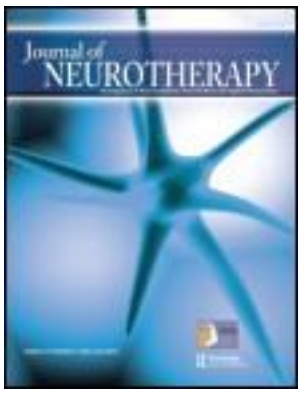

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School Shootings, High School Size, and Neurobiological Considerations

David A. Kaiser PhD [a]

[a] Rochester Institute of Technology , Rochester, New York

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School Shootings, High School Size, and Neurobiological Considerations

David A. Kaiser, PhD

SUMMARY. In the last decade 17 multiple-injury student school shootings have occurred in the United States, 13 at high schools and 4 at middle schools. Research suggests that high schools function best academically as well as socially at enrollments around 600 (150 students per grade), the natural group size of humans. Eleven of 13 high school shootings occurred in schools with enrollments over 600 students, and many with over 1,000 students. Violent and antisocial behavior is associated with deficits in social information processing, which is necessarily exacerbated by complex social environments. School shootings may be in part a response to the unprecedented social complexity of large schools. Median public high school enrollment now stands at 1,200 in suburbs and 1,600 in cities despite the fact that smaller schools are superior to large schools on nearly all academic and social measures of success including graduation rate, student satisfaction, conduct infractions, athletic participation, absenteeism, and dropout rate. Educational institutions should adapt to the neurobiological limitations of children instead

David A. Kaiser is Co-Editor of the *Journal of Neurotherapy* and affiliated with the Rochester Institute of Technology, Rochester, New York.

Address correspondence to: David A. Kaiser, P.O. Box 374, Churchville, NY 14428 (E-mail: davidkaiser@yahoo.com).

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of forcing children to adapt to the unnatural requirements of such institutions.

KEYWORDS. High school size, natural group size, social intelligence, school violence, school shootings

INTRODUCTION

From 1970 to 1993 the homicide rate for teenagers 15 to 19 years of age increased nearly three-fold while it declined for adults 30 years and older (Stanton, Baldwin, & Rachuba, 1997). Between 1992 and 2001, 323 school-associated violent deaths occurred in the United States (Stephens, 2003). In the past decade we have witnessed a very disturbing form of adolescent violence, the mass random shooting of students by other students in public schools. Since 1996, 17 multiple-injury student school shootings occurred in the United States which took the lives of 39 children and 13 adults, and injured 111.

Social-related neurocognitive deficits may predispose many individuals to aggression and violence (Dodge, Pettit, McClaskey, & Brown, 1986; Bradshaw & Garbarino, 2004; Silver, Goodman, Knoll, Isakov, & Modai, 2005). The right ventromedial prefrontal cortex, as well as other areas of the right hemisphere and prefrontal cortex, mediate much of social cognition, individuation of others, and social conduct (Tranel, Bechara, & Denburg, 2002; Mason & Macrae, 2004; Mosch, Max, & Tranel, 2005). Acquired sociopathy, for example, is associated with damage to right orbitofrontal cortex (Blair & Cipolotti, 2000) and socially undesirable behavior is more commonly associated with right-sided than left-sided frontotemporal dementia (Mychack, Kramer, Boone, & Miller, 2001; Mendez, Chen, Shapira, & Miller, 2005). Neuroimaging investigations also report abnormal prefrontal circuitry and activity to be associated with violence and antisociality, especially on the right side (Sterzer, Stadler, Krebs, Kleinschmidt, & Poustka, 2005; Bassarath, 2001; Evans & Claycomb, 1999; Evans & Park, 1997; Deckel, Hesselbrock, & Bauer, 1996). Quantitative EEG studies of violent men find either evidence of right hemisphere dysfunction (Evans & Park, 1997) or greater left-sided activation (Convit, Czobor, & Volavka,

1991; Deckel et al., 1996), which is consistent with right hemisphere dysfunction. Evans and Park (1997) also reported more anterior than posterior QEEG abnormalities in a sample of death row inmates.

However, brain damage or dysfunctions are obviously not the only factors behind violent behavior in school-aged persons. All adolescent primates strive for social status, especially males. The use of aggression, even violence, to improve one's social status is nothing new to our species or order (Wrangham & Wilson, 2004). Decades of research link aggression to social status in humans and nonhuman animals. Low peer acceptance is associated with aggression and conduct problems in children (Newcomb, Bukowski, & Pattee, 1993; Bierman, Smoot, & Aumiller, 1993). Peer rejection directly increases aggressive behavior (Pettit, 1997) and hyperactive children are especially at risk of being rejected by peers (Satterfield & Schell, 1997). With the rise of the mega-schools, high schools with enrollments in the thousands, rejection may become commonplace as adolescent status competition becomes increasingly more intense.

Humans are social animals and children undergo the longest period of socialization of any animal, a dependency of two decades or longer. Intelligence, along with the disproportionately large neocortex of primates, may be an adaptation to the special complexities of primate social life (Byrne & Whitten, 1988), with the relative size of neocortex limiting the number of individuals a primate can significantly interact with on a regular basis (Dunbar, 1992). A so-called natural group size, when exceeded, is socially unstable and often results in social conflict and group splintering (Dunbar, 1993). If the natural group size of adult humans is approximately 150 individuals, as Dunbar (1993) has suggested, then it is irrational to expect children to develop normally in larger groups than they are biologically equipped to deal with. In a seminal study on social functioning and high school size, Barker and Gump (1964) determined that students in smaller schools participated in twice as many extracurricular activities as students in larger schools (grade size of 225 or more). Cotton (1996) reviewed 103 studies that investigated associations between high school size and factors such as academic performance, social behavior, dropout rate, and parental involvement, and concluded that smaller schools are beneficial to students in all domains of function regardless of rural or urban setting. Smaller schools were superior to larger schools on athletic participation, extracurricular activity participation, absenteeism, dropout rate, student satisfaction, minor and serious rule infractions, self-esteem and locus of

control, interpersonal relationships, sense of community, parental involvement, interpersonal relations between teacher and students, and even teacher attitudes (Cotton, 1996). Compared to larger schools (enrollments above 600), smaller schools (400-600 enrollment) experience one-eighth the rate of serious crimes (4% compared to 33%), one-tenth the rate of physical attacks with weapons (2% to 20%), and one-third the rate of theft or larceny (18% to 68%) and vandalism (23% to 62%; Devoe et al., 2002). Academically, math and reading scores improved most for high school enrollments between 600 and 900 (Lee & Smith, 1997), with an even smaller optimum size (i.e., 450-650 enrollment) for mathematics achievement (based on their data scatter plot).

Small schools are more accountable to students and cost significantly less per graduate than larger schools (Stiefel, Latrola, Fruchter, & Berne, 1998). The National Association of Secondary School Principals (1996) recommended that secondary schools be capped at 600 students, and the Cross City Campaign for Urban School Reform recommended a limit of 500 students (Fine & Somerville, 1998). The existence of large schools is an outdated response to economic and social forces of the 1950s and 1960s. In 1959 and again in 1967 James Conant, past president of Harvard University, contended that the small high school was the number one problem in education and advocated for its elimination through district and school consolidation. In 1940, there were 200,000 public elementary and secondary schools, which have since been whittled down to less than a third of this number, 65,000 public elementary and secondary schools in 2005. Ironically this reduction occurred as the US population *increased* by 70 percent. Today some believe the number one problem in education is the large school (Quindlen, 2001).

School shootings are relatively rare, but may reflect systemic problems within educational institutions, ones that otherwise might be overlooked if not for such high-profile events. When the size of our schools exceeds the biocognitive capacity of our children, we are likely to witness fractures in a school's social fabric. Therefore it is hypothesized that a disproportionate amount of school shootings will take place in schools with grade size above our natural group size.

METHOD

Seventeen cases of mass school shootings in public schools by students against students were examined between 1996 to 2005 as well as

ten cases of post-Columbine averted school attacks. A school shooting is defined as an incident that took place on schools grounds, was committed by students of the school with clear lethal intent, and which resulted in multiple victimizations. Only one "school shooting" incident included in this analysis took place without the use of a firearm, when seven fellow students were injured by a machete and tree saw. Excluded from analysis are events perpetrated by adults, ex-students, or unknown assailants. Information about each school involved was acquired from the National Center for Educational Statistics (http://nces.ed.gov/ccd/) for the academic year of each incident, or estimated from the most recent complete data (academic year 2001-2002). Details were also taken from Stevens (2003), Newman, Fox, Harding, Mehta, and Roth (2004), National School Safety and Security Services (schoolsecurity.org), and media reports.

RESULTS

As shown in Figure 1, 11 of 13 high school shootings took place where actual grade enrollment for the assailant(s) was greater than 150 students (Chi-square = 6.2, df = 1), $p < .05$. As brain maturation (and presumably associated social cognitive ability) is not complete until adulthood (age 18 or later), natural group size for immature brains was calculated using gray-to-white matter ratios recorded from Courchesne et al. (2001) in 52 normal children from age 2 to 16. Gray-white matter ratios decrease linearly with age as absolute and relative amounts of white matter increase with brain maturation (Courchesne et al., 2001). This recalculation of natural group size allows for further analysis of incidents perpetrated by younger children at the four middle school incidents. Table 1 presents gray-white matter ratios and adjusted natural group (or grade) size by age.

Fourteen of 17 school shootings took place in age-adjusted grade enrollments of more than 150 students (Chi-square = 7.1, df = 1), $p < .01$. Table 2 presents location, actual grade size, total injuries, and adjusted grade size for all incidents. Injuries per assailant correlated to a modest degree with grade size, $r = .40$, $t(15) = 1.67$, $p < .06$, and with adjusted grade size, $r = .41$, $t(15) = 1.73$, $p < .06$, as shown in Figure 2. No effect of grade size was found for post-Columbine averted school attacks (Chi-square = 1.6, df = 1), $p > .05$; see Table 3). Schools on the list of

FIGURE 1. Number of high school incidents by assailants' actual grade size since 1996.

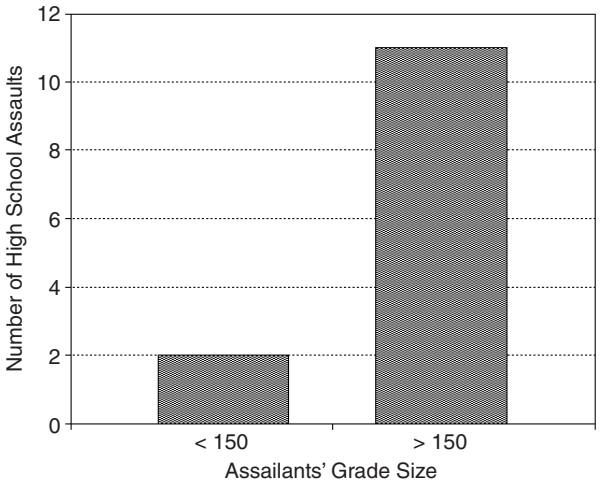


TABLE 1. Yearly Gray/White Matter Cortical Ratios Taken from Courchesne et al. (2001) and Subsequent Adjusted Maximum Natural Adolescent Group Size Assuming Adult Social Neurodevelopment by Age 18.

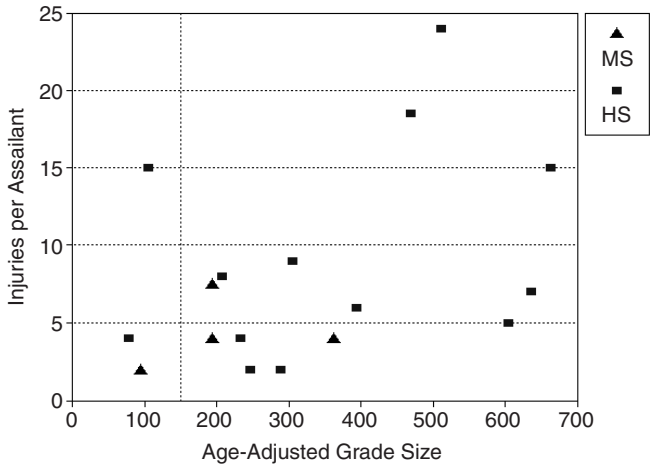
Age in Years	10	11	12	13	14	15	16	17[a]	18[a]
G/W Ratio	2.30	2.21	2.12	2.03	1.95	1.86	1.77	1.68	1.60
Maximum Grade Size	84	92	100	109	117	125	133	141	150

[a]Extrapolated ratios

averted attacks were selected without bias (i.e., without awareness of school size) from those reported in Newman et al. (2004) and schoolsecurity.org.

Public high school size was surveyed from the Common Core Data of the National Center for Educational Statistics for year 2000-2001. Median grade size in U.S. public high schools was 185 in the year 2000. Fifty-seven percent had enrollments above 150 students per grade. Compare this to 85 percent (11 of 13) of high school shootings that happened in schools with enrollments larger than 150 students per grade.

FIGURE 2. Injuries per assailant by age-adjusted grade size for middle and high school assaults.



DISCUSSION

In the past decade 17 high-profile school shootings occurred in public schools. Using census designations, seven shootings occurred in suburbs, four in towns, four in rural areas, and two in cities. Of 13 high school shootings, 7 involved total school enrollments of more than 1,000 students. Median high school grade size where a shooting took place was 272 compared to 185 in all public high schools. The correlation between injuries per assailant and grade size approached significance ($p < .06$), despite all the other possible factors that could influence attack severity including time of day, setting, marksmanship, assault duration, response of school security or police. This relationship between grade size and injuries may reflect the amount of planning, motivation, and determination on the part of assailants. Perhaps the larger the school, the greater the anonymity and the larger eventual response against its social structure.

Most of these attacks have been characterized as assaults against the adolescent social hierarchy (Newman et al., 2004). Schools are prime locations for socialization as well as victimization. Each year nearly 1 in 10 high school students report being bullied at school, and more report being threatened or injured with a weapon (DeVoe et al., 2004). Status

TABLE 2. Location, Grade Size (with and without age adjustment) and Total Injuries of Multiple Injury School Shootings from 1996 to 2005.

Location		Grade Size	Assailant Age(s)	Adj. Size	Total Injuries*
6-8th grade					
Stamps	AR	75	14	96	2
Fort Gibson	OK	141	13	194	4
Jonesboro	AR	120	11,13	194	15
Edinboro	PA	283	14	362	4
9th-12th grade					
Bethel	AK	70	16	79	4
Red Lake	MN	95	16	107	15
West Paducah	KY	163	14	209	8
Moses Lake	WA	182	14	233	4
Cold Spring	MN	206	15	246	2
Richmond	VA	242	14	289	2
Pearl	MS	272	16	305	9
Conyers	GA	351	16	394	6
Littleton	CO	443	17,18	469	37
Springfield	OR	428	15	512	24
El Cajon	CA	604	18	604	5
Valparaiso	IN	532	15	636	7
Santee	CA	555	15	664	15

* includes fatalities

competition is fierce in crowded environments. When more than half of all public high schools exceed our natural group size, it is not surprising that abnormal and atypical social behaviors including violence frequently occur (see Table 4 for grade size as a function of locale). The process of socialization is likely prolonged and diminished in mega-schools. Beside socialization, intellectual development is also likely to suffer in such large social settings as a great proportion of time and resources are spent maintaining an orderly learning environment at the expense of learning. Behavioral regulation through face-to-face interaction and rapport is beyond the capabilities of students, teachers, and administrators in larger schools, so formal institutions of security must be employed.

One hundred and fifty is said to be our species' natural group size, the size of groups that humans survived within for the vast majority of our history. In fact, one hundred and fifty individuals approximates the size

TABLE 3. Planned School Shootings 1999-2001.

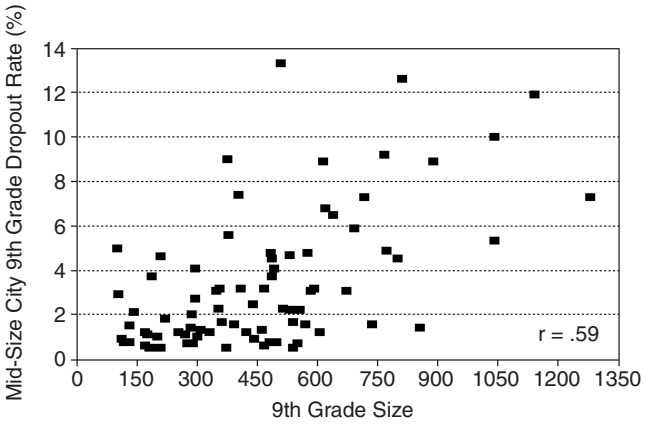
Location	Grade Size
Hoyt, KS	67
Mattawa, WA	95
Glendale, AZ	97
Port Huron, MI	196
Elmira, NY	268
Fort Collins, CO	299
Cleveland, OH	392
Carrollton, TX	709
New Bedford, MA	820
Santa Ana, CA	1136

TABLE 4. Grade Size in Public High Schools as a Function of Locale.

Locale	High Schools Number	Median Grade Size	Largest Size	Grade Size Above 150
City	2,054	408	1,522	93%
Suburb	3,.832	303	1,289	82%
Town	2,175	159	745	53%
Rural	4,980	86	1,244	25%
All Locales	13,041	185	1,522	57%

of many hunter-gatherer bands and horticultural villages today (Dunbar, 1993). When people are faced with a large number of faces (e.g., more than 150), their response has commonly been to leave, to separate. Bands and villages splinter into daughter groups and move apart when there are too many people to feed and figure out (i.e., when the group has become too complex for the tribe members' brain function; Dunbar, 1993). Humanity spread across the globe in a relatively short time in part because of the constant process of division down to appropriate-sized social groups. Children today, given the same chance to leave large numbers, will often take this option. As shown in Figure 3, ninth grade dropout rate correlated with grade size in mid-size cities and large towns (see Cotton, 2001 and Stiefel et al., 1998, for comparisons within cities). Too many faces lead to in-grouping and out-grouping, alienation and depression, cliques and conflicts. A school largely populated with strangers is an environment that children are biologically unsuited for,

FIGURE 3. Dropout rate for 9th graders of mid-size cities (locale 2) as a function of grade size (modified from Kaiser, 2002).

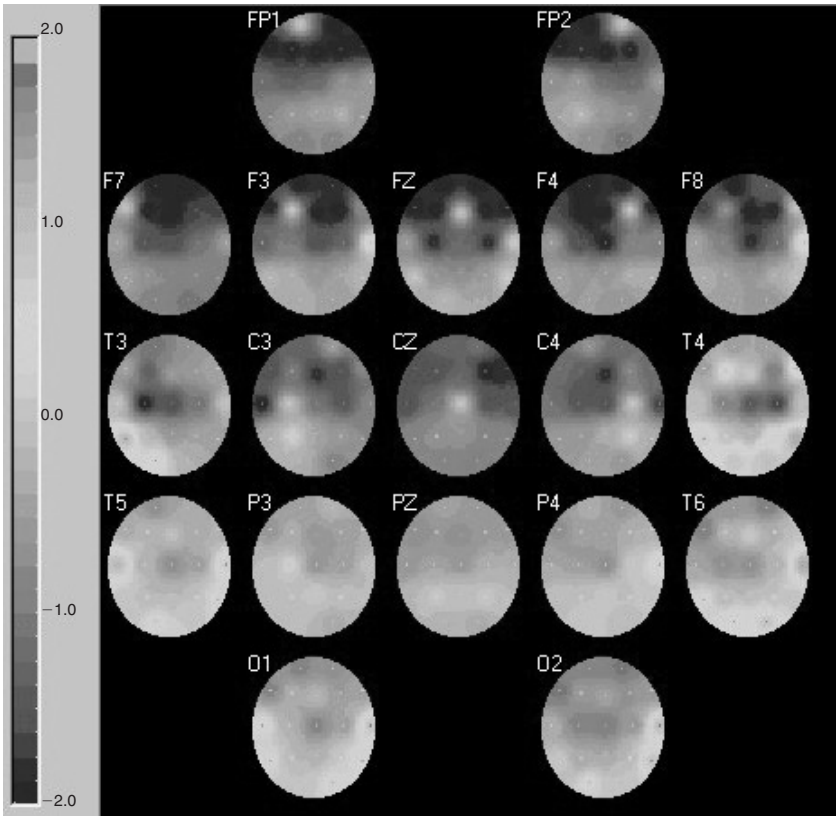


and from which many will retreat, emotionally if they cannot physically.

The assumption that social-related neurodevelopment is completed by 18 years of age is unlikely given post-adolescent brain growth in dorsolateral frontal cortex and other critical brain areas (Sowell, Thompson, Tessner, & Toga, 2001). Quantitative evidence of reduced functional coordination between anterior sites, presumably due to delayed or recent myelination, was found for 9 of 10 college-aged students (Kaiser, unpublished data, April 2005; see Figure 4). Perhaps optimal grade size should be adjusted accordingly even at the college level.

More and more educational and advocacy groups recognize that smaller schools serve our children best. As mentioned above, some have recommended a 600 enrollment limit based on practice and empirical evaluations (e.g., National Association of Secondary School Principals, 1996). This article reviewed literature on brain damage/dysfunction and social competition as factors in school violence, and provided evidence for a biological explanation for optimal school size (i.e., a neurobiological constraint on social relations). Adjusting to larger groups may tax neurocognitive functioning beyond the capabilities of many children. This may be especially true of right hemisphere-related functions such as empathy and other social skills. However, other factors obviously must be considered in cases of school shootings and violence. Recently a 16-year-old boy shot five classmates in a very small school

FIGURE 4. A representative college student's eyes closed comodulation data compared to adult norms. Comodulation is a measure of magnitude consistency between electrode pairs across time. Low magnitude consistency (colored blue, 2 standard deviations below the mean) indicates lower functional connectivity or coordination relative to an adult norm whereas green coloration reflects normal levels of comodulation. Each topograph represents a site compared to all other sites including itself (i.e., 19 pair-wise comparisons).



in Minnesota; clearly not all pressures faced by adolescents can be indexed by the size of the academic environment.

Reducing school size to within children's neurobiological capabilities is a universal prevention, a proactive method of reducing violence and improving intellectual, emotional, and social development. When groups are small enough for members to know one another, they are

more apt and able to police themselves. When natural group sizes are exceeded, formal institutions of behavioral control are necessary, which can be both expensive and ineffective. Some communities have experimented with a schools-within-a-school approach, dividing large student bodies into smaller operational units with dedicated academic and administrative personnel. But common areas (gym, cafeteria, entrance) often remain shared by the entire student body, undermining group cohesion, and students in physically large schools rarely possess the freedoms and responsibilities of students in smaller schools, regardless of administrative strategy. We need to build smaller schools, more schools, and roll back the consolidation of the past half century. Realistically, excessively large schools will continue to be built and there will be children with acquired or inherited brain damage or dysfunction lacking in behavioral control and prone to violence in any size group. Selected and indicated prevention of violence in such individuals will require other approaches. Effective medications for attention deficit disorder, anxiety, depression, and seizure disorders exist and can be useful for many appropriately diagnosed children. In many cases such disorders co-exist in children with histories of violence. However, all have side effects, and often do not directly impact the specific brain systems underlying the type of behavioral dyscontrol involved in violent behaviors. A promising approach to prevention of violence in such at-risk children is neurotherapy (EEG biofeedback). This technique enables self-regulation of the bioelectrical functioning of the central nervous system, has few if any significant side effects, and has been demonstrated through research and extensive clinical use to be effective not only in control of co-existing disorders such as attention deficit disorder, but also in cases of episodic violence (Quirk, 1995). Nevertheless, while neurotherapy may improve an individual's behavior by normalizing brain activity, similar normalization of his or her social environment also seems essential.

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