired to complete a 4.5 hour programming task onsite
- Participants are randomized to warm (29C) or cool (24C) room
- Participants are randomized to work individually or in pairs
- All participants asked to add five features to an existing Java script to implement an application programming interface
- All participants paid a flat fee of 1100 BDT (11 USD) for attendance plus up to 45% of the flat fee in bonuses (9% per feature added)

Theoretical motivation for comparing individuals and teams

- If heat only increases individual cost of effort or individual errors, we should see similar changes in performance between independent and teams of workers
  - Heat may increase individual workers' cost of action
  - Heat may reduce the likelihood that effort results in feature completion by making individual abilities worse

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  - Heat may increase individual workers' cost of action
  - Heat may reduce the likelihood that effort results in feature completion by making individual abilities worse
- If heat increases the cost of coordination or the likelihood of coordination failure, there should be a larger effect on team production relative to individual production
  - Heat may increase the cost of effort more in teams due to a relative increase in coordination costs
  - Heat may reduce the likelihood that effort results in feature completion more in teams by making complementarities harder to realize such that even if effort goes up, success is not realized

The first field experiment on heat and high-skilled worker performance

Results preview:

- No effect of heat on individual output relative to individuals in cool rooms
- Teams in warm rooms were roughly 50 pp. less likely to complete any features compared to teams in cool rooms
  - Quality of output is significantly lower among teams in warm rooms than those in control rooms
  - Teams in warm rooms more likely to take breaks, but no evidence of decreased (observable) effort
  - Noisy evidence that code quality is lower among teams in warm rooms than those in control rooms

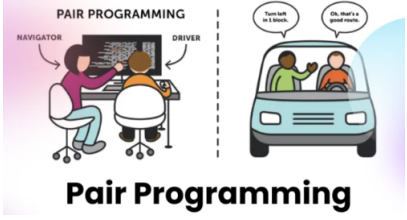
Main Takeaway: Heat reduces the performance of teams of high-skilled workers; no evidence that performance reduction in teams is due to changes in worker effort, weak evidence that it reduces quality of output.

Study setting and sample

- Study setting: Two identical rooms in the offices of our implementation partner, ARCED Foundation, across 25 study-days in Oct-Nov 2022 in Dhaka
  - Ambient temperature in Oct-Nov (start of "**Winter**") in Dhaka: Average highs 30-32C and average lows 19-24C
  - Limited deployment of climate control: Only 200,000 air conditioners were purchased in Bangladesh (pop. >150 million) in 2021 (JRAIA, 2022)
  - Approx. 10% of work force employed in high skill occupations (The Financial Express, 2020)
- Study sample: 2nd to 4th year computer science students at major universities in Dhaka recruited to complete a 4.5 hour Java programming task
  - Recruitment via flyers in computer science departments and via emails to faculty
    - Recruitment information included task description as part of research to understand computer programming work
  - To sign up students filled in a participant survey through a QR code
  - Collected names, phone numbers, and emails, number of university credits, number of semesters completed, and whether they had previously worked with Java

Experiment design

- Survey respondents were randomly ordered for a call to schedule their study-day (three days notice) such that 20 participants were invited on each study-day
- Team treatment: Each study-day was randomly assigned as pair programming or individual programming study-day
  - Pair programming: The driver writes code while the navigator reviews each line of code as it is typed in; the two programmers switch roles frequently



- Temperature treatment: On each study-day one room was randomly assigned as the cool room, the other as the warm room; temperature set via air conditioners
  - Cool room temperature set at 24C; warm room temperature set at 29C
  - On each study-day participants randomly assigned to control room or warm room

Experiment design

Room layout for pair and individual programming

(a) Pair programming layout

(b) Individual programming layout

- Participants were randomly assigned to a given seat number such that team partners are also randomly assigned
- Humidity, temperature, and pollution monitors collected real-time data

Programming task and participant incentives

- Programming task:
  - Participants have to add five features in any order to an existing script to implement an application programming interface (API) in 4.5 hours
  - Even programmers without Java-specific experience but with object-oriented programming could work successfully on the task
  - Performance-based outcome measure: # of features added to the script
  - Input-based effort measures: # of characters typed, # of clicks, # of character deletions, # of scrolls
- Participant incentives:
  - All participants paid a flat fee of 1100 BDT (11 USD) for attendance plus up to 45% of the flat fee in bonuses
    - Bonuses worth 9% of base pay were paid for each feature that participants successfully added to the script
    - Team members do not split the bonus; each receive full bonus per task

Empirical specification

γ_1 (γ_3) captures the effect of heat on individual (team) production

$$Y_{ird} = \gamma_0 + \gamma_1 \mathbf{1}Warm_r + \gamma_2 \mathbf{1}Team_d + \gamma_3 \mathbf{1}Warm_r * \mathbf{1}Team_d + \epsilon_{rd} \quad (1)$$

- Y_{ird} is the outcome of interest for individual or pair i in room r on study-day d
- *Warm* indicates whether the room r is warm or cool room
- *Team* indicates whether the study-day d is for individual or pair programming
- Standard errors are clustered at the room-study-day level rd

Analysis sample and balance

104 pair- and 134 individual programmers

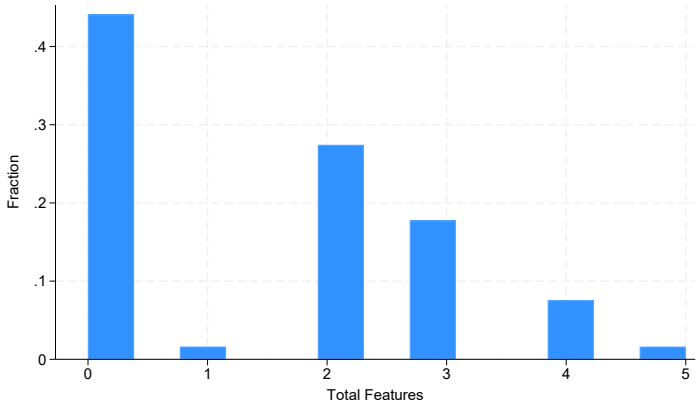
- Total participants: 238
  - Cool room, individual programming: 75
  - Warm room, individual programming: 59
  - Cool room, pair programming: 28 teams*2 (56)
  - Warm room, pair programming: 24 teams*2 (48)

	(1) # Credits β / SE	(2) Current Semester β / SE	(3) Knows Java (0/1) β / SE	(4) Female (0/1) β / SE
Warm (0/1)	-2.86	-0.07	-0.03	-0.08
	(5.24)	(0.49)	(0.02)	(0.06)
Team (0/1)	3.20	0.36	-0.00	0.01
	(5.03)	(0.38)	(0.00)	(0.07)
Warm X Team (0/1)	-1.32	-0.40	0.03	0.09
	(7.77)	(0.69)	(0.02)	(0.11)
Warm=0;Team=0 Mean	100.72	8.95	1.00	0.20
Observations	234	234	234	234
R^2	0.008	0.008	0.026	0.011

Temperature in cool and warm rooms was 24C and 29C, respectively

	(1) Temperature (C) β / SE	(2) Humidity β / SE	(3) PM2.5 β / SE	(4) PM10 β / SE	(5) # of Participants β / SE	(6) Week of Year β / SE	(7) Day of Week β / SE
Warm (0/1)	4.91***	7.32***	-14.36	-15.48	-0.08	-0.47	-0.28
	(0.19)	(2.19)	(11.28)	(11.98)	(1.19)	(0.88)	(0.88)
Team (0/1)	0.07	1.95	-0.09	-0.00	0.60	0.87	0.73
	(0.16)	(2.83)	(10.53)	(11.34)	(1.21)	(0.92)	(0.93)
Warm X Team (0/1)	-0.28	-0.12	9.74	10.52	0.48	-0.03	0.81
	(0.34)	(3.83)	(14.79)	(15.67)	(1.92)	(1.38)	(1.37)
Warm=0;Team=0 Mean	24.14	64.57	64.75	68.03	5.00	44.13	2.87
Observations	45	45	45	45	45	45	45
R^2	0.960	0.288	0.055	0.056	0.020	0.047	0.066

Our output measure: # of features added



Heat has no effect on individual output, but decreases team output

	(1) Any Features β / SE	(2) At Least 2 Features β / SE	(3) At Least 3 Features β / SE	(4) At Least 4 Features β / SE	(5) All Features β / SE
Warm (0/1)	0.17*	0.15*	-0.08	-0.07	0.00
	(0.09)	(0.08)	(0.08)	(0.04)	(0.02)
Team (0/1)	0.37***	0.34***	0.07	0.04	-0.01
	(0.10)	(0.10)	(0.08)	(0.08)	(0.01)
Warm X Team (0/1)	-0.44**	-0.43**	0.16	0.06	0.04
	(0.20)	(0.20)	(0.18)	(0.11)	(0.05)
Warm=0;Team=0 Mean	0.44	0.44	0.27	0.11	0.01
Observations	183	183	183	183	183
R^2	0.066	0.054	0.026	0.022	0.009

Teams in warm rooms more likely to take any breaks

But no change in observable effort

	(1) Total Characters β / SE	(2) Characters per Minute β / SE	(3) Minutes Coding β / SE	(4) Any Breaks β / SE
Warm (0/1)	-2484.62	-16.98	13.33	0.07
	(2098.78)	(11.28)	(20.28)	(0.11)
Team (0/1)	-269.87	-5.62	16.06	-0.16**
	(2620.69)	(11.96)	(18.11)	(0.07)
Warm X Team (0/1)	3096.71	19.66	-9.62	0.36**
	(3388.45)	(15.76)	(29.02)	(0.16)
Warm=0;Team=0 Mean	8254.47	59.38	126.64	0.27
Observations	183	183	183	183
R^2	0.011	0.014	0.009	0.064

Teams have higher quality code, eliminated by warm temperature

	(1) Cyclomatic Complexity β / SE	(2) Code Clarity β / SE
Warm (0/1)	0.38	0.31
	(0.37)	(0.41)
Team (0/1)	1.08**	0.85**
	(0.44)	(0.41)
Warm X Team (0/1)	-0.69	-0.80
	(0.59)	(0.66)
Warm=0;Team=0 Mean	4.19	4.81
Observations	181	183
R^2	0.041	0.023

Post-task survey: participants in warm rooms were irritated

No differential effect amongst teams in warm rooms

	(1) Task Difficult (0/1) β / SE	(2) Task Engaging (0/1) β / SE	(3) Prefer Teamwork (0/1) β / SE	(4) Positive Affect (sd) β / SE	(5)
Warm (0/1)	-0.06	-0.11	-0.03	-0.25	
	(0.08)	(0.06)	(0.09)	(0.27)	
Team (0/1)	-0.07	0.07	0.17**	0.21	
	(0.10)	(0.06)	(0.08)	(0.16)	
Warm X Team (0/1)	0.07	0.00	0.02	-0.07	
	(0.15)	(0.10)	(0.12)	(0.31)	
Warm=0;Team=0 Mean	0.55	0.67	0.57	0.04	
Observations	232	232	232	232	
R^2	0.003	0.018	0.033	0.028	

Team members in warm rooms would prefer a different partner

No change in self-reported perception of the task

	(1) Partner Score (0/1) β / SE	(2) Prefer Different Teammate (0/1) β / SE
Warm (0/1)	-0.00	0.16
	(0.08)	(0.12)
Warm=0;Team=1 Mean	0.69	0.31
Observations	98	98
R^2	0.000	0.028

Conclusion

- No impact of heat stress on individual output in a high-skill task
- Large decrease in team output due to heat in a high-skill task
  - Teams in warm rooms more likely to take breaks, but no evidence of decreased (observable) effort
  - Team members in warm rooms may be less able to capture complementarities
- Policy implications for high-skill work and team production in the Global South

Thank you!

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