COURSE SCHEDULING AND ACADEMIC PERFORMANCE

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and

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Abstract

This paper examines the relationship between course scheduling and student achievement, controlling for student and course characteristics. The literature in psychology recognizes that performance varies by time of day and that spacing out learning time may foster greater long-term memory of items. We use student grades as a measure of performance and find a small, positive time of day effect, much of which is driven by student selection into preferred course times. In addition, we find that students learn more in classes that meet more often.

Keywords: grades, time of day, academic performance

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I Introduction

Duke University recently moved its earliest class time from 8 am to 8:30 am. One motivation behind the change was to give "sleep deprived" students a chance to rest more before class. The new policy was counterproductive: the average student ended up going to class earlier since many classes were moved from the common 9:10 am start time to the new 8:30 am slot. Regardless, the administration used sleep deprivation as a pretext for the policy change (Carleton, 2004).

High schools have also been experimenting with changes in their scheduling. Schools have begun to adopt block-systems, where classes meet for 90 minute periods, instead of the traditional 50 minute periods, and studies have shown the block to improve student performance (Hughes, 2004, Rettig and Canady, 1999). There are two typical ways to organize block scheduling: one has classes meet daily, for half of the semester, while the other has classes meet on alternate days throughout the entire semester. Few studies examine whether students learn more when their classes meet more often—5 times a week instead of 2 or 3 times a week.

Duke and the block systems pose an interesting question: to what extent does student learning depend on class scheduling? Students may learn more or less later in the day; students may learn more or less when classes meet more often. The answer to these questions will help allocate school resources and plan courses to increase student learning. This paper offers some insight into the issues of offering two-day- or three-day-a-week classes and the timing of course offerings.

Many universities typically schedule courses in two ways: those that meet two days a week for about 75 minutes and those that meet three days a week for about 50 minutes. Both types of courses offer the same number of credit hours and class time; the three day a week schedule spreads out the materials over more days. There is accumulating evidence from psychology that distributed practice, spreading out learning into periods of shorter duration but greater frequency, improves skill acquisition as well as long-term recollection of the material (Lee and Genovese, 1988 and Willingham, 2002) although this benefit may be greater for simpler, motor skills than more complex tasks (Donovan and Radosevich, 1999). Although many studies have documented the benefits and costs of block scheduling, few have addressed whether changing the number of times a class meets in a week has any significant effect (Rettig and Canady, 1995). Colleges may also reduce the number of times that classes meet to accommodate faculty preferences. Distributive theory suggests this pressure towards two day a week classes may reduce student learning.

Universities also choose what times to offer their classes. Sleep research provides three predictions about time of class and student performance. First, sleepy students perform worse than rested ones. This effect has been verified among non-traditional graduate students, Mexican undergraduates, and medical students (Austin et al., 1988, Campos-Morales et al., 2005, and Medeiros et al., 2003). Second, adolescents are less likely to be rested early in the morning.[3] Adolescents, in general, when faced with an earlier start to the school day, prefer to sleep less instead of going to bed earlier (Wolfson and Carskadon, 2003). Adolescents are also particularly prone to suffer Delayed Sleep Phase Syndrome: their body clock runs at a rate slower than the sun's, so they tend to go to bed late and wake up late (Dement, 1999). Shinkoda et al. (2000) find that as students progress through high school, they are more likely to fall asleep in class, and have later

[3] Adolescence typically lasts between ages 11 to 13 and ages 18 to 21 (Colman, 2001; Corsini, 1994).

bedtimes. Third, the circadian cycle during the day and its varying wakefulness may be observed in changes in academic performance throughout the day (Carskadon et al., 1998, Carskadon et al., 1999). Circadian rhythms are daily cycles that make people more likely to be sleepy at certain times of the day, with wakefulness peaking at some point in the late morning and again in the afternoon.

Even articles that find no effect of sleepiness recognize the existence of adolescent sleep phase delay and discourage schools away from earlier start times (Eliasson et al., 2002). A well-documented study of Minneapolis high schools finds results consistent with this argument (Wahlstrom, et al., 2001). In the 1997-1998 school year, Minneapolis changed the start time in high schools from 7:15 am to 8:40 am. Attendance rates and continuous enrollment increased and crime on campus decreased. The students' additional sleep did not lead to any measurable effects on grades, though the authors admit that this may be the result of data errors. A better data set would follow students more closely and use comparable sources. Davis (1988) finds that 8th grade students learn more in afternoon English courses than in morning ones. Extending the analysis to college students at a small liberal arts college, Skinner (1985) documents lower average class GPAs for morning courses relative to afternoon and evening courses.

Our study uses administrative data from Clemson University, a public research university in South Carolina to determine the effect of class schedule on student performance. Unlike Skinner (1985), we account for student ability, potential sorting across class times, course content and difficulty, class size, and the number of days per week a course is offered. In addition, we are able to observe the same students in more than one semester, giving us within-student variation in scheduling. We find that students perform slightly better in courses offered later in the day and in those offered more days per week. Given choices among class times, students select courses that best fit their scheduling preferences. This course selection accounts for about fifty percent of the observed time of day effect.

II Conceptual Framework and Methodology

A student's grade in a course depends on many variables: the time of day, frequency of class meetings, student ability, class size, grading practices, the difficulty of the material, and teaching effectiveness. We focus on the effect of time of day and frequency of class meeting: factors typically neglected in studies of student achievement.

Psychologists provide some predictions on how class schedules may affect student achievement. Adolescents are predicted to perform poorly earlier in the day, since they would be sleepy or absent in those early classes. Circadian rhythms affect each student's performance within a day, creating a peak at some point in the morning, and then another in the afternoon. The earliness effect is similar for all students, while the circadian effects vary among students, with the peaks falling at different times. We thus expect an earliness effect to be much more evident than a circadian effect. Distributed practice suggests more frequent class meetings should increase student learning.

We examine the effect of time of day on student grades by estimating the following grade regression for student *i* in section *j* of course *c*:

$$grade_{ijc} = \gamma_0 f\left(time_{jc}\right) + \delta_0\left(\#time/week_{jc}\right) + X'\beta + s_i + d_c + \varepsilon_{ijc} \qquad (1)$$

The vector *X* contains class size and whether the class meets in the fall or in the spring. Smaller classes may increase student learning, although the empirical evidence on this relationship, at least in K-12 education, is mixed (Hanushek 1997 and 1999, Betts 1996). Spreading out course material typically leads to greater retention of knowledge than more intensive instruction, so we expect δ_0 to be positive (Bloom and Shuell, 1981). The student fixed effects, s_i, control for both observable and unobservable student characteristics such as student ability. Course fixed effects, d_c, account for differences in course content, difficulty, and grading. The use of the two sets of fixed effects implies that any scheduling effect is net of the characteristics of the particular course or student. In all the regressions, standard errors are clustered by class time.

We focus on γ_0 and δ_0, the effects of class scheduling on the student's grade. We estimate the time of day effect a variety of ways. In some specifications, we include a set of indicator variables for each of the most common course times; in others, we provide a functional form including linear and quadratic models. The overall picture is similar for all of these specifications.[4]

The above framework assumes students are randomly assigned to courses. Students, however, schedule their own courses. This course selection potentially biases the estimates. Students may register for times where they know they will perform their best. The math-phobic early-bird enrolls in calculus in the morning; the math-phobic night owl enrolls in calculus late in day. Both types of students accommodate their circadian cycles by taking courses that are relatively difficult for them at preferred times. This would tend to bias downwards the time of day effect.

Students may schedule classes using alternate criteria. For example, students may take their favorite classes in the afternoons to reduce the likelihood they skip class for

[4] We also estimate a spline specification that sets knots based on circadian cycles and regressions estimated using an ordered probit instead of OLS. The results are qualitatively similar.

more enjoyable afternoon activities. Similarly, students may take their least favorite classes in the morning to get the hard work over with more quickly. Student preference for afternoons would create a positive selection bias on the time of day effect. Better grades in afternoon classes may reflect both time of day effects and selection effects.

The fixed effects strategy does not account for these optimizing behaviors. To better capture the true effect of time of day on student grades, we employ a differences-in-differences type strategy.[5] Some courses are offered one time each semester, but at different times in the fall and spring semesters. These limited offerings reduce the selection into preferred courses. Although students may defer their course-taking to later semesters to improve the scheduling match, within-semester optimizing is eliminated. To produce estimates of the effect of time of day with minimal course selection, we estimate the following:

$$(2) \quad grade_{ijc} = \alpha_0 time_{jc} + \alpha_1 onesection_{jc} + \alpha_2 (onesection_{jc})(time_{jc}) + \theta_1(\#times/week_{jc}) + \theta_2(onesection_{jc})(\#times/week_{jc}) + X'\beta + s_i + d_c + \varepsilon_{ijc}$$

We continue to include class size, the number of times per week the course meets, the semester (Fall or Spring), student fixed effects, s_i, and course fixed effects, d_c.

One-section courses limit student selection into preferred course times. The estimated effect of time of day excluding this within-semester student selection is the sum of the coefficients on the time of day and on the interaction of time of day and the one-section indicator variable. Comparing this estimate to estimates of α_0, the effect for multiple-section courses, suggests the direction of selection bias.

[5] We thank the anonymous referees for pointing out this limitation and the potential solution to it.

III Selection Problems and Limitations

A serious limitation is that we do not observe who teaches each course. Baird (1984) argues that a large fraction of the unexplainable variation in grading is due to the differences in teachers. This affects our scheduling estimates only if instructor quality or ease of grading is correlated with course scheduling. The same instructor may perform differently at different times of day. However, Skinner (1985) provides suggestive evidence that instructors teaching the same course in a semester, once in the morning and once in either the afternoon or evening, exhibit similar differences in mean grades between the sections as between a morning class and an afternoon/evening class taught by two different instructors. Similarly, professors may prefer teaching fewer days a week and so grade more easily for those courses. This would bias downwards the estimate on number of times per week.

The quality of instructor may be correlated with course schedule. Adjunct instructors, for example, may be assigned less favorable class periods than professors who have more priority in scheduling. Adjust professors appear similarly effective as professors (Terry-Long and Bettinger, 2006). Sonner (2000) and Van Ness et al. (1999), however, find that adjuncts in business and finance courses give higher grades than full-time faculty. If adjuncts are more likely to have morning classes or classes that meet more frequently and assign higher grades, the effect of time would be biased downwards, and the effect of class meetings would be biased upwards. Course fixed effects capture some of this effect if adjunct instructors typically teach some courses and not others. Our sample includes few adjunct instructors, but many graduate teaching assistants. We expect the bias with these graduate instructors to be similar to that of adjuncts.

If students learn more in afternoon classes, whether because of their own preferences or their professors, there is still a benefit to encouraging students to take later classes. If students learn more with more frequent course meetings, shifting towards these types of courses could improve both their grades and their education. One concern that would invalidate our results is if instructors are more apt to assign higher grades later in the day for a given student performance. This motivation would imply that later class start times would only lead to grade inflation and not improved student learning.

Time of day may affect student achievement through class attendance rates. Students may be more likely to skip morning classes if they oversleep or more likely to skip afternoon classes for attractive, alternative non-academic options. Students may be more likely to skip a Monday, Wednesday, Friday (MWF) class as skipping a shorter class period implies missing less course material. If scheduling effects are driven primarily by differences in attendance patterns, this may imply policy changes related to attendance as an easier alternative to changes in scheduling.

IV Data

To examine the effect of the time of a class on a student's performance, we need data on students, courses, and class times. Clemson University (a public, doctoral, research extensive, land-grant institution in South Carolina) archives extensive data on its students, including every grade received and all application information. Grades are recorded without pluses or minuses as A, B, C, D, or F; we recode these respectively as 4, 3, 2, 1, and 0. We use data from these administrative records for students in the fall of 2000 and the spring of 2001. We combine the student records with meeting time information from the schedule of classes. The time of day assigned is the average of the start and end times in which a class meets most often, measured in military time. A unit increase in mean time is one hour.[6]

The unit of observation is a grade in a class. We observe 12,887 students an average of 8.2 times for a total of 105,476 grades in a class. The average student is enrolled in 14.8 credits or just under five courses a semester. The average grade that year was just below a B, a 2.97, with a standard deviation of 1.07. The average class size is 49 students. The students in the sample, at just under 21 years old, are slightly older than the adolescents previously studied in the literature.

Although the sample draws from only a single institution, these students are fairly average college students in the U.S. The median college student in 2000 was white, female, graduating at slightly lower than the top 20 percent of the high school class, scoring a 505 on the SAT math test (College Board, 2000). Clemson students scored somewhat higher on the SAT at 578, and are less female than most colleges, with 54 percent of the student body being male.

Scheduled class times for 80 percent of classes are at regular times, with the school day beginning at 8 a.m. MWF classes typically meet for 50 minutes with a 15 minute break between classes. Tuesday, Thursday (TTh) classes typically meet for 75 minutes with a 15 minute break between classes. There are also many afternoon Monday, Wednesday (MW) classes that meet for 75 minutes at the MWF start times and some two-credit TTh classes that meet for 50 minutes.

Figure 1 shows the average grade for each time of the day. Most classes meet at many of the same times. The figure sizes a data point according to the number of observations represented by that meeting time and grade combination. Focusing on the

[6] For example, a 3:30-4:45 pm TTH class is assigned a mean time of (15.5+16.75)/2 = 16.125.

most common class times, the figure suggests a positive relationship between the time a class meets and average student grades.

Tables 1a and 1b show the average time of day for each grade in TTh courses and MWF courses. The average TTh class meets just after noon, at around 12:10. The average time a class meets is higher for A's than for lower grades. Classes that meet MWF follow a similar, although less pronounced pattern. Average grades are higher for TTh courses than for MWF courses. Tables 1a and 1b verify the impression from Figure 1 of a slightly positive relationship between time of day and academic performance.

V Results

We specify a multivariate regression of student grades on class time in a variety of ways to allow the data to determine the pattern in student performance over the course of a day. We consider a linear specification, a quadratic specification, and a flexible specification that allows the effect to vary for all standard course times. The time of day effect is concentrated in the afternoon. Grades are generally lower for all morning classes; grades increase with time of day in the afternoon. Student grades are higher when a course meets more frequently during a week.

Table 2 reports the results of the more flexible specification. Most classes meet at standard class times on MWF, TTh, or MW. We limit the sample to only courses that meet at typical class times and include indicator variables for these major class times. For example, for MWF classes the start times are: 8:00 am, 9:05 am, 10:10 am, 11:15 am, 12:20 pm, 1:25 pm, 2:30 pm, and 3:35 pm.[7] The omitted class time is 8:00 am MWF. By looking at how the estimated coefficient changes over time, we can observe the effect of time on academic performance. Since we observe students repeatedly, we are able to control for observable and unobservable student characteristics with a student fixed effect.[8] We also include course fixed effects.

The results follow a pattern of increasing grades throughout the day. The increase is most dramatic among MWF classes, but the pattern is consistent throughout. There is a positive relationship between time of day and academic performance, but no evidence of a cyclical pattern in the relationship between time of day and academic performance.[9] Grades are clearly higher in afternoon classes relative to morning classes.

A separate set of regressions imposes a functional form on the relationship between the students' performance and the mean time of the class. These regressions include the full sample of courses. The linear and quadratic specifications are presented in the first two columns of Table 3.

The relationship between time of day and grades is positive. In the linear specification, grades are 0.022 grade points higher in courses taken an hour later in the day. The effect is small, but statistically significant. The magnitude of the effect at the mean is similar in the quadratic specification. The effect of time of day increases in the afternoon, as suggested by the results in Table 2. In estimates not presented here, a spline specification placing knots at times suggested by circadian cycles confirms this

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[7] For Tuesday, Thursday classes the times are: 8:00 am, 9:30 am, 11:00 am, 12:30 pm, 2:00 pm, 3:30 pm, and 5:00 pm. For Monday, Wednesday classes the times are: 8:00 am, 9:05 am, 10:10 am, 11:15 am, 12:20 pm, 1:25 pm, 2:30 pm, and 4:00 pm.

[8] We have also estimated the regressions using student characteristics instead of student fixed effects. The estimates on class time are similar to those reported here.

[9] More restrictive regressions using the cut-offs from expected circadian cycles also show no evidence of circadian cycles and a trend on increasing performance during the day.

impression. Students' grades are higher in courses taken later in the day; early morning classes are particularly bad for students' grades.

Classes that meet more often during the week tend to have higher grades. Given the choice between a MWF and a TTh class, the MWF is the better option. Universities, as a result, may want to schedule more classes to meet thrice, not twice, a week.[10] The magnitude of this effect is comparable to scheduling a class 73 minutes later. Grades are lower in the fall; larger classes tend to have higher grades.

These estimates may confuse student selection into course times with the effects of scheduling on student grades. We take advantage of the two semesters of data to minimize this potential selection bias. Some courses are offered only once a semester and, importantly, offered on different days and times in each semester. For these courses, students have little ability to choose preferred course times within a semester. Estimating the effects of time of day and number of class meetings per week for these classes reduces the effect of student selection.

The last two columns of Table 3 present these estimates. In column (3), the effect of time of day for classes with multiple sections is 0.023: taking the class an hour later increases the grade by two-hundredths of a grade point. This effect consists of both an effect of taking the class later and the fact that students chose that class time. For those one-section courses where students are less able to choose preferred class times, taking a class an hour later increases one's grade by 0.010 grade points. The 0.013 difference

[10] As an alternate specification, we estimated a regression of a student's average performance in a day on his earliest class that day. As before, we observe students in several classes during each day. We found that later starts to the school day have positive effects on students' academic performance. On Monday, for example, if a student starts class an hour later in the day, his grade, on average, is 0.046 grade points higher in all his classes that day. This effect is largest on Mondays and Wednesdays. This possibly reflects an increased tendency for students to skip class and sleep in on Fridays.

between one-section and multiple-section courses reflects student selection. The magnitudes of the selection and time of day effects are similar, at the mean, for the quadratic specification. In addition, the majority, 54 percent, of the effect in columns (1) and (2) of Table 3 is due to student selection. The time of day effect net of selection is economically small—taking a class at 6 p.m. instead of at 8 a.m. increases a student's grade by about 0.1, a tenth of a letter grade. Although later classes offer a benefit to students, the benefit seems too small to make a large difference in a student's optimal schedule.

We use a similar technique to determine whether students select into courses that meet more or fewer times per week. Here, we see little difference in the effect of the number of times per week on grades between one-section and multiple-section courses. When the same course meets one more time per week, students' grades are 0.028 grade points higher. For most courses, this is a choice between TTH and MWF or, MW and MWF. If Friday classes are most often skipped, the lack of selection by times per week suggests these results are unlikely to be driven by attendance.

VI Policy Implications and Conclusions

Multivariate regression analysis of the relationship between course schedule and student performance shows that students perform better in a class that meets later in the day and more often. Student complaints about early classes' hurting their performance find some empirical support in this study. Students benefit a small amount from a later start. To the extent that grades reflect learning, students learn more when attending class later in the day and in courses that meet more often.

Some limitations and cost considerations temper a recommendation of later start times. Our results are biased upwards if professors may be more lenient in the afternoon and grade more easily. The estimated effect of class time on class grades is small, and policies moving classes to later times have high costs. Some professors may prefer to teach in the mornings and research in the afternoons. At research schools, shifting to later class times may improve student learning but reduce research productivity. Classroom space may also be limited; shortening the school day by starting later may strain university resources. In addition, if all students were to take classes at a later time, it is doubtful that everyone's grade would increase by our estimated amounts; however, to the extent that grades measure learning, the students would be better prepared. However, if a student or administrator is indifferent between two class times, then our measures support a choice of the later time.

Additional research, including controlled experiments, would provide supporting evidence of our conclusions. The answers to these questions are not only interesting but essential for institutions of higher education to meet their goals. The findings of these studies might extend even beyond classrooms, helping firms time their production processes more efficiently.

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VII References

Austin, Thomas L., Ronald R. Fennell, and Clay R. Yeager (1988), "Class scheduling and academic achievement in a non-traditional graduate program." *Innovative Higher Education*, 12(2), 79-90.

Baird, Len L. (1984). "Predicting predictability: The influence of student and institutional characteristics on the prediction of grades," *Research in Higher Education* 21, 261-279.

Betts, Julian R. (1996), "Is There a Link between School Inputs and Earnings? A Fresh Scrutiny of an Old Literature," in *Does Money Matter? The Link between Schools, Student Achievement, and Adult Success*, ed. Gary Burtless, 141-91, Washington, D.C.: Brookings Institution.

Bloom, Kristine C. and Thomas J Shuell (1981), "Effects of Massed and Distributed Practice on the Learning and Retention of Second-Language Vocabulary," *Journal of Educational Research*, 74(4), 245-248.

Campos-Morales, Rosa, Matilde Valencia-Flores, Alejandra Castaño-Meneses, Sandra Castañeda-Figueiras, and José Martínez-Guerrero (2005), "Sleepiness, performance and mood state in a group of Mexican undergraduate students." *Biological Rhythm Research*, 36(1-2), 9-13.

Carksadon, Mary A., Susan E. Labyak, Christine Acebo, and Ronald Seifer (1999), "Intrinsic circadian period of adolescent humans measured in conditions of forced desynchrony," *Neuroscience Letters,* 260, 129-132.

Carskadon, Mary A., A.R. Wolfson, C. Acebo, O. Tzischinsky, and R. Seifer, (1998), "Adolescent sleep patterns, circadian timing, and sleepiness at a transition to early school days," *Sleep*, Dec 15, 21(8), 871-81.

Carleton, Nathan, (2004), "On iPods and sleeping in," *The Chronicle*, Aug. 23, from online version, http://www.chronicle.duke.edu downloaded Jan. 27, 2005.

College Board (2000), "2000 College-Bound Seniors, National Report," available on-line at: http://www.collegeboard.com/about/news_info/cbsenior/yr2000/nat/cbs2000.html (December 13, 2006).

Colman, Andrew M. (2001), *A dictionary of psychology*. New York : Oxford University Press.

Corsini Raymond J. editor (1994), *Encyclopedia of psychology*. New York : J. Wiley & Sons.

Davis, Zephaniah T. (1988), "The effect of time of day of instruction on eight-grade students' English and mathematics achievement." *High School Journal*, 71(2), 78-80.

Dement, William (1999, February 26), “Delayed Sleep Phase Syndrome,” Retrieved April 27 from http://www.stanford.edu/~dement/circadian.html.

Donovan, John J. and David J. Radosevich (1999), “A Meta-Analytic Review of the Distribution of Practice Effect: Now You See It, Now You Don’t,” *Journal of Applied Psychology*, 84(5), 795-805.

Eliasson, Arne, Anders Eliasson, Joseph King, Ben Gould, and Arn Eliasson (2002), “Association of Sleep and Academic Performance.” *Sleep and Breathing*, 6(1), 45-48.

Hanushek, Eric A. (1997), “Assessing the Effects of School Resources on Student Performance: An Update,” *Educational Evaluation and Policy Analysis*, 19(2), 141-164.

Hanushek, Eric A. (1999), “Some Findings from an Independent Investigation of the Tennessee STAR Experiment and From Other Investigations of Class Size Effects,” *Educational Evaluation and Policy Analysis*, 21(2), 143-163.

Hughes, Woodrow W. (2004), “Blocking student performance in high school?” *Economics of Education Review*, 23, 663-667.

Lee, T.D. and E.D. Genovese (1988), “Distribution of Practice in Motor Skill Acquisition: Learning and Performance Effects Reconsidered,” *Research Quarterly*, 59, 277-287.

Medeiros, Ana Ligia, Denise B. F. Mendes, Patricia F. Lima, and John F. Araujo, (2003), “The Relationships between Sleep-Wake Cycle and Academic Performance in Medical Students.” *Biological Rhythm Research*, 32(2), 263-270.

Rettig, Michael D. and Robert L. Canady. (1995) *Block Scheduling: a catalyst for change in high schools.* Princeton, NJ: Eye on Education.

Rettig, Michael D. and Robert L. Canady. (1999) “The Effects of Block Scheduling.” *School Administrator*. 56 (3), 14.

Shinkoda, Harumi, Kazuya Matsumoto, Young Man Park, and Hidetoshi Nagashima, (2000), “Sleep-wake habits of schoolchildren according to grade,” *Psychiatry and Clinical Neurosciences*, 54, 287-289.

Skinner, Nicholas F. (1985) “University grades and time of day of instruction.” *Bulletin of the Psychonomic Society*, 23(1), 67.

Sonner, Brenda S. (2000) “A is for ‘Adjunct’: Examining Grade Inflation in Higher Education.” *Journal of Education for Business*, 76(1), 5-8.

Van Ness, Bonnie F., Robert A. Van Ness, and Rob H. Kamery. (1999) "The Effect of Part-Time Instruction on Grades in Principles of Finance." *Financial Practice and Education*, 9(2), 105-110.

Wahlstrom, Kyla L., Mark L. Davidson, Jiyoung Choi, and Jess N. Ross, (2001), "Minneapolis Public Schools Start Time Study Executive Summary," Center for Applied Research and Educational Improvement (CAREI) Working Paper.

Willingham, Daniel T (2002), "How We Learn: Ask the Cognitive Scientist, Allocating Student Study Time: "Masses" versus "Distributed" Practice," *American Educator*, Spring.

Wolfson, A.R. and Mary A. Carskadon, (2003), "Understanding adolescents' sleep patterns and school performance: a critical appraisal," *Sleep Medicine Review*, December, 7(6), 491-506.

Figure 1: Relationship between time and grades, all students

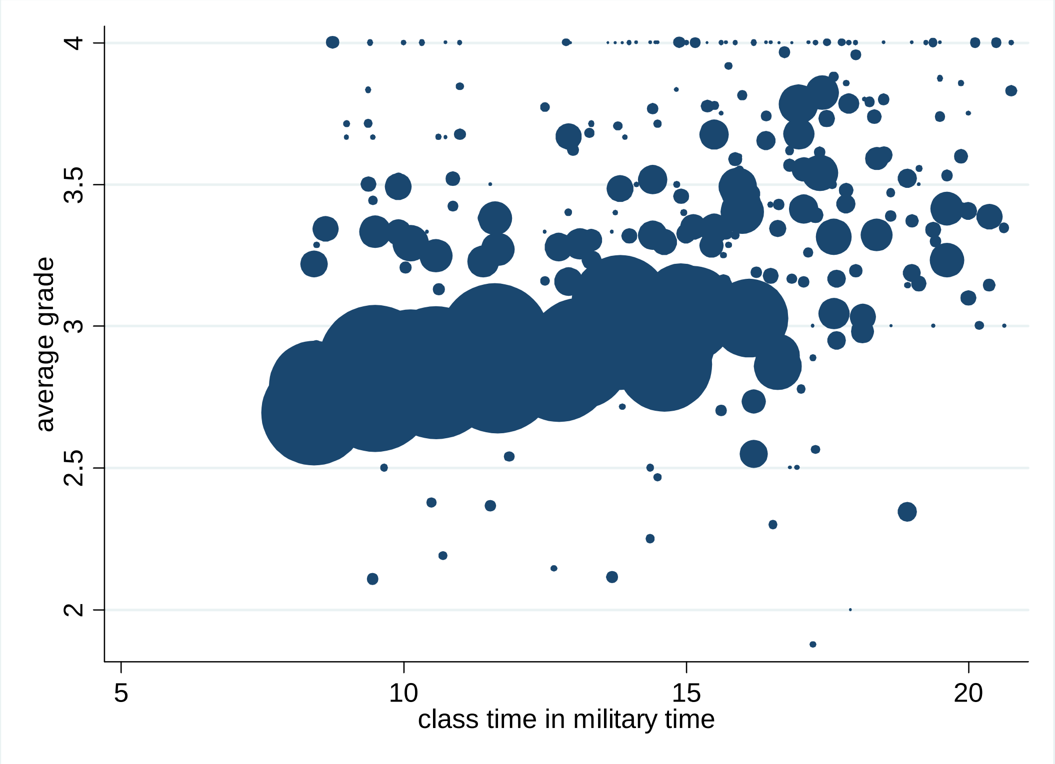

Table 1a: Mean time of day for each grade (T, Th)

Grade	Obs	Mean	Std. Dev.
0	1,295	11.76	2.56
1	2,285	11.84	2.47
2	7,642	11.94	2.54
3	13,515	12.22	2.57
4	13,823	12.37	2.66
All (mean = 2.96)	38,560	12.16	2.60

Table 1b: Mean time of day for each grade (MWF)

Grade	Obs	Mean	Std. Dev.
0	2,117	11.11	2.16
1	2,956	10.98	2.10
2	8,424	10.96	2.04
3	12,664	11.09	2.04
4	12,237	11.20	2.17
All (mean = 2.79)	38,398	11.08	2.09

Table 2: Effect of Class Time on Student Performance

			All Students' Grades					
Start Time	estimate	t-stat		estimate	t-stat		estimate	t-stat
MWF			*TTh*			*MW*		
			8:00 AM	-0.088**	5.09	8:00 AM	0.018	0.18
9:05 AM	0.050**	3.28	9:30 AM	-0.041**	2.46	9:05 AM	-0.146**	3.07
10:10 AM	0.052**	3.33	11:00 AM	0.034*	2.01	10:10 AM	-0.086	1.94
11:15 AM	0.093**	5.76	12:30 PM	0.010	0.58	11:15 AM	-0.006	0.15
12:20 PM	0.030	1.75	2:00 PM	0.063**	3.69	12:20 PM	0.121**	2.79
1:25 PM	0.123**	6.88	3:30 PM	0.160**	7.67	1:25 PM	-0.124**	3.92
2:30 PM	0.085**	3.25	5:00 PM	0.271**	8.90	2:30 PM	0.124**	6.69
3:35 PM	0.011	0.19				4:00 PM	0.141**	5.34
# of Credits	0.208**	2.79						
Fall	-0.043**	6.90						
Class size	0.0004*	2.55						
Observations	84,099							
R-squared	0.61							

Robust t-statistics in parentheses. All regressions include student fixed effects and course fixed effects, although these estimates are suppressed. Standard errors are clustered by time. The omitted class time is MWF 8:00 am. * significant at 5%; ** significant at 1%.

Table 3: Differences in differences estimate of time of day and class meetings per week effects

	(1)	(2)	(3)	(4)
	Student Grade			
time of day	0.022**	0.003	0.023**	0.002
	(16.96)	(0.34)	(16.99)	(0.19)
time of day^2		0.001*		0.001*
		(2.02)		(2.16)
# times/week	0.036**	0.039**	0.036**	0.039**
	(5.39)	(5.65)	(5.15)	(5.45)
class size	0.001**	0.001**	0.001**	0.001**
	(4.05)	(4.14)	(3.58)	(3.69)
Fall	-0.034**	-0.034**	-0.032**	-0.032**
	(5.85)	(5.92)	(5.50)	(5.54)
one section course			0.271**	0.110
			(3.31)	(0.49)
time of day and one-section interaction			-0.013**	0.015
			(2.84)	(0.44)
time of day^2 and one-section interaction				-0.001
				(0.84)
# times/week and one-section interaction			-0.008	-0.011
			(0.42)	(0.61)
R-squared	0.3179	0.3179	0.3182	0.3183

Robust t-statistics in parentheses. Regressions include student fixed effects and course fixed effects. Standard errors are clustered by student. There are 105,476 observations.
* significant at 5%; ** significant at 1%