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ABSTRACT

Hunger and Performance in the Classroom*

Hunger and malnourishment can adversely affect students' performance by lowering their effort and cognition during school hours. We conduct a lab-in-the field experiment, leveraging the extension of India's school meal program from primary to middle grades, to study the effects of school-based supplementary nutrition on students' cognitive effort in the classroom. Using individual level data on the performance of students in a cognitive task both before and after the extension of the program as well as pre and post meal recess on a school day, we find that the provision of meals improved the cognitive performance of students by 13% to 16%. This result is robust to unobserved heterogeneity in school quality and student ability. Our findings suggest that short-term improvements in classroom attention and effort due to school meals can be a mechanism through which longer-term learning outcomes may improve in developing countries.

JEL Classification: I21, I25, H52

Keywords: school meals, malnourishment, performance, classroom, maze puzzles, India

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1. Introduction

It is fairly well-established that the functioning of the human brain is sensitive to temporary variations in the availability of nutrients which in turn impacts cognitive outcomes. Hunger, therefore, can lead to lower cognition not only in the short term but sustained spells of hunger may affect the brain in the longer run, as well.[1] Hunger in the classroom, in particular, can adversely affect learning outcomes of children by lowering their effort and cognition during school hours. This concern is even more relevant in low-income countries where students may not only suffer from hunger more often but also have poor health. The cognitive ability and performance of the brains of children who are nutritionally deficient are particularly susceptible to transitory metabolic changes, carrying implications for learning.[2] In this paper we design a novel school-based experiment in India to study whether the provision of meals to malnourished students during school hours can improve their performance in cognitive tasks in the classroom.

Our data come from tests of effort and cognition we designed and administered to students in randomly selected public schools of Delhi. We conducted our tests before and after the extension of an ongoing free school meal program to upper primary grades (6 to 8) in public schools in Delhi which were providing free cooked meals to primary grades (1 to 5), as part of a federal program popularly known as Mid-Day Meal Scheme, since 2003. The exact date of extension of the program, 29th September 2009, was unanticipated. Since our study was initiated before the extension became effective in August 2009, schools whose randomly selected date of the first round of data collection (called baseline, henceforth) fell before 29th

[1] Several reviews in the nutrition literature establish the link between hunger and cognitive development of children. Nyaradi et al. (2013) conclude that hunger can impair cognition and cognitive development of children. Adolphus et al. (2016) systematically review the evidence related to eating breakfast before school on children's and adolescents' cognition. Findings from 45 studies across developing and developed countries suggest that eating breakfast has an immediate short-term positive impact on cognition.

[2] Neurocognitive domains are of six types- attention, memory, emotions, language, executive function and motor skills. In this paper we focus on attention.

September 2009 had not yet started the school meal scheme for upper primary grades, while those visited after 29th September were serving meals to upper primary grades. Sampled schools were re-visited for a second round of data collection (endline, henceforth) between February and April, 2010 when all public schools were providing the meals in upper primary grades. We define schools that changed their meal implementation status in the upper grades between the two visits as treatment schools and those that did not as control schools. Thus, children in Grade 7 in treatment schools were offered school meals at endline while those in control schools were receiving meals in both rounds. This allows us to use a double difference, intention-to-treat estimation strategy while accounting for unobserved heterogeneity in students' ability. We use Grade 5 students who were receiving school meals throughout the study period (i.e. both rounds) as the placebo group.

We used maze puzzles as tests of students' effort and cognition in the classroom. Thus our main outcome of interest is the number of maze puzzles solved correctly during regular school hours by a student in two sessions we administered during a school visit – a session *before* the school recess when school meals are offered to students (pre-recess, henceforth) and a session *after* the distribution of school meals (post-recess). These cognitive tests were administered by us again after a span of 4 to 6 months to students in all sampled schools after the extension of the program at endline. Hence for each student we have 4 scores – 2 each for baseline and endline. Besides being able to compare the performance of students between the two visits, we are also able to compare their performance before and after the distribution of school meals during recess on the same visit. Since the maze puzzles did not require either reading or writing skills but rather skills such as attention, perseverance and patience (Afridi, Li and Ren 2015; Hoff and Pandey 2006; Gneezy, Niederle, and Rustichini 2003), we are able to focus on the impact of the meal program on class room effort as opposed to standard tests of learning such as reading or math.

We find that school meals significantly improved performance of Grade 7 students. Between baseline and endline, the gain in the number of mazes correctly solved in treated schools exceeded those in control schools by 0.29 additional mazes, a 13% improvement in performance. Since we do not observe Grade 7 students in the control schools before they received the meals, we cannot be sure that the gains we find are not due to different school-level trends. We address this by analysing data on Grade 5 students, who maintained their status quo in both rounds of test and were in the same schools as Grade 7, as a placebo group. By comparing the change in the number of mazes solved of Grade 5 students across both rounds, we are able to confirm that the trends between treatment and control schools were likely to be similar. Our results are also robust to unobserved heterogeneity in student ability.

When we disaggregate students' performance into pre and post recess, we find that the overall improvement in performance of students can be attributed to higher maze scores in the post-recess sessions and in the relatively more difficult maze puzzles. However, students who were severely malnourished were less likely to exhibit improved performance, relative to the moderately malnourished. This indicates that provision of supplementary nutrition to older children in very poor health may not be sufficient for catch-up. However, we do find a significant improvement in treatment schools' Grade 7 students' score in math at endline, suggesting that alleviating classroom hunger can impact learning outcomes via improved effort and cognition.

Overall, our results show that supplementary meals improved students' attention and concentration in the class-room and thereby improved their performance on the assigned tasks. We rule out other mechanisms that may have impacted students' cognition, such as higher attendance or short-term health improvements due to the school meals, during the period of our study. Since the cognitive task was administered by the researchers in a relatively controlled classroom environment, the possibility that school meals reduced disruptive classroom behavior of students and thereby improved students' attention and concentration, is an unlikely explanation of our findings.

The premise of school feeding programs, which were first implemented in developed countries in the early 1960s, such as the School Breakfast Programs in the U.S., was that students tend to come to school hungry. The programs, therefore, sought to increase students' concentration by easing hunger and improving cognitive functions during school hours.[3] To the best of our knowledge ours is the first study to assess the impact of a large-scale school meal program on students' performance in the classroom. While the unanticipated implementation of the program in Delhi provides a natural experiment setting to make a causal interpretation, our experiment design allows us to draw on a panel of individual scores of students to control for time-invariant student characteristics that could influence performance in classroom tasks. Given the widespread prevalence of hunger in low-income countries, understanding the impact of supplementary meals on school children's cognition takes special significance with immediate policy relevance.[4]

While most studies on supplementary nutrition, in the context of developing countries, have focused on learning outcomes, a few have also assessed its impact on cognition, but with conflicting results. Adelman et al. (2008) designed an RCT in Uganda on providing on-site or take home food to 6-14 year olds. They find improvements in Raven's Progressive Matrices and Digit Span tests with stronger impacts on 6-10 year olds. But Kazianga et al. (2009) find no impact of a similar RCT in Burkina Faso on children's cognition. In a review of randomized control trials in the nutrition literature, Khor and Mishra (2012) conclude that there is a consistent impact of micronutrient supplementation on short term memory, but not on other

[3] See Egner et al. (2014) for review of the School Breakfast Program in the United States.
[4] India was ranked 100th among 117 countries on the Global Hunger Index in 2017, 'hungrier' than North Korea, Bangladesh and Iraq. The prevalence of underweight in children in India (48 percent) was almost twice as high as the average prevalence for the 26 sub-Saharan African countries that have similar data (25 percent) around our study period in 2005-06 (NFHS).

mental faculty, of 5-15 year olds.[5] Moreover, in these experimental studies the effect of meals on cognitive tests (or learning achievement tests) is context specific and depends on the baseline nutritional status of the subjects.[6]

Despite a significant body of literature on India's school meal program, the world's largest, only a handful of studies have evaluated the impact of school meals on school-based, cognition and learning. While the majority of the studies have focused on school participation outcomes, a couple have found that the program improves short-term nutritional intakes (Afridi 2010) and long-term health (Singh et al. 2012) of primary school-age children. We are aware of only two studies that analyse the impact of the Indian school meal program on either cognition or learning. Singh (2008) uses data from the southern state of Andhra Pradesh for children aged 10-12 years, and finds improvements in Peabody Picture Vocabulary Tests by 0.6 SD. These results are, however, suggestive and the author clarifies that the assumptions of the propensity score matching estimation strategy are strong. In a recent study, Chakraborty and Jayaraman (2019) find improvements in primary school students' reading and math score by taking advantage of the staggered implementation of the school meal program across the country using a nation-wide dataset. These effects were larger for children with longer exposure to the program. However, they are unable to convincingly disentangle the contribution of improved nutrition and school participation in the overall impact on learning. Our findings suggest that improvements in classroom attention and effort may be one possible mechanism through which longer-term learning outcomes improve due to school meals.

[5] A few small sample studies in India on micronutrient fortification suggest links between meal content and cognition. Kumar and Rajagopalan (2010) find that providing micronutrient fortified food supplement to 600 students age 7-11 years in India led to an improvement in memory and attention-concentration test scores in the treatment group compared to the control group that received nothing. Vazir et al. (2006) find similar effects in a study that provided fortified beverages as part of school lunch in a school in India compared to another school that got a placebo.

[6] Grantham-McGregor et al. (1998) find that providing breakfast to school children in Jamaica improved the concentration of students in the better organized schools.

To summarize, our study attempts to fill the gap in the literature on school-based, supplementary nutrition by examining the impact of school meals on cognition during school hours of post-primary age children. The maze games we administered measure attention and effort as opposed to reading or math skills, which may be influenced by the quality of the education system. Thus, since we abstract away from the curriculum based outcomes, we are able to evaluate the effect of supplementary nutrition on fundamental mental faculty. Moreover, our lab-in-the field study design allows us to not only account for unobservable variations in school quality but also administer the tests in a relatively controlled classroom environment. This enables attribution of the observed impacts to school meals plausible as and allows us to identify the mechanism clearly.

Our research also contributes to the broader literature on the crisis in students' learning outcomes in the often dysfunctional public schools (ASER 2014) in India. From a policy perspective these findings suggest that school based nutrition programs have significant short-term benefits and their sustained uptake can translate into improved cognitive ability in the long-term. While these impacts are independent of learning in the short-run, our study highlights a policy tool that can directly impact both children's health and attainment in the long-run in developing countries.

The remainder of the paper is organized as follows, Section 2 provides the background on the school meal program while Section 3 explains the classroom experiment we conducted. We describe the data and methodology in Section 4. Section 5 discusses the results and we conclude in Section 6.

2. Background

The National Program of Nutritional Support to Primary Education or the Mid-day Meal Scheme (henceforth, MDM) was initiated by the federal government of India in August 1995

(Government of India, 1995). It mandated the provision of cooked meals during school hours to all children enrolled in public primary schools (grades 1 to 5). In 2007 the program's mandate was extended to upper primary grades (grades 6 to 8) of public schools. While the vast majority of public schools in the country failed to implement this extended mandate until several years later, we take advantage of the extension of the program in the national capital, Delhi, in September, 2009 to study the effect of school meals on students' classroom performance. Although the extension of the program was in the offing since 2007, the exact timing of the program's expansion was unanticipated in Delhi.

Public schools in Delhi are managed either by local municipalities or the state government. While most primary schools (i.e. schools with grades 1-5) are run by local municipalities, upper primary schools (with grades 6 to 8) are managed by the education department (also known as the Directorate of Education (DoE)). Amongst the schools administered by the DoE there exist schools that house grades 1 to 12, known as *Sarvodaya* schools. Of over a 1000 DoE schools, there were approximately 364 *Sarvodaya* schools at the time of our survey, comprising the majority of public schools that offer both primary and secondary education across all municipal zones of Delhi. Our experiment was designed to exploit the extension of the program to upper grades and hence required both primary and upper primary grades in the same school to avoid unobserved school heterogeneity between grades. Our sample, therefore, consists of *Sarvodaya* schools alone. With the extension of the program to upper primary grades in Delhi, approximately 2.5 million students were receiving cooked school meals in 2009-10 across more than 2000 schools, as of the period of our study.[7]

In 2005-06, around our study period, 42.2 percent of children (under age 5) in Delhi were moderately malnourished (according to height-for-age) while 20.4 percent were severely

[7] According to the Planning Department, Government of Delhi (2003), there are approximately 1695 municipal primary schools and 1030 DoE schools at up to varying grade levels in the National Capital Territory of Delhi (http://edudel.nic.in/directorate.html)

malnourished, comparable with 48 and 23.7 percent, respectively, for the country as whole (National Family Health Survey (NFHS), 2006).[8] The average height-for-age Z score was -1.6 and -1.9, in Delhi and India, respectively. The school meal program, therefore, carries relevance for the population we are studying. Under the program's mandate the calorific value of a mid-day meal was stipulated to be at least 300 calories and 8-12 grams of protein per child per day for primary grade students and 700 calories and 20 grams of protein for upper primary grades during the period of our study. These form a significant proportion of the daily nutrient requirement of children in the age-group of 5-14 years (Afridi, 2011). A typical school meal consisted of either rice or wheat bread with pulses or vegetables along with a local sweet once a week. Meals were served during the school recess and the daily meal menu varied across days in a week.

3. Experiment Design

We take advantage of the unanticipated extension of the school meal program to upper primary grades in September, 2009 and the timing of school meals within a school day, to study the program's impact on children's performance in the classroom. Below, we describe our experiment design, beginning with the classroom task that we assigned to students during school hours.

Cognitive task

Our main outcome of interest is the performance of students on a test of cognition and effort: solving maze puzzles. Maze puzzles have been used extensively to study subjects' effort, since performance in these puzzles is not conditional on reading, writing or math skills. Instead,

[8] The proportion of under-5 who are malnourished has fallen but continues to be high according to the NFHS (2015-16) - 38.4 (moderately) and 16.3 (severely) in India and 31.9 (moderately) and 10.7 (severely) in Delhi. Similar data for children above age 5 are not available for India.

solving these puzzles requires skills such as attention, perseverance and patience and have been used in studying children's effort both within (in China - Afridi, Li and Ren 2015) and outside the classroom (in India - Hoff and Pandey 2006).[9]

We administered these maze puzzles to students during regular school hours in their classroom by a trained team of women researchers.[10] In every sampled school, we administered two such sessions on the same day, one before and the other after recess. In each session, before conducting the test a female experimenter (along with an assistant) showed a sample maze and explained the task to the students– to find a path through a field from one side to the other of a maze without crossing the solid lines (see Figure A1 in Appendix A for a sample maze). She then demonstrated how to solve the simple maze to the students. Thereafter, test booklets with five unsolved mazes, along with a pencil and an eraser, were distributed to all children present in the classroom. Students were instructed to start with the first maze and proceed forward. Subjects were then given 8 minutes to solve the five mazes. The first two mazes were of the lowest difficulty level – level 1, while the next three mazes were increasing in difficulty levels from 2 to 4, respectively.[11] The difficulty levels of the first two mazes were kept identical and the students were instructed to treat the first maze as a practice maze. Experimenters ensured that seating was such that there was sufficient space between students and classroom decorum was maintained before the students took the tests.

Following the completion of the allotted 8 minutes, the maze booklets were collected from the students. The experimenter then administered a booklet containing four multiple-

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[9] Most studies measure attention using tests to directly assess short-term memory, concentration and attention span such as Letter Cancellation Tests, Knox Cube Tests and Digit Span tests. These are difficult to implement collectively and in contexts where class sizes are large and time limited. Most of the above mentioned tests require testing of individuals in a laboratory environment and take up to 1.5 to 2 hours. In our sample, the average grade size is 32 and one class is of approximately 45 minutes. We used maze puzzles from Yahoo! Games in our experiment.
[10] Detailed instructions for administering the tests in the classroom are in Appendix A.
[11] We selected these mazes such that they would be of appropriate difficulty level for 10 year olds (or fifth-graders).

choice, curriculum based tests to all students in the classroom in the session. These tests included simple math questions on addition and subtraction and language questions such as antonyms and synonyms of common words in Hindi and English based on Grade 5 curriculum. An additional IQ based question was included in this booklet. Students were given 10 minutes to solve the five questions in this booklet. Once the allotted time was over, the test booklets were collected from the students. Research assistants, then, measured and recorded the heights and weights of each student while a regular school teacher took over the subsequent class. The entire session lasted no more than 45 minutes – the duration of one class in these schools.

School meals are distributed during recess. While most *Sarvodaya* schools hold classes in the morning from 8.00 AM to 1.00 PM, there are some schools that hold classes in the evening for boys (from 1.00 PM to 6 PM). The meals are served at around 10.00 AM in the morning shift schools and at 3 PM in the evening schools. The second session of the maze puzzles was administered on the same school day to the same set of children in their class room following recess. We allowed a gap of at least one class (approximately 45 minutes), post-recess, before administering the puzzles to avoid possible post-meal sluggishness in the performance of students. Hence, the average time between the two sessions was around 1.7 hours. We varied the maze puzzles and curriculum based questions between the two sessions to avoid confusing short-term memory with effort and concentration but the difficulty levels were exactly the same as in the session before recess. To summarise, two sessions of tests were conducted on the same day for the same set of children – pre-recess and post-recess – in each school.

Following the administration of the curriculum based tests in the post-recess session, the students were requested to fill-up a questionnaire on their food-intake in which they were asked to list what they had eaten before coming to school and during school hours on that day, including the school meal.[12] As before, a regular school teacher continued usual classroom activity after the experimenters departed.[13]

Within 4 to 6 months of the initial or baseline visit, as outlined above, a follow-up or endline visit was made to the same schools during which the above procedure was repeated. The tests were administered to the same grade-section at baseline and endline to generate a panel of student level data. The maze puzzles and the curriculum based questions were identical between baseline and endline, except two additional curriculum based questions (2 language and one math in both sessions) were added. The test booklets (mazes and curriculum based) did not vary by grade. In addition to the post-experiment questions, at endline we administered a detailed questionnaire on household level socio-economic characteristics to 10 randomly selected students in each school-grade.

Sample

Our sample consists of students in grades 5 (primary) and 7 (upper primary) (approximately 10 and 12 year olds, respectively) in 18 randomly sampled *Sarvodaya* schools across Delhi. *Sarvodaya* schools are well-suited for our study for several reasons. First, as pointed out above, *Sarvodaya* schools contain primary (grades 1 to 5) and upper primary grades (grades 6 to 12). This allows us to compare the effect of the cooked meals on students in primary grades (who were receiving school meals since grade 1) and upper primary grades (to whom the mandate of providing school meals was extended in 2009), holding the characteristics of the school constant. Second, as in other public schools, *Sarvodaya* schools did not charge tuition or screen students through admission tests or interviews for admission during our study period. Hence

[12] We could not administer this questionnaire in one school at the baseline, hence, the dietary information of students is available for 17 schools.
[13] During the baseline visit to the school the survey team gathered administrative records on grade level enrolment, attendance and information on school characteristics.

our sample of students should be comparable to the average public school student in Delhi. Third, since *Sarvodaya* schools are spread across all districts of Delhi our sample of students should be largely representative compared to say, schools which are located only in one municipal zone of Delhi.

We sampled students from one randomly selected section in grades 5 and 7, each, of these schools. We exclude grades 6 and 8 (upper primary grades to whom the school meals were also extended) from our study because Grade 6 students would not have received school meals for only about 3 school months at the baseline of our study (since they were receiving meals until Grade 5).[14] They may have internalised the benefits of the meal program. Second, one of the objectives of our study is to compare the performance of primary grade students to middle grades in the same schools. We chose Grade 7 (students who transitioned to receiving school meals after a gap of more than a year of completing Grade 5) as these students were closer in age to Grade 5 (students who were receiving school meals continuously since Grade 1), relative to Grade 8 students.

Timeline

We initiated our study in August 2009 with the expectation (based on communications with the DoE) of introduction of cooked meals in upper grades by the end of the calendar year 2009. However, the program was introduced in grades 6 to 8 earlier, from 29th September, 2009. By this date we had conducted tests of students and surveyed 10 of our 17 randomly sampled schools. We continued with our baseline survey in the remaining 7 schools, a week after this extension. We re-visited the schools for the endline between February and April 2010. Note that the date of visit to a school was randomly selected and the date of expansion of the program

[14] The academic year begins in April, followed by summer holidays from mid-May through June. Thus, part of the endline survey overlapped with the first month (April) of the new academic year.

(29th September, 2009) was unanticipated. Schools which were administered the tests *before* 29th September, 2009 form our treatment group while schools visited *after* this date had already begun receiving meals in grades 6 to 8. The latter form our control group of schools. Thus whether a school falls in the treatment or control group is determined exogenously by the timing of the policy change.

Table 1 summarizes the timeline of this study along with the overall sample sizes for both grades 5 and 7.

4. Data and Methodology

4.1 Data

Table 2 shows the characteristics of students in our sample using survey data and administrative records obtained from the DoE. The top panel reports the individual characteristics of Grade 7 at baseline, our main sample of interest, while the bottom panel shows the same variables for Grade 5. Columns 1 and 2 report the overall summary of student characteristics. The typical student in the Grade 7 sample was 11.8 years old, more likely to be female (67 percent of sample) with low weight (34.35 kg) and height (144.42 cm) for age. Not surprisingly, therefore, the average height-for-age Z-score of these children is -1.19 SD and BMI-for-age is -1.03 SD, suggesting that our sample of children were undernourished. They also have relatively poor learning levels (average score of our sample of students on Grade 5 curriculum based tests was 0.62 in language and 1.02 points in math, out of a maximum of 2).

In columns 3 to 6 in Table 2, we report the average characteristics of the sample by treatment status. The two groups are comparable on all observable characteristics except gender composition (the proportion of girls was higher in control schools) and math score (higher average score in control group). The observed age difference is simply due to the fact that the age of the students in the control group was recorded a few weeks after the treatment groups' at baseline. The bottom panel for Grade 5 is also comparable between treatment and control groups, except similar differences in age (which is again expected since treatment schools were visited before control schools) and math score as for Grade 7.

Based on our post-recess survey at baseline, 56.4 percent of all Grade 5 and 68 percent of Grade 7 students in the control group (to whom meals were being offered) had consumed the school meal on the day of our visit. Although nearly 95 percent of our sampled 7^{th} graders report consuming *some* breakfast at baseline, the majority had just had tea (52 percent), bread (38 percent) or milk (25 percent). Only 9-15 percent had a substantive meal of eggs and/or bread and vegetables. Approximately 30 (45) percent of children in the treatment group (control group) did not carry any lunch with them to school to eat during recess. Hence a substantive proportion of the students were coming to school without an adequate meal.

For a random subsample of children, we also obtained detailed information on their household characteristics, shown in Table A1 in Appendix B. In the top panel we summarise the household characteristics for Grade 7. 64 percent of these students' fathers either had a salaried job or were in occupations that required some skill, such as, a mechanic. 22 percent of the students' mothers were working and these families had reasonable access to public utilities in their residential areas. We find similar distribution of characteristics for Grade 5 students in the bottom panel of Table A1. Even though the small sample makes the standard *t*-tests imprecise, we note that the reported means are quite similar in the two school groups. Table 3 compares school characteristics, at baseline, by treatment status. For all indicators, treatment and control schools are similar except in the average number of Grade 5 students to whom our tests were administered in the control schools was significantly higher than in the treatment schools.

Based on the above summary statistics, we conclude that students in treatment schools were comparable to those in the control group on health and nutritional status. If anything, students in the treatment schools may have been of lower ability than those in the control group, as suggested by the difference in the math scores. However, we will account for time-invariant student characteristics by using student-fixed effects in our estimation strategy. Note that our urban sample of students are relatively less disadvantaged compared to students in rural areas of India. Hence, if school meals are likely to have greater effect on socio-economically disadvantaged students, then our estimates here would be a lower bound on the program's nation-wide impact on classroom performance.

Figure 1 shows the kernel density functions of the average maze score (averaged across pre and post meal sessions during each visit) using data pooled across each survey round for Grade 7 students. Note the insignificant difference in the distribution of the average scores of Grade 7 students between treatment and control groups at baseline. At endline, however, there is a significant rightward shift in the distribution of the scores of students in both the treatment and control group, suggesting learning effects. However, the treatment group's distribution shifts significantly further to the right at endline, relative to the control group. This suggests that the extension of the school meal program to the treatment group significantly improved their performance at endline, relative to the control group.

The above finding is mirrored in Table 4 which compares the average maze score between control and treatment group using the same pooled sample of students at baseline and endline as in Figure 1. The top panel reports mean differences for Grade 7 and the bottom panel for our placebo group, Grade 5 students, who were receiving school meals at both baseline and endline in all schools. Since the extension of the program did not impact Grade 5 we should observe insignificant mean difference-in-differences in the performance of Grade 5 students in the treatment and control schools. The difference-in-difference estimate for Grade 7 would be consistent if pre-program trends in test scores are comparable between treatment and control schools.

In column 1, the difference in the average maze score between control and treatment groups is insignificant at -0.03 and rises to a positive, but insignificant, 0.27 at endline. The difference in these differences is 0.30 and statistically significant, as shown in column 3 for Grade 7. On the other hand, the mean difference-in-difference maze score is comparatively smaller, negative and insignificant for Grade 5 (shown in the bottom panel). The improvement in performance between rounds suggest a learning effect as well as the impact on classroom performance of Grade 7 children who were offered school meals at endline due to the extension of the meal program (treatment group). While the learning effect would be valid for students in both the control and treatment schools in grades 5 and 7, the latter effect would exist only for the Grade 7 in treatment schools. The difference in performance between rounds and between treatment and control schools of 0.30 in Grade 7, can therefore be attributed to the school meal program. Our identifying assumption here is that the trends, including any learning effects, of control and treatment school students is similar. This is held up by the insignificant DID estimate reported for Grade 5 in the bottom panel of Table 4.

The analysis in Table 4 does not account for a host of observable and unobservable determinants of class room performance which could be driving the mean differences. In the following section we discuss our empirical methodology in detail.

4.2 Methodology

We use a difference-in-differences (DID) strategy in a regression framework to rigorously estimate the effect of school meals on students' classroom effort and performance. We identify the treatment and control schools on the basis of the randomly chosen date of baseline visit. Thus the timing of the policy change and the date of school visit exogenously determine whether a school falls in the treatment or control group. Since treatment status is determined at the school-level, and not by whether the students ate meals on the day of visit, we use the

Intention-to-Treat (ITT) estimator, appropriate for our context: first, given the non-universal uptake of the meal program, whether a child eats a school meal on the day of our school visit or not could be endogenous to the school meal menu on that day, whether the child ate a meal at home before school (e.g. breakfast) and other individual or school level unobservable characteristics. The ITT estimate enables us to capture the average effect of school meals on a child's classroom performance irrespective of whether she ate a school meal on the day the tests were administered since children may eat meals on one school day but not another.

More formally, our main specification is:

$$Y_{ijt} = \gamma_0 + \gamma_1 Treat_j + \gamma_2 Endline_t + \gamma_3 Treat_j \; x \; Endline_t + \gamma_4 \mathbf{X}_{\mathrm{ijt}} + \mu_{j+} \varepsilon_{ijt} \quad (1)$$

where Y_{ijt} is the maze score of student *i* in school *j* at time *t*. $Endline_t$ takes value 1 if the score is from the mazes administered at endline and 0 for baseline. The variable $Treat_j$ equals 1 if school *j* falls in the treatment group. We include baseline child characteristics such as age, gender, height-for-age Z-score and score in math and language in vector $\mathbf{X}_{\mathrm{ijt}}$. As noted earlier, uptake of the school meals was not universal. The meal uptake data of the control schools (which were serving meals at both baseline and endline) indicate considerable variation within schools across school days.

While meal consumption by individual students can directly influence their performance in mazes through the nutrition-cognition channel, there are likely to be spill-over effects on those who do not eat as well. From our interviews of the random sub-sample of students, we deduced that children had strong preferences for certain menu items. The school meal menu is fixed for each school by the meal provider with a different menu item being served every day of the week as mandated. Thus, students knew beforehand the meal item that would be served on any given day based on the day of the week. It is not surprising therefore that the menu is a good predictor of school meal take-up. This is shown in the pooled sample analysis in Table A2 in Appendix B for the control group. Regressing a binary variable that takes value 1 if a student reports consuming a school meal at time *t* (baseline/endline) on a host of possible factors that could influence meal uptake, we find that getting the single item menu (e.g. sweetened semolina) relative to two-item menu (e.g. wheat bread and vegetables) lowers the probability of students eating the meal. We, therefore, include a dummy for whether a school served a single-item menu at time *t* in equation (1).

μ_i, accounts for time-invariant, school characteristics that could be correlated with school quality and students' performance on the mazes. ε_{ijt} is the error term. Our main coefficient of interest is γ_3 which can be interpreted as the gain in performance of students in the treatment schools between the baseline and endline relative to the control group - the DID-ITT estimate.

5. Results

5.1 Impact of school meals on average maze score

Table 5 reports our main results using equation (1). The dependant variable is the average maze score of a student (averaged over pre and post recess) during a school visit. Column (1) reports the results for the pooled sample of all students who participated in the experiment either at baseline or endline, including school fixed effects as the only controls. The constant (2.21) can be interpreted as the average score of control schools at baseline, after accounting for time-invariant school characteristics. We find that the average score in treatment schools increased by 0.364 at endline, as suggested by the coefficient on the interaction term, the DID-ITT estimate of the impact of school meals. It indicates that the number of mazes solved by a student increased by 0.364 or 16.32 percent due to the school meal (at average control school score of 2.23 as shown in Table 4). In columns (2) and (3) we include controls for individual student characteristics. This reduces our sample somewhat, since we do not have baseline characteristics of all students. However, the coefficient on the interaction term continues to be significant. In column 3, in addition to student characteristics we include a dummy for whether a single-item menu was served on the day of the school visit. The point estimate is robust and close to the point estimate in column 1. In column 4, we show the results with student fixed effects which restricts the sample to only those students who participated in the experiment at baseline and endline. We observe an increase of 0.289 mazes, a 12.95 percent rise, for these students in treatment schools, comparable to the estimates in columns 1-3.

To allay any concerns about classification of schools into treatment group being selective, in column 5, we use the date of selection of a school for the first visit as an instrument for treatment status. The exact date of expansion of the program to grades 6 to 8 was unexpected and we make use of this policy shock for our analysis. Table A3 in Appendix B shows the results of our first stage regression. The coefficient on the instrumental variable (date of baseline visit) is negative and significant, suggesting that schools visited on a later date were likely to be in the control group. Our 2SLS estimate, as expected, is close to the OLS estimates.

We conduct our placebo test using Grade 5 students using the same estimation procedure reported in Table 5. The results are reported in Table A4 in Appendix B. We see no significant changes in the performance of Grade 5 students for whom there was no change in the school meal program unlike the upper grades. This suggests that there are no differential trends between the two groups of schools. Our control group of schools is, therefore, a reasonable counterfactual for the treatment group and the estimated impact on performance of Grade 7 students can be attributed to the school meal program.

5.2 Robustness

A first concern relates to attrition between baseline and endline. Of the 660 Grade 7 students present at baseline, 487 were re-tested at endline. Our attrition rate at 26.2%, is large enough to warrant concern that our estimates reported in Table 5 may be biased if the students who were less healthy or of lower ability in the treatment group were absent at endline, relative to the control group. To address this concern we first test whether the characteristics of the attriters differed by treatment status in Table A5, Appendix B. We regress observed individual characteristics at baseline - maze score, age-for-height Z-score, score in language and math - on a dummy for whether the student was present in both rounds, treatment status and the interaction of the two variables. These observables would indicate the health and ability of the child. We find that neither treatment status nor presence in both rounds is significantly correlated with these variables, as shown in Table A5. Furthermore, the interaction between treatment status and presence in both rounds is insignificant, except marginally significant in column (4), suggesting that the characteristics of students who drop out of the sample do not differ significantly by treatment status. On the contrary, those who are present in both rounds in the treatment group are likely to be less healthy (p-value>0.10, column 2) and of lower ability (p<0.10, column 4). This would bias our DID estimates downwards. We also report results of inverse probability weighting of individual observations to address attrition in Table A6 in Appendix B. Our results remain valid even when we assign greater weightage to students who left the treatment group at endline.

A second concern relates to the small number of schools or clusters in our sample. We have 18 schools in our sample and our standard errors are clustered at the school-level. Given the small number of clusters our results may be biased. We, therefore, report school-level cluster bootstrapped standard errors with 300 replications in Table 6. Each column corresponds to the OLS specifications reported in Table 5. Our standard errors are higher with the cluster bootstrap but the point estimates continue to be significant at 5% level.

We now turn to assessing whether the observed improvements in cognition varied by student or school characteristics.

5.3 Heterogeneity

To explore these gains in performance further, we analyse students' maze scores by session (i.e. pre and post recess on the same day) and by the level of difficulty of the maze. In Table 7, we report our results of this analysis using our strictest specification, controlling for individual fixed effects. In column (1) we reproduce the result for the average maze score reported in column (4) of Table 5. We then break-up this score into performance in the pre (columns 2-4) and post recess sessions (columns 5-7). The coefficient on the interaction term is columns 2 and 5 suggest that the overall gain in average performance is driven by improved performance in the post-recess session. In the post-recess session, students solved 0.309 (p<0.10) more mazes correctly compared to 0.27 (p>0.10) in the pre-recess session.

In columns 3-4 and 6-7, we further classify the mazes by the difficulty level – mazes 2 and 3 corresponded to difficulty levels 1 and 2 (easy), while the last two mazes were of difficulty level 3 and 4 (difficult), respectively. The marginally significant coefficient on the DID term in column 7 suggests that students' performance improved in terms of higher probability of solving the more difficult mazes in the sessions after the school meal (0.20 more mazes solved correctly, p<0.10). Our results, therefore, suggest that students were able to perform better on the more difficult tasks after they consumed the school meal.

Next, we analyse our results by the baseline health status of students to assess which students' performance improved due to the program extension. We construct a dummy variable 'stunted' that takes value 1 if the student's height-for-age Z score was less than -2 SD at baseline.[15] This variable is then interacted with 'endline' and 'treat' as shown in Table 8. Our main coefficients of interest 'treat x endline' again indicate that student performance improved

[15] A stunted child has a height-for-age Z-score that is at least 2 standard deviations (SD) below the median WHO Child Growth Standards. Stunting is a long-term indicator of nutritional status because it does not vary significantly by short-term variations in food consumption. We do not include weight-for-age measures because standardized growth charts are available only for children up to 5 years of age. Instead, we analyse BMI-for-age Z-scores as a short-term indicator of child health.

due to school meals in the post-recess sessions (columns 1 and 3). However, the triple interaction term 'treat x endline x stunted' is significantly negative in column 3 (but not in column 1) suggesting that our impacts are driven by students whose height-for-age was above -2 SD. Hence severely malnourished (i.e. stunted) students showed no improvement in maze scores because for them the school meal may not be a sufficient supplement for catch-up. We find similar results when we analyse the program impact by thinness or lower than -2 SD BMI-for-age in columns 4-6 in Table 8.[16] This suggests that school meals may be effective in improving classroom performance of moderately to marginally malnourished students.

5.4 Mechanism

Our results show that the consumption of school meals improved students' performance on non-curriculum related cognitive tasks that required attention and concentration in the classroom. We interpret these results as indicative of improved cognition in the short-run due to the supplementary meals attenuating fluctuations in food intake during school hours. Could school meals have led to some other impacts and thereby affected students' performance on our assigned task? We explore possible changes in factors measured at the school or student level that may have impacted students' performance, besides our proposed mechanism of classroom attention, in Table 9.

First, the availability of school meals may have improved the students' average attendance rate, which in turn may have had an impact on classroom performance. Using data on the school level attendance rate in the DID specification in column 1, we find an insignificant effect of treatment on average Grade 7 attendance rate. This result is in line with the existing literature which suggests that school meals improved attendance rates at lower grades (Grades 1-2) but not in higher grades in primary schools (Afridi, 2011). Moreover, our

[16] We find no heterogeneous impacts by students' math and language score at baseline.

maze puzzles were not curriculum based and therefore our measure of performance is unlikely to be affected by regular school attendance.

We may, however, be worried that the number of participants in our sessions in the section to which we administered the mazes may have fallen at endline, affecting performance positively in the treatment group due to less classroom disruptions. However, the number of participants in our classroom sessions were not significantly different between baseline and endline in the treatment schools vis-à-vis control (column 2, Table 9). Furthermore, any classroom behavioural changes, such as reductions in disruptions because students may be more attentive after receiving supplementary nutrition, are unlikely to explain our findings given that the tests were administered in a relatively 'controlled' environment. Hence spillover effects through changes in program uptake, do not appear to have impacted performance on our cognitive task. We also rule out gains in performance due to any systematic changes in administrative efficiency (column 3) between the two groups of schools. [17]

Second, did the school meals improve students' health and thereby affected their classroom performance directly? In columns 4-5 the coefficient on the interaction term is insignificant, suggesting that there were no improvements in students' height-for-age Z score or BMI-for-age Z score as a result of school meals. Note that the gaps between the baseline and endline varied between 4 to 6 months (including 1-2 months of school vacations). Neither was this a long enough period to result in improvements in long-term health or learning, nor was our study intended to capture these outcomes. Overall, our findings indicate that the smoothening of temporary variation in nutrient availability, rather than fundamental

[17] We analysed the impact of program extension to Grade 7 on the time spent on meal distribution during recess in column 3 of Table 9. We do not find a significant coefficient on the DID term, suggesting that schools' administrative efficiency was not impacted due to the extension of the school meal program. Instead school meals were distributed to lower and upper primary grades simultaneously. If anything, treatment schools would have more administrative learning to do and so meal distribution efficiency or time may be longer in these schools which could adversely affect instruction time and thereby possibly classroom performance of students.

improvements health indicators or regular attendance, was a channel through which classroom effort improved. Not surprisingly, therefore, students did not substitute school meals with meals from home by reducing consumption of lunch from home during recess (column 6). Hence school meals did appear to have provided supplementary nutrition to the students. These results reinforce our interpretation that the students' attention and concentration improved due to the alleviation of hunger in the classroom.

We find suggestive evidence that even in the absence of improvements in school participation or health indicators, learning can improve due to the alleviation of fluctuations in food intake. Table 10 shows that the proportion of math questions correctly answered by Grade 7 students improved by 19.6 percentage points on the two questions that were common between rounds and 18.3 percentage points for all three questions asked at endline. We do not find any significant improvements in the language score although the point estimate on the DID term is positive. We interpret these results as suggestive since the math score of students in the treatment group was significantly lower at baseline. The estimated improvement in math score could, therefore, be biased upwards.

6. Conclusions

This paper examines the impact of school meals on students' short-term performance in the classroom. We measure students' cognition by their ability to solve maze puzzles administered in a class room setting. We find that school meals enhanced students' effort and cognition and those in treatment schools improved their performance in solving maze puzzles. Performance, assessed by the number of mazes solved correctly, increased by 13% - 16% for treated students.

There are two possible mechanisms through which school meals can improve cognition. One is the health-nutrition channel- school meals lead to an improvement in health status and, thereby, cognition. The second is the hunger alleviation channel- school meals reduce hunger in classroom. Our study suggests that the increments we observed were due to the hunger alleviation mechanism. First, we see no improvement in students' health outcomes in treatment schools compared to the control group. Second, we only see improvements in scores in the puzzle-solving sessions held after the meals were distributed on a school day. We see no significant gains in maze scores in sessions held before meal distribution, something we would have expected to see if this was driven by improved health status.

Students in our sample were receiving school meals for 6 to 8 months. This may be insufficient to cause improvements in health outcomes. Additionally, we do not have any information on the actual quantities of meals consumed by students to be able to assess if these are adequate for students of this age-group. Perhaps it is not surprising then that we are unable to find any impact on stunted students' performance even though these students are more likely to consume meals. However, we are able to establish that consumption of school meals can have short term impacts on students' effort through higher attention in the classroom which may be one of the mechanisms through which learning outcomes could improve (Chakraborty and Jayaraman, 2019) even without fundamental improvements in child health. Hence the longer-term effects of school meals on learning may be even larger.

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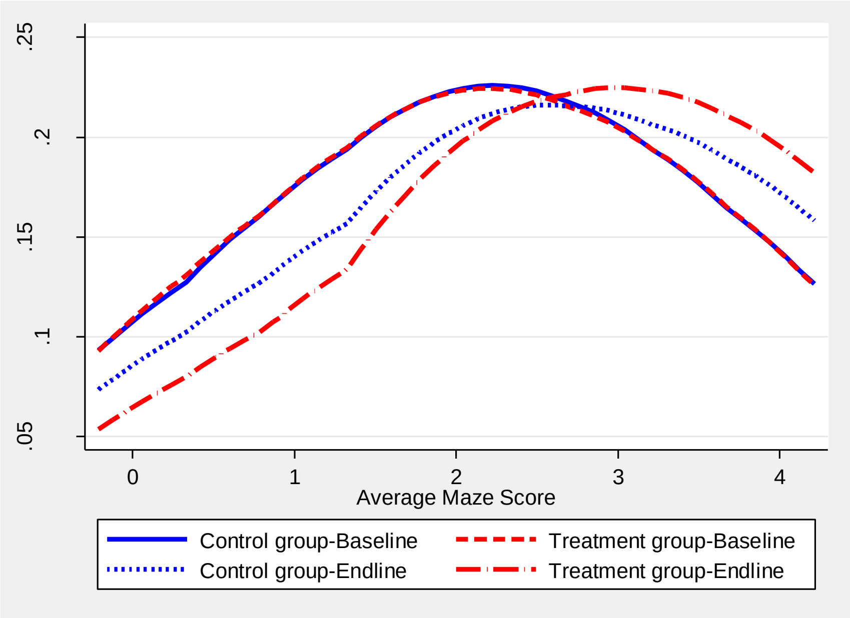
Figure 1: Kernel density of average maze score



Note: The average maze score is the number of mazes solved correctly by a student out of 4 mazes in each session, averaged across pre and post-meal session, during a school visit. The *p*-value of the Kolmogorov-Smirnov test for the null hypothesis that the treatment and control groups come from the same distribution is 0.864 at baseline and 0.041 at endline. The sample consists of Grade 7 students - 619 at baseline and 626 at endline.

Table 1: Timeline of study

Date	Round of visit	Number of schools	Number of students in Grade 5	Number of students in Grade 7
1st August-8th September, 2009	Baseline	11	358	368
29th September, 2009	PROGRAM EXTENSION: Meals introduced in upper grades of all schools			
8th October-3rd November, 2009	Baseline	7	321	251
1st February-31st April, 2010	Endline	18	557	626

Table 2: Summary of student characteristics by treatment status (baseline)

	All		Control		Treatment		Difference
	N	Mean	N	Mean	N	Mean	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)=(4)-(6)
Grade 7							
Age (years)	612	11.8	246	12.01	366	11.7	0.30***
		(1.13)		(1.17)		(1.07)	[0.09]
Female	613	0.67	249	0.76	364	0.61	0.15***
		(0.47)		(0.43)		(0.49)	[0.04]
Weight (kg)	604	34.35	245	34.52	359	34.22	0.30
		(7.56)		(7.53)		(7.60)	[0.63]
Height (cm)	607	144.42	248	144.95	359	144.07	0.87
		(8.901)		(9.06)		(8.79)	[0.73]
BMI	604	16.31	245	16.28	359	16.33	-0.06
		(2.51)		(2.46)		(2.55)	[0.21]
Height for age Z-score	600	-1.19	243	-1.27	357	-1.14	-0.12
		(1.12)		(1.23)		(1.20)	[0.10]
BMI for age Z-score	597	-1.03	240	-1.07	357	-1.02	-0.07
		(0.04)		(0.07)		(0.06)	[0.09]
Average score in language	619	0.62	251	0.59	368	0.64	-0.06
		(0.41)		(0.39)		(0.43)	[0.03]
Average score in math	619	1.02	251	1.15	368	0.94	0.22***
		(0.55)		(0.59)		(0.51)	[0.04]
Grade 5							
Age (years)	669	9.34	352	9.41	317	9.26	0.25***
		(0.72)		(0.72)		(0.72)	[0.07]
Female	676	0.58	356	0.55	320	0.62	-0.07
		(0.49)		(0.50)		(0.49)	[0.04]
Weight (kg)	546	25.28	228	25.39	318	25.21	0.18
		(5.48)		(5.25)		(5.66)	[0.48]
Height (cm)	548	129.93	230	130.13	318	129.79	0.34
		(6.99)		(7.01)		(6.99)	[0.61]
BMI	546	14.82	228	14.86	318	14.82	0.06
		(2.08)		(1.96)		(2.16)	[0.18]
Height for age Z-score	543	-1.26	227	-1.33	316	-1.22	-0.11
		(0.99)		(0.96)		(1.02)	[0.09]
BMI for age Z-score	541	-1.12	225	-1.12	316	-1.12	-0.00
		(0.048)		(0.068)		(0.068)	[0.09]
Average score in language	679	0.45	358	0.48	321	0.42	0.05
		(0.37)		(0.37)		(0.38)	[0.03]
Average score in math	679	0.89	358	1.04	321	0.74	0.31***
		(0.56)		(0.59)		(0.48)	[0.04]

Notes: Data on age and gender are from the administrative records of the Directorate of Education. Age is missing if date of birth is either not recorded/incorrectly recorded. Heights and weights missing for 2 grade-sections. Z-scores calculated using WHO standards. Math and language score is out of maximum score of 2. Standard deviations in parentheses. Standard error of differences in square brackets. * significant at 10% ** 5% and *** 1%.

Table 3: Summary of school characteristics by treatment status (baseline)

	Control (N=7)	**Treatment (N=11)**
	(1)	(2)
Primary grades are co-ed	0.86	0.64
	(0.143)	(0.152)
Upper primary grades are co-ed	0.14	0.36
	(0.143)	(0.152)
Number of participants in experiment in Grade 5	**51.14**	**29.18**
	(8.738)	**(3.352)**
Number of participants in experiment in Grade 7	39.53	39.25
	(0.519)	(0.454)
Attendance rate in Grade 5	0.89	0.84
	(0.023)	(0.040)
Attendance rate in Grade 7	0.84	0.81
	(0.029)	(0.021)
Proportion passing Grade 10	86.15	87.80
	(2.973)	(2.614)
Recess duration (in minutes)	24.29	22.27
	(2.020)	(1.408)

Notes: Number of participants is the number of students who took our tests in a grade-section at baseline. Using enrolment data are from the administrative records of the Directorate of Education, attendance is measured as the total number of students across all sections in a grade who were present on the date of baseline visit divided by the total number of students enrolled in that grade. 1 school in the treatment group did not have Grade 7. All schools had a toilet and access to drinking water. Significantly different characteristic in bold (p<0.10). Standard errors in parentheses.

Table 4: Average individual performance

	Treatment status	Grade 7		
		Baseline	**Endline**	**Difference**
		(1)	(2)	(3)=(2) – (1)
(1)	Control	2.23	2.56	0.33
		(1.178)	(1.279)	[0.611]
		[N=251]	[N=264]	
(2)	Treatment	2.20	2.83	0.63
		(1.192)	(1.216)	[0.429]
		[N=368]	[N=362]	
(2) – (1)	Difference	-0.03	0.27	0.30**
		[0.293]	[0.294]	[0.121]
		Grade 5		
		(1)	(2)	(3)=(2) – (1)
(1)	Control	1.73	2.41	0.69
		(1.201)	(1.226)	[0.392]
		[N=358]	[N=208]	
(2)	Treatment	1.51	1.99	0.48
		(1.198)	(1.247)	[0.358]
		[N=321]	[N=349]	
(2) – (1)	Difference	-0.22***	-0.42**	-0.21
		[0.251]	[0.255]	[0.208]

Notes: Mean student scores in mazes averaged over pre and post meal sessions in each round. The top panel shows the mean scores for Grade 7 while the bottom panel shows the same for Grade 5. Standard deviations in parenthesis. Standard errors, clustered at the school level, in square brackets. *significant at 10% ** 5% and *** 1%.

Table 5: Impact of school meals on individual performance

	OLS				2SLS
	(1)	(2)	(3)	(4)	(5)
Treatment x Endline	0.364***	0.245*	0.352**	0.289**	0.304***
	(0.138)	(0.140)	(0.132)	(0.128)	(0.122)
Endline	0.301***	0.471***	0.413***	0.460***	0.452***
	(0.104)	(0.100)	(0.096)	(0.087)	(0.085)
Constant	2.210***	2.664***	2.732***	2.298***	2.300***
	(0.034)	(0.569)	(0.564)	(0.042)	(0.042)
Individual characteristics	No	Yes	Yes	-	Yes
Single-item menu dummy	No	No	Yes	Yes	Yes
School FE	Yes	Yes	Yes	-	Yes
Individual FE	No	No	No	Yes	Yes
Number of observations	1245	1080	1080	974	974
Number of students	670	660	660	487	487
R-square	0.209	0.312	0.320	0.837	

Note: The dependent variable is the number of correctly solved mazes, averaged across pre and post recess, in each round, by a student in Grade 7. Individual controls include gender, age, height-for-age Z score, score in math and score in language test at baseline. Columns 1 shows the results for the pooled sample of students. Columns 2 and 3 show the results for the sample of students who were present at baseline. Columns 4 and 5 show the results for students present at both baseline and endline. Column 5 shows the results 2SLS estimation where treatment status is instrumented by the date of first visit (baseline) to the school. Standard errors, clustered at school level, in parentheses. *significant at 10% ** 5% and *** 1%.

Table 6: Impact of school meals on individual performance (bootstrapped std. errors)

	(1)	(2)	(3)	(4)
Treatment x Endline	0.364	0.245	0.352	0.289
	[0.149]**	[0.148]*	[0.138]**	[0.135]**
Endline	0.301	0.471	0.413	0.460
	[0.110]**	[0.103]***	[0.106]***	[0.096]***
Constant	2.210	2.664	2.732	2.298
	[0.133]***	[0.522]***	[0.535]***	[0.155]**
Individual characteristics	No	Yes	Yes	-
Single-item menu dummy	No	No	Yes	Yes
School FE	Yes	Yes	Yes	-
Individual FE	No	No	No	Yes
Number of observations	1245	1080	1080	974
Number of students	670	660	660	487
R-square	0.221	0.289	0.293	0.822

Note: This table shows the results of Columns 1, 2, 3 and 4 of Table 5 with cluster bootstrapped standard errors at the school-level, with 300 replications, in square brackets. *significant at 10% ** 5% and *** 1%.

Table 7: Impact of school meals on individual performance, by session

	All Sessions	Pre-recess Sessions			Post-recess Sessions		
	All	**All**	**Easy**	**Difficult**	**All**	**Easy**	**Difficult**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treatment x Endline	0.289**	0.270	0.123	0.147	0.309*	0.113	0.196*
	(0.128)	(0.212)	(0.092)	(0.148)	(0.160)	(0.090)	(0.107)
Endline	0.460***	0.537***	0.173**	0.364***	0.384**	0.0911	0.293***
	(0.087)	(0.167)	(0.087)	(0.113)	(0.133)	(0.064)	(0.079)
Constant	2.298***	2.146***	1.420***	0.727***	2.450***	1.571***	0.880***
	(0.042)	(0.080)	(0.036)	(0.049)	(0.040)	(0.021)	(0.026)
Number of observations	1948	974	974	974	974	974	974
R-square	0.145	0.225	0.111	0.197	0.165	0.0522	0.181

Note: The dependent variable is the number of correctly solved mazes in each session in a round. This ranges from 0 to 4 in Column 1, 2 and 5 and 0 to 2 for column 3, 4, 6 and 7. The panel is balanced at the child level (487 students) and includes the single-item menu dummy and individual-fixed effects (specification 4 in Table 5). Column 1 shows the results for all rounds and sessions taken together - 4 observations per student while columns 2 to 7 split this by sessions - 2 observations per student. Standard errors, clustered at school level, in parentheses. * significant at 10% ** 5% and *** 1%.

Table 8: Impact of school meals on individual performance, by baseline health status

	All Sessions	Pre-recess	Post-recess	All Sessions	Pre-recess	Post-recess
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment x Endline	0.353**	0.262	0.444**	0.298*	0.236	0.361*
	(0.144)	(0.217)	(0.175)	(0.142)	(0.214)	(0.187)
Endline	0.454***	0.575***	0.333**	0.455***	0.565***	0.345**
	(0.105)	(0.168)	(0.144)	(0.094)	(0.163)	(0.156)
Treatment x Endline x Stunted	-0.295	0.020	-0.610**			
	(0.25)	(0.334)	(0.274)			
Endline x Stunted	0.040	0.152	0.231			
	(0.215)	(0.253)	(0.195)			
Treatment x Endline x Thin				-0.042	0.169	-0.253
				(0.210)	(0.221)	(0.248)
Endline x Thin				0.024	-0.131	0.179
				(0.180)	(0.180)	(0.200)
Constant	2.292***	2.145***	2.440***	2.297***	2.150***	2.445***
	(0.038)	(0.080)	(0.040)	(0.0416)	(0.0785)	(0.0366)
Number of observations	1948	974	974	1948	974	974
R-square	0.147	0.227	0.174	0.068	0.087	0.056

Note: The dependent variable is the number of correctly solved mazes in each session in a round. The sample is the balanced individual panel of 487 students. The regressions include the single-item menu dummy and individual fixed effects. Column 1 and 4 show the results for all rounds and sessions taken together - 4 observations per student while columns 2, 3, 5 and 6 split this by sessions - 2 observations per student. Students are categorised as stunted if their baseline height-for-age Z-score is less than -2 SD. Students are categorised as thin if their baseline BMI-for-age Z-score is less than -2 SD. Standard errors, clustered at school level, in parentheses. * significant at 10% ** 5% and *** 1%.

Table 9: Impact of school meals on student and school level characteristics at endline

	School level characteristics			Student level characteristics		
	Attendance rate	**Number of participants in experiment**	**Meal distribution time**	**Height-for-age Z-score**	**BMI-for-age Z-score**	**Ate lunch brought from home**
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment x Endline	0.087	-2.289	4.286	0.016	0.071	-0.040
	(0.150)	(4.112)	(18.500)	(0.044)	(0.139)	(0.198)
Endline	-0.234**	1.857	0.714	0.033	0.023	0.030
	(0.104)	(2.787)	(17.160)	(0.035)	(0.122)	(0.106)
Constant	0.821***	29.52***	41.18***	-1.223***	-1.039***	0.624***
	(0.036)	(1.058)	(4.077)	(0.010)	(0.031)	(0.054)
Fixed effects	School	School	School	Individual	Individual	Individual
Single-item menu dummy	No	No	No	No	No	No
Number of students	-	-	-	486	486	487
Number of schools	16	17	17	17	17	17
R-square	0.701	0.894	0.812	0.986	0.934	0.577

Note: Attendance data were obtained from the administrative records of the Directorate of Education. This is missing for one school. Attendance rate is calculated as the number of students present in all sections of a grade over the number of students enrolled in the grade on the day of survey. Number of students who participated in the maze sessions (column 2) and the time spent in minutes by schools to distribute meals to all grades (column 3) were obtained through our school surveys at baseline and endline. Student characteristics were obtained from our student survey data. Height and BMI data is missing for one student. Standard errors, clustered at school level, in parentheses. *significant at 10% ** 5% and *** 1%.

Table 10: Impact of school meals on math and language test scores at endline

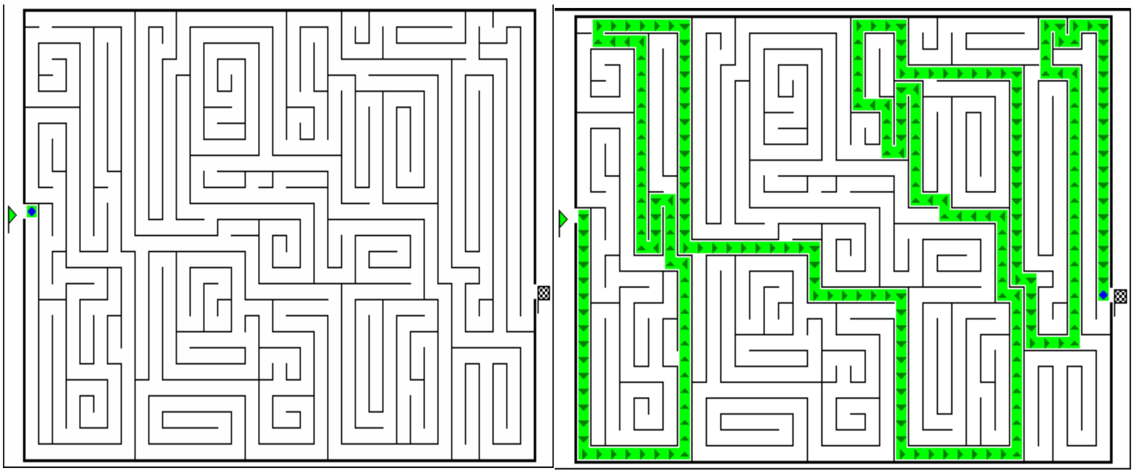
	Proportion correctly answered			
	Common questions		All questions	
	Math	Language	Math	Language
	(1)	(2)	(3)	(4)
Treatment x Endline	0.196***	0.029	0.183***	0.035
	(0.066)	(0.039)	(0.057)	(0.036)
Endline	0.005	0.183***	-0.025	0.280***
	(0.033)	(0.013)	(0.024)	(0.011)
Constant	0.536***	0.327***	0.535***	0.332***
	(0.014)	(0.007)	(0.011)	(0.007)
Individual FE	Yes	Yes	Yes	Yes
Single-item menu dummy	Yes	Yes	Yes	Yes
Number of observations	1948	1948	1948	1948
Number of students	487	487	487	487
R-square	0.068	0.126	0.049	0.312

Notes: The dependent variables are the number of questions that a student was able to answer correctly over the total number of questions in each subject. There were 2 language and 2 math questions in each session at baseline. There were 4 language and 3 math questions in each session at endline. Columns 1 and 2 show the change in proportion of correct answers when the denominator is the number of common questions, i.e, 2 at baseline and endline. Columns 3 and 4 show the change in proportion of correct answers when the denominator is the number of total questions, i.e. 2 in both subjects at baseline and 4 and 3 for language and math, respectively, at endline. Standard errors, clustered at school level, in parentheses. *significant at 10% ** 5% and *** 1%.

FOR ONLINE PUBLICATION

Appendix A: Experiment Details

Figure A1: Sample maze puzzle with solution



Experiment Instructions

Please make sure the children are all seated at their desks with adequate space between each other. Please handout pencils and erasers to the students. Please follow the script closely for administering the test booklets.

Hello, children! Today we will play some fun puzzles. Each of you will get a booklet such as this one*. [Hold a booklet up].*

In this there are 5 maze puzzles. You will have to trace the path from the end with the triangular flag to the end with the square flag. You cannot cross over the 'walls' of the puzzle. You will get eight minutes to solve 5 puzzles. You must start from maze 1, then 2, 3,4 and 5. Consider the first maze as a practice maze. You must try and attempt all mazes. If you are unable to solve one maze, do not waste time on it- move to the next one. Let me show you how to solve a puzzle.
[Take the example maze and with a pencil solve it, holding it up. Then distribute the booklets. After all booklets have been distributed, ask students to fill in their names and roll numbers. Once you are sure all students have done this, you can start the session].

You have 8 minutes to solve all the puzzles. Please start now.
8 minutes are now over. Please close your booklets and put the pencil and eraser away.
[Collect the puzzle booklets]

Now we will give you another booklet with Hindi, English and Math questions. You will get 10 minutes to solve these. You must try and attempt all questions. If you are unable to solve one question, do not waste time on it- move to the next one. Let me take you over the examples on how to answer the questions.

[Discuss the examples in the booklet. Then distribute the booklets. After all booklets have been distributed, ask students to fill in their names and roll numbers. Once you are sure all students have done this, you can start the session].

You have 10 minutes to solve these 5 questions. Please start now
10 minutes are now over. Please close your booklets and put the pencil and eraser away.
[Collect the booklets]
After you have collected the booklets, please administer the post-survey questionnaire that students will fill at their desks. Read aloud each question so that students understand it.

Before taking the height and weight measurements, please ask students to take off their shoes but not socks.

Appendix B: Additional Analysis

Table A1: Student characteristics by treatment status

	All		Control		Treatment		Difference
	N	Mean	N	Mean	N	Mean	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)=(4)-(6)
Grade 7							
Father's occupation							
Salaried employee	124	0.26	51	0.29	73	0.23	0.06
		(0.45)		(0.46)		(0.42)	(0.08)
Skilled worker	124	0.38	51	0.32	73	0.43	-0.11
		(0.49)		(0.48)		(0.50)	(0.09)
Businessman	124	0.17	51	0.21	73	0.15	0.06
		(0.35)		(0.39)		(0.35)	(0.07)
Unskilled worker	124	0.12	51	0.09	73	0.14	-0.04
		(0.32)		(0.29)		(0.38)	(0.06)
Mother is employed	127	0.22	51	0.24	76	0.21	0.02
		(0.42)		(0.42)		(0.41)	(0.07)
Owner-Occupied Home	129	0.69	52	0.71	77	0.68	0.03
		(0.46)		(0.46)		(0.45)	(0.08)
Water Connection at Home	129	0.86	52	0.83	77	0.88	-0.05
		(0.32)		(0.38)		(0.30)	(0.05)
Grade 5							
Father's occupation							
Salaried employee	159	0.31	58	0.31	101	0.32	-0.01
		(0.46)		(0.47)		(0.47)	(0.08)
Skilled worker	159	0.42	58	0.43	101	0.42	0.02
		(0.49)		(0.50)		(0.50)	(0.08)
Businessman	159	0.13	58	0.10	101	0.15	-0.05
		(0.33)		(0.31)		(0.36)	(0.06)
Unskilled worker	159	0.09	58	0.12	101	0.08	0.04
		(0.29)		(0.33)		(0.27)	(0.05)
Mother is employed	167	0.22	59	0.22	108	0.23	-0.01
		(0.42)		(0.42)		(0.42)	(0.07)
Owner-Occupied Home	167	0.69	59	0.66	108	0.71	-0.05
		(0.46)		(0.48)		(0.45)	(0.07)
Water Connection at Home	167	0.90	59	0.86	108	0.93	-0.06
		(0.29)		(0.35)		(0.26)	(0.05)

Note: Sub-sample of 10 students in each school interviewed at endline. Standard errors in parentheses. *significant at 10% ** 5% and *** 1%.

Table A2: Determinants of students' school meal uptake (control schools)

	All	Grade 7	Grade 5
	(1)	(2)	(3)
Single-item Menu	-0.341***	-0.235***	-0.463***
	(0.010)	(0.007)	(0.020)
Score in mazes at baseline	-0.011	-0.018	-0.022
	(0.011)	(0.012)	(0.018)
Height-for-age Z score at baseline	-0.029	-0.055*	0.001
	(0.015)	(0.026)	(0.022)
Age at baseline	-0.001	-0.001	-0.001
	(0.003)	(0.002)	(0.003)
Average language score at baseline	-0.042	-0.025	-0.091
	(0.034)	(0.015)	(0.093)
Average math score at baseline	0.030	0.047	0.126
	(0.076)	(0.110)	(0.098)
Constant	0.921**	0.861**	1.027**
	(0.332)	(0.291)	(0.371)
Number of observations	1676	890	786
R-square	0.138	0.231	0.235

Note: The student sample is from control schools, i.e. the schools that were providing school meals to both grades at baseline and endline. The dependent variable takes value 1 if a student reports consuming school meals at endline and 0 if not. Standard errors, clustered at school level, in parentheses. *significant at 10% ** 5% and *** 1%.

Table A3: First-stage regression

	Treatment
Date of baseline x Endline	-0.014***
	(0.001)
Endline	262.67***
	(17.389)
Constant	0.013***
	(0.024)
Individual FE	Yes
Single-item menu dummy	Yes
Number of observations	974
F-stat (3, 954)	37.10
p-value of F-stat	0.000

Note: The first-stage regression corresponds to the 2SLS results reported in column 5 in Table 5. The dependent variable equals 1 if the school was assigned to the treatment group and 0 otherwise. Standard errors, clustered at school level, in parentheses. * significant at 10% ** 5% and *** 1%.

Table A4: Impact of school meals on performance of Grade 5 students

	(1)	(2)	(3)	(4)
Treatment x Endline	-0.120	-0.213	-0.218	-0.097
	(0.192)	(0.167)	(0.159)	(0.167)
Endline	0.628***	0.851***	0.845***	0.767***
	(0.169)	(0.146)	(0.130)	(0.146)
Constant	1.612***	-0.24***	-0.221***	1.578***
	(0.039)	(0.056)	(0.532)	(0.056)
Individual characteristics	No	Yes	Yes	-
Single-item menu dummy	No	No	Yes	Yes
School FE	Yes	Yes	Yes	-
Individual FE	No	No	No	Yes
Number of observations	1236	958	958	852
R-square	0.161	0.263	0.262	0.084

Note: The dependent variable is the number of correctly solved mazes, averaged across pre and post recess, in each round, by a student in Grade 5. Individual controls include gender, age, height-for-age Z score, score in math and score in language test at baseline. Columns 1 shows the results for the pooled sample of students. Columns 2 and 3 show the results for the sample of students who were present at baseline. Column 4 shows the results for students present at both baseline and endline. Standard errors, clustered at school level, in parentheses. *significant at 10% ** 5% and *** 1%.

Table A5: Attrition of students present at baseline

	Maze score	Height-for-age Z score	Language score	Math score
Treatment	-0.104	0.288	0.039	-0.042
	(0.380)	(0.231)	(0.107)	(0.117)
Present in both rounds	-0.049	0.046	-0.023	0.190*
	(0.191)	(0.190)	(0.062)	(0.067)
Treatment x Present in both rounds	0.092	-0.206	0.023	-0.217*
	(0.283)	(0.265)	(0.076)	(0.090)
Constant	2.271***	-1.306***	0.604***	1.000***
	(0.337)	(0.182)	(0.079)	(0.082)
Number of observations	619	600	619	619
R-square	0.01	0.01	0.01	0.04

Note: 'Present in both rounds' is a binary variable which takes value 1 if a student is present in both baseline and endline and 0 if they are present at baseline but not at endline. The dependent variables are measured at baseline. The data structure is, therefore, cross-sectional and the sample comprises of 619 students of Grade 7. Standard errors, clustered at school level, in parentheses. * significant at 10% ** 5% and *** 1%.

Table A6: Inverse probability weighted average treatment effect

	All Sessions	Pre-recess Sessions	Post-recess Sessions
	(1)	(2)	(3)
ATE	0.165*	0.061	0.254*
	(0.095)	(0.111)	(0.138)
Control Mean	2.743***	2.753***	2.745***
	(0.081)	(0.097)	(0.121)

Notes: This table shows the inverse probability weighted treatment effect on average, pre-meal and post-meal sessions maze scores of 480 Grade 7 students for whom all baseline characteristics are available. The treatment assignment model is estimated by students' maze score at baseline, gender, baseline height-for-age Z-score, baseline score in math, baseline score in language. The predicted probabilities of treatment assignment are then used as weights to account for observable differences between the treatment and control samples. Weighted control means are provided. As observed, the weighted control means are greater than the unweighted means reported in Table 4. Robust standard errors are in parentheses.
* significant at 10% ** 5% and ***1%.