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by

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Material Incentive Motivation and Working Memory Performance of Kindergartners: A Large-Scale Randomized Controlled Trial*

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Abstract

This paper investigates the effect of material incentive motivation on the working memory performance of kindergartners using a large-scale randomized controlled trial covering 7,123 children from 19 provinces of Thailand. This study measures working memory of young children using the digit span task. The first finding is that material incentive motivation raises the working memory performance of young children ($p < 0.05$) but the impact is not practically significant (less than 4 percents of the mean of the control group). The second one is that young children with different background characteristics respond to material incentive motivation uniformly except with respect to child age. The third finding is that school readiness is the most predictive variable for the working memory performance of young children.

Keyword: working memory; material incentive motivation; extrinsic motivation; early childhood; school readiness; skill measurement

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JEL Code: C93; I21; I25; O15.

Highlights

- Material incentive motivation raises the working memory performance of young children but the impact is not practically significant.
- Young children with different background characteristics respond to material incentive motivation uniformly.
- School readiness is the most predictive variable for the working memory performance of young children.

1 Introduction

Working memory capacity is an important cognitive domain for the academic success of children (e.g., Bergman Nutley and Söderqvist, 2017; Maehler and Schuchardt, 2016; Smolak et al., 2020). The literature has provided strong evidence showing that kindergarten age is an important period for working memory development (Diamond, 2012; Roman et al., 2014; Gray et al., 2017; Spencer, 2020). Neuroscience research has revealed that the prefrontal cortex which is the main area of working memory and cognitive function develop rapidly during early childhood (Moriguchi and Hiraki, 2013; Uytun, 2018). Recent research has also shown that the working memory performance at kindergarten age has a predictive power for math and reading achievements in elementary school, and young children with working memory difficulties are at high risk of academic failure (e.g., Sabol and Pianta, 2012; Gathercole et al., 2016; Imal et al., 2018; Vandenbroucke et al., 2017).

Since working memory is the capacity to hold, update and actively manipulate information in a person's mind through three processes: encoding, maintenance, and retrieval, working memory performance depends on personal perception and processing ability of an individual (e.g., Baddeley, 2010; Diamond, 2013; Garon et al., 2008). On the other hand, an incentive motivation can potentially affect personal perception and processing ability through an activation of brain function of reward system (e.g., Szatkowska et al., 2008; Matyjek et al., 2020). Previous research has shown that the amount of incentive affects on the working memory performance of adults and children with Attention Deficit Hyperactivity Disorder (ADHD). Adults and ADHD children performed significantly better in a complex or multi-phased working memory task, such as corci's block tapping, when they were incentivized with a higher reward (e.g., Shiels et al., 2008; Sanada et al., 2013; Dovis et al., 2012). To sum up, most previous studies confirmed that incentive motivation can improve the working memory performance of adults and ADHD children but, not there is not much evidence that it does so with young children. In addition, several studies in economics of education have shown that financial incentives do not seem to have a practical significant impact on secondary and high school student achievements (e.g., Fryer Jr, 2011; Bettinger, 2012; Gneezy et al., 2019). Therefore, it is interesting to study whether material incentive motivation can affect cognitive performance of kindergarten students.

To the best of our knowledge, this paper is the first to quantify the impact of material incentive motivation on working memory performance in kindergartners using a large-scale randomized controlled trial. Moreover, with rich information from the survey data, our analysis controls for various individual background characteristics of children, including child age, child gender, school readiness, attention skill, an indicator of being a child with special needs, household wealth, and caregiver education. These controls are chosen based on previous research. Several studies have shown that child attention and school readiness are highly correlated with the working memory performance of young children (Bergman Nutley and Söderqvist, 2017; Maehler and Schuchardt, 2016; Smolak et al., 2020). Children from lower socioeconomic status (measured by wealth and parental education) are more likely to perform poorer in a working memory assessment, such as digit span memory task (e.g., John et al., 2019; Piccolo et al., 2016). Another key contribution of this paper is to investigate whether young children with different background characteristics (i.e., gender, school readiness, child attention, an indicator of being a child with special need, wealth index and caregiver education) respond to material incentive motivation heterogeneously or not.

The remainder of this paper is organized as follows. Section 2 describes data sources, testing procedure and measurement of key variables. Statistical analysis is presented in section 3. Section 4 presents descriptive statistics, main results, heterogeneous effects and robustness checks. Discussion and conclusion are in section 5 and section 6, respectively.

2 Method

2.1 Data Source and Participants

The data for this study come from the 2020 Thailand school readiness survey (TSRS2020), operated by the Research Institute for Policy Evaluation and Design (RIPED) with the financial support from the Equitable Education Foundation (EEF). The survey covered 19 out of 77 provinces across all four regions of Thailand: North (Chiang Rai, Lamphun, Lampang and Phrae); Northeast (Udon Thani, Khon Kaen, Roi Et, Amnat Charoen and Surin); Central (Lop Buri, Pathum Thani, Samut Sakhon, and Chachoengsao); South (Phatthalung, Satun, Songkhla, Pattani, Yala, and Narathiwat). See figure 1 for the map of surveyed provinces. The survey was conducted between January and March 2020, before COVID-19 could affect schooling in Thailand.[1]

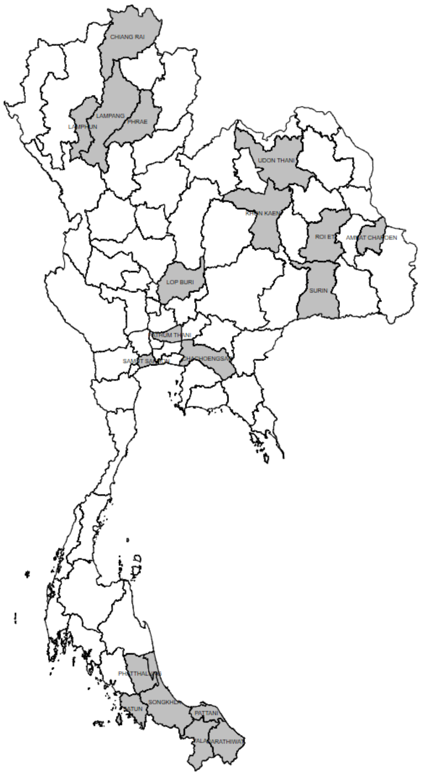

Figure 1: Map for 19 provinces surveyed in the 2020 Thailand school readiness survey.

The TSRS2020 employed a stratified random sampling based on province, district, school size, and classroom (figure 2). First, 19 out of 77 provinces were chosen based

[1]See Kilenthong et al. (2022) for an analysis of learning loss due to COVID-19 pandemic in Thailand using the 2021 Thailand school readiness survey (TSRS2021) collected in 2021.

mainly on operational reasons. The district of each province was classified into 5 groups ordered by the poverty map index, except Samut Sakhon[2]. The first group was the central district (called Amphoe Mueang in Thai). The rest were ranked based on poverty map index, generated by the office of the National Economic and Social Development Board in 2015, and divided into four groups with an equal number of districts whenever possible. Then, for each district, schools were ranked and randomly chosen based on school size: four small schools (less than the 64th percentile); two medium schools (more than the 64th but less than the 86th percentile); and one large school. For each small and medium schools, one classroom was randomly chosen while two classrooms were chosen for large schools. Finally, 15 students from each classroom were randomly invited to participate in this study. If there were less than 15 students in the classroom, all the students were included. Additional small school would be added into the sample until the total number of sampled students in each province was no less than 490.

The total number of sampled students in TSRS2020 is 9,510 kindergarten (50 to 144 months old). Unfortunately, around 25% of children could not identify all ten basic numbers (zero to nine) which is a prerequisite of the digit span task. So, only 7,123 children could perform the task. To avoid an influence of age outliers, we focus mainly on the sample of students aged between 69-84 months old[3] (6,789 students). In addition, significant number of samples (1,793 students) were dropped when more covariates are added into the analysis. Excluding samples with relevant missing data leads to the main sample of 4,996 kindergartners.

2.2 Measures

Assessment tools and questionnaire of the TSRS2020 are based primarily on the Measure of Development and Early Learning (MODEL) under the Measuring Early Learning and Quality and Outcomes (MELQO), which is a collaboration of UNESCO, World Bank, Brookings Institution and UNICEF (UNICEF, 2012). These instruments were designed

[2]Samut Sakhon has only three districts, all of which were chosen automatically.

[3]Most of relatively old children (older than 84 months old) were migrant children from neighboring countries and most of relatively young children (younger than 69 months old) were from mixed-age classrooms, which are quite common in rural Thailand. Fortunately, they were only a small fraction of our sample. We had to drop only 141 children older than 84 months old and 193 children younger than 69 months old in this step.

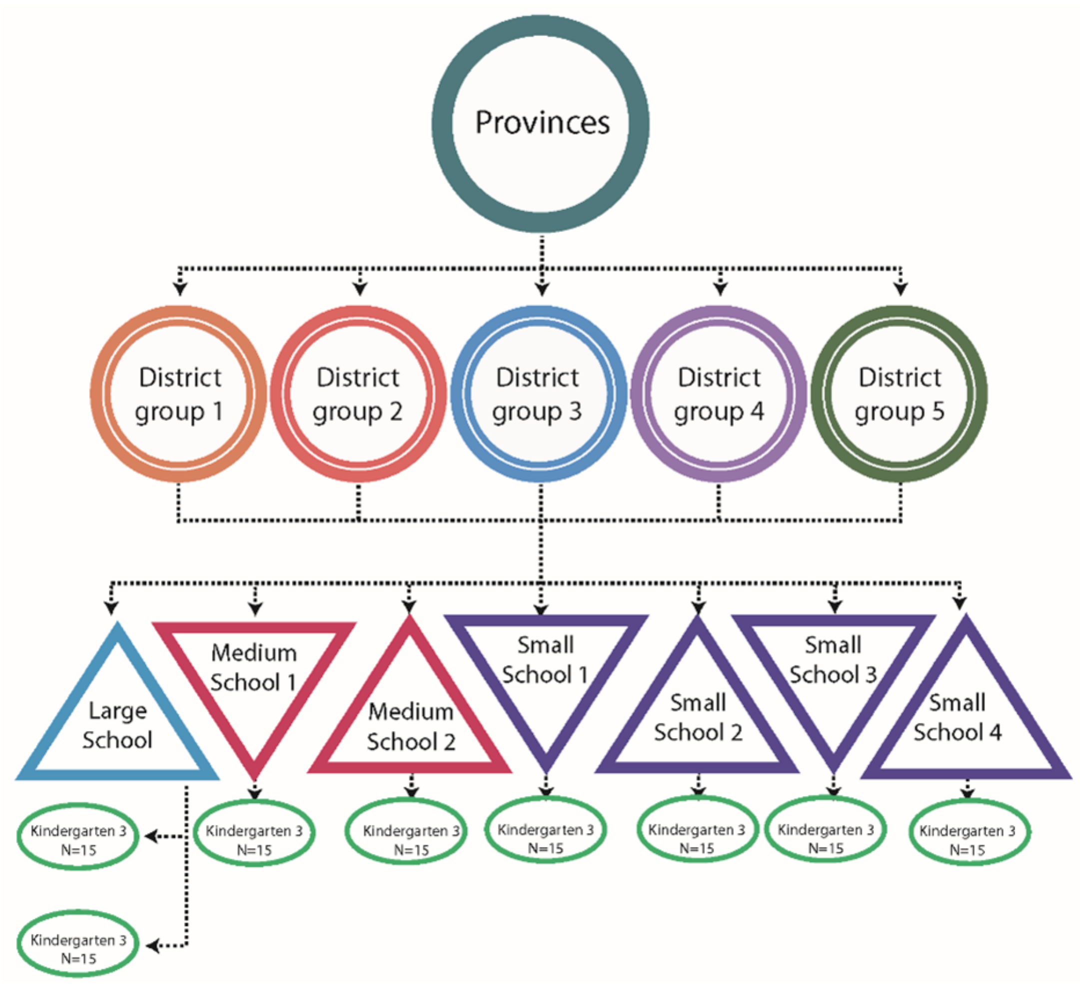

Figure 2: The diagram of the stratified random sampling in this study.

to be implementable at scale and feasible for use in low and middle income countries. In this survey, direct assessment tools were used to assess working memory and school readiness of children, while parent and teacher questionnaires were used to assess children skills such as attention and social-emotional skills, and to collect child and household characteristics such as an indicator of being a child with special needs (henceforth, special-needs), household wealth index, and caregiver's education.

2.2.1 Digit Span Memory Task and Randomized Material Incentive Motivation

The digit span task was used to measure the working memory capacity (Wechsler, 2012; Guo et al., 2018). Each participant will be presented with a sequence of numbers for ten seconds and must wait for another ten seconds before repeating the same sequence back to the examiner in order (forward span) or reversed order (backward span). There are two trials for each number of digits, and each participant has to perform both trials. The task begins with two digits and will add an additional digit whenever the participant answers correctly for one or both trials. The task will stop when the participant answers incorrectly for both trials or it reaches the maximum number of digits, which is set at ten digits.[4] The final number of digits that the participant can repeat correctly for forward and backward tasks were collected. The main outcomes are not only forward and backward digit spans but also total digit span, which is the sum of forward and backward digit spans.

In order to study the impact of material incentive motivation, we employed a randomized experiment approach. Each participant was randomized into two groups: incentivized and non-incentivized, via an online computer algorithm. At the beginning of the task, each participant in the non-incentivized group would learn about the rule of the task only while the incentivized group would also be told that "In the next game, you will receive rewards, equal to the number of total digits you can answer correctly. So please do your best." Once finished, the incentivized group would received rewards of their choice, sweets or stationery (e.g., marshmallow, jelly, biscuit, pencil, eraser, and pencil sharpener) up to the number of total digits while the non-incentivized would receive no rewards from this particular task.

2.2.2 School Readiness (SR)

We measure school readiness (SR) of a kindergarten student using test scores of language/literacy and mathematics/numeracy domains. There are four subdomains for language including Thai alphabet identification, English alphabet identification, listening comprehension and receptive spatial vocabulary, and five subdomains for mathematics including number identification, producing a set, number comparison, simple addition and mental transformation. There are 37 individual items/questions in total (19 for language and 18 for mathematics). Each item will be assigned a score of one if answered correctly and zero otherwise. The assessment took approximately 20 minutes. The assessment is done by trained examiners with the support of a web application system. The percentage of correct answers (a full score equals to 100) is used for data analysis. Figure 3 show kernel densities of school readiness for both incentivized and non-incentivized

[4] None of participants in this study reached the maximum limit.

groups. They are visually indistinguishable and statistically indifferent from each other and see table 1 for a formal test.

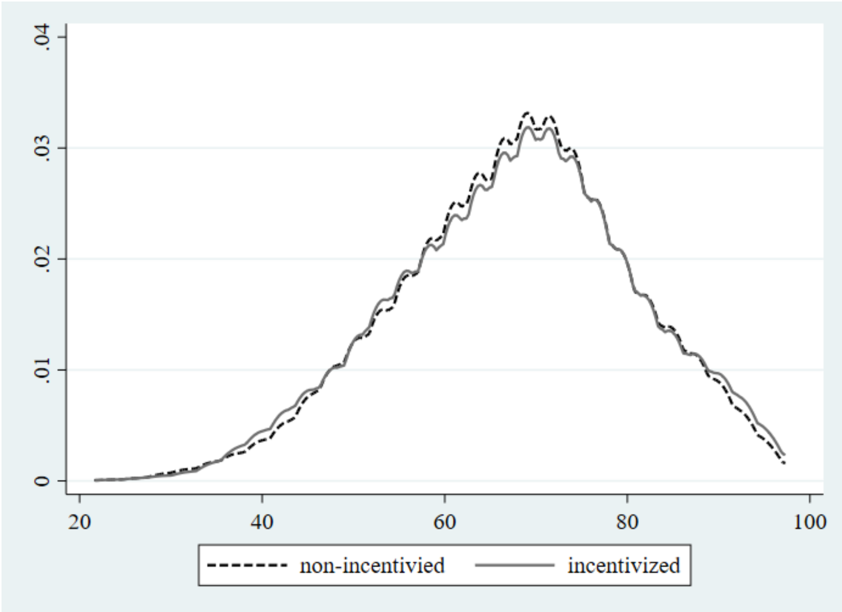

Figure 3: Kernel densities of school readiness score for incentivized and non-incentivized groups, which are indistinguishable.

2.2.3 Background Characteristics

This paper controls for several background characteristics of children and household, including child age, child gender (female = 1), child attention score, an indicator of being a child with special needs, household wealth index and caregiver's education, some of which are described below.

Child attention score

The score of child attention is derived from three items of behavioral problem index (BPI) in the teacher questionnaire.[5] The items include (1) the child has difficulty concentrating/ paying attention; (2) the child is easily confused, seems in a fog; and (3) the child is restless, overly active, cannot sit still. Teachers answered each item using a 3-point Likert-type scale (0 = often true, 1 = sometimes true, 2 = not true). The scoring system implies that a higher score means better attention skill. Technically, we first applied the exploratory factor analysis technique to confirm that all three items belong to the same

[5]BPI items were developed by Peterson and Zill (1986), and were widely used in human capital development research (e.g., Cunha et al., 2010) to measure behavioral problems in children.

latent factor, and then estimated the factor score using the Bartlett method (Bartlett, 1937).

Special needs

The variable is also taken from the teacher questionnaire, which asked the teacher if each sampled child needs special care or help.

Wealth index

We measure the socio-economic status of the child's family using a wealth index. Technically, we estimated it using a principal component factor based on household asset data of 20 items, including house owner, the number of houses/building, cars, van/pickup trucks, trucks, motorcycles, farm tractors, motorized tractors, boats with a small motor, mobiles, computers/laptops, tablets, VDO / VCD / DVD players, TVs, fans, water heaters, washing machines, air conditioners, microwaves and refrigerators, taken from the parent questionnaire.

Caregiver's education

Caregiver's education is a dummy variable indicating that caregiver graduated from college. This variable is also taken from the parent questionnaire.

2.3 Procedure

7,123 kindergartens performed the direct assessments including school readiness and digit span task one-on-one in an isolated room at their schools in the morning before lunchtime. Up to three children could be tested in the same room concurrently but they were located sufficiently far from each other in order to ensure that they would not hear others' answers. The assessment began with school readiness and was followed by the digit span task. The randomization was performed at an individual level via a computer algorithm built in a web application. Balanced tests based on the main sample of 4,996 children using the standard t-test confirm that key characteristics of the incentivized and non-incentivized groups were statistically indistinguishable. There were no significant differences between groups based on age, gender, school readiness, attention skill, special-needs, wealth, and caregiver education ($p > .05$, see table 1). At the end of the assessment, every participant would receive some pieces of stationery as a token of gratitude. But the incentivized participants may receive more due to their performance on the digit span memory task.

All direct assessments took 20 minutes on average.

Table 1: The descriptive statistic of data

Variable	Non-incentivized			Incentivized			T-test	
	Avg.	S.D.	Obs.	Avg.	S.D.	Obs.	Diff.	P-value
female	0.513	0.500	2,469	0.496	0.500	2,527	-0.017	0.243
School Readiness	67.711	12.879	2,469	67.769	13.265	2,527	0.058	0.876
Child Age	75.700	3.805	2,469	75.832	3.814	2,527	0.132	0.223
Attention Skill	0.015	1.184	2,469	0.045	1.132	2,527	0.030	0.358
Special-Needs	0.038	0.191	2,469	0.031	0.173	2,527	-0.007	0.163
Wealth Index	-0.013	0.973	2,469	0.012	1.033	2,527	0.025	0.387
Caregiver Edu.	0.155	0.362	2,469	0.165	0.371	2,527	0.010	0.341

Note: Avg. is the average, S.D. is the standard deviation, and Obs. is the number of child observation. Caregiver Edu. denotes a dummy variable indicating that caregiver graduated from college.

Teachers were interviewed for their own personal background, and basic information and child development of every sampled student, after all of them were tested. This part took approximately 30 minutes. Students were asked to bring the parent questionnaire to their main caregiver to fill in, and bring them back to the teachers, who would send the filled-in questionnaires by mail to the research team. Teachers and main caregivers were blinded from the randomization result of their students/children. All questionnaires were electronically entered twice and then compared for accuracy.

All parents were provided written legal guardian informed consent. The study protocol was approved by the University of Thai Chamber of Commerce Review Board (No. A03004/2564) and was in accordance with the 1964 Helsinki declaration and its later amendments.

3 Statistical Analysis

To evaluate the predictive power of observable characteristics and material incentive motivation on working memory capacity, we conduct a multiple linear regression model (independent/predictive variables: observable characteristics and incentive indicator; dependent variable: forward, backward or total digits) using the following linear regression model:

$$WM_i = \alpha + \gamma Inc_i + \boldsymbol{\beta}\boldsymbol{X}_i + \varepsilon_i \tag{1}$$

where WM_i is the forward, backward or total digits of child i; Inc_i is an incentive indicator of child i which is equal to one if he/she is in the incentivized group and zero otherwise; $\boldsymbol{X}_i$ are control variables including child age, child gender (female = 1), child attention score, special-needs, household wealth index, caregiver's education and province fixed effect (for the main model). For robustness, we also analyze an alternative model with the whole sample of 7,123 kindergarten students. In addition, we perform a robustness analysis by dropping some covariates (including child attention score, special needs, household wealth index and caregiver's education), which leads to a larger sample of 7,123 children.

In addition, we investigate whether the impact of incentive motivation is heterogeneous across subgroups. Technically, we estimate the following linear regression model with interaction terms:

$$WM_i = \alpha + \gamma Inc_i + \boldsymbol{\eta} Inc_i \times \tilde{\boldsymbol{X}}_i + \boldsymbol{\beta}\boldsymbol{X}_i + \varepsilon_i, \tag{2}$$

where $\tilde{\boldsymbol{X}}_i = \boldsymbol{X}_i - \overline{\boldsymbol{X}}$ are the differences between the original values and their averages or demeaned values[6] of the variables of interest, including child age, child gender, child attention score, special-needs, household wealth index and caregiver's education. The coefficients of interaction terms $\boldsymbol{\eta}$ measure the heterogeneous impacts of incentive motivation with respect to those variables of interest.

We estimate all models using an ordinary least square (OLS). To account for an intra-correlation within schools, we cluster standard errors at school level. The identification assumption for the impact on incentive motivation is that the error term ε_i is not correlated to the incentive indicator Inc_i. This is a reasonable assumption because the incentive condition was randomized.

[6] This demeaning is to ensure that the main effect of incentive motivation is not affected systematically by the interaction terms.

4 Results

4.1 Descriptive Statistics

We first perform balanced tests between the incentivized and non-incentivized groups using the standard t-tests. The results reveal that there are not significant differences between the incentivized and non-incentivized groups with respect to child age, child gender, school readiness, child attention, special-needs, wealth index, and caregiver education ($p > .05$; see table 1). This implies that the randomization was conducted properly.

The descriptive statistics also show that the incentivized group has a better working memory performance than the non-incentivized. That is, the average of total, forward, and backward digit spans for the incentivized are larger than the non-incentivized 0.272, 0.134, and 0.138 digits, respectively. In particular, the average of total, forward, and backward digit spans for the incentivized are 6.764, 3.602, and 3.161, respectively while the non-incentivized are 6.492, 3.468, and 3.023, respectively (figure 4).

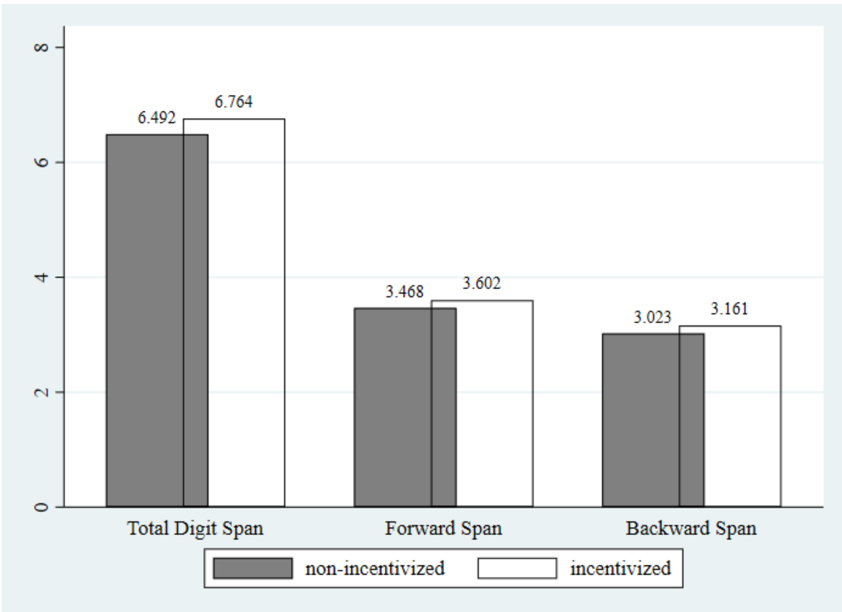

Figure 4: The averages of total, forward, and backward digit spans for incentivized and non-incentivized groups.

4.2 Effects of Material Incentive Motivation and Covariates: Regression Results

Multiple linear regression confirms that material incentive motivation had a positive and significant impact on the working memory performance of kindergarten students, after controlling for child and household characteristics. In particular, material incentive motivation significantly enhance total ($\beta = 0.235, SE = 0.061, p < .001$), forward ($\beta = 0.117, SE = 0.034, p < .001$), and backward digit spans ($\beta = 0.117, SE = 0.039, p < .01$). See panel A of table 2. In words, young Thai children positively respond to material incentive motivation when performing a working memory task.

Moreover, panel A of table 2 also presents the effects of each covariates. We find that all but child gender have a significant impact on working memory performance. Child age, school readiness, child attention skill, wealth and caregiver education are positively and significantly associated with the working memory performance while special-needs is negative and significant. A month older leads to an increase of 0.041 digits for total ($SE = 0.010, p < .001$), of 0.017 digits for forward ($SE = 0.006, p < .01$), and of 0.024 digits for backward ($SE = 0.006, p < .001$). A one unit increase of school readiness is associated with an increase of 0.083 digits for total ($SE = 0.003, p < .001$), of 0.041 digits for forward ($SE = 0.002, p < .001$), and of 0.041 digits for backward ($SE = 0.002, p < .001$). A one standard deviation increase of child attention skill is related to an increase of 0.078 digits for total ($SE = 0.034, p < .05$) and of 0.049 digits for forward ($SE = 0.019, p < .05$), but the effect on backward digit span is insignificant ($p > .05$). Children with special-needs have a significantly lower total, forward and backward by 0.815 digits ($SE = 0.188, p < .001$), 0.331 digits ($SE = 0.112, p < .01$), and 0.484 digits ($SE = 0.102, p < .001$), respectively. Being wealthier by one standard deviation leads to an increase of 0.104 digits for total ($SE = 0.042, p < .05$), of 0.076 digits for forward ($SE = 0.025, p < .01$), but the effect on backward digit span is insignificant ($p > .05$). Finally, children whose caregivers graduated from college have a significantly larger total and backward by 0.301 digits ($SE = 0.109, p < .01$) and 0.190 digits ($SE = 0.065, p < .01$), respectively, but the effect on forward digit span is insignificant ($p > .05$).

Table 2: The Multiple Regression Analyses of Independent Variables and The Interaction Effect on Total, Forward, and Backward Digit Span Performance of Children

	Panel A			Panel B		
	Total	Forward	Backward	Total	Forward	Backward
Incentive (INC)	0.235***	0.117***	0.117**	0.231***	0.116***	0.115**
	(0.061)	(0.034)	(0.039)	(0.062)	(0.034)	(0.039)
Age	0.041***	0.017**	0.024***	0.062***	0.024**	0.039***
	(0.010)	(0.006)	(0.006)	(0.013)	(0.008)	(0.007)
Female	0.054	-0.008	0.062	0.066	-0.012	0.078
	(0.067)	(0.039)	(0.039)	(0.094)	(0.055)	(0.055)
School Readiness (SR)	0.083***	0.041***	0.041***	0.081***	0.041***	0.040***
	(0.003)	(0.002)	(0.002)	(0.004)	(0.002)	(0.002)
Attention	0.078*	0.049*	0.029	0.121**	0.068**	0.053
	(0.034)	(0.019)	(0.020)	(0.046)	(0.026)	(0.027)
Special-Needs (SN)	-0.815***	-0.331**	-0.484***	-0.880***	-0.383*	-0.497***
	(0.188)	(0.112)	(0.102)	(0.259)	(0.160)	(0.136)
Wealth Index	0.104*	0.076**	0.028	0.162**	0.090**	0.072*
	(0.042)	(0.025)	(0.024)	(0.051)	(0.032)	(0.030)
Caregiver Edu. (EDU)	0.301**	0.111	0.190**	0.301**	0.111	0.190**
	(0.109)	(0.062)	(0.065)	(0.108)	(0.062)	(0.065)
INC × Female				-0.023	0.009	-0.031
				(0.131)	(0.077)	(0.077)
INC × Age				-0.042*	-0.012	-0.029**
				(0.016)	(0.009)	(0.010)
INC × SR				0.003	0.001	0.003
				(0.005)	(0.003)	(0.003)
INC × Attention				-0.086	-0.039	-0.047
				(0.061)	(0.034)	(0.036)
INC × SN				0.168	0.124	0.044
				(0.357)	(0.207)	(0.202)
INC × Wealth				-0.111	-0.027	-0.083
				(0.068)	(0.039)	(0.043)
INC × EDU				0.191	0.112	0.078
				(0.181)	(0.107)	(0.109)
Constant	-2.818***	-0.886*	-1.932***	-4.347***	-1.357*	-2.990***
	(0.792)	(0.434)	(0.463)	(0.976)	(0.570)	(0.557)
R^2	0.267	0.207	0.212	0.269	0.208	0.214
Observations	4996	4996	4996	4996	4996	4996

Note: Standard errors are in parenthesis and * p<0.05, ** p<0.01, *** p<0.001 and clustered at school level. Caregiver Edu. denotes caregiver graduated from collage. All regressions control for the province fixed effects.

4.3 Heterogeneous Effect of Material Incentive Motivation

This section investigates whether children with different characteristics respond to material incentive motivation differently or not. The estimation results are presented in panel B of table 2, where our interest is on the estimation coefficients of the interaction terms.

The results in panel B of table 2 show that young Thai children responded to incentive motivation homogeneously regardless of their background characteristics, including child gender, school readiness, child attention, special-needs, wealth index, and caregiver education. The estimation coefficients of all interaction terms are insignificant ($p > .05$) except the one with child age, which is negative and significant for total ($\beta = -0.042, SE = 0.016, p < .05$) and backward digit span ($\beta = -0.029, SE = 0.010, p < .01$). The negative result of the interaction term with child age implies that the effect of incentive motivation is larger for younger children (in the sample).

4.4 Robustness Checks

Table 3 presents alternative estimation results for robustness checks. Panel A of table 3 shows that the estimation results for the whole sample of 7,123 children are relatively similar to the main model (panel A of table 2). In particular, material incentive motivation can significantly raise total, forward and backward digit spans by 0.244 ($SE = 0.051, p < .001$), 0.107 ($SE = 0.028, p < .001$) and 0.136 ($SE = 0.032, p < .001$) digits, respectively. This suggests that there is no significant effect of restricting child age to 69-84 months old in the main sample. This confirms that the main results are robust.

Additionally, we find that school readiness is the most predictive variable for digit span memory test by comparing R^2, which is the proportion of the variation of the outcome variable explained by independent variables. This is evident in the difference between $R^2 = 0.248$ of the model with school readiness (for the total digit) in panel A of table 3 and $R^2 = 0.087$ of the model without school readiness in panel B of table 3. That is, school readiness alone accounts for at least 16% of the variation of total digit. In other words, school readiness captures more than half of the R^2 presented in panel A. We also explore the contribution of other covariates and find that all of them contribute only marginally.

Table 3: The Multiple Regression Analyses of Independent Variable on Total , Forward, and Backward Digit Span Performance for Children in Robustness Checks

	Panel A			Panel B		
	Total	Forward	Backward	Total	Forward	Backward
Incentive	0.244***	0.107***	0.136***	0.249***	0.110***	0.139***
	(0.051)	(0.028)	(0.032)	(0.056)	(0.031)	(0.034)
Age	0.033***	0.014***	0.019***	0.054***	0.025***	0.029***
	(0.007)	(0.003)	(0.004)	(0.007)	(0.004)	(0.004)
Female	0.110	0.020	0.089**	0.193**	0.063	0.130***
	(0.058)	(0.033)	(0.034)	(0.063)	(0.036)	(0.036)
School Readiness	0.087***	0.044***	0.042***			
	(0.003)	(0.001)	(0.001)			
Constant	-2.522***	-0.852**	-1.670***	1.955***	1.433***	0.522
	(0.521)	(0.270)	(0.320)	(0.584)	(0.306)	(0.336)
R^2	0.248	0.195	0.193	0.087	0.060	0.079
Observations	7123	7123	7123	7123	7123	7123

Note: Standard errors are in parenthesis and * p<0.05, ** p<0.01, *** p<0.001 and clustered at school level. All regressions control for the province fixed effects.

5 Discussion

This current study investigates the effect of material incentive motivation on child cognitive performance. Based on our large-scale randomized controlled trial, we confirm that children who were incentivized performed significantly better for total, forward, and backward digit spans, which are standard measures of working memory. This implies that material incentive motivation can improve the working memory performance for young children. This result is consistent with previous studies conducted in adults and ADHD children, which found that those who received incentive motivation had higher scores on working memory performance than the non-incentivized group (e.g., Dovis et al., 2012; Sanada et al., 2013; Shiels et al., 2008). This paper contributes to the literature by showing that the positive effect of incentive motivation exists not only in adults and ADHD children, but also in general population of young children with various background characteristics.

Our work is also related to the literature studying how material incentive affect a brain functions (e.g., Krawczyk and D'Esposito, 2013; Thurm et al., 2018; Liu et al., 2022). Material incentive motivation can modulate working memory performance via top-down signals function by facilitating the encoding and maintenance processes of working memory. Incentive motivation also plays a role in activating the brain function of a reward system via an increase of dopamine neurotransmission in association with brain processing (prefrontal cortex, vision, and perception). This mechanism of incentive motivation supports selective attention, accuracy processing, and enhanced effort of children during task performances.

It is also important to determine if the incentive effect is practically significant. To answer that question, we compare the effect of incentive motivation with both the average digit span of the non-incentivized group and the effect of child age. The first calculation reveals that the incentive effects on total, forward, and backward digit spans are approximately 3.6, 3.4, and 3.7, percents of the corresponding averages of the non-incentivized group (the effect of incentive is divided by the average score of the non-incentivized group and multiplied with 100, see table 2), respectively. The second procedure indicates that the incentive effects on total, forward, and backward digit spans are equivalent to being older by 5.7, 6.9, and 4.9 months, respectively (the effect of incentive is divided by the effect child age, see table 2). In other words, the working memory performance of an average child with material incentive motivation would be at the same level as the same child if he/she has been five to seven months older but with no incentive. Overall, these results indicates that the material incentive motivation has a positive but limited impact (not practically significant) on the working memory performance of young Thai children. This practical insignificance result is in line with, for example, Bettinger (2012) and Fryer Jr (2011), which found that the effect of financial incentives on student achievements are practically insignificant. For parents and teachers, this practical insignificance result implies that they should realize that providing material incentives to promote cognitive development and learning of young children may not be as fruitful as expected. For researchers, this result also implies that the usual and non-incentivized cognitive performance tasks can deliver relatively accurate outcomes. On the other hand, concerns with incentivized cognitive performance tasks are not consequential.

Our heterogeneous or interaction analysis indicates that young Thai children with different background characteristics (i.e., gender, school readiness, child attention, an indicator of being a child with special need, wealth index and caregiver education) respond to material incentive motivation uniformly. The only significant result is the heterogeneous effect with respect to child age, which is a negative effect. That is, older children respond to incentives less than the younger children. This, in fact, implies that we should expect to see an insignificant impact for older students, which is consistent with the results for Chinese teenagers in Gneezy et al. (2019), who found that the incentive effects on PISA scores for Shanghai students are practically small in magnitude and not statistically significant. One potential explanation for this insignificant result is that there may be a counter-productive effect of material incentive (lower performance), under which individuals perceive rewards as a stressful opportunity or enter the state of "choking" (e.g., Ariely et al., 2009; Murty and Dickerson, 2016), and this effect may get larger with age. Unfortunately, we cannot test this hypothesis in this study because we did not collect the perception on reward data of the children nor perform the task with and without incentive motivation on the same children.

This paper also finds that school readiness is the most predictive variable for digit span memory performance. This finding is consistent with the previous study that working memory is highly correlated with school readiness and academic success of children (e.g., Bergman Nutley and Söderqvist, 2017; Maehler and Schuchardt, 2016). When children perform language/ literacy and mathematics/ numeracy domains of school readiness, those tasks the require working memory to hold, update and actively manipulate information in their mind. This process potentially leads to a positive intercorrelation between working memory, school readiness, and academic success of children (e.g., Imal et al., 2018; Welsh et al., 2010; Vandenbroucke et al., 2017).

Besides the incentive motivation, we also find that other background characteristics, including child age, school readiness, child attention, special-needs, wealth index, and caregiver education, have significant impact on the working memory performance in children. Our finding is consistent with the previous studies, which found that working memory is positively correlated with age (e.g., Zuber et al., 2019; Zimmermann et al., 2021; Vandenbroucke et al., 2017), school readiness (e.g., Bergman Nutley and Söderqvist, 2017; Maehler and Schuchardt, 2016), and attention skill (e.g., Smolak et al., 2020). Moreover, the family background also plays an important role in working memory performance of children (e.g., John et al., 2019; Piccolo et al., 2016). Contradicting with the literature, we do not find a significant impact of child gender (e.g., Zimmermann et al., 2021; Pezzuti and Orsini, 2016; Wang et al., 2017).

6 Conclusion

The paper investigates the effect of material incentive motivation on the working memory performance of kindergartners using a large-scale randomized controlled trial in Thailand. Our findings confirm that young children respond to material incentive motivation positively and statistically significant but the impact is not practically significant. Taking advantage of rich information of children and household characteristics, we show that the effect of incentive motivations is homogeneous with respect to children and household characteristics except child age. We also find school readiness is the most predictive variable for digit span memory performance; that is, school readiness alone can explain more than half of the variation of the outcome than other covariates employed in this analysis.

One potential future research is to perform a cognitive performance task with and without incentive motivation on the same subjects. This might enable us to measure the distribution of the incentive effect and also potentially measure the stress or anxiety from receiving rewards. Researchers may also consider applying a similar procedure to other working memory performance tasks. With more relevant measurements, we might be able to generalize the result as the effect on working memory more confidently. Another potential research is to compare different types of incentive motivations, e.g., material, social support or encouragement. This might lead us to the most effective way of providing incentives to promote cognitive development in young children.

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