Background—Early, Targeted, Layered Containment (TLC)
Political and public health leaders are avoiding the closure of schools as part of the response to COVID-19. Their arguments include:

1. Children may not be important in disease transmission and when kids do become infected, their illness is mild;
2. Closing schools is too disruptive, it will require parents to stay home from work to mind their children (and this absenteeism could adversely impact critical sectors such as healthcare);
3. Large number of children depend upon school meals and the closure of schools could have serious consequences;
4. By keeping kids home, they have more time to be around older adults in the household and potentially transmit disease to more vulnerable groups (the thinking is that it would be safer to keep them at school for at least 8 hrs of the day to decrease contact time with older adults in the household);
5. Children will just mix again the community (that kids will "hang out at malls").

I certainly agree that children have very mild illness compared to adults. One piece of data where all children were tested for COVID-19 was the Diamond Princess cruise ship. An overlooked study posted by Japan on Feb 21, 2020, provided detailed data on the cruise ship passengers. [Field Briefing: Diamond Princess COVID-19 Cases, 20 Feb Update. National Institute of Infectious Diseases. Published Feb 21, 2020. https://www.niid.go.jp/niid/en/2019-ncov-e.html]

Table 1. Percent of persons aboard confirmed with COVID-19 by age group and symptom status at the time of specimen collection. (As of 20 February).

Age group	Symptomatic confirmed cases (%)	Asymptomatic confirmed cases (%)	Total confirmed cases (%)	Persons aboard on 5 February
00-09	0(0)	1(6)	1(6)	16
10-19	2(9)	3(13)	5(22)	23
20-29	25(7)	3(1)	28(8)	347
30-39	27(6)	7(2)	34(8)	428
40-49	19(6)	8(2)	27(8)	334
50-59	28(7)	31(8)	59(15)	396
60-69	76(8)	101(11)	177(19)	923
70-79	95(9)	139(14)	234(23)	1015
80-89	27(13)	25(12)	52(24)	216
90-99	2(18)	0(0)	2(18)	11
Total	301(8)	318(9)	619(17)	3711

6/39 kids (age<20) were confirmed to have infection (15.4%)
5/23 kids (age 10-19) were confirmed to have infection (22%)

https://www.niid.go.jp/niid/en/2019-ncov-e.html

Although the cruise ship population was elderly, there were 39 children under age 20 aboard. All were tested. The attack rates in kids were similar to the adults. Given this data, I would be careful about concluding that kids aren't becoming infected or playing a potential role in disease transmission. I do find that the arguments they are raising a bit amusing. On one hand the opponents of school closure claim that disease transmission in kids is not important, while later raising concerns that if schools are closed and kids stay home, they can increase the spread of COVID to older household members.

We did look at other coronavirus infections (SARS and MERS) and found that kids were relatively spared in both. Both SARS and MERS had significant nosocomial transmission though.
Effects of Coronavirus Infections in Children. Principi N, Bosis S, Esposito S. Effects of coronavirus infections in children. Emerg Infect Dis. 2010;16(2):183–188.
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2957994/

It is well known that all HCoVs cause respiratory infections. SARS-CoV is the most aggressive, although the disease seems to be substantially less severe in children than in adults. In patients <12 years of age, the clinical course of SARS was generally milder and shorter than in those >12 years: no death was reported, only 5% of the infected children were admitted to an intensive care unit, and <1% required mechanical ventilation (28). Leung and Chiu found that several children with SARS-CoV infection recovered without any sequelae after receiving supportive

therapy alone (36). The only pediatric patients with severe respiratory problems associated with SARS-CoV infection were >12 years (36).

There is much we don't know. I just would not dismiss school closure so quickly. I do not believe that would be a prudent decision in this case (precautionary principle).

In 2006, H5N1 was a serious concern. We had no vaccine and very few dose of antiviral medications. A strategy was needed to protect Americans in the event of a pandemic. A strategy called early, targeted, and layered containment (TLC) was developed to respond to this threat. This strategy leverages public health interventions called NPIs (non-pharmaceutical interventions) that include isolation, quarantine, and social distancing to slow the spread of disease. These NPIs serve to keep infectious people apart from those who have not been infected.

The combination of NPIs included in TLC was intended to:
•   slow disease transmission in the community
•   protect the community and reduce the burden of disease, and
•   keep our healthcare system functioning

This translates to fewer ill, fewer hospitalized, fewer ICU admissions, fewer deaths.

The effect of the combination of NPIs is to reduce disease transmission in the community and effectively shunt disease into 120M individual households (small compartments where disease transmission can be terminated). Early targeted and layered containment (TLC), or community mitigation is really a set of simple rules that when applied to a community (population) have an effect that is non-linear. The rules are pretty simple and result in complex interactions with results that are not what most people would expect. And the words *early, targeted* and *layered* are critical.

The simple rules are:
1. If you are sick, stay home (home isolation)
2. If someone in your household is sick, stay home (home quarantine)
3. Close schools and daycare (social distancing)
4. Social distancing in the community and in the workplace (really avoiding socially dense situations)

Every American could easily operationalize these rules. Each one of these interventions is only minimally effective in terms of reducing transmission. One cannot view this as an ala carte menu that public health leaders can pick and choose, although they think they can. It isn't that simple because the effectiveness of the layered approach is not equal to the simple addition of the effectiveness of each individual intervention. The effect is nonlinear. When you add these interventions together you get the equivalent of a phase shift (a discontinuity). Take out one piece and it is not easily predictable what the result would be. One would need to employ sophisticated computer models to evaluate the relative effectiveness of those different combinations to see how changing the simple rules, changes the outcomes. And the outcomes of complex systems are exquisitely sensitive to initial conditions (including timing). TLC is no different.

Back in 2006, a scientist at Los Alamos, Bob Glass, modeled a community outbreak to assess the effectiveness of various combinations of interventions. He shared his raw data with us. Richard Hatchett and I graphed it in Excel and we had one of those Eureka moments.
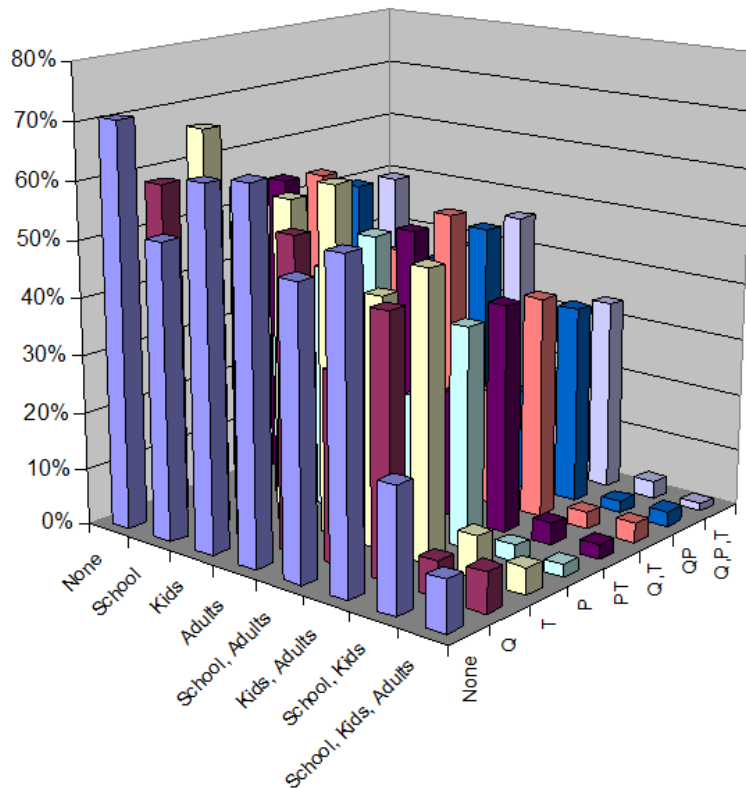
Here is the original graph. Bob Glass looked at all the possible combinations of social distancing interventions (doing nothing, closing schools, social distancing of kids in the community, social distancing

of adults in the community and at work, and all the possible combinations) and home quarantine (Q), antiviral treatment (T), antiviral prophylaxis (P), and all the possible combinations). Only Q applies to COVID-19 (we have no antiviral medications, so T or P). We found that phase transition, that discontinuity and we called it a cliff effect. As soon as Bob Glass combined school closure with social distancing of kids, something magical happened. Attack rates fell dramatically.

Over the next year, we faced critics from everywhere. What we learned thru that process is that very smart people (scientists), are not as data driven as they think. They made all sorts of assumptions about things they knew little about (juvenile crime, school meal programs, household data, child minding, social density in schools and school transportation). We heard these same tired arguments 15 years ago. What they failed to do was collect data on school meal programs and understand: (1) how kids survive 3 months of summer with no school; (2) household data on the number of households with school age children—and single parent households and two parents (both working) households with kids; (3) classroom size (social density), school transportation (school buses), juvenile crime, etc. Their arguments were not based on data but based on their beliefs.

School Closure
Adults are concerned about social distancing in the workplace and the community. They tend to focus on teleworking and social density in the workplace and will likely raise concerns regarding crowded public transportation. They almost seem oblivious to the social density in schools and the transportation used by half of the 60 M or so K-12 school children in the United States.
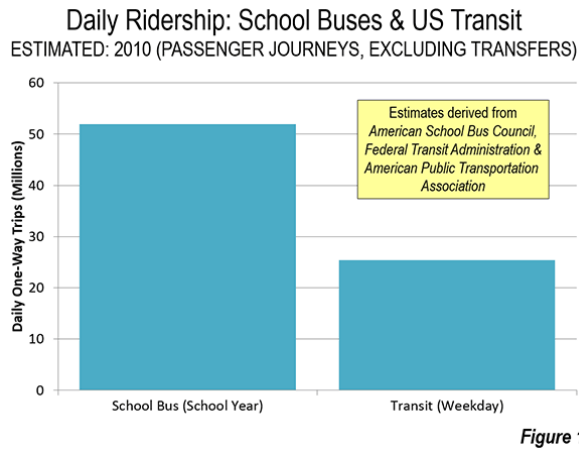
It is worth visiting a school in the middle of the day (especially at a time when students are moving between classes) to get a feel for the numbers below. Average elementary school classroom size is 49 sq. ft. per person (roughly a circle with a radius of just under 4 feet for each person in the classroom). For secondary school, the classroom size is 64 sq. ft. per person (roughly a circle with a radius of 4 ½ feet for each person in the classroom). Each state publishes state specific guidelines for elementary school and secondary school classroom size and gross school square footage per student. The state recommended classroom sizes are generally within the range provided below.

Number of Students plus 1 Teacher	Elementary School sq ft	Elementary School sq ft per person	Secondary School sq ft	Secondary School sq ft per person
10	539	49	704	64
11	564	47	768	64
12	637	49	832	64
13	686	49	896	64
14	735	49	960	64
15	784	49	1,024	64
16	833	49	1,088	64
17	882	49	1,152	64
18	931	49	1,216	64
19	980	49	1,280	64
20	1,029	49	1,344	64

We generally recommend spacing of 6 feet between individuals to minimize the transmission of disease.

Children, especially young children, have a different sense of social spacing than adults (kids are like the close talker on Seinfeld). School buses seats are designed based upon a child's hip size (13") to

accommodate 3 kids per seat. The seats are also closely spaced (not much knee room for an adult). About half the school age kids ride a school bus twice per day—60 M person trips per day. Just to put things into perspective, there are about 480K school buses compared to about 96K public transit buses. http://www.newgeography.com/content/004801-school-buses-americas-largest-transit-system   On school days, twice as many children ride on a school bus as all Americans using public transportation in the US.

Daily Ridership: School Buses & US Transit
ESTIMATED: 2010 (PASSENGER JOURNEYS, EXCLUDING TRANSFERS)

Estimates derived from American School Bus Council, Federal Transit Administration & American Public Transportation Association

Figure 1

Richard loved to say that kids weren't particularly careful with their secretions. Just watch kids with runny noses and coughing and sneezing and touching one another (especially the younger ones). You couldn't design a better system to spread disease. Schools and daycare centers are clearly amplifiers of disease transmission.

I attached some of the background material we collected back in 2006. Given the urgency, it is not worth the effort to update this information (I doubt much of it has changed drastically). I did update the data on school meal programs and household data from the American Community Survey. The major change is how much of the learning now in web-based. Kids are issued laptops now instead of books. Homework is done online. Education can continue pretty easily with the closure of schools.

CMG - Schools and Education.docx

US Household Demographics from A

Back in 2006 when community mitigation efforts were being developed, the greatest pushback was around school closure. The concerns that were raised included the impact on families if a parent had to stay home to watch their children for weeks on end (loss of household income plus the potential impact of this additional workplace absenteeism on the functioning of society and critical infrastructure) as well as the interruption of school meals to low income families. Other concerns raised included a surge in juvenile crime with the closure of schools, or children just re-congregating in shopping malls, etc. Given the length of time since those discussions, we predicted weeks ago that the same issues would be raised when school closure is considered among the array of NPIs to be implemented.

As of 2019, there are 50.6 M children enrolled in public schools K-12; 5.8 M enrolled in private schools; and 1.7 M homeschooled.

The National School Lunch Program operates in more than 97,000 public and non-profit private schools and residential childcare institutions, and the School Breakfast Program operates in nearly 91,000 schools. School lunch and breakfast are free for students at or below 130 percent of the poverty level and are available at reduced price for students between 130 percent and 185 percent poverty level. Two thirds of the thirty million students that participate in the School Lunch Program received free meals in 2019. During the summer, a Summer Food Service Program operates at more than 47,000 sites, providing breakfast, lunch and snacks to children living in low-income areas; the program served approximately 2.7 million total students in 2019.

As we were planning for implementing these community mitigation measures, CDC commissioned a Harvard School of Public Health public opinion poll conducted in the fall of 2006 to explore some of these concerns. According to the Harvard School of Public Health public opinion poll, 13 percent of households with children receiving free school meals reported that they would have a major problem if schools were closed and meals discontinued. Approximately 20 million children currently receive free school meals; thus, it is anticipated that about 2.6 million would have a major problem associated with the interruption of school meals. Many of these households also depend upon other Federal nutrition programs, including SNAP, the Special Supplemental Nutrition Program for Women, Infants, and Children, and the Child and Adult Care Food Program, and community food pantries. Schools are closed during the summer and the Summer Food Service Program fills the gap due to the absence of the School Lunch/Breakfast Programs over the summer. The Sumer Food Service Program provided meals to 2.7 M children in 2019—a number very similar to the 2.6 M estimate based on 13% of households with children receiving a free school meal who reporting that they would have a major problem if school meals are interrupted.

US Households
It is important to have baseline information on household demographics to better understand the challenges associated with implementation of NPIs (especially school closure). We collected detailed data back when we were developing these strategies (2006). Attached is current American Community Survey data (latest data available online is from 2017).
https://www.census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html?s_areas=00000&s_year=2017&s_tablename=TABLE1&s_bygroup1=1&s_bygroup2=1&s_filtergroup1=1&s_filtergroup2=1

A brief summary of the data is included below:
- Total US Households: 121.6 M
- 1-person households: 33.3 M (27.4%)
- Households with no children: 84.7 M (69.7%)
- Households with children: 36.9 M (30.3%)
- Households with 1 person age 65+: 22.9 M (18.8%)
- Households with 2 persons age 65+: 12.0 M (9.9%)
- Households with a single senior : 12.9 M (10.6%) [twice as many females--male seniors living alone 4.3 M; female seniors living alone 8.6 M]
- **Households with a senior and children under age 18: 1.3 M (1%)**

The purpose of looking at this data is to get our heads around the issues of concern (scope and scale) and target our strategies (shrinking the problem). We don't need to worry about home quarantine for 27.4% of households. Given the concern that older adults are being hit hard, the senior data is also important. States can query the survey for state specific data—suspect they already know this data pretty well. Given the concern that children staying home from school could spread disease to older

adults in the household, it is interesting to note that only 1% of US households have both children and an adult age 65+.

Back in 2006 we looked closely at households with kids. In 2006, there were 300 million Americans living in 116 million households in the United States. Approximately one-third of U.S. households (40 million) included children less than 18 years of age. In slightly more than half of these households (22 million), all adults present were working. Five million of these households had only a single working adult present. These households with children and only one working adult would be impacted disproportionately—potentially requiring the single working adult in the household to remain home to mind the children if students were dismissed from schools or childcare facilities were closed.

Depending upon the age threshold assumed for children requiring adult supervision, the impact of dismissing students from school and closure of childcare programs on working families would vary. The number of households impacted could range from 12.4 million (assuming children <13 years of age would require adult supervision) to 15.4 million (assuming children <15 years of age would require full-time adult supervision).

The projected impact of these estimates, however, does not fully account for the strategies families already employ to care for their children and remain in the workforce. Families with all adults in the household working currently utilize a number of strategies for child minding, including the assistance of other family members, such as grandparents and siblings, assistance from separated/divorced spouses, children minding themselves, staggered work/child-minding shifts for parents, and parents working from home. There are 60 million children under the age of 15. Over half these children (32 million or 56 percent) have a working mother. Nearly one-third (29 percent) of these children have a mother who works a non-day shift. Nearly one-third (29 percent) have a mother working part time. Nearly one-third (30 percent) of children under age 5 living with only their father in the household were regularly cared for by their mother while their father was working or in school. One of seven (14 percent) school age children, 5-14 years of age, living with only one parent in the household were regularly cared for by the other parent while their father or mother was working or attending school.

A Harvard School of Public Health public opinion poll conducted in the fall of 2006 reported that 86 percent of families with children under age 5 in childcare or children 5-17 years of age would be able to arrange for childcare to allow at least one adult in the household to continue to work if classes and childcare were cancelled for 3 months. These findings, when applied to the overall population, suggest that approximately one in seven households with children attending school or childcare would be unable to have at least one adult continue to work during a prolonged period of school and childcare cancellation.

One could easily envision strategies that would help us sustain school closure (and the benefits derived to the entire community in terms of helping to reduce disease transmission) and help families cope with child minding responsibilities resulting from school closure. Two or three families could work together to support one another (for example relatives or friends) to share child minding responsibilities. It will slightly weaken the effect of social distancing (effectively reducing the number of households to shunt disease from 120 M to say 100 M if 10 M families shared child minding). That would be a small price to pay to improve adherence.

In 2006, the Department of Labor was able to utilize the American Community Survey to examine households with school age children and no non-working adults present. That survey data also includes

occupation and income data. DOL assumed the adult with the lowest income would stay home to mind the children. They identified the top 3 occupations impacted. Healthcare 1.8M, Education 1.6M (but schools would be closed anyhow), and Food Service 1.2M.

DOL Estimates from
Survey.xlsx

The feasibility of following pandemic mitigation interventions is of particular concern for vulnerable populations (e.g., people who are living alone, the poor or working poor, elderly, [particularly those who are homebound], homeless, recent immigrants, disabled, institutionalized, or incarcerated). More than 33 million individuals in the United States live alone (27 percent of all households) and one-third of these individuals are age 65 years or older. According to the Harvard School of Public Health public opinion poll, 45 percent of respondents living in one-adult households report they would not have anyone to take care of them in the event of a pandemic. More than four in ten respondents living in one-adult households (45 percent) and about one-third of low-income (36 percent), disabled (33 percent), or chronically ill (32 percent) adults said they would not have anyone to take care of them if they were ill and had to remain at home. Similarly among people age 65 or over, those who live in one-adult households were far more likely (41 percent vs. 15 percent) than those who lived in two-adult households with another person age 65 or over to say they would have no one to take care of them.

TLC is fractal. We don't need to exhaust ourselves searching for perfect solutions to address all these challenges associated with the 2nd and 3rd order consequences of school closure. We can target our approach (shrinking the problem as much as possible) and develop a layered strategy of multiple partially effective interventions to minimize the impact to the most vulnerable groups and improve adherence and compliance.

The bottom line is that we need to stay focused on the purpose of NPIs—reducing community transmission. My fear is that an ala carte approach would make sense if the impact of these interventions was linear (remove school closure and effectiveness is reduced by 20%). But because the effect of layering NPIs is nonlinear, removing school closure could reduce effectiveness disproportionately. The data from Bob Glass would suggest that if they pull out school closure from TLC, the effectiveness will significantly diminished. The other point is that the effectiveness and efficiency of two of the NPIs (isolation and quarantine), depends upon the ability to quickly identify and confirm infection. You need rapid diagnostics to do that. We don't have rapid diagnostics; what we do have is limited testing capacity that takes a couple of days to get results. The social distancing measures do not require diagnostics. You pull the trigger once and you are done. For isolation and quarantine you need to pull the trigger potentially tens of millions of times depending upon the attack rate.

We can guarantee that if the US does not close schools now, they will eventually close all the schools and universities out of desperation. That is what happened in 1918. It will happen. And it will be a replay of Philadelphia 1918 across an entire nation. We will realize no benefit at that point and only the pain as well as experiencing something that not even Wuhan experienced, an unmitigated pandemic.

Many schools are closing now for 1 week for spring break (many this week and some in the next week or two). This is happening at a critical point of the acceleration of this outbreak in the US. In the next couple of weeks our healthcare system is likely to be stressed. A good number of parents take time off over spring break to be with their kids (many times both parents for two parent households). We have
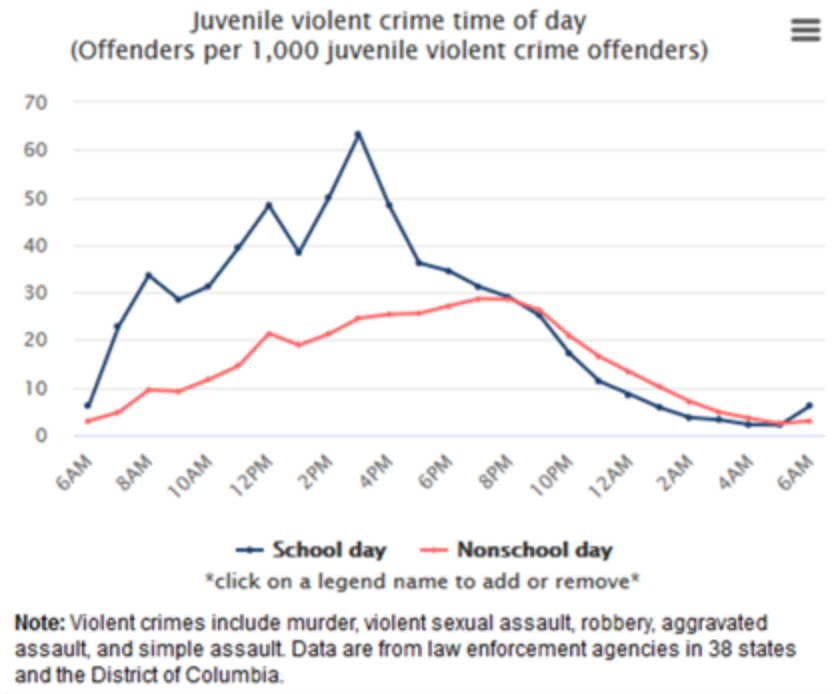
looked at annual leave usage and find a consistent pattern year after year. We see a spike in annual leave usage at Thanksgiving, another larger spike around Christmas/New Years, a bump in the spring (spring break), and another broad bump in the summer months when families tend to take vacations (because children are out of school).

Given the argument of those opposed to closing schools, should we cancel spring break and keep the schools open so that parents don't have to stay home to mind their kids at this particularly vulnerable time when our healthcare system is about to be stressed by both a surge of patients and a staffing shortage due to illness? Should we also keep the schools open so that children can be kept away from older adults in the household for much of the day during this period of acceleration? That is pretty much the logical extension of these arguments.

We close schools for 1 week for spring break and the world does not fall apart. The nutrition of children does not suffer. Do we think if schools closed for two weeks the world would come crashing down? Why not close schools for two weeks and then reassess (at least it gives us time). We can never get that time back.

I understand that "going to the mall" is code for kids re-congregating outside of school. Even if they do they are in a less socially dense environment and in much smaller groups. The whole school doesn't all go together anywhere, except to school.

Lastly, a comment on juvenile violent crime. Crime is more common on schools days (just the opposite of what most people assume). https://www.ojjdp.gov/ojstatbb/offenders/qa03301.asp This pattern is very different from adults.

Juvenile violent crime time of day
(Offenders per 1,000 juvenile violent crime offenders)

— School day   — Nonschool day
click on a legend name to add or remove

Note: Violent crimes include murder, violent sexual assault, robbery, aggravated assault, and simple assault. Data are from law enforcement agencies in 38 states and the District of Columbia.

[Text only] [CSV file]

- Juvenile violence peaks in the afterschool hours on school days and in the evenings on nonschool days.
- On nonschool days, the incidence of juvenile violence increases through the afternoon and early evening hours, peaking between 7 p.m. and 9 p.m.
- The number of school days in a year is essentially equal to the number of nonschool days in a year. Despite this split, most (62%) violent crimes committed by juveniles occur on school days. Nearly one-fifth (18%) of juvenile violent crimes occur in the 4 hours between 3 p.m. and 7 p.m. on school days. A smaller proportion of juvenile violent crime (13%) occurs during the standard juvenile curfew hours of 10 p.m. to 6 a.m. (inclusive of both school and nonschool days).
- The annual number of hours in the curfew period (i.e., 8 hours every day in the year) is 4 times greater than the number of hours in the 3 p.m. to 7 p.m. period on school days (i.e., 4 hours in half of the days in the year). Therefore, the rate of juvenile violence in the afterschool period is more than 5 times the rate in the juvenile curfew period (inclusive of both school and nonschool days).
- Consequently, efforts to reduce juvenile crime after school would appear to have greater potential to decrease a community's violent crime rate than do juvenile curfews.

You do have to ask yourself why just about every other country is closing schools and universities but we won't. I guess it will be an experiment. I really hope I am dead wrong. I just don't like experimenting and gambling with the lives of the 70 M Americans age 60 or older. If we close schools and we are wrong and things aren't as bad as we fear, we can open them back up (like a long spring break). If we don't close the schools and the opponents to closing school are wrong, the consequences will be unthinkable. There is no reset button.