Thought Question: Does environmental ambient noise in high school classrooms make learning more challenging and affect student mathematics achievement?

Research Article: *Effects of Ambient Noise on the Measurement of Mathematics Achievement for Urban High School Students*

Subject Area:

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Summary
Researchers examined the impact of ambient classroom noise in an urban high school on students' test-taking performance. The study measured the student's annoyance level of the background noise and found one-third of the students "rushed through the test, felt frustrated, or just zoned out." Two "noise-coping" strategies were identified where students try and resolve the noise issue or regulate stress related to the noise. Findings suggest the more bothered a student was by the noise, the lower the test score. The most prevalent noise came from doors (slamming, opening), followed by talking, and the third most noticeable background noise involved screaming and yelling in the hallways. When students "tune out" the ambient noise, they also "shut down channels for learning." Students who try to increase their attention level to mitigate the noise distractions reach "increased arousal," however, researchers warn students cannot maintain this over time.

Enjoy the article! **And remember**...the background noise in the learning environment can impact student achievement in mathematics.

Keywords: Urban high school, noise, mathematics achievement, measurement, minority academic success, urban education

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Effects of Ambient Noise on the Measurement of Mathematics Achievement for Urban High School Students

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Abstract

Students from urban high schools are usually faced with adverse environmental factors in their pursuit of academic success. These factors make learning more challenging and may confound the measurement of academic performance itself. This study explores how one such factor, ambient noise, affects the measurement of mathematics achievement. Overall, about 40% of students were bothered by noise during testing. The more bothersome the noise is, the lower the math score tends to be. Noise coping explains about 10% of the test score difference, comparable with that by grade point average. These findings indicate a clear association between noise and math achievement measurement.

Keywords

urban high school, noise, mathematics achievement, measurement, minority academic success, urban education

For students living in busy urban environments, ambient noise level is usually significantly higher than the recommended acceptable levels, such as that by the American National Standards (American National Standards Institute

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[ANSI], 2002). Compared with their peers in suburban and rural schools, these students are exposed to excessive ambient noise on a constant basis (California Department of Transportation, n.d.). In addition, urban schools typically have large classes. As more students are packed into one classroom, noise levels from inside schools are also likely to rise. The excessive noise can be problematic in that it may not only cause health problems (Cohen, Evans, Stokols, & Krantz, 1986; Lupien, King, Meaney, & McEwen, 2001; Spreng, 2000) but also affect cognitive processing and academic performance (Klatte, Bergström, & Lachmann, 2013). Actually, the detrimental effects of excessive noise have been documented on many aspects of student learning, such as speaking, reading, writing, and numeracy (e.g., Airey & MacKenzie, 1999; Bistrup, 2003; Dockrell & Shield, 2006; Elliott, 1979; Haines, Stansfeld, Job, Berglund, & Head, 2001; Lundquist, Holmberg, & Landstrom, 2000; Maxwell & Evans, 2000; Shield & Dockrell, 2003). For instance, Elliott (1979) found that younger students are susceptible to noise. Their recognition of sentences in noisy environments deteriorates from 15- and 17-year-olds to 11-year-olds and then further to the 9-year-olds. Shield and Dockrell (2003) provided a comprehensive review of studies on the negative impact of noise on student learning. Their 2006 study showed that elementary students perform significantly worse on arithmetic under more noisy conditions.

Of particular concern is the noise that has abrupt changes in frequency and pitch (e.g., door slamming and screaming). This type of noise seems to be particularly disruptive (Loeb, 1986; Shield & Dockrell, 2003). One possible reason is this type of noise is more likely to capture attention, thus interfering with what is being processed in short-term memory (Klatte et al., 2013). Also, ambient noise is deemed more detrimental to working on new tasks than on familiar tasks (Zentall & Shaw, 1980). Moreover, noise exposure has been found to affect the complex cognitive tasks more than the daily routine work (Banbury & Berry, 1998; Szalma & Hancock, 2011). As expected, noise has a large impact on special education students, such as those with hearing impairments (Nelson & Soli, 2000) and with learning difficulties (Bradlow, Krauss, & Hayes, 2003; Klatte et al., 2013).

Theories have been constructed in the attempt to explain how exactly noise affects student learning adversely. One intuitive theory is avoidance. Students struggling with excessive noise simply tune out all the stimuli, which automatically shuts down the channels for learning (Cohen et al., 1986). Another theory stipulates that to combat the excessive noise in the learning environment, students would have to increase their attention level to the so-called increased arousal stage (Evans & Lepore, 1993). The problem is that this increased arousal is not sustainable over time, resulting in an overall lack of attention to learning tasks.

Facing excessive noise, the typical response for most students is annoyance. Some students may be aware of noise without necessarily being annoyed by it. Others develop various coping strategies, such as "wearing headphones", "thinking about something else", telling others to turn down the noise, or going to a quiet place (Haines, Brentnall, Stansfield, & Klineberg, 2003). There is a stronger relationship between academic performance and annoyance level than between the performance and the sheer sound level itself (Lundquist et al., 2000).

In general, noise-coping strategies fall into two categories (Lazarus, 1999). The first is the "problem-focused" strategy where the individual actively looks for a solution to the noise problem, such as telling the person who makes the noise to stop or reporting the noise to the classroom teacher. The second category is more "emotion-focused" where individuals attempt to regulate their emotions tied to the stress situation, such as trying to ignore the noise.

While how noise affects student learning has attracted many researchers, little attention has been given to how noise affects the measurement of student achievement. Considering how noise in schools is usually intermittent (e.g., door slamming and yelling) and taking a test by nature is a highly demanding complex cognitive task, it is reasonable to believe that excessive noise will affect test-taking behaviors. As test scores from standardized tests are taking an increasingly more important role in schools, the study of the relationship between the noise level and the measurement of achievement becomes more crucial. For instance, if a student failed a test not due to the lack of knowledge but due to the overwhelming noise during testing, the logical next step would not be to send the student to a remedial program but rather to address the noise issue. This research sets out to look at the effects of ambient noise and the coping mechanisms utilized by students during a standardized assessment. Specifically, two research questions for this study are as follows:

Research Question 1: How bothersome is the ambient noise to students when taking a test on computer?

Research Question 2: What is the relationship that noise coping has with the achievement test score and grade point average (GPA)?

In answering these questions, both qualitative and quantitative data were collected and analyzed. To address the first question, the level of ambient noise during the testing sessions was measured. A noise coping scale was developed and used to measure how annoyed students were by noise while taking a test. In addition, the main sources of noise were identified. To address the second question, a noise-coping score was derived and correlated with a math test score and GPA.

Method

Subjects

Subjects were high school students from a large urban school district in the Midwest United States. Altogether, 122 students were tested and surveyed. The demographics of these students were as follows: Ages ranged from 14 to 18 with the mean at 15.50 and standard deviation at 0.93; grade distribution was 81 students in the ninth, 31 in the 10th, nine in the 11th, and one in the 12th. The GPA ranged from 0 to 3.43 with a mean of 1.39 and a standard deviation of 0.76 on a 4.0 scale. Clearly, many of these students were in the lower end of the achievement spectrum. Eighteen (14.7%) students were in the special education program. Six regular education students were English language learners. Given that 80% of the students in the school are eligible for free and reduced lunch, many of these students are considered at-risk students. Altogether 86.9% of the students in this school are classified as "economically disadvantaged."

Institutional review board as well as both student and parent consent forms were obtained before data collection started.

Computer-Based Testing

The Measures of Academic Progress (MAP) assessment is a computerized adaptive assessment given to students three times a year in this school district. Scores from the MAP test were used for improving instruction as well as for promotion and retention; thus, it is reasonable to believe that students treated this test seriously. The survey results indicated that about 94% of students said that they were highly or somewhat motivated to do well on this test.

Developed by the Northwest Evaluation Association, MAP aims to adapt to the student's ability by selecting items not too hard or too easy for them. Each testing session takes about an hour. The mathematics test measures math knowledge in a number of important content areas, such as functions and algebra, geometry and measurement, number sense and computation, and statistics and probability.

As the subjects were from different grades, one concern is the comparability of the test scores. In reality, computerized adaptive tests assemble a tailored test for each individual. However, instead of using the raw score from each test, MAP reports a scaled score. The scale covers all high school grades (Northwest Evaluation Association, 2011), and hence, math test scores used in this study are actually on the same scale.

Noise Level and Noise-Coping Survey

A decibel meter (A weighting-Amprobe SM-10, IEC 651 Type 2 made by Amprobe, Everett, WA) was used to measure the environmental noise in the room where students took the test. As the maximum background noise level recommended by American National Standards Institute (2002) and World Health Organisation (WHO; 1999) is 35dB(A) for classrooms, this number was set as the criterion to ascertain whether excessive noise existed during the testing sessions. At each reading, the source of noise was also recorded in a short note. To identify the primary sources of noise, this text-format information was analyzed using QSR International's NVivo 9 software. Specifically, word frequency search using "synonyms" as the criterion was conducted. All the synonyms were combined into a general word category. For example, words "singing, speak, speaking, talking" were all counted under the "talk" category. Categories with the highest frequency were then identified as the primary sources of noise.

A noise coping survey designed for this study was administered after the MAP test. As the most widespread and well-documented subjective response to noise is annoyance, this survey was designed to measure how bothersome or annoying the ambient noise is. Two types of noise-coping strategies were tapped: problem solving and emotional coping. The former asks what actions students take to reduce the noise level and the latter asks questions on the emotional reaction to the excessive noise. Survey questions can be found in the factor analysis results table (Table 1). These questions were phrased to describe typical actions and reactions to noise from the sample of students, either observed by classroom teachers or through the account of the students themselves. Response to these questions was in the simple yes or no format. In the statistical analyses, all responses were coded in the way that larger values mean higher annoyance by the noise.

Factor Analysis of the Noise-Coping Scale

To explore the internal structure of the constructed noise-coping scale, factor analysis was run. The primary goal was to determine whether noise coping is unidimensional or multidimensional. Practically, a score also needs to be derived for the annoyance scale to explore the relationship between noise coping and test scores.

Table 1. The Sources of Noise.

General word	Count	%	Similar words
Door	75	6.61	Door, doors
Noise	58	5.11	Disturbance, noise, noises
Room	53	4.54	Room, rooms
Talking	47	4.08	Singing, speak, speaking, talking
Yelling	47	4.01	Call, screaming, yelling, yells
Hallway	30	2.64	Hallway
Talking	40	2.33	Asked, asks, brings, directions, get, getting, makes, making, reading, remove, take, taking
Sound	28	2.10	Go, going, phone, sound, sounds, voices
Pounding	21	1.85	Pounding
Rings	20	1.41	Call, environment, phone, rings, surrounding

One challenge in conducting factor analysis is to determine the number of factors that actually exist. In this study, statistical criteria (e.g., eigenvalue, scree plot, and fit indices) were combined with the conceptual knowledge of the two types of noise-coping strategies. Specifically, solutions with one and two factors were obtained and compared. As recommended by many researchers (e.g., Chen, Curran, Bollen, Kirby, & Paxton, 2008), multiple model data fit indices were used. The goal was to have a solution that shows adequate model data fit and at the same time, the meaning of the extracted factors is well established.

Due to the dichotomous nature of item responses, tetrachoric correlation among items was used. Accordingly, the robust weighted least square method as implemented in the Mplus program (Muthén & Muthén, 1998-2010) was used in factor extraction. Moreover, in assessing model data fit, two fit statistics were applied: the traditional chi-square statistic and the root mean square error of approximation (RMSEA) fit statistic. The evaluation of the former takes the form of hypothesis testing. The latter is evaluated by these cut-off values: over 0.1, unacceptable; 0.08 to 0.1, mediocre; 0.06 to 0.08, acceptable; and 0.01 to 0.06, close fit (Hu & Bentler, 1999).

Results

The results are presented in the following order. First, information on background noise is given. Second, the effectiveness of the noise-coping survey is evaluated. Finally, the relationship between noise coping and performance on the MAP math test is described.

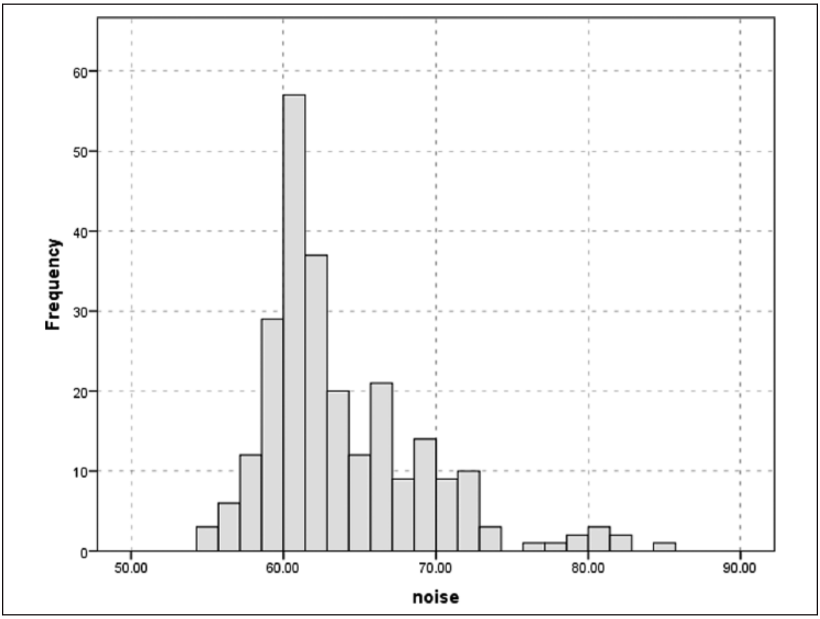

Figure 1. Noise level during testing.

Noise Level

Altogether, 252 readings of the decibel meter were taken throughout the two testing days. The results definitively show that these students were subjected to excessive noise. The average noise level being read was 63.70 dB(A) with a standard deviation of 5.33, which is much higher than the recommended 35 dB(A). The range of the noise is 55 to 85 dB(A); hence even the lowest reading was higher than the recommend level. Moreover, an independent *t* test showed no difference of the noise level between 2 days, $t(250) = .10$, $p = .92$, indicating that the observed high noise level could be more chronic than accidental. The distribution of the noise is illustrated in Figure 1.

Table 1 presents the word frequency search results. As shown in the table, the most frequent word is door, meaning door was the most frequent source of noise, such as door closing, door pounding, and door slamming. The next frequent source is talking. This included student and teacher talking, chatting, speaking, and singing in the room or the hallway. After that, it is yelling and screaming. In these 2 days, 47 incidents of yelling were recorded. These results are consistent with one previous study showing that the main source

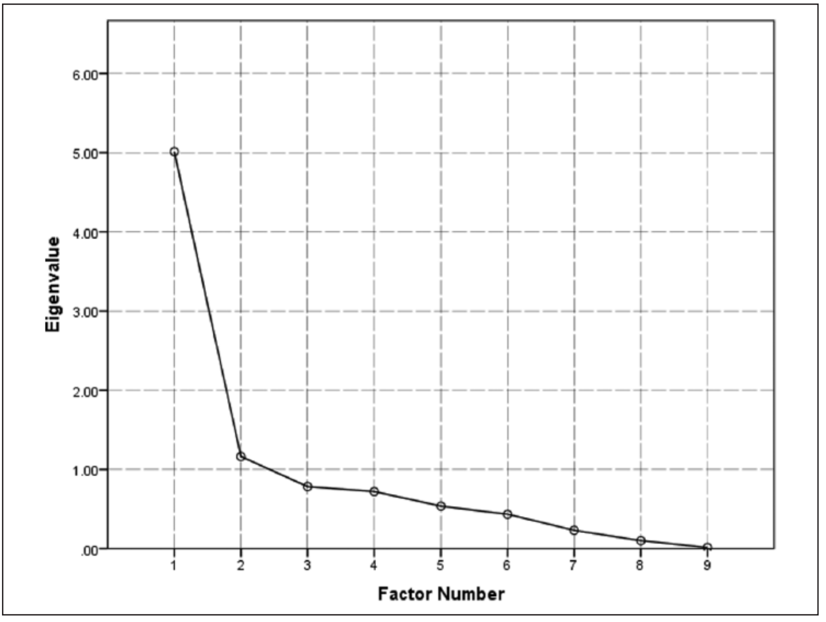

Figure 2. Scree plot for the factor structure of the noise coping scale.

of the excessive noise actually comes from inside the school (Eysel-Gosepath, Daut, Pinger, Lehmacher, & Erren, 2012).

Effectiveness of Noise Coping Survey

Next, to uncover the underlying structure of the noise-coping scale, an exploratory factor analysis was run. All indicators suggested a one-factor solution for the data, implying that noise coping is one dimensional rather than the two distinct types of strategies described in the original survey. The first factor accounts for 56% of the total variance. After that, there is a considerable drop to 13% by the second factor. The scree plot (Gorsuch, 1983) in Figure 2 also illustrates that the elbow is at the second factor, signaling only one factor should be retained. The chi-square test of model data fit indicates that the one-factor solution fits the data at the .05 level, $\chi^2(13) = 18.22$, $p = .15$. The RMSEA is 0.057, also implying an acceptable fit. However, the chi-square difference test shows that the two-factor solution fits the data significantly better than the one-factor solution, $\chi^2\ (2) = 8.15$, $p = .017$. On careful examination of the structure under the two-factor solution, only Questions 1

Table 2. Factor Loadings of the Noise-Coping Scale.

Questions	Percentage endorsing (%)	Factor loading
During this MAP test, what action did you take in response to distracting noise?		
1. I ignored the noise, but it bothered me	36.3	.72
2. I told the person causing the noise to stop	17.9	.81
3. I rushed through the test	16.3	.76
4. I told the teacher about the noise	10.6	.88
During this MAP test session, how did you respond emotionally to the noise?		
5. I got angry	15.4	.82
6. I was frustrated	33.1	.66
7. I felt trapped	11.3	.80
8. I zoned out	35.5	.47
9. I felt sad	5.7	.59

Note. MAP = Measures of Academic Progress.

and 6 in Table 1 are loaded on the second factor, which adds little to the substantive interpretation to the one-factor solution. Based on the unidimensional structure of the scale, a factor score was derived as the measurement of the noise-coping level for each student.

Table 2 gives the percentage by which each item was endorsed. The highest numbers show that about one third of the students felt annoyed by the noise while taking the test. Also one third felt frustrated. While 18% of the students told the person causing the noise to stop, only 10% actually reported to the teacher. Table 2 also provides the factor loading of each item on the noise-coping scale. Considering all the items are yes or no questions, these loadings are quite high, indicating that they have measured the annoyance factor quite well. One item that is not included in the table and the scale is, "During this MAP test session, how did you respond emotionally to the noise? I felt fine." The loading of this item is either too low for the one-factor solution (less than 0.3) or too hard to interpret in the two-factor solution (aligned with Items 1 and 6). The reliability of this scale measured by Cronbach's alpha is .76, high enough for a study like this for research purpose.

Relationship Between Noise and Performance

The relationship between noise coping and academic performance was explored next. As shown in Table 3, the noise coping score had a −0.31 correlation with the MAP math score. The negative relationship indicates that

Table 3. Correlation Among the Noise-Coping Score, the MAP Score, and GPA.

	MAP score	GPA
GPA	−.34**	
Noise-coping score	−.31**	−.05

Note. MAP = Measures of Academic Progress; GPA = grade point average.
**Correlation is significant at the .01 level (two-tailed).

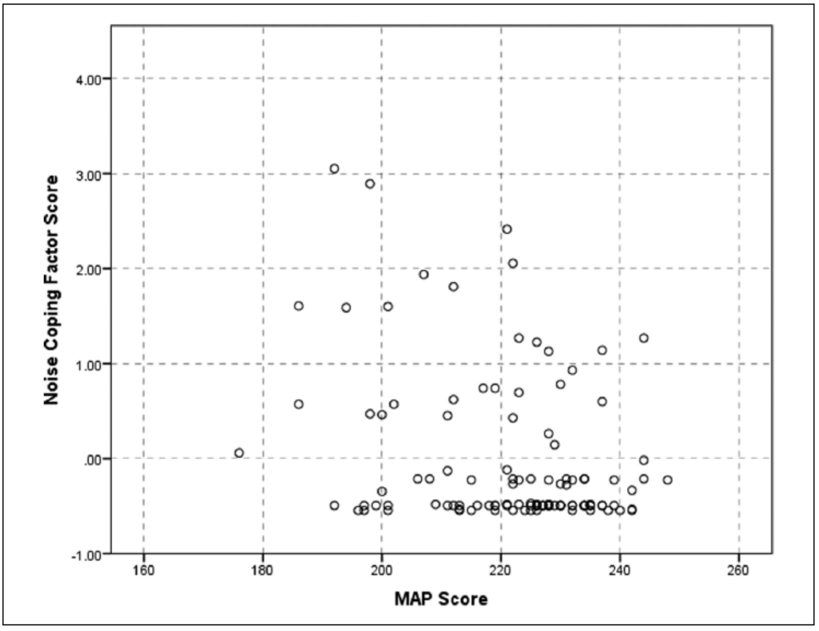

Figure 3. Scatterplot for the relationship between the noise coping and MAP scores.
Note. MAP = Measures of Academic Progress.

the more a student feels bothered by the noise, the lower his or her test score tends to be. This downward relation is also depicted in Figure 3. Note that many noise-coping scores in the figure are quite low, which means those students were not bothered much by the noise. More interesting is the magnitude of this correlation. The noise coping accounts for about 10% of the variance of the MAP score. Although this magnitude may not sound high, it is almost the same as that accounted by the GPA, usually considered as the most prominent predictor of a test score in a specific subject. That is to say, how a student copes with the environmental noise is as strong a predictor of the performance on this computer-based test as the GPA. Table 3 also shows no relationship between noise coping and GPA.

Finally, the hypothesis whether students in higher grades are less affected by the noise was tested. For that, an analysis of variance test was run to compare the noise coping scale score across grades. Grade 12 was not included as it had only one student. The test showed no significant difference among Grades 9, 10, and 11, $F(2, 118) = 1.10$, $p = .34$.

Discussion

In many districts across the United States, computer-based assessments, like the MAP, are being used to measure student achievement as well as teacher effectiveness. Moreover, in the near future, SMARTER Balanced and the Partnership for Assessment of Readiness for College and Careers (PARCC), both computer-based assessments, will be used by States and the federal government in the United States to measure student achievement. With students at risk disproportionally failing standardized tests and thus being sent to remedial services, it is essential to ensure that these test scores accurately represent their achievement levels. This study examines how one factor, ambient noise, may confound the measurement of academic achievement of urban students, who are susceptible to high levels of ambient noise.

Although classroom teachers widely believe that noise has a negative impact on student learning, empirical evidence on how students actually respond to noise has been limited. One possible reason is that the research on the effect of ambient noise on performance has actually decreased significantly in recent years (Szalma & Hancock, 2011). By taking a unique perspective on how noise affects the measurement of academic performance, this research delivers more interesting results than the obvious truth that the quieter the environment, the better it is for learning. First of all, the amount of noise students in urban schools may be subjected to is astonishing. The lowest noise level recorded in this study is 55 dB(A) with the average almost doubling the recommended level, which happens to be very close to the critical 70 dBA recommended by some researchers as unfavorable for young learners (Eysel-Gosepath et al., 2012). To exacerbate the situation, many students in this study have already lagged behind considerably in school work. Moreover, about a third of them responded in the follow-up survey that they were bothered or frustrated by the noise during testing. This number is actually lower than the 57% reported in another study (Ali, 2013). These three factors combined, one has to question the validity in interpreting or using the score obtained under these conditions. In other words, there may have been too much "noise" in the score for making high-stake decisions, such as receiving remedial work based on the MAP test results.

Second, this study shows how noise actually interferes with the measurement. About two thirds of students were able to ignore the noise and worked through the test. For the other one third, things were much harder. They either rushed through the test, felt frustrated, or just zoned out.

Finally, the strength of the association between noise annoyance and test performance is surprisingly high. Although one can easily predict the negative relationship, it is startling to discover that noise annoyance is almost as strong a predictor of the test score as the GPA. This finding clearly establishes the association between noise annoyance and the measurement of academic achievement.

Limitations and Future Work

By nature, this study is exploratory and observatory. In other words, no condition has been controlled or manipulated, such as deliberately varying the noise level and studying its effects on student behaviors. That is exactly why all the conclusions have been phrased in strictly "associative" terms. To see how noise actually changes test-taking behaviors or test performance, a more in-depth experimental design is required. One such example would be for students to take a test with and without wearing isolation headphones. That way, one may be able to single out the noise effect. The current study provides a strong motivation to conduct such an experiment. It will be interesting to see whether the 10% variance of test score due to noise conclusion from the current study will be replicated.

Findings from this study may have been affected by two characteristics of the sample used. The sample size of 122 students is relatively small. In addition, the sample is quite homogeneous, consisting of mainly students with low GPAs. These two features combined, the design may have lacked adequate power to detect all the effects, such as the association between GPA and the noise annoyance scale score. One would assume if nosing coping affects the exam test score, it should also affect the overall GPA. An alternative explanation for this lack of association is that GPA embraces more than in-class test scores, such as take-home assignments and projects. Future studies can also use overall math achievement as a predictor. As it is specific for the math subject, it should be a stronger predictor than the GPA.

An important topic to be addressed in the future apparently is how to reduce this noise effect. Granted that tremendous efforts have been made in the past few decades to reduce the impact of physical facilities on student learning, such as the establishment of the ANSI and WHO standards for school building, this study reveals that most noise actually comes from inside the school, such as door slamming or yelling, which the above standards will not apply to. Future research can be designed to explore the best strategies to reduce those behaviors, such as conducting noise reduction education. Meanwhile, one could also look into effective strategies in dealing with noise. An easy start seems to be using isolation headphones during testing. In addition, this study also shows that two thirds of the students are less affected by the excessive noise. Future studies can focus on who these students (e.g., auditory learners vs. visual learners) are and what strategies they use to deal with such a noisy stressful environment.

Declaration of Conflicting Interests

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References

Airey, S., & MacKenzie, D. (1999). Speech intelligibility in classrooms. *Proceedings of the Institute of Acoustics*, *21*(5), 75-79.

Ali, S. A. A. (2013). Study effects of school noise on learning achievement and annoyance in Assiut city, Egypt. *Applied Acoustics*, *74*, 602-606.

American National Standards Institute. (2002). *S12.60-2002: Acoustical performance criteria, design requirements and guidelines for schools* (Secretariat, ASA). New York, NY: Author.

Banbury, S., & Berry, D. C. (1998). Disruption of office-related tasks by speech and office noise. *British Journal of Psychology*, *89*, 499-517. doi:10.1111/j.2044-8295.1998.tb02699.x

Bistrup, M. (2003). Prevention of adverse effects of noise on children. *Noise & Health*, *19*(5), 59-63.

Bradlow, A. R., Krauss, N., & Hayes, E. (2003). Speaking clearly for children with learning disabilities: Sentence perception in noise. *Journal of Speech Language and Hearing Research*, *46*, 80-97. doi:10.1044/1092-4388(2003/007)

California Department of Transportation. (n.d.). *Loudness Comparison Chart (dBA)*. Retrieved from http://www.dot.ca.gov/dist2/projects/sixer/loud.pdf

Chen, F., Curran, P. J., Bollen, K. A., Kirby, J., & Paxton, P. (2008). An empirical evaluation of the use of fixed cutoff points in RMSEA test statistic in structural equation models. *Sociological Methods & Research*, *36*, 462-494.

Cohen, S., Evans, G. W., Stokols, D., & Krantz, D. S. (1986). *Behavior, health, and environmental stress*. New York, NY: Plenum Press.

Dockrell, J. E., & Shield, B. M. (2006). Acoustical barriers in classrooms: The impact of noise on performance in the classroom. *British Educational Research Journal*, *32*, 509-525. doi:10.1080/01411920600635494

Elliott, L. L. (1979). Performance of children aged 9 to 17 years on a test of speech intelligibility in noise using sentence material with controlled word predictability. *The Journal of the Acoustical Society of America*, *66*, 651-653.

Evans, G. W., & Lepore, S. J. (1993). Nonauditory effects of noise on children: A critical review. *Children's Environments Quarterly*, *10*(1), 31-51.

Eysel-Gosepath, K., Daut, T., Pinger, A., Lehmacher, W., & Erren, T. (2012). Sound levels and their effects on children in a German primary school. *European Archives of Oto-Rhino-Laryngology*, *269*, 2475-2483.

Gorsuch, R. L. (1983). *Factor analysis* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Haines, M. M., Brentnall, S. L., Stansfeld, S. A., & Klineberg, E. (2003). Qualitative responses of children to environmental noise. *Noise and Health*, *5*(19), 19.

Haines, M. M., Stansfeld, S. A., Job, R. F. S., Berglund, B., & Head, J. (2001). A follow-up study of effects of chronic aircraft noise exposure on child stress responses and cognition. *International Journal of Epidemiology*, *30*, 839-845. doi:10.1093/ije/30.4.839

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*, 1-55.

Klatte, M., Bergström, K., & Lachmann, T. (2013). Does noise affect learning? A short review on noise effects on cognitive performance in children. *Frontiers in Psychology*, *4*, 578.

Lazarus, R. S. (1999). *Stress and emotion*. New York, NY: Springer.

Loeb, M. (1986). *Noise and human efficiency*. Chichester, UK: Wiley.

Lundquist, P., Holmberg, K., & Landstrom, U. (2000). Annoyance and effects on work from environmental noise at school. *Noise & Health*, *2*(8), 39-46.

Lupien, S. J., King, S., Meaney, M. J., & McEwen, B. S. (2001). Can poverty get under your skin? Basal cortisol levels and cognitive function in children from low and high socioeconomic status. *Development and Psychopathology*, *13*, 653-676.

Maxwell, L., & Evans, G. (2000). The effects of noise on pre-school children's pre-reading skills. *Journal of Environmental Psychology*, *20*, 91-97. doi:10.1006/jevp.1999.0144

Muthén, L. K., & Muthén, B.O. (1998-2010). *Mplus user's guide* (6th ed.). Los Angeles, CA: Author.

Nelson, P. B., & Soli, S. (2000). Acoustical barriers to learning: Children at risk in every Classroom. *Language, Speech and Hearing in Schools*, *31*, 356-361. doi:10.1044/0161-1461

Northwest Evaluation Association. (2011). *RIT scale norms study*. Retrieved from http://legacysupport.nwea.org/sites/www.nwea.org/files/resources/NWEA%20 2011%20Norms%20Report_01.17.2012_2.pdf

NVivo 9.0. (2010). NVivo qualitative data analysis software; QSR International Pty Ltd. Version 9, 2010.

Shield, B. M., & Dockrell, J. E. (2003). The effects of noise on children at school: A review. *Journal of Building Acoustics*, *10*(2), 97-116. doi:10.1260/135101003768965960

Spreng, M. (2000). Possible health effects of noise induced cortisol increase. *Noise & Health*, *2*(7), 59-63.

Szalma, J. L., & Hancock, P. A. (2011). Noise effects on human performance: A meta-analytic synthesis. *Psychological Bulletin*, *137*, 682-707.

World Health Organisation. (1999). *Guidelines for community noise*. Available from http://www.who.int/peh/

Zentall, S. S., & Shaw, J. H. (1980). Effects of classroom noise on performance and activity of second-grade hyperactive and control children. *Journal of Educational Psychology*, *8*, 830-840. doi:10.1037/0022-0663.72.6.830

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